INDIA'S
CENTURY OF
CHEMISTRY

THE CENTENNIAL
FOUNDATION DAY
Celebrations
of
Indian Chemical Society

09th May, 2023

Venue:

Ramakrishna Mission Institute of Culture
Golpark, Kolkata

Organized by :

Indian Chemical Society, Kolkata

FOREWORD

Indian chemical society was established on May 09, 1924 with Acharya Prafulla Chandra Ray as its founder president. His associates were J. N. Mukherjee (Honorary Secretary), J. C. Ghosh, S. S. Bhatnagar, N. R. Dhar and such other great personalities. Thus, the Society is entering into the 100th year of its glorious existence on this very day. We have undertaken a year long programme to commemorate this joyous occasion. During these years, the Society contributed immensely towards all round development of Chemical Sciences in our Country.

To make this occasion of the inauguration of the Centennial Celebration memorable, a Souvenir is being published. It contains, the inaugural address delivered by Acharya Prafulla Chandra Ray as the first Annual General Meeting of the Indian Chemical Society held at Benaras Hindu University and some important articles reproduced from the first issue of the Journal of the Indian Chemical Society.

We are extremely grateful to my predecessors in the Indian Chemical Society and also our present colleagues & all the staff members of the Indian Chemical Society for their sincere cooperation for implementing our ideas. We sincerely express our grateful thanks to

Padma Vibhushan Prof. M. M. Sharma, FRS, FNA

Padma Vibhushan Dr. R. A. Mashelkar, FRS, FNA

Padmashri Prof. Goverdhan Mehta, FRS, FNA

Padmashri Dr. S. Sivaram. FNA

Dr. J. S. Yadav, FNA

Invited Lectures

Prof. Tapas Chakraborty, IACS, Kolkata

Prof. Anindya Datta, IIT Bombay

Prof. Tanmaya Pathak, IIT Kharagpur

For their kind consent to deliver

We sincerely thank Swami Suparnananda Maharaj Ji for giving his kind permission to hold to the programme at Ramakrishna Mission Institute of Culture

We also acknowledge the patronage of

Pidilite Industries Ltd.

Clean Science and Technology Ltd

Oriental Aromatics

Aether Industries

Avra Lab Pvt. Ltd.

M/s. Apex Centre

Prof. G. D. Yadav

Mr. M. N. Mathur

To make this occasion a grand success.

Prof. G. D. Yadav
President

Prof. Sudip K. Das
Honorary Secretary

PROF. M.M. SHARMA, FRS

MESSAGE

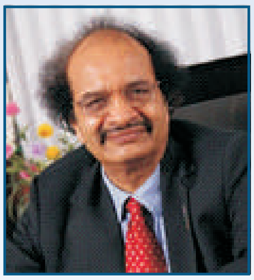
I should like to heartily congratulate the INDIAN CHEMICAL SOCIETY (ICS) for entering into the CENTINEAL YEAR. ICS has played an important role in furthering the relevance of Chemistry and has now a vigorous programme under the truly outstanding leadership of PROF.G.D. YADAV, who has made outstanding contributions in the world of Chemical Sciences and Technologies.

Life is not possible without Chemistry but there is better life possible with Chemistry. Chemistry is in everything and everywhere, including in the human body. Chemistry is a central science and no branch of sciences has made such a great impact on quality of life and made life healthier and wealthier.

Chemistry is interdisciplinary and is international and is an enabling science. The ever exciting field of Material Science has Chemistry as its core. Chemists and Biologists work together to create wonders. The family planning owes a lot to Chemistry.

N.L Todd said that the greatest contribution of Chemistry is to make polymers.The world of Catalysis leads to some astonishing and unbelievable tranformations.

In Chemistry sky is the limit.Let us celebrate,in a vigorous way,the prowess of chemistry to be more useful to the society and be colourful and fragrant.



Professor Ganapati D. YADAV

B. Chem. Eng. Ph.D. (Tech.), D.Sc. (*Hon. Causa, DYPU Kolhapur*), D. Eng. (Hon. Causa, NIT-Agartala) USNAE, FNAI (US),
FTWAS, *FNA, FASc, FNASc, FNAE, FRSC (UK), FIE (India),*
FISTE, FIChemE (UK), FIIChE, FICS, FBRSI (hon.), FISTE (hon.)

MESSAGE

Marching into the Next Century with Pride and Hope:
The Centennial Jubilee Year Celebration शताब्दी महोत्सव

A century of any occasion is celebrated with pomp and show when we reflect on the history of its genesis and progress made since then. I am indeed most overwhelmed that I have been entrusted with the huge responsibility as the President for two successive terms by the Fellows and Members of the Indian Chemical Society to celebrate our success, ponder on our failures and plan for the next century. Only history will judge us.

Ladies and Gentlemen, I stand before you today in all humility in my command before the galaxy of the stars of our profession to remember our Founding President, Acharya Prafulla Chandra Ray, the great Rishi and his compatriots J. N. Mukherjee, J.C. Ghosh, S.S. Bhatnagar and all the patriotic members of the first Council. Their cherished dream, first visualized in University College, London of having a Society on the lines of the Royal Society of Chemistry, was realized with active support and cooperation of many others. Thus, the Indian Chemical Society was founded on this Day a century ago, with Sir Prafulla Chandra Ray as the first President. Many of the distinguished personalities in the field of Chemical Sciences of that time in British India took active interest in nurturing the newborn Society. I salute and remember all of them with great reverence. But for them today would not have arisen.

Any organization becomes triumphant due to a Stable Trinity of Purpose, Leadership, and Openness. Indian Chemical Society has witnessed it in the leadership of Acharya Ray, his commitment in giving his time, wealth, and wisdom for guiding the fledgling Society. We were simply lucky to have his guidance. Openness is the base of science. Truth is its soul. In 100 years, Chemistry is no longer a voodoo or magic, but it has changed dramatically for brining luxury, comfort, instant gratification, and instant communication. Chemistry has revealed its centrality in all sciences and engineering. Its spectacular advances have amazed us. Life is Chemistry and Chemistry is Life. On this Day, we must bond and pledge to take our Society to a glory and created a positive image in the minds of public. I need you support and participation.

We will celebrate the Centennial Jubilee Year plus from May 9, 2023- August 2, 2024 with a general theme of:

The Critical Role of Chemical Sciences in The Net Zero Goal, Circular Economy & Sustainability

The inaugural programme is being blessed by the gracious presence of Hon'ble Governor of West Bengal, Dr. C.V. Ananda Bose, eminent civil servant, management guru, housing expert, innovator, writer, and orator retired from the Indian Administrative service in the year 2011.

The august presence of 5 Padma Awardees, three Fellows of Royal Society, three Members of the US National Academy of Engineering, two Fellows of US National Academy of Inventors, two Fellows of the Royal Academy of Engineering, and six fellows of Indian National Science Academy among several other prestigious international academies and recipients of more than 65 honorary doctorates from Indian Universities, foreign universities, IITs, and NITs; former Directors of prestigious institutes, CSITR laboratories and Govt. secretaries and a Director General of CSIR for the function today is extraordinary and amazing. All conceivable awards and honours, perhaps more than a thousand have decorated them. We have our heroes, in body and soul in front of us. These are Padma Vibhushan Professor M.M. Sharma, Padma Vibhushan Dr. R.A. Mashelkar, Padmashri Professor Goverdhan Mehta, Padmashri Dr. S. Sivaram and Dr. J.S. Yadav.

It is a matter of great coincidence that Dr. Sukh Dev, the most revered organic chemist in India is going to celebrate his 100th birthday soon. We decided to honour him by creating a new endowment in his name. The five new corpuses are created and the first awardees need no introduction.

• Padma Vibhushan Prof. M.M. Sharma, *FRS,FNA*, Emeritus Professor of Eminence, Institute of Chemical Technology, Mumbai	Clean Science & Technology Bharat Ratna Prof. C.N.R. Rao ICS Centennial Jubilee Award for Leadership of Chemical Sciences and Engineering
• Padma Vibhushan Dr. R.A. Mashelkar, *FRS, FNA* National Research Professor, Former Secretary DSIR, and Former DG, CSIR	Pidilite Industries Padma Vibhushan Professor M.M. Sharma ICS Centennial Jubilee Award for Leadership of Applied Sciences and Chemical Industry
• Padmashri Prof. Goverdhan Mehta, *FRS, FNA* K. Anji Reddy Chair, Dr. Reddy's Institute of Life Sciences, University of Hyderabad	Oriental Aromatics Dr Sukh Dev ICS Centennial Jubilee Award for the Most Outstanding Organic Chemist and Thought Leader
• Padmashri Dr. S. Sivaram, *FNA* Former Director, CSIR-NCL Pune, Honorary Professor Emeritus and INSA Emeritus Scientist, Indian Institute of Science Education and Research, Pune	Aether Industries Padma Vibhushan Dr. R.A. Mashelkar ICS Centennial Jubilee Award Research, Innovation and Technology Development
• Dr. J.S. Yadav, FNA Former Director, CSIR-IICT Hyderabad, Pro-Chancellor, Indrashil University, Ahmedabad	Dr. A.V. Ramarao ICS Centennial Jubilee Award for Innovation in Industrial Research

The financial support to create these orations through corpuses and donations was possible due to the generous and spontaneous support of my friends in industry: Shri Ashok R. Boob (Managing Director, Clean Science & Technology Ltd), Shri Madhukar B. Parekh (Chairman, Pidilite Industries Ltd), Shri Dharmil Anil Bodani (Chairman & Managing Director, Oriental Aromatics Ltd), Shri. Ashvin J. Desai (Managing Director, Aether Industries Ltd), Dr. A.V. Ramarao (Dr. A.V. Ramarao Foundation and AVRA Laboratories). All these inaugural awards are of Rs. 1 lakh, a citation, and a plaque.

Besides, many others have promised more awards and prizes. The following are already received.

Meghmani Organics Ltd (Shri. Jayanti Patel, Chairman), Shri. Ravi Raghavan (Chemical Weekly, Mumbai), Shri. Dilip Raghavan (Colour Publications, Mumbai), Prof. R.K. Verma, Shri N.D. Mathur, Prof. G.D. Yadav & Dr. (Mrs.) Vasanti G. Yadav and Prof. C.R. Sinha have already donated funds to create special awards.

दातव्यमितियद्दानं दीयतेऽनुपकारिणे।
देशे काले च पात्रे च तद्दानं सात्त्विकं स्मृतम्।।

Dātavyamiti Yaddānaṁ Dīyate Anupakāriṇe.
Deśe Kāle Cha Pātre Cha Taddānaṁ Sattvikaṁ Smṛtaṁ.

It means, "Giving Charity is Duty in such a spirit that the donation given by seeing the country, time and deserving character, without any feeling of retribution, is said to be a SATTVIK charity."

While will start with a grand Inaugural Programme here in Kolkata, I had given a glimpse of different activities, conferences, awards, etc. in the last AGM in December 2022.

We would like to have the second big event of three days in Delhi during August 2-4, 2023 to mark the birth Anniversary of Acharya P.C. Ray who was not only the first Indian to be a Professor but also an industrialist, having started the Bengal Chemicals & Pharmaceuticals Ltd., now a PSU of Govt. of India. The startup culture is his gift which we talk a lot during the Azadika Amrut Mahotsava. Hydroxychoroquine, the much talked about drug during the corona pandemic is his legacy. We would like to invite some VVIPs, many industries, scientists, Nobel Laureates, policy makers and bureaucrats, students to make it a memorable conference with the same theme.

To honour his legacy, the Government of India should declare 2nd August as the National Chemistry Day during the year of Azadika Amrut Mahotsava**.**

We would like to hold the Annual Chemists Convention in Mumbai during second week of December. Two more important conferences will be held in different parts of India. Several mini conferences, one day events and student conference will also be organized.

विद्यां चाविद्यां च यस्तद्वेदोभ्य सह ।
अविद्यया मृत्युं तीर्त्वाऽमृतमश्नुते ॥

vidyāṃ cāvidyāṃ ca yastadvedobhya saha |
avidyayā mṛtyuṃ tīrtvā'mṛtamaśnute || (from Isha Upanishad)

It means, "One who knows both, the material science as well as the spiritual science, transgresses fear of death by the former, i.e., by proper bodily and mental efforts, and attains salvation by the latter, i.e. by the purity of mind and soul." Chemistry is the soul of all: material science, emotions, thoughts, and spirituality. It should be revered and nurtured in the service of society.

Thank you for being present in large numbers to rejoice the Foundation Day; 100th at that!

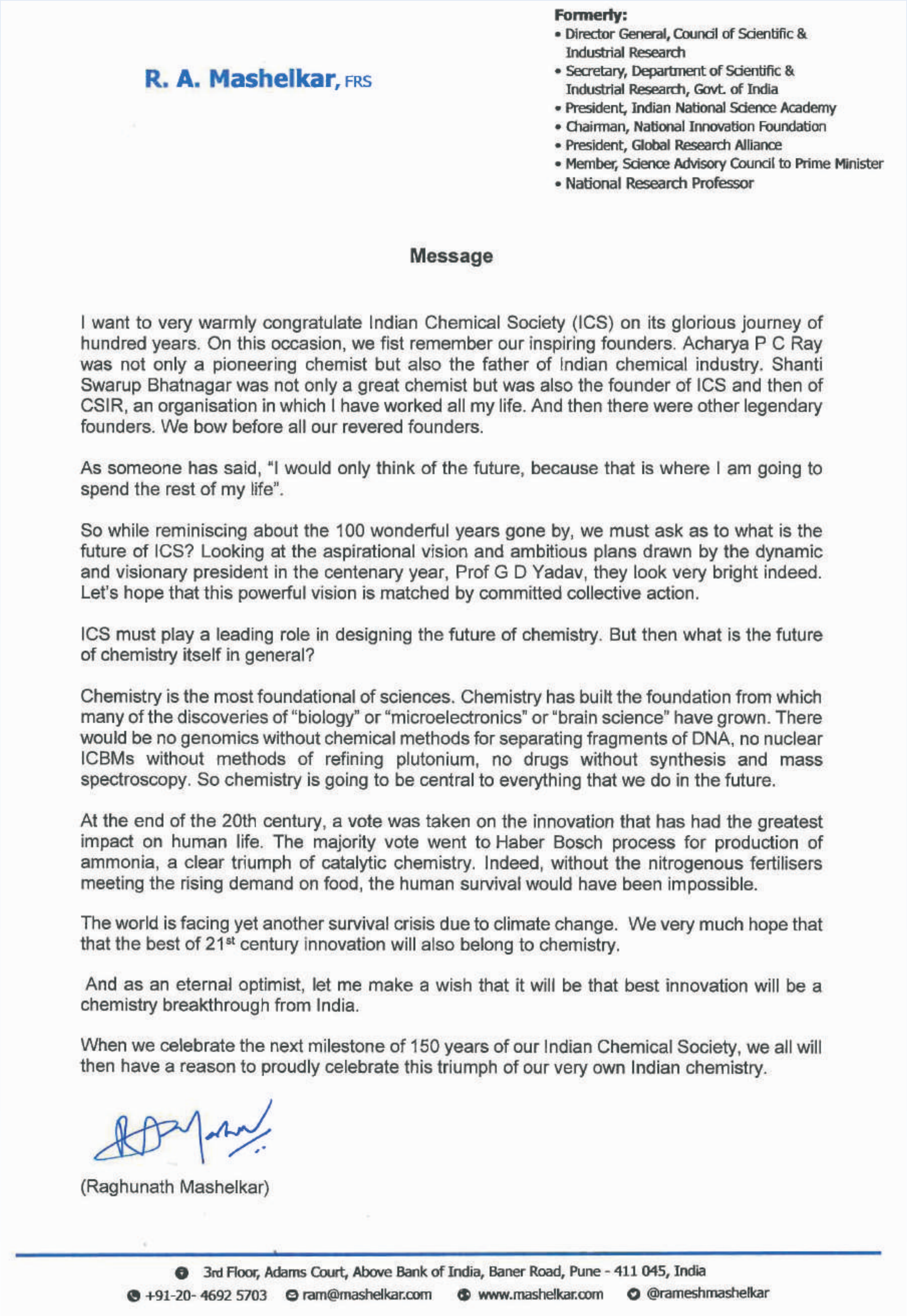
Professor Goverdhan Mehta

MESSAGE

Delighted to learn that the Centennial Jubilee Year of the Indian Chemical Society (ICS), a venerable legacy of the founder Acharya Prafulla Chandra Ray, is being launched from May 9, 2023. Acharya Ray, regarded as the father of modern Chemistry and Chemical Industry in India was well ahead of his times in many domains, who could integrate ideas with idealism, pursue science for societal good and promote industrial activities with values and set bench marks of simplicity, humility and philanthropy through personal example. Acharya could visualize that a country like India needed a structured, participative framework for promoting the discipline and its practitioners and established the 'Indian Chemical Society'. During its 100 year journey, ICS has gone through many ups and downs and has been on a steep descending trajectory for the past few decades. Centenary is therefore an opportune time to **r**evive, **r**eform and **r**eideate ICS to serve its intended purpose in the emergent context. It is very encouraging to notice some 'green shoots' in such a direction through the efforts of current President Dr. G. D. Yadav and other like minded individuals and let this event be a symbolic curtain raiser for a fresh beginning.

I hope ICS will prosper along a new trajectory and promote chemistry to be counted among world's leading Chemical Societies befitting a rising, aspirational India and also ensure participation and nurturing of young scientists and entrepreneurs to make it sustainable.

My Greetings and very best wishes to all.



R. A. Mashelkar, FRS

Formerly:
- Director General, Council of Scientific & Industrial Research
- Secretary, Department of Scientific & Industrial Research, Govt. of India
- President, Indian National Science Academy
- Chairman, National Innovation Foundation
- President, Global Research Alliance
- Member, Science Advisory Council to Prime Minister
- National Research Professor

Message

I want to very warmly congratulate Indian Chemical Society (ICS) on its glorious journey of hundred years. On this occasion, we fist remember our inspiring founders. Acharya P C Ray was not only a pioneering chemist but also the father of Indian chemical industry. Shanti Swarup Bhatnagar was not only a great chemist but was also the founder of ICS and then of CSIR, an organisation in which I have worked all my life. And then there were other legendary founders. We bow before all our revered founders.

As someone has said, "I would only think of the future, because that is where I am going to spend the rest of my life".

So while reminiscing about the 100 wonderful years gone by, we must ask as to what is the future of ICS? Looking at the aspirational vision and ambitious plans drawn by the dynamic and visionary president in the centenary year, Prof G D Yadav, they look very bright indeed. Let's hope that this powerful vision is matched by committed collective action.

ICS must play a leading role in designing the future of chemistry. But then what is the future of chemistry itself in general?

Chemistry is the most foundational of sciences. Chemistry has built the foundation from which many of the discoveries of "biology" or "microelectronics" or "brain science" have grown. There would be no genomics without chemical methods for separating fragments of DNA, no nuclear ICBMs without methods of refining plutonium, no drugs without synthesis and mass spectroscopy. So chemistry is going to be central to everything that we do in the future.

At the end of the 20th century, a vote was taken on the innovation that has had the greatest impact on human life. The majority vote went to Haber Bosch process for production of ammonia, a clear triumph of catalytic chemistry. Indeed, without the nitrogenous fertilisers meeting the rising demand on food, the human survival would have been impossible.

The world is facing yet another survival crisis due to climate change. We very much hope that that the best of 21st century innovation will also belong to chemistry.

And as an eternal optimist, let me make a wish that it will be that best innovation will be a chemistry breakthrough from India.

When we celebrate the next milestone of 150 years of our Indian Chemical Society, we all will then have a reason to proudly celebrate this triumph of our very own Indian chemistry.

(Raghunath Mashelkar)

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J. S. YADAV, FNA, FTWAS

MESSAGE

I, Dr. J. S. Yadav (Bhatnagar fellow, former director, CSIR IICT), Mentor & Research Director, [Previous Vice Chancellor annd Trustee] Indrashil University, Ahmedabad cordially congratulate hhe ndian Chemical Society for the birth centenary celebrations. For years, ICS is responsibly performing its duty towards the community of chemists and allied societies of Inida. I whole heartedly congratulate the current president, ICS Prof. G. D. Yadav for taking he initiatives for keeping up the vibe of the organization. Many congratulations.

(Prof. Suresh C. Ameta)

Past President (2000-2001),
Indian Chemical Society

MESSAGE

I am glad to learn that Indian Chemical Society, Kolkata is going to celebrate its Centenary Year on 9th May, 2023. It's a great occasion to rememorize the contributions of Chemists, who have initiated the formation of society and nurtured it for 100 years to attain a indelible mark on International level. I wish this celebration function a grand success and wish that the society will grow further with flying colors.

D C Mukherjee

Past President (2017-2019),
Indian Chemical Society

MESSAGE

I am extremely happy to learn that the Indian Chemical Society has taken a year long program for its entering into the Centennial year. Since its foundation on May 09, 1924, the Society has completed 99 glorious years of its eventful existence and has been playing a vital role in promoting education and research in Chemical Sciences. Many illustrious personalities like Acharya Prafulla Chandra Ray, J. N. Mukherjee, J. C. Ghosh, S. S. Bhatnagar, N. R. Dhar, U. N. Brahmachari, P. R. Ray, T. R. Sheshadri, Sukh Dev and such other stalwarts had been our past Presidents.

I remember their contributions with reverence for all round development of the Society. I also express my appreciation to Professor G. D. Jadav, our President, for providing dynamic leadership for the progressive activities of the Society. The Journal of the Indian Chemical Society with Professor G. D. Jadav as the Editor-in-Chief has received a new dimension on being published by the Elsevier which is a matter of great achievement for the Society.

I hope that the Society will continue to progress more and more and add significantly to the glorious tradition it has already created. I wish a grand success of the Centennial Celebration program throughout the year.

aether
elementally innovative

MESSEGE

May 6, 2023

Dear Professor Dr. G. D. Yadav,

On behalf of Mr. Ashvin Desai (Chairman and Managing Director) and Aether Industries, it is with great pleasure that we confirm our participation towards creating the **Aether Industries Padma Vibhushan Dr. R. A. Mashelkar ICS Centennial Jubilee Award for Research, Innovation, and Technology Development**.

It is our privilege to associate our company's name with the gigantic occasion of the ICS centennial year and that of a living legend and icon, Padma Vibhushan Dr. R. A. Mashelkar. It is also very fitting that the first award in this series is being awarded to Padma Shri Dr. S. Sivaram.

Thank you for giving us this opportunity to create this award, and we greatly look forward to a perennial association with ICS on this award.

Our very best wishes for an absolutely successful and grand occasion of the ICS Centennial celebration.

Our highest regards,
Yours sincerely,

AETHER INDUSTRIES LIMITED
Authorised
SURAT

Dr. Aman Desai
Director
Aether Industries Limited

Aether Industries Limited

Registered Office: Plot No. 8203, Near Rajkamal Chokdi, Road No. 8, Sachin GIDC, Sachin, Surat - 394230, Gujarat - India.

Phone: +91-261-6603000 II **Email:** accounts@aether.co.in II **Web:** www.aether.co.in II **CIN No.:** U24100GJ2013PLC073434

Factory: Plot No. 8203, Beside Shakti Distillary, Near Rajkamal Chokdi, Road No. 8, Sachin GIDC, Sachin, Surat - 394230, Gujarat - India.

CLEAN SCIENCE AND TECHNOLOGY LIMITED

innovation at work

MESSEGE

Clean Science and Technology Limited is privileged to be part of Centennial Jubilee year celebration of the Indian Chemical Society. We unequivocally endorse this initiative of honouring the eminent thought leaders who are relentlessly contributing to the Indian Chemical Society.

We are invited to confer the award to Padma Vibhushan Prof. M.M. Sharma! Interestingly, I had a privilege of his pedagogy while pursuing bachelor of chemical engineering from UDCT (1974 batch). His extensive contribution to the subject continues to inspire and systemically foster innovation. Under his stewardship, the fraternity has achieved many firsts.

Further, we are extremely pleased to have the award created in name of our Company and Bharat Ratna Prof. C.N.R. Rao! We believe there is striking resemblance between our contribution and philosophy of innovation through profound research and emphasis on value creation.

Thank You

Ashok Boob

Managing Director

Clean Science and Technology Limited

PROF. M.M. SHARMA, FRS

BIOGRAPHICAL SKETCH

(Born May 1, 1937 in Jodhpur, Rajasthan) is an Indian chemical engineer. He was educated at Jodhpur, Mumbai, and Cambridge. At age 27, he was appointed Professor of Chemical Engineering in the Institute of Chemical Technology, Mumbai. He later went on to become the Director of UDCT, the first chemical engineering professor to do so from UDCT.

In 1990, he became the first Indian engineer to be elected as a Fellow of Royal Society, UK. He was awarded the Padma Bhushan (1987) and the Padma Vibhushan (2001) by the President of India.[4] he has also been awarded the Leverhulme Medal of the Royal Society, the S.S. Bhatnagar Prize in Engineering Sciences (1973), FICCI Award (1981), the Vishwakarma medal of the Indian National Science Academy (1985), G.M. Modi Award (1991), Meghnad Saha Medal (1994), and an honorary Doctor of Science degree from Indian Institute of Technology, Delhi (2001).

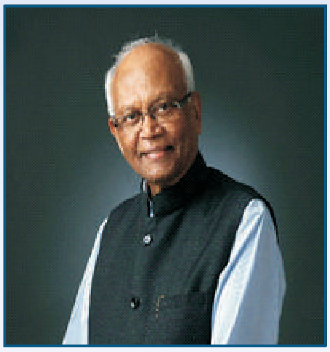
Professor Goverdhan Mehta

BIOGRAPHICAL SKETCH

Professor Mehta is a leading researcher in the area of chemical Sciences and is presently University Distinguished Professor and Dr. Kallam Anji Reddy Chair at the University of Hyderabad. In the past he has held positions as faculty at IIT, Kanpur, Vice Chancellor of the University of Hyderabad, Director of the Indian Institute of Science, Bangalore, Srinivasa Ramanujan Research Professor of the Indian National Science Academy, CSIR-Bhatnagar Fellow, National Research Professor of Government of India and Lilly-Jubilant Chair Professor at the University of Hyderabad. He has published nearly 600 research papers, mentored over 100 doctoral and post-doctoral fellows and delivered over two hundred named and distinguished lectures world-wide. He has received over hundred medals, awards and Honorary Doctorate degrees.

His research interests have been diverse but the main focus has been on organic synthesis, natural products, conceptualization and creation of new molecular entities and stereogenesis. During the past decade, as a member of an international group, Professor Mehta has been passionately promoting chemistry as sustainability science. He has been actively involved with science policy and higher education issues both nationally and internationally

Prof. Mehta is a Fellow of the Royal Society (FRS), a Foreign Member of the Russian Academy of Sciences, Fellow, of The World Academy of Sciences (TWAS), Trieste, Foreign Member, Acadèmi Royale des Sciences d'Outre-Mer, Belgium and Honorary Fellow of the Royal Society of Chemistry (Hon. FRSC) and some others. He is also a Fellow of all the three Science Academies in India and was the President of the Indian National Science Academy (INSA), International Council for Science, Paris (ICSU) and the Chemical Research Society of India (CRSI) among many others. He has been conferred 'Padma' award by the President of India, 'Chevalier de la Legion d''Honneur' by the President of France and 'Cross of the Order of Merit' by the President of Germany.



R.A. MASHELKAR, F.R.S.

WWW.MASHELKAR.COM

BIOGRAPHICAL SKETCH

Dr R.A. Mashelkar served (1995-2006) as the Director General of Council of Scientific and Industrial Research (CSIR), also as President of Indian National Science Academy (2004-2006), Chairman of National Innovation Foundation (2000-18), President of UK Institution of Chemical Engineers (2007) as also the President of Global Research Alliance (2007-17), a network of RTOs from US, Europe, Asia Pacific and Africa with around 60,000 scientists.

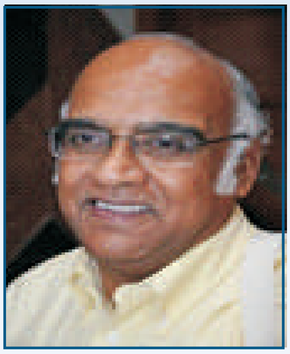
46 Universities from around the world have honored him with honorary doctorates. He was elected a Fellow of Royal Society (FRS), Foreign Associate of US National Academy of Science (2005), Foreign Associate of National Academy of Engineering (2003), Associate Foreign Member, American Academy of Arts & Sciences (2011), Fellow of Royal Academy of Engineering, U.K. (1996), Foreign Fellow of Australian Technological Science and Engineering Academy (2008), Corresponding Member of Australian Academy of Sciences (2017), Fellow of World Academy of Arts & Science, USA (2000), Fellow of US National Academy of Inventors (2017).

He won the TWAS-Lenovo Science Prize (2018), which is the highest science award of The World Academy of Science. He also won the JRD Corporate Leadership Award (1998), the only scientist to win it so far.

Dr. Mashelkar has been on the Board of Directors of several reputed companies ranging from Reliance Industries Ltd. to Tata Motors Ltd. to Hindustan Unilever Ltd.

Dr Mashelkar served as a member of Science Advisory Council to the Prime Minister set up by successive Indian governments for over three decades. He chaired the so called 16 Mashelkar Committees set up by the Government dealing with complex national challenges.

He has received the Business Week (USA) award of 'Stars of Asia' at the hands of George Bush (Sr.), the former President of USA. He was the first Asian Scientist to receive it. The President of India honored Dr. Mashelkar with Padmashri (1991), with Padmabhushan (2000) and with Padma Vibhushan (2014), three of the highest civilian honors.



Swaminathan Sivaram

BIOGRAPHICAL SKETCH

(Born 4 November 1946) is an Indian polymer chemist, inventor, institution builder and a former director of the National Chemical Laboratory, Pune. His early college studies were at Madras Christian College from where he passed the graduate degree (BSc) in chemistry in 1965 after which he secured his master's degree (MSc) from the Indian Institute of Technology, Kanpur in 1967. Moving to the US, he did his doctoral research under Nobel Laureate Herbert C. Brown at Purdue University and secured his doctorate (PhD) in 1972. He continued in the US for two more years and worked as a research associate at the Institute of Polymer Science of the University of Akron, Ohio. He returned to India in 1973 and joined the Indian Petrochemicals Corporation Limited (IPCL), Baroda as a research scientist where he worked in various capacities such as research manager and deputy general manager till 1988, when he moved to the National Chemical Laboratory (NCL) as the Head of the Department of Polymer Chemistry. In 2002, he was promoted as the director of the institution and worked there till his superannuation in 2010.

Sivaram has served as visiting faculty at many universities in India and abroad. He was a visiting scientist at the Blaise Pascal University in 1991 during September–October. In 1993–94, he was involved with the Institute of Chemical Technology as the K. S. S. Raghavan Chemical Weekly Visiting Professor of Polymer Science and Technology and has served the Universite Bordeaux in September – October 1995 as the visiting professor. He was also a guest lecturer at the Free University of Berlin in May 1999 and the Harold A. Morton Distinguished Visiting Professor at the University of Akron in 2006.

He has been involved with the Government of India and its various autonomous bodies and is a former member of the Scientific Advisory Committee to the Cabinet (SAC-C). He is also a former member of the Task Force on Public Sector of the Ministry of Heavy Industries and Public Enterprises, Innovation Council on Chemicals and Petrochemicals of the Ministry of Chemicals and Fertilizers and the Board of Trustees of the Oil and Natural Gas Commission (ONGC). He was the vice president of several science forums and societies such as the Indian Academy of Sciences from 2007 to 2012, the Indian National Science Academy from 2004 to 2006, the Chemical Research Society of India from 2005 to 2008 and the Materials Research Society of India from 2004 to 2007. He has sat on the Board of Governors of the Indian Institute of Technology, Mumbai, the Indian Institute of Science Education and Research, Pune and the Institute of Chemical Technology, Mumbai. He has served as the faculty selection committee of the Indian Institute of Technology for their Mumbai, Kanpur, Chennai and Hyderabad institutes and is a member of the Scientific Council for Catalysis of the Russian Academy of Sciences, Moscow.

J.S.Yadav, FNA, FTWAS,

(former Director and Bhatnagar Fellow, CSIR-IICT)
(Previous Vice Chancellor & Trustee)-
Mentor & Director - R & D,
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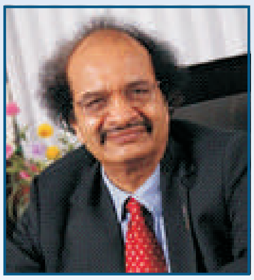
Website : www.indrashiluniversity.edu.in

BIOGRAPHICAL SKETCH

Dr. Jhillu Singh Yadav, Vice Chancellor, Director and Trustee, Indrashil University (former CSIR Bhatnagar and J C Bose Fellow & Director, Indian Institute of Chemical Technology Hyderabad) carried out extensive basic and applied research investigations in organic chemistry for the synthesis of over 190 complex natural products of biological relevance. Dr. Yadav specializes in the state-of-the art Asymmetric Synthesis to create new Chiral centers. He extensively utilized them very effectively in the synthesis of drugs and agrochemicals having self-defensive properties against rice-blast disease, hypersensitive metabolites, anticancer, antibiotics and antifungal agents in a highly innovative manner. He excelled in creating and generating diverse chemical entities relevant to both agro and drug industry. Dr. Yadav's insightful instincts made him foresee the versatility of insect sex pheromones in Indian agro-system. He pioneered the alternative eco-friendly and environmentally safe pest control technologies in India through the application of insect pheromones as major tools in Integrated Pest Management (IPM) for better and cleaner agro-products. The pheromone application technologies include the control of pests on cotton, rice, groundnut and other vegetable crops. His technology development efforts are highly commendable. Dr. Yadav successfully developed cost effective technologies for drugs which have been well received by several Indian Industries like Diltiazem, Ketotifen, Mefloquin (Cadila Pharma) Ondasetron (Cipla), Pyrazinamide (SPIC Pharma), Tamoxifen (Cipla) Misoprostol and Carboprost (AVRA Laboratories) etc.

Dr. Yadav is an architect of distinction in building potential research groups with state-of- the-art facilities. He is an outstanding Organic Chemist of India. The Web of science (Science Citation Index) has referred him as the best and organic chemist par excellence in the country. His vibrant research group is a center for developing quality scientific human resources. More than 250 students have received their Ph.D degrees under his able guidance in organic chemistry. To his credit, he has more than 1250 scientific publications over 35000 citations. Dr. Yadav has the unique distinction of excelling in both basic and industrial research and received recognition accordingly. He is a fellow of The World Academy of Sciences (TWAS) for the advancement of science in developing countries and has received numerous national and international awards which include the prestigious, Shanti Swarup Bhatnagar Prize, Vigyan Gaurav Samman Award, Jawaharlal Nehru Science Award, KIA Award (Iran-UNESCO), Ranbaxy Award, Vasvik Award, Goyal Award, CSIR Technology Award, ICC D.M. Trivedi Lifetime Achivement Award for Contribution to Indian Chemical Industry and Life Time Achievement Award (Gold Medal)-2021 from Chemical Research Society of India. He is also the fellow of all Indian Science Academies. Dr. Yadav is an eminent organic chemist with a high level of commitment to his profession. He is an avid researcher, an inspiring leader and truly an institution builder.



Professor Ganapati D. YADAV

B. Chem. Eng. Ph.D. (Tech.), D.Sc. (*Hon. Causa, DYPU Kolhapur*), D. Eng. (Hon. Causa, NIT-Agartala) USNAE, FNAI (US),
FTWAS, *FNA, FASc, FNASc, FNAE, FRSC (UK), FIE (India),*
FISTE, FIChemE (UK), FIIChE, FICS, FBRSI (hon.), FISTE (hon.)

BIOGRAPHICAL SKETCH

NATIONAL SCIENCE CHAIR (SERB/DST/GOI)
EMERITUS PROFESSOR OF EMINENCE
Former J.C. Bose National Fellow (Govt. of India)
Former Vice Chancellor and R.T. Mody Distinguished Professor and
Tata Chemicals Darbari Seth Distinguished Professor of Innovation and Leadership
INSTITUTE OF CHEMICAL TECHNOLOGY MUMBAI
Padmashri Awardee (2016)
Conjoint Professor, University of New Castle, Australia
Adjunct Professor, University of Saskatchewan, Saskatoon, Canada
Former Adjunct Professor, RMIT University, Melbourne, Australia
Distinguished Adjunct Professor, Indian Institute of Technology, Guwahati
Distinguished Visiting Professor, Siksha 'O' Anusandhan (SOA) University, Bhubaneswar
Founding Chair, ACS India International Chemical Sciences Chapter
President, Maharashtra Academy of Sciences
President, Indian Chemical Society
Former President, Catalysis Society of India
Former President, Indian Institute of Chemical Engineers (2001)
Council Member, Indian National Science Academy (2019-21)
Elected to the US National Academy of Engineering (2022) (only 21 Indians in this honour so far)
Elected as the Fellow of the US National Academy of Inventors (2022). Only the second Indian so far.
In top 0.2% of researchers in Physical Chemistry in the World, No. 1 in India & at No. 66 in the world consecutively for the last 3 years (Stanford University Surveys of October 2020, 2021 &2022)
509 peer reviewed papers, 120 granted patents, 900+ Lectures/seminars/orations
Over 125 honours, accolades, distinctions, fellowships, editorships
Guidance of 107 Ph. D.s, 135 Masters and 48 Post-docs as a single supervisor (National record for any engineering professor)
h index of 66, i10 index of 338, 16800+ citations
Contributions to the net zero goal: production of green hydrogen (less than a USD/kg), carbon dioxide refineries and (waste) biomass valorization
2 Honorary Doctorates: NIT Agartala and DYPU Kolhapur
Independent Director 6 public limited companies and consultant to industry for past 42 years
Metamorphosed ICT Mumbai as VC for 10.5 years and established 2 off campuses in Bhubaneswar with the help of IOCL & Jalna Marathwada with help of Maharashtra Govt. in 2018
Chairman, Lab Research Council, DRDO DIBER Haldwani
Chairman, Expert Advisory Committee, Waste Management Taskforce, DST, Govt. of India
Member, Expert Group, Tertiary Education, The World Bank

He has live connection with industry all these years as a consultant (both ad hoc and retainer) having done over 82 assignments, technology developer, and is connected will many industries associations like FICCI, ASSOCHAM, CII, ICMA (now ICC) and others in advisory capacities. He serves as an Independent Director, on six renowned limited companies: Aarti Industries Ltd, Godrej Industries Ltd, Meghmani Organics Ltd, and Bhageria Chemicals Ltd, Clean Science and Technology Ltd, and Survival Technologies Ltd.

He is fond of literature, etymology, and Sanskrit. The ICT's University song is written by him. There are over 80 video clips covering his biography (both English & Marathi), orations, lectures, panel discussions, interviews, etc. on YouTube.

https://www.youtube.com/playlist?list=PLclyJH91-TwvTScCVrcih3nrrPGgf8U8R

Dr. A. V. Ramarao

BIOGRAPHICAL SKETCH

Dr A.V. Ramarao is the Chairman & Managing Director, Avra Group of Laboratories, Hyderabad. He is an outstanding synthetic organic chemist, Institution builder, Entrepreneur and inventor known for his Pioneering research in the field of drug technology. He received his B.Sc.(Tech.) in Technology of Fine Chemicals & Pharmaceuticals from the UDCT (now ICT), University of Mumbai and joined NCL to do his Ph.D. (Tech.) under the guidance of Prof. K. Venkatraman who was the Director of UDCT and then NCL.

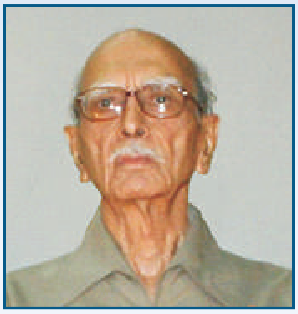
He started his career at NCL Pune as a Scientist B (1965) and rose to the position of Head of the Organic Chemistry Division. In 1985, He moved to another CSIR laboratory in Hyderabad as a Director and transformed the Regional Research Laboratory (RRL) into a more globally respected Indian Institute of Chemical Technology (IICT). After retirement as a Director of IICT Hyderabad in 1995, he founded the A. V. Rama Rao Research Foundation, a non-governmental promoting research and doctoral studies in chemistry and Avra Laboratories, a multi-million-dollar pharmaceutical company which currently has over 600 employees.

Born in 1935 at Guntur (presently in Andhra Pradesh), Dr Rao had his early education at his native place. He did B.Sc. (Tech) in 1960 from Bombay University and Ph.D. in 1964 at NCL Pune with Dr. K. Venkataraman. While at NCL, he took his sabbatical to work with Prof E.J. Corey at Harvard University (1975-1977).

During the early part of his stay at NCL, Rama Rao worked on the isolation and structural elucidation of plant and insect pigments, and on synthetic dyes. After his return from Harvard University, his research was marked by fantastic achievements in synthesising biologically active natural products such as antitumor antibiotics, macrolides, immunosuppressants, cyclic peptides, etc., including Vancomycin representing complexity, diversity and aesthetics of modern asymmetric synthesis.

Dr Rama Rao has trained 112 PhD students and published more than 260 papers in international journals. His work has been recognized with several awards, including Padma Shri (1991) and Padma Bhushan (2016). He is a fellow of all science academies in the country and a fellow of the World Academy of Sciences (TWAS). He is the first Indian to receive the technology award from the TWAS.

He was kind to establish the Dr. A.V. Ramarao ICS Centennial Jubilee Award for Innovation in Industrial Research.



Dr. Sukh Dev

BIOGRAPHICAL SKETCH

Dr. Sukh Dev received the MSc (1945) from Panjab University, Lahore (now in Pakistan), PhD (1950) from Indian Institute of Science (IISc), Bangalore, and DSc (1960) also from IISc. He was conferred DSc (*hc*) by Bundhelkhand University, Jhansi (2000) and also by IIT Delhi (2008). He served as Research Associate (1948-53) and Lecturer (1953-1959) at IISc; Research Associate (1957) at University of Illinois, Head, of the Division of Organic Chemistry, National Chemical Laboratory, Pune (1960-74), and Research Director, Malti-Chem Research Centre, Vadodara (1974-88). He was Visiting Professor, Stevens Institute of Technology (1968), University of Georgia (1969), and University of Oklahoma (1970-71). Currently, he is visiting professor at Dr. B R Ambedkar Centre for Biomedical Research and is also consultant with several chemical companies.

Academic & Research Achievements: Sukh Dev made significant contributions to our knowledge of organic chemistry by uncovering scores of novel, complex, plant secondary metabolites such as zerumbone, himachalenes, malabaricol, cheilanthatriol, kodocytochalasins, bakuchiol, guggulsterones, guggultetrols; development of new techniques and processes: silver nitrate-silica gel (for thin layer chromatography, organic reactions in a solid matrix, heterolytic cleavage of homoallylic alcohols), and concepts: Absolute Stereochemistry Biogenetic Rule. He worked on the Indian economic raw materials, such as lac, Indian turpentine oil, *devadaaru*, and Indian medicinal plants. Longifolene, a typical component of Indian turpentine was converted into useful aroma compounds, which are being manufactured not only in India, but also in foreign countries. Carene, another characteristic constituent of this oil, was fashioned into several commercially important molecules. Himachalenes, hydrocarbons from *devadaaru*, were recognised as effective against ectoparasites and have been commercialised as a veterinary drug. Several Ayurvedic crude drugs were investigated and evaluated for their therapeutic claims. For example, *guggulu* is claimed in Ayurveda for treating lipid disorders. Investigations led to the isolation of compounds (guggulsterones) responsible for this activity, and products based on this are being manufactured not only in India, but also by several parties abroad. Currently, there is much scientific interest in these molecules globally. Bakuchiol, a compound isolated from baakuchi, has been converted into a highly potent juvenoid, and has been successfully evaluated for its use in sericulture. He has more than 390 scientific publications to his credit including 55 patents. Ninety two students received their PhD under his direct supervision. He is the author of 10 books, and has contributed chapters in over 18 other books.

Other Contributions: Sukh Dev served on the Editorial Advisory Board of *Tetrahedron* and *Tetrahedron Letters* (1976-95), *Tetrahedron Asymmetry* (1990-95) and *Dictionary of Organic Compounds*, 5th Edn.

Awards and Honours: Dr Sukh Dev was conferred the Sudborough Medal by IISc (1949), Guha Research Medal by IISc (1958), SS Bhatnagar Award (1964), Acharya PC Ray Medal by Indian Chemical Society (1970), Dr KG Naik Gold Medal by MS University, Baroda 1977), Vishwakarma Medal by INSA (1979), Ernest Guenther Award by American Chemical Society (1980), Distinguished Alumni Award by IISc (1980), VASVIK Award (1980), FICCI Award (1980), Professor TR Seshadri 70th Birthday Commemoration Medal by INSA (1981), Meghnad Saha Medal by INSA (1987), Satyendra Nath Bose Research Professorship by INSA (1988-93), TWAS Award in Chemistry (1988), Srinivasan Ramanujan Birth Centenary Award by Indian Science Congress Association (1992), Lifetime Achievement in Chemical Research and Education Award by Indian Chemical Society (1999), Lifetime Achievement in Chemistry Award by Chemical Research Society of India (2000). He was elected as Fellow of the Indian Academy of Sciences, Allahabad (1974), the Academy of Sciences for the Developing World (1992); President, Indian Chemical Society (1978-79), Organic Chemistry Division, IUPAC (also Co-opted Member, Titular Member, Secretary, 1983-85, and Vice-President); and Trustee (1983-) and Chairman (1987-91), National Organic Symposium Trust, India and Padma Bhushan (2008). Recently, ACS Board of directors have recognised him for sixty years of service.

Bio-data

Name: Tapas Chakraborty, Ph.D.
Present Position: Senior Professor, Indian Association for the Cultivation of Science, Kolkata

Positions held:

1994-2005	IIT Kanpur	Assistant, Associate and Full Professor
2005-present	IACS Kolkata	Senior Professor

Served as the Director of IACS for 2 years, April 21, 2021- April 05, 2023

Research interests: Molecular spectroscopy of cold molecules and clusters, atmospheric photochemistry and mass spectrometry

Number of research paper published: 125

Number of Ph.D. students guided: 21

Awards and Honours:

- Fellow, Indian Academy of Sciences, 2015
- Fellow, Indian Chemical Society and J C Ghosh Memorial Lecture Award, 2013
- Ramanna Fellowship Award of Department of Science and Technology, Govt of India: 2007-2010, and 2011- 2014
- Visiting Associate Professorship at Aarhus University, Denmark, 2005
- DFG Fellowship Award as visiting Scientist at Technical University of Munich, 1996
- INSA Young Scientist Medal Award, Year: 1993
- Associate Editor, Journal of Chemical Sciences, Indian Academy of Sciences

Tanmaya Pathak, PhD

Former Professor (Higher Administrative Grade)
Department of Chemistry, Indian Institute of Technology Kharagpur
Kharagpur 721 302, India
Tel.: 03222-283342 ; E-mail: tpathak@chem.iitkgp.ac.in
B.Sc. & M. Sc.: Jadavpur University, Kolkata
Ph. D.: Uppsala University, Sweden, 1988

BIOGRAPHICAL SKETCH

Postdoctoral Research

Southampton and St.Andrews University, UK, 1989 - 1990
University of Karlsruhe, Germany, 1997

Employment

Organon (India) Ltd: (1981- 1983)
National Chemical Laboratory: Scientist C & E1 (1991 - 2001)
Indian Institute of Technology Kharagpur:
Associate Professor (2001 - 2004) & Professor (Since 2004)
Head, Chemistry (2014 - 2017)

Teaching Interest: Teaching organic chemistry at all levels of Bachelor and Master degrees with special interests in biomolecules, enzymes as reagents and medicinal chemistry.

Research Interest: Carbohydrate modification leading to unnatural carbohydrates, carbocycles, heterocycles; vinyl sulfone chemistry in carbohydrate modification and in the metal free synthesis of triazoles; modified nucleosides as ribonuclease A inhibitors.

Awards/Fellowships/Honours

"Life Time Achievement Award-2022" for contribution in Carbohydrate Chemistry and Glyco-biology (Association of Carbohydrate Chemists and Technologists, India.)

Fellow: Indian Academy of Sciences Bangalore, 2015.

Fellow: West Bengal Academy of Science and Technology, 2014.

"Dr. D. S. Bhakuni Award for the year 2010" (Indian Chemical Society, 2012)

"Excellence in Carbohydrate Research-2010" (Association of Carbohydrate Chemists and Technologists, India.)

Bronze Medal awarded (Chemical Research Society of India, 2010).

Editorial Board Member of Carbohydrate Research published by Elsevier (2009-2012).

"Prof. M. K. Rout Memorial Lecture" (23rd Annual Conference of Orissa Chem. Soc. 2009)

Research grant from "Indo–French Centre for the Promotion of Advanced Research" (2006-2009).

Life member: Chemical Research Society of India (1999); Indian Chemical Society (2001); Indian Association for the Cultivation of Science (2000); The Association of Carbohydrate Chemists and Technologists of India (2005).

Alexander von Humboldt Fellow, 1996-1997.

National Scholarship (Certificate of Merit): Government of India, 1975

Anindya Datta

BIOGRAPHICAL SKETCH

Education

Ph. D.: 1998, Indian Association for the Cultivation of Science, degree from Jadavpur University
M. Sc.: 1994, University of Calcutta
B. Sc. (Hons.): 1992, Presidency College, University of Calcutta

Experience

Professor: 2012 - Present, IIT Bombay
Associate Professor: 2007 - 2012, IIT Bombay
Assistant Professor: 2002-2007, IIT Bombay
Visiting Scientist: 2000-2002, Raja Ramanna Centre for Advanced Technology
Postdoctoral Researcher: 1998-2000, Iowa State University
Lecturer: 1997-1998, Raidighi College

Publications

147 journal papers, 2 book chapters

Ph. D. Student guidance

22 have graduated. 6 are pursuing Ph. D.

Administration

Head, Department of Chemistry, May 2018 - May 2021
Head, Center for Research on Naotechnology and Center for Sophisticated Analytical Instrumental Facility (CRNTS-SAIF):September 2016 - May 2018
Associate Dean (Student Affairs): 2013-2015
Chairman, Hostel Co-ordinating Unit: 2009-2013

Awards and Recognition

Bronze Medal, Chemical Research Society of India: 2018
Fellow of National Academy of Sciences, India (FNASc): 2017
Departmental Award for Excellence in Teaching, IIT Bombay: 2017
G. V. Bakore Memorial Award, Indian Chemical Society: 2011

Young Researcher Award, Chemical Research Society of India: 2006

IIT Bombay Young Investigator Award: 2005

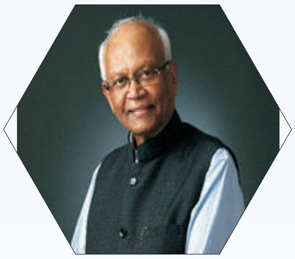
His Excellency Hon'ble Governor of West Bengal
C. V. Ananda Bose

Swami Sampurnanda ji Maharaj

Prof. M M Sharma
Emeritus Professor of
Eminence, ICT Mumbai

Prof. G D Yadav
President
Indian Chemical Society

Professor Goverdhan Mehta
K. Anji Reddy Chair,
Dr. Reddy's Institute of Life Sciences
University of Hyderabad Campus
Gachibowli, Hyderabad



Dr. Ramesh A Mashelkar
National Research
Professor & Former D. G.
CSIR

Dr. Swaminathan Sivaram
Honorary Professor and
INSA Scientist, Emeritus
IISER Pune

Dr. J S Yadav
Pro-Vost,
Indrashil University
Former Director,
CSIR-IICT Hyderabad

Prof. Tapas Chakraborty
IACS, Kolkata

Prof. Anindya Datta
Department of Chemistry, IIT
Bombay, Mumbai

Prof. Tanmaya Pathak
Department of Chemistry, IIT
Kharagpur, West Bengal

PROF. M.M. SHARMA, FRS

Madhukar B. Parekh
Chairman, Pidilite Industries Ltd.

MY TRIBUTES

I have known and associated with Prof. Sharma in multiple ways, as a family friend, as a professor, as a professional of international repute, as a consultant and above all as a wonderful human being.

My connection with Prof. Sharma started when he was a close friend of my cousin, Vipin Shah when they were studying together in UDCT (now ICT). Their friendship continued after they graduated, and his friendship also included connection to my uncle, Narendra Parekh who was also in UDCT and has been a close friend of Prof. Sharma ever since.

When I was doing my Chemical Engineering in then UDCT, Prof. Sharma was our professor. Although he had done cutting-edge research in Chemical Engineering and was already a renowned Chemical Engineer, he was able to understand how to explain complex subjects of Chemical Engineering to students with clarity.

He has coached large number of Chemical Engineering students' batch after batch with impressive clarity and depth. Most of his students have done well in their professional life after graduating. It is worth noting that most of Prof. Sharma's students remember him with great warmth and many have remained in touch with him. The commitment of Prof. Sharma to his students has been so deep that he remembers by name almost every student he has taught even after more than 50 years.

There is no need to elaborate on the international reputation of Prof. Sharma as an excellent Scientist and Chemical Engineer. What amazes most of us is his encyclopedic knowledge about the current state of affairs in Chemical Industry across the world. You name any subject, and he has the latest, facts and figures and latest technology update on all these subjects.

Above all Prof. Sharma has been a remarkable and exemplary human being. In spite of earning all possible accolades, he has never been after fame or money. His sole aim is pursuit of knowledge and dissemination of knowledge while maintaining a close and loving relationship with everyone who comes in contact with him. Such human beings are rare, and we are all fortunate to have benefited from his presence amongst us for so many years.

It is our pleasure to institute the Pidilite Industries Padma Vibhushan Professor M.M. Sharma ICS Centennial Jubilee Award for Leadership of Applied Sciences and Chemical Industry in recognition of his multifarious contribution to education, research, innovation, industry, and government. He is an unbelievable human being; very simple and humble. My tributes to him on this momentous occasion.

FUNCTIONAL POLYMERS FOR ENERGY APPLICATIONS: STRUCTURE, PROPERTY AND FUNCTIONS

S. Sivaram
Indian Institute of Science Education and Research,
Pune- 411 008, INDIA
s.sivaram@iiserpune.ac.in

Abstract

Functional polymers are invisible components of devices used for generating and storage of energy. Examples are proton conducting polymers as membrane electrode assembly in PEM fuel cells, lithium-ion transporting separator membranes in batteries, membranes for hydroxyl-ion transport in electrolysers and as light harvesting materials in organic photovoltaic devices. Polymers were earlier exploited for their insulating or dielectric properties. However, in recent times, it is their functional properties that have made these materials attractive in energy generation and storage.

Separator membrane is a critical component of a battery. It provides a barrier between the anode and the cathode while enabling the exchange of ionic charge carriers from one side to the other. Separators currently used in lithium-ion batteries are made of porous polyolefins. They are rendered porous by a mechanical biaxial extrusion process. As the battery heats up, the protective layer on the anode breaks down followed by breakdown of electrolytes into flammable gases. This, in turn, causes the polyolefin separators to undergo catastrophic shrinkages above 120° C leading to shorting of cells causing sparks that ignite the electrolyte resulting in a fire. The inherent safety risks associated with the separator membranes threaten the continued advances of lithium-ion battery in applications requiring higher energy density.

Polymers are critical to, both, the efficiency of such devices as well as safety in their operation. It is, therefore, not surprising that considerable amount of current research is devoted to the identification of suitable polymer substrates, the ability to transform them into functional materials through chemical and physical methods, as well as better understand the relationship between polymer structure, function and device performance. Functional polymers are, thus, poised to play a significant role in the emerging energy generation and storage devices.

This lecture will provide an overview of this area in terms of the nature of polymers that are of interest and their structure-function relationship [1]. Methods of modifying the polymers will be discussed in

relation to their performance in specific applications. The concept of porosity in polymers will be introduced as a key parameter that defines ion mobility across polymer membranes. The nature of lithium cation solvation and ion pairing in liquid electrolytes as well as its speciation has been probed using ^{7}Li solution state NMR and HOESY NMR experiments as well as ^{7}Li NMR self-diffusion measurements [2]. Porous functional polybenzimidazoles (PBIs) with intrinsic porosities as well as macroporous PBIs have been prepared [3,4]. Their applications as separators for lithium-ion battery will be discussed. Porous PBIs show useful properties as safe and non-flammable separators for lithium-ion battery applications. The influence of porosity on electrical conductivity and kinetics of lithium-ion transport has been studied. Identification of an efficient separator polymer material for lithium-sulfur battery is still a challenge. Some early understanding on principles of designing functional porous polymers that can facilitate lithium-ion transport and at the same time inhibit the transport of polysulfide ion will be illustrated [5]. Functional polymers designed for enhanced lithium intercalation can also find application as anodes in lithium-ion batteries. Some recent results from the author's laboratory in this area of research will be discussed [6].

References:

[1] Vikas Kumar, A. Gupta, C.V. Avadhani and S. Sivaram, Invited Perspective, ACS Energy Letters, 2023, submitted

[2] Vikas Kumar, R. R. Reddy, B. V. N. Phani Kumar, C. V. Avadhani, S. Ganapathy and S. Sivaram**, J. Phys. Chem., C, 2019, 123. 9661**

[3] Vikas Kumar, S. Chatterjee, C.V. Avadhani, P. Sharma, S. Chakraborty, and **S. Sivaram,** J. Polym. Sci., Part A: Polym. Chem., 2018, 56, 1046

[4] Vikas Kumar, S. A. Joshi, R. R. Reddy, B. V. N. Phani Kumar, S. Ganapathy, C. V. Avadhani, and S. Sivaram, in preparation

[5] Aritrajit Gupta and S. Sivaram, Energy Technology, 2019, 7, 1900819

[6] Unpublished results

PRESIDENTS OF THE INDIAN CHEMICAL SOCIETY

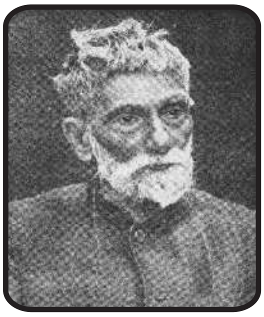
Tenure	Name
1924-1926	Acharya Prafulla Chandra Ray
1927-1928	Professor Gilbert John Fowler
1929-1930	Acharya Prafulla Chandra Ray
1931-1932	Professor Bawa Kartar Singh
1933-1934	Professor Nil Ratan Dhar
1935-1936	Sir Upendranath Brahmachari
1937-1938	Professor Jnan Chandra Ghosh
1939-1940	Professor Hemendra Kumar Sen
1941-1942	Professor Shanti Swarup Bhatnagar
1943-1944	Professor Biman Behari Dey
1945-1946	Professor Jnanendra Nath Mukherjee
1947-1948	Professor Priyadaranjan Ray
1949-1950	Professor Jnanendra Nath Ray
1951-1952	Professor Prafulla Chandra Guha
1953-1954	Professor Mata Prasad
1955-1956	Professor Bires Chandra Guha
1957-1958	Professor Prafulla Kumar Bose
1959-1960	Professor Krishnaswami Venkataraman
1961-1962	Professor Tiruvenkata Rajendra Seshadri
1963-1964	Professor Ramanlal Chhoganlal Shah
1965-1966	Professor Syed Husain Zaheer
1967-1968	Professor Ranchhodji Dajibhai Desai
1969-1970	Professor Jagdish Shankasr
1971-1972	Professor Tuticorin Raghavachari Govindachari
1973-1975	Professor Ram Narayan Chakravarti
1976-1977	Professor Ram Chasran Mehrotra
1978-1979	Professor Sukh Dev
1980-1982	Professor Sailendra Mohan Mukherji
1983-1987	Professor Krishna Kamini Rohatgi Mukherjee
1988-1989	Professor Debabrata Banerjea
1990-1991	Professor Hira Lal Nigam
1992-1993	Professor Y. K. Gupta
1994-1995	Professor Dhananjay Nasipuri
1996-1997	Professor Dewan Singh Bhakuni
1998-1999	Professor Jai Pal Mittal

PRESIDENTS OF THE INDIAN CHEMICAL SOCIETY

2000-2001	Professor Suresh C. Ameta
2002-2003	Professor Sunil Kumar Talapatra
2004-2005	Professor Ramesh Chandra
2006-2007	Professor K. B. Pandeya
2008-2010	Professor Girjesh Govil
2011-2013	Profesor Mahesh C Chattopadhyaya
2014-2016	Professor R N Prasad
2017-2019	Professor Dulal C Mukherjee
2020-	Professor Ganapati D Yadav

HONORARY SECRETARIES OF THE INDIAN CHEMICAL SOCIETY

Tenure	Name
1924-1927	Professor J. N. Mukherjee
1928-1930	Professor H. K. Sen
1931-1932	Professor P. C. Mitter
1933-1936	Professor Priyadaranjan Ray
1937	Professor B. C. Guha
1938-1941	Professor P. K. Bose
1942-1947	Professor Bhupandra Nath Ghosh
1948	Professor J. K. Chowdhury
1949-1954	Professor Dukhhaharan Chakravarti
1955-1956	Professor Sushil Kumar Mukherjee
1957-1960	Professor Monindra Mohan Chakrabarty
1961-1962	Professor Sushil Kumar Mukherjee
1963-1968	Professor Monindra Mohan Chakrabarty
1969-1972	Professor Sukumar Aditya
1972-1975	Professor Debabrata Banerjea
1975-1979	Professor Debi Prasad Chakraborty
1980-1987	Professor Skunil Kumar Talapatra
1988-1989	Professor Hari Gopal Mukherjee
1990-1993	Professor Avijit Banerji
1994-1997	Professor Dulal Chandra Mukherjee
1998-2001	Professor Priya Lal Majumder
2002-2005	Professor Dulal Chandra Mukherjee
2006-2010	Professor Priya Lal Majumder
2011-2016	Professor Dulal Chandra Mukherjee
2017-2022	Professor Chittaranjan Sinha
2022-	Professor Sudip Kumar Das



Acharya Prafulla Chandra Ray
(1924-26, 1929-30)

Born August 2, 1861; D.Sc (Edinburgh, 1887); Assistant Professor and the professor of Chemistry Presidency College, Calcutta(1889-1916); Palit Professor of Chemistry, Calcutta University (1916-1937).

Societies: President, Chemistry Section (1915), General President (1920), Indian Science congress Association: Foundation Fellow National Institute of Science (Now INSA); FCS(London); Hon. Member Deutche Akademie (Munich). Awards and Honours: Gilchrist Scholarship (1882); Hope Prize (Edinburgh, 1888); D.Sc (h.c, Durham, 1912); C.I.E (1911): Knighted (1917).

The first notable work which brought worldwide recognition was the isolation of Mercurous Nitrite (1896). Later works involved the study of compounds of metals with organic sulphur derivatives, particularly the mercaptans and sulphides; double sulphates of triethyl and trimethl sulphonium bases with metal of Cu-Mg Group; similar double salts with phosphonium bases; a number of compounds of Cadmium and mercuric iodides and antimony halides with sulphonium iodides etc.

Prf. Ray cherished the desire for the application of chemical knowledge to the welfare of the country. With his undaunted efforts , savings from his salaries and locally available raw materials sprang up the concern under the name of Bengal Chemical and pharmaceuticals works ltd//. The monumental piece of work, History of Hindu Chemistry bears the testimony to his love for literature and history of Science. He inspired a generation of chemists thereby building an Indian School of Chemists for which he is aptly called the Father of Indian Chemistry and an Acharya(preceptor).

Died on June 16, 1944

Gilbert John Fowler
(1927-28)

Born January 23, 1868. B.Sc (Manchester, 1886), Demonstrator and Lecturer (1886-95)

Chemist and later Superintendent of the Municipal Sewage works, Manchester Corporation (1886); Consulting Chemist to Rivers Committee (1904) D.Sc, Heidelberg (1904) Director, Indian Institute of Science, Bangalore (1915); Professor of Biochemistry (1916-24), Principal, Harcourt Butler Technological Institute , Kanpur (1927-29);

Societies: Honorary Corresponding Secretary for India of the Royal Institute of Chemistry of Great Britain and Ireland; Finally settled in India, Fellow, Royal Institute of chemistry (Council member, 1914-16), Chemical Society of London(President, 1927);Society of Biological Chemists, India(President, 1947-49), Royal Sanitary Institute(Now the Society of Health); Foundation Fellow, National Institute of Sciences of India; Honorary member, Manchester Literacy and Philosophical Society; Member, Industrial research council, Government of India (1937-39); President, Chemistry section, Indian Science congress association (1918).

Made significant contributors to the practical's development of the activated sludge process of sewage treatment which marked a new chapter in environmental sciences and technology.

Died on 21, 1953

Bawa Kartar Singh
(1931-1932)

Born April 17, 1866; D.Sc (Dublin) and Sc.D.(Cantab, 1941);Professor of Chemistry, Government College, Dacca (1910-18); Lahore (1821); I.E.S., Ravenshaw College , Cuttack (1921); Professor and Head, Science College, Patna (1936-40) , Professor and later Emiretus Professor. Allahabad University, (1940-46); Hony Professor and Associate Director, Punjab Institute of Chemistry, Lahore, Hony. Professor, Banaras Hindu University (1948-60).

Societies: President, Chemistry Section, Indian Science congress association (1920), President, Philosophical Society, Lahore (1920).Foundation Fellow, Indian Institute of Science (Now INSA), Foreign Secretary, INSA (1944-46).

Worked mostly in the field of stereochemistry, prepared and resolved substituted azonium compounds with an asymmetric N-atom.

Worked out a new method for the preparation of tertiary amines, studied and kinetics of mutarotation of oxomethylene Camphores; brought out a relation between optical activity and chemical constitution of several types of compounds ad attempted to generalized it. Also studied condensation products of deoxybenzoin with aromatic aldehydes and carried out chemical examination of the fruit and kernel of Palmyra palm.

Died June 15, 1960.

Nil Ratan Dhar
(1933-34)

Born January 9, 1982; D.Sc (London; 1917), Dr. (Paris, 1919), Lecturer, Calcutta University (1913), Professor, Muir Central College, Allahabad (1919), Director of Public Instruction, U.P (1944), Professor and Head, Allahabad University (1946).

Societies: Founder, Shila Dhar Institute of Soil Science, Allahabad, President; Member, International Agricultural Congress (1937); President Chemistry Section (1927), General President (1961), Indian Science congress Association, Corresponding member, Academy of Sciences, France, Member, French Academy of Agriculture, foundation member and President, INSA, Indian Society of Soil Sciences, Foundation member, Society of Biological Society, India, Agricultural Society , India.

Awards and Honours: Griffith Memorial Prize, Calcutta University (1913), Elliot Prize and Medal, Asiatic, Society of Bengal (1914), D.Sc, (h.c, Allahabad, Jadavpur, Gorakhpur, Calcutta, Viswa-Bharati, and Banaras Hindu University),

Made original contributions on the influence of light in nitrogen fixation and nitrogen loss in soils and also relationship between the nitrogen and phosphate status of soils. His work has been extensively quoted in the text books of colloid chemistry, photochemistry and soil science.

Brahmachari, Sir Upendranath
(1935-36)

Born June 7, 1875.M.Sc. in Chemistry (1894), M.B (1898), Ph.D. Calcutta (1904).Additional Physician, Calcutta Medical College, Professor, Tropical Medicine, Carmichael Medical College, In –charge, Tropical disease Ward, National Medical institute, Professor and Head, Physiology Department, Calcutta University , Vice President, Presidency college, Kolkata, Chairmen, Ambulance Association, Bengal; Hony Assistant Surgeon to the viceroy and Governor-general of India.

Societies: Member, Asiatic Society (President (1928-29), Indian Institute of Science ,Bangalore, Member, Society of Biological Chemistry, India, Indian Committee of International Microbiological Congress, Paris, Physiological Society of India, Indian Provincial Medical Service Association, Royal Society of Medicine, London. Royal Society of Tropical Medicine and Hygiene, London; Honorary Fellow, State Medical Faculty of Bengal, International Faculty of Science, London, member, Calcutta

Medical School, Council of School of Tropical Medicine and Hygiene, International congress of Medicine, London(1913), Council of Medical Registration, Bengal, Indian Research Fund Association, Zoological Garden, Calcutta, Board of Trustees of Indian Museum, (Vice-Chairman), Calcutta, Sanitary Board, Bengal.

Awards and Honours: Rai Bahadur (1911), Coates Medal and Griffith prize, Minto Medal (1921), Kaiser-e Hind Gold Medal (1924), Sir Williams Jones Medal; Sectional President(1934, 1936, 1938), Indian Science Congress Association.

Notable contribution was discovery of urea stibamine as the specific medicine in the treatment of Kala-azar, would also remembered for pioneering work in the treatment of Dermal Leishmarold Malari, the old Burdwan fever, Quartan and Black water fever etc, Author of ‘Kala-Azar- its treatment’ and ‘Gleaming from my Mesearches’.

Jnan Chandra Ghosh
(1937-38)

Born September 4, 1983; D.Sc Calcutta University (1918); Lecturer in Chemistry, Calcutta university (1917-20), Professor and Head of the Department of Chemistry, Dacca University (1921-39); Director, Indian Institute of Science, Bangalore (1939-47), Director General of Industries and supplies, Government of India (1947),Director, Indian Institute of Technology, Kharagpur, Vice-Chancellor, Calcutta University (1954), Member, Planning Commission (1955-59); Societies: Member, Royal Society Empire Scientific Conference (London), Common Wealth Scientific Conference (London), Council of Scientific and Industrial Research; Indian Scientific Mission to U.K and U.S.A.(1945); President Chemistry Section (1925), and General President (1939), Indian Science Congress Association; Foundation Fellow and president (1943-44). National Institute of Science of India.

Awards and Honours: Premchand Roychand Scholarship (Calcutta, 1918), Knighted)1943), Made Significant Contributions to Photochemistry, kinetics or reactions, Photosynthesis, electrochemistry, Power engineering, Fermentation Technology and high pressure and industrial gas reactions , suggested the formation of complexes involving the catalyst in the Fischer-Tropsch synthesis of liquid fuel from carbon monoxide and hydrogen, elucidated a stepwise mechanism of ammonia synthesis from its elements. With Scientific attainments he combined administrative ability and had been able to open several new departments in various branches of Science at the Indian Institute of Science, Bangalore. Died on January 2, 1959.

Hemendra Kumar Sen
(1939-40)

Born, 1888, M.A. (Calcutta 1911), Lecturer, City College, Calcutta (1912); D,Sc. London (1915), Chemistry, Tata Iron and steel works, Jamshedpur (1916); Chief Chemist, Sulphuric acid works of Jamal Brothers, and later of DE Souza and Co Burma (1916-19), Professor of Applied Chemistry, Calcutta University (1920-36); Director, Lac Research Institute, Ranchi (1935-44);Director of Industries Bihar (1944-45), Societies: President , Institute of Chemist, , India ;(1930-32) and (1935-36); Foundation fellow, National Institute of Science of India, President, Chemistry Section, Indian Science Congress Association (1927).

Awards and Honours: Premchand Roychand Scholarship (1912), Sukhraj Rai Readership (Paltna, 1927), Adhar Chandra Memorial Lectureship (Calcutta 1931). Devoloped a method of estimation of nitrites and detection of nitrites in presence of nitrates; studied the action of hydrazine and hydroxylamine on alkaline ferricyanide; worked on the condensation of ketones with phenols and naptholes, prepared aldol compounds by condensations of choral with a variety of ketones. Made valuable contributions in fermentation chemistry and developed new uses of Shellac and the improved the method of its manufacture. He is also well known for book entititled "High temperature flames and their thermodynamics".

Died on June 6, 1945

Shanti Swarup Bhatnagar
(1941-42)

Born on February 21, 1884, D.Sc, (London 1921); Professor of Chemistry, Banaras Hindu University (1921-24), Professor and Director, The University Chemical Laborotaries, Lahore (1924-40); Dean, University Instruction, Punjab University, Lahore, Director, Scientific and Industrial Research, Government of India (1940); Secretary, Atomic Energy Commission, Government of India (1947-48), Secretary, Ministry of natural Resources and Scientific Research, Government of India (1951), Chairman, University Grants Commission, New Delhi, Societies Fellow, Royal Society , London(1943), Honorary Fellow and later Vice-President of the Society of Chemical Industry(1945), Foundation fellow and President (1947-48), National institute of Sciences of India; President , Chemistry Section, (1928 and 1938) and General President (1945), Indian Science Congress Association ; Chairman, Indian Scientific Mission to U.K AND U.S.A(1945); D.Sc (h.c) Oxford. Patna, Allahabad, Delhi, Punjab, Benaras, Lucknow, Agra and Saugor.

Awards and Honours: Knighted (1941), Recipient of special award of Altock oil Co, Rawalpindi, Padma Bibhusan. Well known for its outstanding contributions in magnetochemistry and emulsions. Devised the method for lowering the viscosity of mud suspension by the addition of an Indian gum and stabilizing against the flocculating action of electrolytes. Designed the well-known Bhatnagar-Madhur Balance very useful for determining changes in diamagnetic susceptibilities very small far its stability and quick operation. It was taken up Adam Hilgee & Co. Made extensive original researches on the conversion of emulsions by electrolytes. He is the author of the well-known book "Principals and Applications of Magneto-chemistry"

A dynamic Scientist with great administrative capabilities, professor Bhatnagar was responsible for the establishment of a chain of National Laboratories in the country when he was the director of Scientific and Industrial Research.

As a tribute to his Contributers, the C.S.I.R (India) instituted the prestigious Shanti Swarup Bhatnagar Prizes in 1957 to awarded for outstanding scientific work.

Biman Behari Dey
(1943-44)

Born November 1, 1889. D.Sc (London 1915); Professor of Chemistry, Presidency College, Calcutta University (1916-20) Professor of Chemistry, Presidency College, Madras (1938). Director , Director, Public Instruction, Madras (1944-46): Director of Researches, CSIR, India, Director, Biochemistry Department, University of Madras (1948-50), Director, Central Electrochemical Research Institute (1953-57).Societies: President , Chemistry Section, Indian Science Congress Association (1926); Foundation fellow, National Institute of Sciences of India, Fellow, Royal Society of Chemistry.

Made Notable contributions in the fields of plant products, biochemical problems, became famous for his works on peroxidases. During Second World War supplied scores of strains to the army for use in biological analysis. By carrying out purification of commercial dyes and tens of thousands of ampules of pituitrin to hospitals by processing pituitary glands collected from the slaughter houses in Madras, also developed an electrolytic process for the production of some important dyestuff intermediates.

Died on January 18, 1956

Jnanendra Nath Mukherjee
(1945-46)

Born April 23 1893 (Calcutta M.Sc. 1915); Assistant Lecturer and lecturer in Chemistry. Calcutta University (1915-19); D.Sc (London 1921); Professor of Chemistry Calcutta University (1921-45), Director, Indian Agricultural Research Institute, New Delhi (1945); Foundation Director, Central Building Research Institute, Roorkee; Leader, Indian Delegation Imperial Bureau Review Conferences (1946); Leader Indian Delegation Commonwealth conference of

Social Scientists, London (1948) Societies: President Chemistry Section (1929), General President (1952), Indian Science congress Association :Fellow, Indian Academy of Sciences, Indian Chemical Association and Royal Institute of Chemistry, London, Member Council (1935-38);Additional Vice President (1930-40 and 1952)Vice President (1941-42), Foreign Secretary (1943-44) and 1947-51) and Editor of Publications (1945-46), National Institute of Sciences of India.

Awards and Honours: Premchand Roychand Scholarship Mouat Medal (Calcutta 1916) C.B.E (1944), Chairman, Committee on Social conservation and afforestation, National Planning Committee (Indian National Congress).Made outstanding contributions to colloid chemistry electrochemistry of clays and soil science, founder of the colloid research laboratory in the University College of Science, Calcutta, was also a pioneer in the field of Chemical Engineering in India. He was mainly responsible for the formation of the Indian National Science Academy and the Indian Chemical Society.

Died on May 10, 1983

Priyadaranjan Ray
(1947-48)

Born January 16, 1888 M.A. (Calcutta 1911); Professor of Chemistry, City College, Calcutta; Assistant Palit Professor, (1919), Khaira Professor (1937),Later alit Professor of Chemistry and Head 91952).University of Calcutta, Honorary Professor and later Director (1956-58) , Indian association for the cultivation of Science, Calcutta. Honorary Secretary (1933-35), Societies: President (1958-59), Indian Science News Association; Foundation Fellow, National Institute of Sciences of India; President. Chemistry Section; Indian Science Congress Association(1932) Acharya P.C.Ray (1954), Acharya J. C. Ghosh Lecturerships (1963), Indian Chemical Society, Mahendra Lal Sircar Memorial Lecturerships (1960), Indian Association for the cultivation of Science; Rajsekhar Bose Memorial Lectureships (1963) and Sivaprasad Chatterjee Memorial lectureship (1973), Bangia Vignan Parisad ; S.S Bhatnagar Memorial Lecturer (1968), Indian National Science Academy; J.C Bose Memorial Lectureship (1971), Bose Institute.

Carried out extensive work in inorganic, Analytical and nuclear chemistry, introduced substances like rubeanic acid and its derivatives, quinaldinic acids, dimercaptothiozole biguanide, cystine etc as useful analytical reagents for volumetric gravimetric and spectrometric determination of metal, established for the first time the isomerism of thiosulphuric acids, regarded as an authority on coordination complexes, valency and microchemistry and pioneer in the field of magneto-chemistry in India ; Isolated of ^{60}Co for the first time ; using radioactive isotope of Iodine ^{128}I could prove that there is no essential difference between normal co-valency and cooperative covalency.

With meticulous care professor Ray Revised Acharya P.C,Ray 's books History of Hindu Chemistry updated it into History of Chemistry in Ancient and medieval India. He also made scientific synopsis in English of Ancient Ayurvedic texts, Charka Samhita and Susruta Samhita published by Indian National Science Academy.

Died on December 11, 1982

Jnanendra Nath Ray
(1949-50)

Born February 1897; D.Sc (Manchestar 1934); Professor OF Pharmacology and Chemistry, Punjab university, Lahore; Director Drugs and Dressings, New Delhi, Technical Advisor, Planning Department, Government of India; Honorary Professor of Chemistry of Bombay University, Advisor, M/s Calcutta Chemicals, Calcutta; Societies: Fellow Royal Institute of Chemistry. London (President, India Branch), National Institute of Sciences of India; President, Chemistry Section, Indian Science Congress Association (1937).

Honours: O.B.E well known for pioneering work on alkaloids and steroids and chromatographic techniques, made notable contributions to anesthetics. Under his leaderships, Calcutta Chemicals, Calcutta become a center for research activities.

Died on April 9, 1970

Prafulla Chandra Guha
(1951-52)

Born February 15,1894;D.Sc (Calcutta 1923); Reader in Chemistry, Calcutta University; Professor and Chairmen, Department of Organic Chemistry, Indian Institute of Science, Bangalore, Societies Foundation Fellow, National Institute of Science of India; President, Chemistry Section, Indian Science Association (1936).

Did pioneering work on the synthesis of mono and sesquiterpenoids and bridged bicyclic compounds; on geometrical isomerism, steric hindrance, steric effect in aromatic substitution and heterocyclic compounds and heterocyclic compounds, pioneered work on synthetic drugs and developed preparative synthetic methods for well-known antimalarials, sulphur drugs, local anasthetics and a variety of other useful products. He would also be remembered for his notable contributions to the study of Indian essential oils and naturals products.

Died on November 6, 1962

Mata Prasad
(1953-54)

Born February 15,1898; D.Sc (Banaras Hindu University, 1925), Professor, Physical and Inorganic Chemistry and later Principal (1946-53), Royal Institute of Science, Bombay; Director, Salt Research Institute (Later renamed as Central Salt and Marine-Chemicals Research Institute, Bhavnagar) Vice Chancellor, Vikram University, Ujjain (1956-60),Emeritus professor of Chemistry, St John College, Agra, Societies: Fellow, Indian Academy of Sciences, National Academy of Sciences ,India (1935).Chairmen Salt Research Committee D.Sc (h.c) Vikram University, P. C. Ray and J. C. Ghosh Memorial Lecturership, Indian Chemical Society, H.K.S Memorial Lectureships, Institute of Chemists, India.

Made notable ontributions in the field of sol-gel transformations and thixotrophy; preparation and characterization of oxides of Nickel. X-ray crystals structure, and photochemistry. Later, become interested in measurements or magnetic susceptibility and its correlation with structure of complex molecules. Devoloped a method of producing high purity salt from sea water and is olsling potassium chlorides and bromine from bitts.

Died on 1979

Biresh Chandra Guha
(1955-56)

Born June 8, 1904; D.Sc.(London) Chemist; Bengal Chemical and Pharmaceutical work (1932), Professor n Applied Chemistry and Head of the Department of Applied Chemistry, Calcutta University (1936), Chief Technical Officer , Department of Food, Government of India(1944);

Societies: Fellow National Institute of Sciences of India (1941); Member, Indian Science Congress Association: Association of Scientific Workers of India; President, Chemistry Section (1946) and General President (1962), Indian Science Congress Association: most important contribution was on ascorbic acids biosynthesis, made extensive investigations for determining the role of kidney and liver in providing the key enzymes systems mediating ascorbic acids synthesis in amphibians, reptiles, avian, and other species which laid the basis at the molecular level of for the biochemical mechanism of formation of this vital metabolite in different species in their evolutionary stages also worked on problems of coal gasification and waste utilization in the interest of the National Economy and developed methods for utilization of Jute wastes, large scale microbiological rating of Jute, Fermentative production of citric acid and gluconic acids initiated studies on the Biochemistry of tea leaves at the various stages.

Under his dynamic leaderships the department of applied Chemistry of the University of Calcutta had risen to the highest peak of its reputation, He was also instrumental for the creation of the Department of Biochemistry in the University of Calcutta. A Research Institute, Under the university of Calcutta, built after his death bears the name.

Prafulla Kumar Bose
(1957-58)

Born September 5, 1898; D.Sc (Calcutta 1927); Lecturer in Chemistry, Calcutta University (1934-42), Deputy Director, Drugs and Dressings DGIMS; Director, Indian Lac Research Institute, Head, Department of Chemistry, and later joint Director, Bose Institute Calcutta, Emeritus Scientist, CSIR, India.

Soaictius: Fellow, National Institute of Sciences of India (1944); President, Chemistry Section, Indian Science Congress Association (1947).

Awards and Honours: Premchand Roychand Scholarships, Mouat medel, Nagarjuna Prize and medal (Calcutta), H. K. Memorial Medal (1957), Institution of Chemist, India, P. C. Roy Memorial Lecture (1960), Indian Chemical Society.

Well known for his pioneering work in the field of phytochemistry, particularly on coumarins, flavonoids and alkaloids. Under his leadership the phytochemical reaction of Bose Institute had flourished to a center of great reputation; also made significant contribution to synthetic organic Chemistry and to the chemistry of marcaptans.

Died on November 1, 1983

Krishnaswami Venkatraman
(1957-58)

Born June 7, 1901; D.Sc.(Manchester); Reader, Technical Chemistry, Department of Chemical Technology, University of Bombay (1935-38); Professor of Organic Chemistry, Forman Christian College, Lahore (1929-34), Mody Professor Of Chemical Technology and Director, Department of Chemical Technology(1938), Director , National Chemical Laboratory, Poona; Societies. F.R.C Fellow, London; F.C.S.(London), Fellow, Institution of Chemists, India, Indian Academy of Sciences, National institute of Sciences of India(1939), Member, Indian Science Congress Association; Associate, Institute of Chemical Engineers; President, Chemistry Section (1945),Indian Science Congress Association .

Awards and Honours: T. R. Seshadri 70th Birthday Commemoration Lecture (1975).Well known for outstanding contribution to technical chemistry, particularly synthesis of acacetin groups, worked on oxycellulose and hydrocellulose, antiseptics, anthelmintics chemical process and technology; made notable contributions on flavonoids and xanthones. He will be particularly remembered for the well-known Baker-Venkataraman Transformation. He is the author of the well-known book “the Chemistry of synthetic Dyes”, Vols. 1 to VI.

Died on May 12, 1981.

Tiruvenkata Rajendra Seshadri
(1961-62)

Born February 3, 1900, Ph.D,(Manchester, 1930); Professor of Chemistry, Andhra University , Waltair (1937-49), Head and Emeritus Professor, Department of Chemistry and center of Advanced study for the chemistry of Natural Products, Delhi University (1949-75);

Societies: Fellow, Royal Society, London; National institute of Sciences of India (1942), President Indian Academy of Sciences, Indian Pharmaceutical Association, Oil Technology Association and Indian Pharmaceutical congress ; North India Section, Royal Institute of Chemistry.

Awards and Honours: Cochbehar Professorship, Indian Association for the cultivation of Science, Calcutta; H. K. Sen Lecturership, Institution of Chemists, India, B. C. Guha Lecturership, Indian Science Congress Association, B.M. Singh Lectureship, Punjab University, K. Venkataraman Lectureship, Bombay University, Honorary Professor, Andhra and Osmania University, Acharya P. C. Ray, Memorial lectureship, Indian Chemical Society, Acharya Gnanendra Ghosh Medal, Calcutta University, Shanti Swarup Bhatnagar Medal and Meghnad Saha Medal, Indian National Science Academy; Ph.D, (h.c),(Andhra, Banaras, Delhi, Osmania), President Indian National Science Academy, (1967-68), General President, Indian Science Congress Association (1967);Awarded Padma Bhusan (1963).

Well known for extensive work on various types of oxygen heterocycles. Converting essential methylation of anthoxanthins and glycosides; oxidative and selective demethylation, nuclear oxidation, reduction, hydrogenation and dehydrogenation,anthocyanins;leucoanthocyanides and quionoids; anhydrobases and nuclear methylation, allylation and prenylation, Studies on Wesley-moser rearrangement, alger-flynn-Oyamada reaction and reaction of chaconne, epoxides;synthesis of furano-chromones, Chromeno-chromones and chromeno-flavones, flavonones, and isoflavonones, neoflavonoids,cyanomaclurin, bioflavonoids, pterocaptans, santalin pigments, bicoumarinyl, flavonolignans, C-glycosides. He also studied chemistry of lichen substances and terpenoids and theories of biogenesis.

Died on September 27, 1975

Ramanlal Chhganlal Shah
(1963-64)

Born October 7, 1899; Ph.D (London, 1931); Head, Department of Chemistry, Ismail Yusuf College, Bombay; Professor of Organic Chemistry, Institute of Science, Bombay, Assistant Director, Deputy Director and Head, Organic Division, National Chemical Laboratory, Poona, Development Officer (Antigas) and deputy Director of Chemicals, Government of Bombay; Secretary of Chemicals Sub-committee of the National Planning committee.

Societies: Fellow, Indian Academy of Sciences, National Institute of Sciences of India (1941), Chairman, IUPAC(1965), President Chemistry Section, Indian Science Congress Association (1951), President, Gujrat Parisad (1949), Acharya Prafulla Chandra Ray Medal, Indian Chemical Society; K.G. Naik Medal, M. S. University of Baroda

Major areas of his research include (i) imidochlorides (ii) coumarins and chromones (iii) g-substitution in resorcinol nucleus (iv) fixation of the kekule double bonds, (v) chemistry of natural products like oroxylin, wogonin, calycopterin, anacardic acids etc(vi) saccharin, chloramine-T and synthetic drugs.(vii)D.D.T and synthetic insecticides. Of special interest was the use of dry ether as a solvent for anhydrous $AlCl_3$ for pechmann reaction; invented a new process for the manufacture of Chloramine-T, which was taken up by the Government of India for the indigenous manufacture of antigas ointment No. 2 for the Defense services.

Died on September 6, 1969

Syed Husain Zaheer
(1965-66)

Born 1901; Studied at oxford and Heidelberg; lecturer in Lucknow University, Elected Member of the U.P legislative Assembly to represent the University constituency :Parliamentary Secretary to the Education Minister, Government of U.P, Took active part in the Indian freedom movement and was imprisoned during 1940-42; Principal, Government City College, Hyderabad (1946) and ;later Director, Central laboratories for Scientific and Industrial Research (Since renamed Regional Research laboratory, Hyderabad) and concurrently professor and Head, Department of Chemical Technology, Osmania University; Director General , CSIR, India(1962).

Awards and Honours: Recipient of K.G Naik Gold Medal, M.S. University of Baroda and H. K. Sen lectureships. Institution of Chemists, India; Awarded Padma Bhusan. Prof Zaheer put an emphasis on utilization of coal and development of relevant Technology. It is largely on account of his vision that India today possesses expertise of very high order in the field of coal Technology.

Died on December 22, 1975

Ranchhodji Dajibhai Desai

(1967-68)

Born May 4, 1897, D.Sc. (London 1931); Professor, Department of Chemical Technology, University of Bombay, Principal, M. G. Science Institute, Ahmedabad.

Societies: Fellow, Royal Chemical Society, Indian Academy of Sciences, Indian institute of Sciences and National Institute of Sciences (1942),President chemistry Section, Indian Science congress Association (1952).

Awards and Honours: Acharya P.C.Ray Memorial Lecturership (1965), Indian Chemical Society

Notable contributions were concerned with (i) the strainless character of alkyl cyclopentene and alkyl cyclohexane rings on the basis of valeruydeflexion,(ii)studies on kostanecki, Fries and Friedel–crafts reactions (iii) tautomerism of metero-triads, (iv) new methods for the synthesis of coumarins, chromones, xanthones, quinolones and acridones, (v)Vat dyes from phenanthraquinines (vi)g-substitution in aromatic compounds (vii) fluorescent brightening agents (vii) azoic dyes using hydroxyketones as coupling agents.

Died 1991.

Jagdish Shankar

(1969-70)

Born October 3, 1912, Ph.D, (Bombay 1940), Head, Chemistry Division, Bhaba Atomic Research Centre; Advisor to Department of Atomic Energy, Director, Science Research Council, UGC; Professor, Centre for Ecodevolopment, University of Kashmir, Societies: Fellow, Indian Academy of Sciences and National Institute of Sciences of India (1969).President: Chemistry section.(1964,1965).Indian Science Congress Association.

Made outstanding contribution to the study of the consequences of recoiling atoms solid metal complexes and radiation damage. Another area which made-extensive study Radiation Chemistry of aqueous solution substances using ^{60}Co Gamma Rays. His postulate that the ejected electron from a pair with an ion molecule has been widely accepted. He also worked on X-rays and crystal structure.

Died January 31, 1992.

Tuticorin Raghavachari Govindachari

(1971-72)

Born 30th July 1915, Ph.D (Madras 1946); Chief Professor (1952-62), Principal (1961-62), Presidency

College, Madras, Director, Ciba-Geiba Research Centre (1963-75), Consultant to CLRI, Madras, (1976-78), Director, Amrutanjan Limited(1977-86), Advisor, Spic, one of the founder of NOST.

Societies: FNA (1959), FASc Fellow, Indian Chemical Society, Member, INSA Council

Awards and Honours: S. S. Bhatnagar Prize (1960), Meghnad Saha Medal (1975), Golden jubilee Commemoration Medal of INSA, Acharya Prafulla Chandra Ray Memorial Lectureship (1976), Sir J. C. Ghosh Memorial Lectureships and Medal (1975), And P. K. Bose memorial Lectureships (1989) of the Indian Chemical Society, Plenary Lectureships at the first IUPAC natural Products symposium, Memberships of the Bureau of IUPAC.80th Birthday Commemoration issue (1997), Indian Chemical Society.

For nearly six decades Professor Govindachari has been studying the vast flora of this country with his single-minded devotion, unparallel perseverance and incisive chemical insight. Over the year his research groups have isolated diverse classes of complex natural products like alkaloids, oxygen hetercycles and terpenoids, many skeletal patterns were not encountered earliar nature. Some of them showed potent biological activities. He discovered a rich source of anticancer alkaloid comptothacin. Currently he is working on the antifeedant principals of neem and plant sources with pesticidal properties.

He guided a number of Ph.D students and published a large no of papers

Ram Narayan Chakravarti
(1973-74)

Born august 1916, D.Sc (1945), post Doc: (With R Robinson, Oxford, 1945-47,) Professor of Chemistry and Deputy Director, Calcutta School of Tropical Medicine,(1948-68), Director, Indian Institute of Experimental Medicine (now IICB), Calcutta (1968-76); Emeritus Scientist, CSIR(1976-78), Director and R& D. Dey, Medical stores (MFG) ltd, Calcutta,

Societies: FNA (1956) Member, Asiatic Society, Institution of Chemistry (India), Indian Public Health Association, Indian Chemical Society, Indian Science congress association, Indian Association for the cultivation of Science, Indian Science News Association, Foreign Member, Swiss Chemical Society.

Awards and Honours: K.G. Naik Medal (1964), Baroda University, P. C. Ray, Indian Chemical Society, Capt. N. N. Medal (1969), Calcutta medical Club, Sisir Kumar Mitra Lectureship (1972), INSA; Padma Bhusan (1972), H.K.SEN Medal (1976), Institution of Chemists (India), Barcley Medal (1979), Asiatic Society, Member and add member , INSA Council (1965-67, 1982).

Dr Chakrovarti's significant research achievement are :Raney Nickel isomerization and finalisation of structure if strychnine; use of LAH in steroids and partial synthesis of a-spinasterol and Vitamin D3; synthesis of complex counmarins; isolation, degradation and synthesis of plant products; pioneering work on Diosgenin of Dioscorea Deltoidea, D.Prazeri; Kallastromia pubesens, etc, basic products for establishment of Indian Steroid Industry, Malda paralysis (TOCP poisoning); Epidemic dropsy (argemone poisoning); HCl cum Flouroscence spot Test for detection of tonic argemone contamination; basic work for establishment of medicinal plantation at Rongo, Dargeeling. Published many important research papers and guided a number of Ph.D. students.

Ram Charan Meherotra
(1976-77)

Born on February 1922, D.Phil (Alld), Ph.D (1952), D.Sc(1965, London), Professor Emeritus (Chemistry), University of Rajasthan, Teacher in Universities of Allahabad, Lucknow, Gorakhpur and Rajasthan, Former Vice-chancellor, Rajasthan, Delhi and Allahabad Universities.

Societies: FRIC, FNA Sc, FASc, FNA(1964), FFACS; 60th birthday commemoration Issue of the Journal of the Indian Chemical Society, AND J, Organometallic Chemistry were published.

Awards and Honours: S. S. Bhatnagar Prizes (1965),FICCI Award(1975); Seshadri Award , INSA(1976), P. C. Ray(1977), J. D. Ghosh(1982) and P. K. Bose (1997), Awards of the Indian Chemical Society; Clarence Karcher Awards, USA(1982), Golden Jubilee medal of Ins Science Bombay (1984);First Foundation Lecture, FACs, Seoul (1987), Dhar Awards, Nat. Sci Academy (1991), popularization of Science Highest Awards. U.P. and National (1985,1988); distinguished service (1988), Chatterjee (1991), Asutosh Mukherjee (1993), and P. C. Ray, (1988), Awards of Indian Sc. Congress Assoc.; Life-time Achievement (1999), Invited to deliver plenary lectures at dozens of sessions of International Conferences of Co-ordination; macromolecular; organometallic; and sol-gel chemistry.

Member: International Advisory Committee of the above International Journal. The Indian Chemical Society published his 60th birthday Commemoration Issue.

Research interests includes synthetic element-organic chemistry, especially first synthesis of alumunium tricarboxylates, followed by synthesis and structural elucidation of a large number of compounds , many of them containing M-O-C bonds, Guided over 100 Ph.D students and published over 700 original papers and dozens of review and invited articles.

Sukh Dev
(1978-79)

Born 17 June, 1923, (Chakwal now in Pakistan), M.Sc (Punjab, 1945)(Ph.D.1950; D.Sc.1960; IISC Bangalore, Post Doc :Cambridge, with Professor J.D. Roberts (1950), University of Illinois, Urbana with Professor E J Corey(1957-58),IISC, Bangalore an NIS senior research fellow (1951-53) and a lecturer in organic chemistry(1953-59).

Head (1960-74) of the division of the organic chemistry, Assistant Director (1960-68) and Deputy Director (1968-74) of the NCL, Pune, Director (1974-88), Malti-Chem Research Center, Nandesari, Baroda; Consultant (since 1994) to several chemical companies with natural and synthetic organic products, both in India and Abroad; Visiting professor (since 1996) in Dr B R Ambedkar centre for biomedical research , Delhi University.

Societies: FNA (1968), FASc (1974), Life Member, Indian Chemical Society.

Professor Sukh Dev's enormous scientific contributions have earned him many coveted Awards and Distinctions, Notably : Guha Research Medal(1958) of the IISC, Bangalore ; S. S. Bhatnagar Awards in Chemistry(1964), Acharya P.C. Ray memorial medal (1970) of the Indian CHEMICAL Society; INSA Viswakarma medal (1979), ACS Ernest Guenther Award (1980), FICCI Awards (1980), Professor T.R. Seshadri 70th Birthday Commemoration Medal (1981), INSA Meghnad Saha Medal (1987), IUPAC Secretary(1983-85), Vice President (1985-87), President (1987-89),; Third World Science Academy Award in Chemistry (1988),Trustee(since 1983), and chairmen (1987-91), of the NOST, Srinivasa Ramanujan Birth Centenary Award (1992) of the ISCA; Member , Honorary Editorial Advisory Board; Tetrahedron(1979-95), Tetrahedron Letters(1979-95),Tetrahedron Asymmetry (1990-95), Tetrahedron Computer Methodology, Member , Editorial Committee, Wealth of India (1980-90) and Dictionary of Organic Compounds(5th Edition);INSA S N Bose Research Professor (1988-93), IIT, New Delhi.

Plenary Speaker (18)/ President (2)/ Chairman at several International symposia and Seminar and in 1990 organized (Chairman) the 17th IUPAC. International Symposium on the Chemistry of Natural Products, New Delhi. One of the founders of NOST, 75th Birth day Issue (1998) by and lifetime achievement awards from the Indian Chemical Society.

His research interests include natural products chemistry especially terpenoids and ayurvedic drug plants, non-benzenoids aromatic systems, organic reagents and reactions photochemistry and new technology development. Several Process and products developed are in commercial production.

92 students have received their Ph.D Degree from various Indian Universities for work carried out under his direct supervision. He has to its credit over 375 publications including more than fifty patents. He is the author /co-author of nine books and several other book chapters.

Prof Sukh Dev firmly believes that we should explore science not only for curiosity sake, but should also exploit it as a tool for country's economic development.

Sailendra Mohan Mukherji
(1980-82)

Born 1 November, 1915, M.Sc,(1937, C.U), D.Sc. (1944, C.U),Ph.D (1948,U.K),Post Doc (Oxford with A J Fisher), INSA Sr Research Fellow, (19490, Reader, IACS(1950), professor and Head Punjab University (1951-61), Professor and Head (1961-80), Hony Professor (1981-82), Kurukshetra University.

Societies: FNA (1959), Life Member, Indian Chemical Society and served the society in various capacities, Indian Science Congress Association.

Awards and Honours: President, Chemistry Section (1965-66), Indian Science Congress, delivered invited lectures in a number of Rumanian Universities and Research Centers (1972).

Prof Mukherjee made original contributions in organic chemistry, particularly in alicyclic and homocyclic group of compounds such as terpenoids (such as synthesis of zingiberene), steroids, sex hormones, (such as synthesis of 19 nor testosterone), poly-nuclear aromatic hydrocarbons including a number of carcinogenic hydrocarbons. Of special significance is his discoveries and development of acid catalyzed alkylation reaction now internationally quoted as the Colonge-Mukherji Reaction .Prof Mukherji collaborated with Prof A J Birch at Oxfordin the development of metal-ammonia reduction, now generally known as the Birch Reduction.

Professor Mukherjee possesses unusual fair for research one said by Sir Robert Robinson. Co-authored two valuable books published 100 original research and articles; an outstanding and inspiring teacher guided 25 Ph.D Students.

Collaborative work with N. P. Bnn-Hoi Institul du Radium. Pass (1958) with I. F. Fisher Havard, (1947-48).

Krishna Kamini Rohatgi Mukherjee
(1983-87)

Born 2 August 1924 (Patna), M.Sc (1945) Ph.D (Oxford with E J Bowen, 1952), Sir P C Ray Research Fellow, Reader (J.U 1958). Professor (J.U 1974), Head (Chemistry, J.U 1979-82), Asst. Professor (Chemistry, IIT Kanpur, 1963-64), Vising Scientist (JNU, New Delhi, 1973-74).

Societies: FNA (1985), Foundation Secretary, Indian Photobiology Society (1963) (Affiliated with International body, 1964), Life Member, Indian Chemical Society,

Awards and Honours: Basanti Devi Gold Medal (B.Sc), Jagamaya Devi Gold Medal (M.Sc).1 st Asian to act as Chairperson, Commission on Photobiology under IUBS (1984-88).President, Tenth International congress on Photobiology (1988) Jerusalem; President ; Chemistry Section, Indian Science Congress Association. She also served as member of Scientific organization; National Committee on Environmental Planning and Coordination (1977-79).Chemical Research Committee (CSIR, 1982-86).

Extensively travelled in connection with academic assignments, presenting papers, delivering invited talks, cultural exchange programs etc.

She has published a large number of original research paper and guided many Ph.D Students.

Debabrata Banerjea
(1990-1991)

Born 1929, M.Sc(1950)(With Priyadaranjan Ray, 1955), D.Sc(1968).Post Doc (With R G Pearson and F Basalo, USA), Teacher /Reasearcher in St Xaviers college, Calcutta, Gauhati University, NCL, Pune, R E College, Durgapur, IACS, Calcutta and Sir Rashbehary Ghosh, Professor of Chemistry, Calcutta University.(1970-94) and Head of the Dept.

Societies: FNASc (1979), Foundation Fellow, West Bengal Academy of Science and Technology, Fellow of the Chemical Society, London (Now RSC (1978)), Life Member (1950), Indian Chemical Society, served the society in various capacities.

Awards and Honours: Recipient of several awards of Indian Chemical Society, Sir P.C Ray memorial gold medal of St Xavier's College, Calcutta, Convener, XX-ICCC, India (1979), Delivered Invited Lectures at the Alfred Werner Centennial Conference, Denver (USA)(1993) and 10 other International Conferences; Spent Short Periods in many Countries as visiting professor / Scientist and for attending conferences, delivering lectures etc.in various foreign Universities and also for collaborative research, Indian Chemical Society Published.

At IACS and CU he established an active school of research in dynamics and mechanisms of reactions of metal complexes and is regarded as the pioneer in this field in India.

Published about 180 research papers, including articles and review and 5 advanced level books; guided several Ph.D students.

Hira Lal Nigam
(1990-1991)

Born 1 October 1922, Deorajnagar Village (MP), D.Phil (Allahabad with N R Dhar, 1949), Ph.D(University of London) with Sir Ronald Nyholm); Teaching in Allahabad University , (1947-82), Indore University (1976-1977) (Invited to organize the post-graduate Department) Vice- chancellor, APS University, Rewa (1982-88), Chairman environmental Planning & Coordination Organization (Rural wing), Govt of MP(1983-87).

Societies: FNA (1977), FNASc (1952), Member of the Council (1976-84), Life Member, Indian Chemical Society and served the society in various capacities.

Awards and Honours: Member state council of Science & Technology, U P Govt (1972-78), P.C. Ray Memorial Medal (1987), J. C. Ghosh Memorial Medal (1988), Indian Chemical Society. Leverhulme visiting Fellowship (1999),D.Sc (h),S.S.J.M University of Kanpur (1998).

65th Birthday Commemoration Issue (1993), Indian Chemical Society.

Extensively travelled in connection with academic assignments, presenting papers, delivering invited talks, cultural exchange programmes, and guest of honour at quinquineal Mendeleev Congress (1981).

He has made significant contribution in the study of metal-ligand bond with regard to fundamental probes like oxidation state, coordination number, and stereo-chemistry and pioneering work in India on the application of X-ray Absorption Spectroscopy to coordination compounds. In course of his works on metal carbonyls, using O-phenylence-bis-dimethyl di-tertiary arsine as a ligand, he was able to stabilize for the first time Fe(I), and seven co-ordinate Mo(II).The first tetra-substituted hexacarboyls of group VI were also synthesized and characterized.

His other interest lie in correlation of redox and spectral properties of co-ordination compounds where using polarographic method, he has made valuable contribution.

Activation of small molecules has interested him greatly and he published the first-ever review on the chemistry of thionitrosyl (NS).Review on chemistry of COS with transition metal has also been published.

Published 150 research paper and guided two dozen Ph.D students.

Y .K. Gupta
(1992-93)

Born 24 December 1924, M.Sc(1951), Ph.D(1958). Teacher in DAV college, Kanpur; DSB Government College, Nainital; MLN Regional Engineering College, Allahabad, and Professor and Head (1981-82) at Rajasthan University, Jaipur; Emeritus Scientist of CSIR(1987-92).

Societies: Foundation Secretary and Later President, Association of Kinetics of India, FNASc, Life Member, Indian Chemical Society.

Awards and Honours: Awards of Uttar Pradesh Government for writing monographs (Hindi): 'Phase Rule and its application' and 'Mechanism of Electron transfer system'; National representative for six years in the Kinetics division of IUPAC.

Research interest includes, work on the mechanism of redox system and Analytical Chemistry. Some of the significant system which he studied and introduced for the first time in the country, consisted of Thallium (III), Peroxidiphosphate, permanganate, and peroxidisulphate as standards. He established how variation of stoichiometry could be correlated with the mechanism. He proved the existence of IODITE during the reduction of iodate, and the oxidation of iodide in acid solutions.

Published about 200 research papers and one comprehensive review on Hydrogen-ion dependence of the rates and mechanism; guided 43 Ph.D students; wrote the text book of Physical Chemistry for B.Sc students and several popular scientific articles of general interest and delivered lectures extensively throughout the country even after retirement.

In his younger age he did some original writing in Hindi in the form of poems and short stories, and was sub-editor of a monthly magazine 'Gahoi Bandhu'.

Dhananjay Nasipuri
(1994-95)

Born 1 April, M.Sc (1948, CU). (Ph.D, 1956; D.Sc. 1964, CU), (Lecturer 1950-61; Reader 1962-68; Head), Research Scientist (Under Colombo plan with Professor A J Birch, Univ, Manchester 1957-58).

Societies: FNA (1978), FASC (1976), elected FRIC (London) in 1966, Life Member, Indian Chemical Society and served the society in various capacities.

Awards and Honours: Leverhulme Visiting Fellow, University of New South Wales, Australia (1968), Royal Society Bursar Fellow (Senior), Dyson Perrin Laboratory, Oxford University (May-July, 1977), Visiting Fellow (Notre Dame, USA 1963-65 and North Carolina (Short stay) with E. L. Eliel), Visiting professor, Faculty of Forestr, Univ.Toronto (Sept.1986-March 1987), CSIR Emeritus Scientist (1986-90), INSA Senior Scientist (1990-92), IICB, Calcutta. Basudev Memorial Lectureship (1962), Indian Chemical Society. Fulbright Travel Grant (1963), Khudiram Bose Memorial Lecturership (1966), Adhar Chandra Mukherjee Memorial Lectureship (1983), CU, 5^{TH} Birthday Commemoration Issue (Indian Chemical Society. Nov-Dec, 1999).

His Scientific Contribution includes stereoselective and enantioselective reducing agents, Study of energy barrier around some crowded aryl-C and aryl-N single bond by Dynamic NMR, biomimetic synthesis, synthesis of homocycles, heterocycles, mechanism of reaction including Birch reduction, SET mechanism etc.

Published 130 original research papers and guided 25 Ph.D students.

Dewan Singh Bhakuni
(1996-97)

Born D.Phil (Allahabad), Ph.D (London), D.Sc. (London) DIC

Societies: FNSc, FNASc, FNA, Members Chemical Society (London) Chile Sci Cong. and Indian Sci Cong Assoc

Awards and Honours: S S Bhatnagar Prize (1975), Ranbaxy Research Award (1988), Sir C V Raman Award (1989), Delivered Platinum Jubilee lecture, Indian Science Congress Association(1993); Dr RC Shah Memorial Lecture (1993), Biresh Chandra Guha Memorial Lecture (1985), Dr Sukh Dev Endowment Lecture(1995)Delivered Plenary/invited Lecture in National and International Conferences; Vising Professor, University of Concepcion, Chile, Vising Scientist, Institute de chimie des Substances Naturelles, Gif-sur-Yvette, France; Stevens Institute of Technology, Hoboken, USA, former Scientist (Director's Grade) CDRL, Lucknow.

Member: Editorial Board, Proc. Indian National Science Academy; Indian Journal of Chemical Sciences, National Academy of Science Letter, and 'Wealth of India'.

His research interest includes the chemistry of Natural Products of Plant and Marine origin, biosynthesis, carbohydrates, nucleosides and medicinal chemistry and published more than 250 research papers.

Jai Pal Mittal
(1998-99)

Born 1940, M.Sc. (Agra 1959), Ph.D (Notre Dame, USA 1967), Post-Doc (UCLA, with W.F. Libby NL, 1969), Visiting Scientific advisor to US Army, Natik Labs, USA (1972-73), Vising Professor at Radiation Lab at University of Notre Dame, USA(1982-83), Head of Chemical Dynamics Section at BARC (1983), Head of Radiation Chemistry Section and Head, Chemistry Division (1986),Associate Director of Chemistry Group (1991), Director, Chemistry group (1993), Director, Chemistry & Isotope Group of BARC(1999)

Societies, FNASc, FASC, FNA, ex FRSC, Life Member, Indian Chemical Society and Fellow of Maharashtra Academy of Sciences; served the society in various capacities.

Awards and Honours: Fr Yedanapalli Award of Indian Chemical Society, DAE-CV Raman Lecture Award in Chemistry; SM Sethna Memorial Lecture Award in Chemistry, Prof T R Seshadri Seventieth Birthday Commemoration Medal(INSA); Dr Mahendra Lal Sircar Prize IACS, Calcutta, Decennium Commemoration Award of Mahatma Gandhi University, Kottayam.

President , Indian Society of Radiation and Photochemical Sciences(1991-2001), Chairman: Programme Advisory Committee (Chemistry), DST, and Basic Sciences Committee of Board of Research in Nuclear Sciences (DAE); Member: Chemical Sciences and Technology Committee (CSIR), Panel on Photochemistry (UGC), Editorial Board of Indian Journal of Chemistry and Process of Indian Academy of Science, Radiation of Physics and Chemistry(UK) AND International Journal of Chemical Kinetics (USA); Hony Professor, Jawaharlal Nehru Centre for Advanced Scientific Research (Bangalore).

His research interest includes the diverse areas of Radiation and Photochemistry, Laser Chemistry and dynamics of Chemical and Biological Reaction etc. Studies of transient reactive species in the real timescales of nano and pico-seconds; some basic understanding of photo and radiation biology of thymine and amino acids, the electron and energy transfer studies in the radiation and photochemistry of several substances in the gas phase , in solution as well as in rigid transparent matrices at 77k; pioneering research on Infra-Red Laser Chemistry, including multi-photon reaction dynamics, investigation on the dynamics of charge-transfer reactions involving fullerenes, C_{60} and C_{70} utilizing pulse radiolysis, nano and pico-second laser photolysis, steady-state, and time-resolved fluorescence studies etc.

Dr Mittal has over 200 research paper and guided 25 Ph.D students.

Suresh C Ameta
(2000-01)

Prof. Suresh C. Ameta obtained his Master Degree from University of Udaipur and was awarded Gold Medal-1970. He secured First position in M. Phil-1978 in Vikram University, Ujjain (M. P.). He also obtained Ph. D degree from this

University in 1980. He has served as Professor & Head, Department of Chemistry, North Gujarat University, Patan (1994) and M. L. Sukhadia University, Udaipur (2002-2005) & Head, Department of Polymer Science (2005-2008). He also served as Dean, P.G. Studies for a period of four years (2004-2008). He has served as Dean, Faculty of Science, PAHER University, Udaipur for six years (2011-2017). Presently, he is working as Professor of Eminence (Distinguished Professor of Chemistry) in Pacific University, Udaipur.

Prof. Ameta has occupied the coveted position of President, Indian Chemical Society, Kotkata (2000-2001) and is now lifelong Advisor (2002-continue). He was awarded a number of prizes during his career like National prize twice for writing Chemistry books in Hindi (1976 & 1978), Scientist of the Year Award (2002), Prof. M. N. Desai Award (2004), Prof. G. V. Bakore Award (2007), Prof. W. U. Malik Award (2008), National Teacher Award (2011), and above all, Life Time Achievement Awards by Indian Chemical Society, Kolkata (2011), Indian Council of Chemists, Agra (2015), Association of Chemistry Teachers, Mumbai (2018), North Gujarat University, Patan (2022). He has successfully guided 110 students for Ph. D. Dr. Ameta has more than 450 research papers and 36 books to his credit. He has contributed Chapters in Books published by Trans-Tech, Switzerland: Nova Science, Taylor & Francis, and Apple Academic Press, USA. Three books on Green Chemistry, Microwave Assisted Organic Synthesis and Chemical Applications of Symmetry and Group Theory have been published by Apple Academic Press, USA. Two more books on Solar Energy Conversion & Storage and Photocatalysis; An Emerging Technology have been recently released by Taylor & Francis, USA and a book on Waste Water Treatments by AOPs by Elsevier. He has completed 5 Major Research Projects by DST, UGC, CSIR, and Ministry of Energy, Govt. of India. Prof. Ameta has delivered lectures and chaired sessions in National Conferences organized in almost every part of this country. He is also reviewer of number of International Journals. Prof. Ameta has an experience of more than 50 years of Teaching and Research.

Indian Chemical Society, Kolkata has published a Special issue of Journal of Indian Chemical Society in December 2008 to felicitate him on his 60th birthday and has instituted aa Award in his name as Prof. Suresh C. Ameta Award to be given to a senior chemist of repute from 2003 onwards. He has delivered Keynote Addresses in International Conferences at Tokyo, Japan in May 2022, Hangzhou, China in July 2022 and Kunming, China in 2023. Above all, he has pointed out some problems in h-index and proposed a complimentary index as Ameta or A-index for further improving h-index and for this, he received approval of copyright for this improvement.

Sunil Kumar Talapatra
(2002-03)

Born on October 28, 1933 at Kalikachha in the district of Brahmanbaria (now in Bangladesh), Professor Talapatra had his early education in his village and passed the Matriculation Examination in 1947 from his village School with a brilliant result and maintained a very good academic record all through. He obtained the MSc degree in Chemistry in 1953 and the PhD degree in 1958 from the University of

Calcutta for his research on Indole Alkaloids under the supervision of the well-known Natural Product Chemist Professor (Mrs.) Asima Chatterjee (since deceased). He then carried out his post doctoral research with Professor Michael P. Cava at the Ohio State University, USA during 1960- 1964. He derived inspiration from both these erudite personalities to pursue a career of teaching and basic research in Chemistry. On his return from the USA, he joined the Department of Chemistry, University of Calcutta in 1965 as a Lecturer, became a Reader in 1971 and a Professor in 1975, the position from which he retired in 1998.

Professor Talapatra is a highly acclaimed teacher in Reaction Mechanism, Stereochemistry and Conformational Analysis in Organic Chemistry. His significant research contributions include, *inter alia*, the isolation and identifica- tion of the first natural fluorenones from Indian medicinal plants and a triterpene of a new skeleton from a Pacific Ocean sponge, unravelling a double skew boat conformation of rings, D/E in the terpenoids multifluorenol and friedelin and a skew boat conformation of ring E in another terpenoid bauerenol.

Professor Talapatra has published more than 175 papers in international Journals and inspired innumerable students who are now bearing the torch of his mission. He is held in high esteem by the community of chemists of India and abroad. An upcoming notable contribution to Chemical Education from Professor Talapatra is that he has authored jointly with his wife, Professor (Mrs.) Bani Talapatra, an advanced level text-cum-reference book entitled 'Plant Natural Products: Stereochemistry, Conformation, Synthesis, Biology and Medicine' which will be shortly. published by Springer-Verlag, Heidelberg, Berlin, New York.

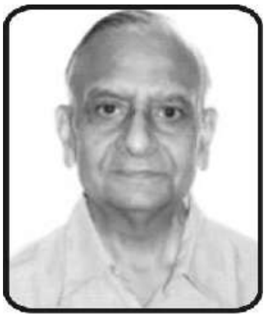
Professor Talapatra has been associated with the Indian Chemical Society since 1974 and has extended his dedicated service to the Society in all the capacities - as a Council Member, Associate Editor, Honorary Treasurer, Honorary Editor, Honorary Secretary (8 years), Vice-President and President (2002-2003), and he is at present its Ex-officio Vice-President. In recognition of his outstanding contribution to teaching and research, Professor Talapatra was honoured with the Life Time Achievement Award of the Indian Chemical Society in 2003. The Society is extremely happy to bring out this publication in honour of such a versatile personality.

Ramesh Chandra
(2004-05)

Prof. Ramesh Chandra is a distinguished scientist; Fellow of the Royal Society of Chemistry, London and an outstanding researcher in the field of Biomedical Sciences. Currently, he is the Vice-Chancellor at Maharaja Surajmal Brij University, Bharatpur, Rajasthan, and Founder Director of Dr. B. R. Ambedkar Center for Biomedical Research (ACBR), University of Delhi. He is Official resource person to the Minister and Department of Science and Technology in the kingdom of Lesotho, South Africa. Prof. Chandra has been Vice-Chancellor, Bundelkhand University, Jhansi for six years (1999-2005) as well as President of the Indian Chemical Society (2004-2006), Member, Planning Commission, Government of U.P. India; Secretary - Zaheer Science Foundation, New Delhi and Non-Official Director, Rashtriya Ispat Nigam Ltd (RINL), Government of India. He was also Head of the Department of Chemistry, University of Delhi for 3 years (August 2017- August 2020).Professor Chandra shows deep commitment to the cause of higher education & research and possess in ample measure quality of dynamic leadership, vision required for building academic institutions. He started his research career at the University of Delhi; thereafter he went to pursue his research at The New York Hospital-Cornell University Medical College, New York jointly at The Rockefeller University, New York; State University of New York at Stonybrook as Assistant Research Professor. He conducted advanced research at the Harvard University Medical School-Massachusetts General Hospital (MGH) jointly at MIT, Cambridge, USA.An outstanding Scientist and revered teacher, Prof. Chandra is the recipient of several professional national/ international recognitions: J. William Fulbright Scholarship (1993); The Rockefeller Foundation USA-Biotechnology Career Award (1993); Award of the Highest Honor of Soka University, Tokyo, Japan (2000); Millennium Plaques of Honor (Life Time Achievement Award for contribution in Science & Technology) by the Indian Science Congress Association (ISCA) {2017-2018}, Lifetime Achievement Award of the Indian Chemical Society (ICS) (2003); UGC Research Scientist Award (1988); UGC Career Award (1993); Rajib Goyal Award for Young Scientists (2002); Fellowship of: Indian Academy of Biomedical Sciences (IABS); International Academy of Physical Sciences; Institution of Chemists, India; Indian Chemical Society and others.Prof. Chandra has made outstanding contributions in Medicinal Chemistry. During the past more than three decades, he is engaged with anticancer drug discovery focused on tubulin binding cytotoxic agents and new therapeutic combinations to more effectively treat Cancer, that spare peripheral neuropathies. He has contributed to address the urgent need to provide chemotherapeutic approaches and “kindler and gentle” chemotherapy modalities. He has done intensive work towards design and development of drugs for management of human cancer; and the mysteries of this sinister, iconic disease. He has demonstrated that Noscapine and its derivatives (Br-Nos, Rd Br-Nos), which are effective in texane resistant cancer, and does not show sign of neurotoxicity or immunosuppression. He has also integrated in-silico analysis, in-vitro and in-vivo studies, to identify and validate novel therapeutics. Most importantly, these compounds are highly potent against cancer cells that have become resistant to currently used drugs, like vinblastine, teniposide and paclitaxel, as compared to their respective sensitive-parent lines.Prof. Chandra has excelled in his academic pursuits. To illustrate, he has to his credit several international patents, 9 Books; 28 Book Chapters; and more than 375 original Scientific Research Papers including Review Articles/Monographs in International journals of repute. He has mentored more than 100 Ph.D. and M.Phil. Students, who are now occupying high positions globally. He is member of several International Scientific Societies; Associate Editor of Artificial Cells, Nanomedicine and Biotechnology (Taylor & Francis Publishers) and member of editorial boards of several high-quality journals. Professor Chandra clearly understands the role of leadership in higher education. He has the ability to envision the ongoing changes and the direction that higher education and research should take. To give just two examples of his contribution in this regard; he has established Dr. B. R. Ambedkar Center for Biomedical Research (ACBR) – pioneering Biomedical Education and Research Institute at Delhi University in 1991, which has acquired an international status in the field of Biomedical Research through its original and creative research. It is one of the few institutions in India that have entered into collaborative and contractual research with leading universities and corporate houses across the world.For the second example, during his tenure as Vice Chancellor at Bundelkhand University, Jhansi for six years, among his monumental achievements were the following:He has established 36 institutes and that, too, with minimal financial support of the State Government. These institutes are in the fields Pure and Applied Radiation Biology, Pharmacy, Criminology and Forensic Sciences, Mass Communication & Journalism, Law, Ayurveda and Alternate Medicine, Planning and Architecture, Computer Science, Engineering, Biotechnology, Hotel Management and others. At a very young age, Prof. Chandra contributed for the academic development of Guru Nanak Dev University, Amritsar – as an Institute of Applied Science & Technology including Centre for Genetic Disorders (1988 - 1996). As an advisor, he has been instrumental in various academic developments of Indian Institute of Information Technology (IIIT - Allahabad). Prof. Chandra's programs are never constrained by resource crunch. He firmly believes in the Public-Private Partnership and trusts that necessary funds can always be procured from business, industry, and the public, provided the educational and research programs can meet the development requirements of the country in new and emerging areas of knowledge and professions, such as physical, mathematical, and biotechnological sciences, social sciences, business, and management.He has also been Consultant and Advisor to the various multinational companies like- Polaroid Corporation, USA; Diakron Pharmaceuticals, USA; HIKMA Pharmaceuticals-UK; Proviva Pharma Inc. Canada and Director, BIZ SHAKTI, USA etc; as well as Advisor to various academic institutions and also non-official Director of PSUs of the Govt. of India - (RINL). He has been Chairman and member of the Governing Council, BOG, Executive/ Academic Councils, Finance Committee of several Universities/ Institutions globally and also Member – U.P Council of Higher Education; U.P. State Youth Welfare Council, President, World Congress of Nanomedical Sciences, USA and others. He has been Prof. Chandra is a prolific writer and displays extraordinary flair for writing on themes particularly to Higher Education and social issues.As an accomplished scientist and scholar who is widely recognized internationally, Professor Ramesh Chandra also has stellar administrative experience of establishing institutions and providing leadership, and he has the requisite experience to advise governments on the developments necessary for maintaining standards and bringing improvements in university education.

K. B. Pandeya
(2006-07)

Born on April 1, 1942, in a farmers family in village PakariSewar of Allahabad District, Krishna Bihari Pandeya completed his school education from Lala Ramlal Agrawal Inter College Sarsa, Allahabad. He obtained his B.Sc.(1961), M.Sc.(1964) and D.Phil.(1969) degrees from Allahabad University. His research supervisor Prof. H.L. Nagam, FNA, is a world renowned Transition Metal Chemist. Dr. Pandeya began his carrier as University teacher in August 1968 as Lecturer at Allahabad University and moved to Delhi University in April 1970, where he worked first as Post Doctoral Fellow, and then as Lecturer and Reader in Chemistry. In 1985, Dr. Pandeya took over as Professor & Head of the Department of Chemistry at A. P.S. University Rewa (M.P.) and was elevated to the position of Vice-Chancellor of C.S.J.M. University, Kanpur in 1998, where he is remembered for his administrative and academic excellence. Soon after in April 2000, the Government of Uttar Pradesh appointed him as Chairman of U.P. Public Service Commission, the assignment that he completed with laurels on March 31, 2004. For a brief span of nearly one year, he rendered a voluntary service as Vice-Chancellor of J.R.H. University Chitrakoot (U.P.). He was also working as Vice-Chancellor Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya Chitrakoot (M.P.). Dr. Pandeya has had a brilliant teaching and research career. He has supervised 22 Ph.D. theses (10 at Delhi Univ. and 12 at Rewa Univ.) and has published over 200 research papers. He is Fellow of the National Academy of Sciences, India and has been President of Indian Chemical Society. He has won several academic awards like Acharya P.C. Ray memorial medal and lectureship and Prof. P.K. Bose memorial medal and lecturership. Prof. Pandeya was awarded Commonwealth Academic Staff Fellowship to work at the University of Leeds, UK. He was also awarded INSA-Slovak Academy of Sciences exchange visitorship to work at Slovak Technical University, Bratislava. An expert in EPR and Mossbauer spectroscopy, Prof. Pandeya is well known for his work on Synthetic models of Copper Proteins, specially Copper-Zinc Superoxide Dismutase. His present research interest is natural and synthetic α-glucosidase inhibitors with antihyperglycemic properties.



Girjesh Govil
(2008-10)

Born in Khurja (dist. Bulandshahar, U.P.), Govil had a brilliant academic career. He did his B.Sc. from Lucknow University in 1956 and M.Sc. from Allahabad University in 1958. He then joined the prestigious Training School at the Atomic

Research Establishment, Bombay (now BARC) in the year 1958 and, having topped his batch, decided to join the Tata Institute of Fundamental Research (TIFR) the following year. He obtained his Ph. D in the year, 1963, working under the mentorship of Prof. S. S. Dharmatti, the pioneer of NMR in India and the inventor of NMR Chemical Shift. Thereafter, the young scholar carried out his post-doctoral studies at the National Physical Laboratory (United Kingdom) and the National Research Council (NRC), Canada. After his return to TIFR, he established himself as an independent researcher, eventually becoming Senior Professor and Chair of the Chemical Physics Group (now the Department of Chemical Sciences) and the Dean of the School of Natural Sciences. Prof. Govil superannuated from TIFR in 2003, but continued working, first as a Raja Ramanna Fellow, and then as INSA Golden Jubilee Research Professor, till 2018.

At TIFR, Govil laid the foundation for the Molecular Biophysics program in 1969, with a focus on determining the structures of biomolecules. He foresaw that the establishment of a state-of-the art NMR facility was crucial to remain at the forefront of research. In this endeavour, he and the late Prof. C. L. Khetrapal (a TIFR alumnus working at the Raman Research Institute), Bangalore) joined forces to obtain funds from the Department of Science and Technology (DST), and established the first Superconducting 270 MHz NMR spectrometer at the IISc, Bangalore (1978).

Prof. Govil, along with his colleagues at TIFR, made substantial original contributions in the broad area of structural biology – structure and dynamics of long DNA duplexes, triplexes etc, structure and dynamics of proteins, software development for automated analysis of multidimensional NMR spectra of proteins. His work demonstrated that single-stranded nucleic acids have the intrinsic tendency to form helices, and the H-bonding and base-stacking interactions provide additional stability to the higher order structures. His notable work in *in*

vivo NMR was the study of the motility of spermatozoa. Simultaneously, Govil ventured into applied research, namely Biochemical Fuel Cells and Molecular Electronics, which yielded a few patents. He had more than 250 research publications, and 5 books, which are highly cited. His books are used by many researchers for teaching fundamental principles and applications of NMR.

Prof. Govil also took initiatives towards Education and Capacity Building in the less-developed countries. He served on a number of national and international committees for chemistry and biophysics and was involved in many international activities, such as organising International Conferences, Workshops, and training scientists from neighbouring countries. He played major roles in international bodies such as International Conference on Magnetic Resonance in Biological Systems (ICMRBS), International Union of Pure and Applied Biophysics (IUPAB), Asian Biophysics Association (ABA), Royal Society of Chemistry (West India Section), and NASI (West-India Section). He was, in fact, Vice-President of the IUPAB and served as Chair of the ICMRBS Council. Having established a good rapport with the international community, he always succeeded in organising many important international conferences in India.

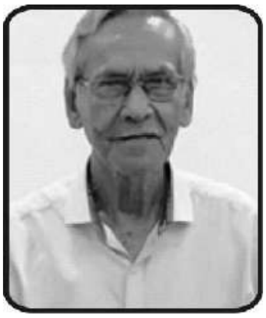
The late scientist's contributions were recognised by numerous awards and honours, including the S.S. Bhatnagar Award, the FICCI award, the Goyal Award, the R.K. Asundi Memorial lecture, the P.C. Ray Memorial Lecture, the Lifetime Achievement Award of the Indian Chemical Society and also of the Indian Science Congress Association, the N.R. Dhar Award, the J.C. Ghosh Memorial lecture, to name a few. He was elected Fellow of all the three Science Academies in India and was also a Fellow of The World Academy of Sciences (TWAS) and of the International Society of Magnetic Resonance (ISMAR).

Mahesh C Chattopadhyaya (2011-13)

M.C. Chattopadhyaya is a retired Professor of Department of Chemistry, University of Allahabad, Allahabad (U.P.) India. He did P.G. course in Radiological Physics by BARC, Mumbai. Then he obtained PhD degree from IIT Bombay. He was elected as Fellow of Cambridge Philosophical Society, Fellow of Chemical Society, London, Indian Chemical Society, Institution of Chemists, India. He was the President of the Indian Chemical Society from 2011-2013. He has published 150 papers & guided 28 PhD students.

R N Prasad (2014-16)

Born on January 6, 1949 in a small village Gobra in Tehsil Kiraoli of Agra District (UP) he completed his B.Sc. and M.Sc. (Chemistry) from Agra University. He has very brilliant academic record and is recipient of Gold Medal of the University in M.Sc. in 1970. He did his Ph.D. in 1974 from University of Rajasthan, Jaipur and joined there as Assistant Professor in 1973 and retired as Professor in 2009. He has also served as Associate Professor in Jiwaji University Gwalior and as Professor and Head in M D S University Ajmer. Prof Prasad is very well known for his research in the fields of coordination, Bio-inorganic, macrocyclic and environmental chemistry. He has completed several research projects of UGC, CSIR etc. and has guided 28 students for their Ph.D. and has published 125 research papers in reputed International journals with high impact factor. He has been National Associate of UGC (1980-85) and is recipient of UGC Career Award in 1985. He has worked at University of Oxford (1980), University of Sheffield (1984) and at University of Notre Dame, USA (1985). He has attended several National conferences and has chaired many International conferences in USA, UK, Australia etc. and has delivered lectures in various universities and institutes in India and abroad. He has been founder secretary of Vigyan Bharti, Rajasthan. He has been associated with Indian Chemical Society since long and has served as Scientist in-charge, Inorganic Chemistry Section of Convention of Chemists, Council member (1998-2000, 2008-2010), Vice President (2006-2007, 2011-2013) and as President (2014-2016) and presently as Advisor. He has been member of IUPAC National Committee and ICSU-INSA National Committee during 2014-2016. Besides his research activities, he has been very good administrator also and has worked as Director of S D Institute of Tecchnology, Rajasthan (2009-10) and as Senior Advisor and Dean of Science Faculty in JECRC University, Jaipur (2014-21).



D C Mukherjee
(2017-19)

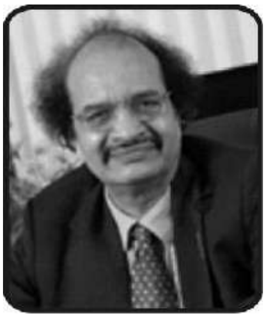
Professor Dulal Chandra Mukherjee obtained Ph.D Degree under the guidance of (Late) Professor A.K. Chandra, a renowned Quantum Chemist of India from the University of Calcutta.

His Postdoctoral Research was on Chlorophyll one electron photochemistry related to primary mechanism of photosynthesis in the University of Arizona, USA with Professor Gordon Tollin. He was also a Postdoctoral Research Associate in the Eye Research Institute of Retina Foundation, Boston and worked on biophysical aspects of some important ocular processes.

Professor Mukherjee later worked on Molecular Spectroscopy, Quantum Chemistry, Oscillatory Chemical Reactions, Graph Theory and Conducting Polymer and published about 110 research articles in the Journals of International repute and guided 15 research students. Presently he is associated with the Heritage Institute of Technology, Kolkata as Professor Emeritus in Chemistry.

Professor Mukherjee rendered his sincere service to the Indian Chemical Society as its past Honorary Secretary, past Honorary Editor (Journal of the Indian Chemical Society), and past President.

He is a Fellow of many Scientific Societies such as Indian Chemical Society, Royal Society of Chemistry (London), the West Bengal Academy of Science and Technology.



Ganapati D Yadav
(2020-

Professor Ganapati D. Yadav is one of the topmost, highly prolific, and accomplished engineering-scientists in India. He is the National Science Chair of Govt. of India, which is a very prestigious national honour and is Emeritus Professor of Eminence and is the former Vice Chancellor of the Institute of Chemical Technology, Mumbai. He is internationally recognized by over 125 prestigious and rare awards as an academician, researcher and innovator, including his seminal contributions to education, research and innovation in Green Chemistry and Engineering, Catalysis, Chemical Engineering, Energy Engineering, Biotechnology, Nanotechnology, and Development of Clean and Green Technologies. His patented work on the net zero goal, green hydrogen production technology, carbon dioxide refineries and valorization of (waste) biomass and waste plastics is internationally acclaimed. He serves as the Adjunct Professor at University of Saskatchewan, Canada; Conjoint Professor, University of New Castle, Australia; Distinguished Adjunct

Professor, IIT Guwahati and SOA University Bhubaneswar. He was conferred Padma Shri by the President of India in 2016.

As the VC he created several records, brought ICT to an international ranking, with establishment of 2 new campuses in Bhubaneswar and Jalna, creation of 23 new programmes, several centers of excellence and 5 departments, and collection of huge funds. He has been the recipient of two honorary doctorates and has addressed 6 convocations of renowned universities. He is elected to the fellowship of all Science and Engineering academies in India, TWAS, RSC (UK), IChemE (UK) among others. He was elected to two prestigious US academies: The US National Academy of Engineering; only 23 living Indians are elected to this Academy, and as a Fellow of the US National Academy of Inventors in December 2022 to be only the second Indian to be so honoured. He has been involved with many prestigious policy making committees of the Central government and as a consultant to industries and industry associations for 40 years. His research productivity is phenomenal with supervision of 107 Doctoral and 140 master's Theses, which is the first record for any Engineering Professor in India. Besides, he has supervised 48 post-doctoral fellows, several summer fellows and research staff. His productivity is phenomenal: 520+ original research papers, 120 granted national and PCT patents, 8 new patent applications; written 3 books; h-index of 68, i10 index of 337; 16,650+ citations, and given over 925 invited lectures/orations/seminars. He is on the board of 6 listed companies as an independent director such as Godrej Industries, Aarti Industries, Clean Science & Technology, Meghmani Organics, Bhageria Industries and Survival Technology. He is on the editorial boards of international journals of ACS, RSC and Elsevier. He has been decorated with many prestigious life time achievement awards by professional bodies, industries associations, philanthropic organizations and institutions of higher learning; the most recent is by the Indian Drug Manufacturers Association (IDMA) in Feb 2023. Currently he is the President of the Indian Chemical Society and the Maharashtra Academy of Sciences, and chairs committees of DST and DRDO labs. • He had the honour of addressing 6 Convocations of renowned universities in India. He is an author and poet in English and Marathi having written the University song of ICT and is fond of Sanskrit, Vedas, Philosophy and Etymology.

LIST OF COUNCIL MEMBERS, 2023 – 2025

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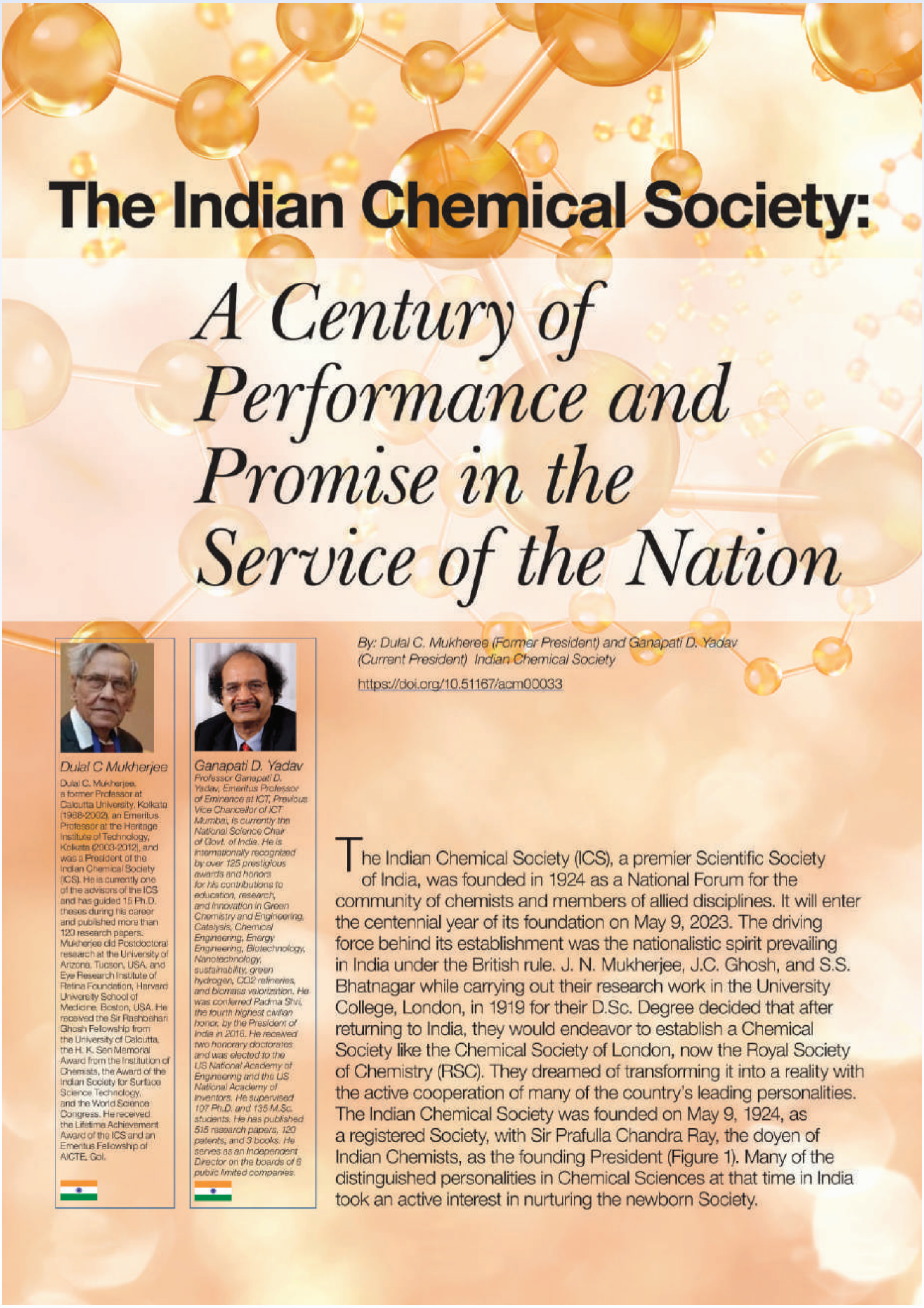


The Indian Chemical Society:

A Century of Performance and Promise in the Service of the Nation

By: Dulal C. Mukheree (Former President) and Ganapati D. Yadav (Current President) Indian Chemical Society

https://doi.org/10.51167/acm00033

Dulal C Mukherjee

Dulal C. Mukherjee, a former Professor at Calcutta University, Kolkata (1968-2002), an Emeritus Professor at the Heritage Institute of Technology, Kolkata (2003-2012), and was a President of the Indian Chemical Society (ICS). He is currently one of the advisors of the ICS and has guided 15 Ph.D. theses during his career and published more than 120 research papers. Mukherjee did Postdoctoral research at the University of Arizona, Tucson, USA, and Eye Research Institute of Retina Foundation, Harvard University School of Medicine, Boston, USA. He received the Sir Rashbehari Ghosh Fellowship from the University of Calcutta, the H. K. Sen Memorial Award from the Institution of Chemists, the Award of the Indian Society for Surface Science Technology, and the World Science Congress. He received the Lifetime Achievement Award of the ICS and an Emeritus Fellowship of AICTE, GoI.

Ganapati D. Yadav

Professor Ganapati D. Yadav, Emeritus Professor of Eminence at ICT, Previous Vice Chancellor of ICT Mumbai, is currently the National Science Chair of Govt. of India. He is internationally recognized by over 125 prestigious awards and honors for his contributions to education, research, and innovation in Green Chemistry and Engineering, Catalysis, Chemical Engineering, Energy Engineering, Biotechnology, Nanotechnology, sustainability, green hydrogen, CO_2 refineries, and biomass valorization. He was conferred Padma Shri, the fourth highest civilian honor, by the President of India in 2016. He received two honorary doctorates and was elected to the US National Academy of Engineering and the US National Academy of Inventors. He supervised 107 Ph.D. and 135 M.Sc. students. He has published 515 research papers, 120 patents, and 3 books. He serves as an Independent Director on the boards of 6 public limited companies.

The Indian Chemical Society (ICS), a premier Scientific Society of India, was founded in 1924 as a National Forum for the community of chemists and members of allied disciplines. It will enter the centennial year of its foundation on May 9, 2023. The driving force behind its establishment was the nationalistic spirit prevailing in India under the British rule. J. N. Mukherjee, J.C. Ghosh, and S.S. Bhatnagar while carrying out their research work in the University College, London, in 1919 for their D.Sc. Degree decided that after returning to India, they would endeavor to establish a Chemical Society like the Chemical Society of London, now the Royal Society of Chemistry (RSC). They dreamed of transforming it into a reality with the active cooperation of many of the country's leading personalities. The Indian Chemical Society was founded on May 9, 1924, as a registered Society, with Sir Prafulla Chandra Ray, the doyen of Indian Chemists, as the founding President (Figure 1). Many of the distinguished personalities in Chemical Sciences at that time in India took an active interest in nurturing the newborn Society.

Figure 1. Founders of the Indian Chemical Society and members of the first Council (1924). Top row from left: P. C. Mitter, Shanti Swarup Bhatnagar, J. C. Ghosh, and Sir P. C. Ray; bottom raw: Sir J. L. Simonsen, J. N. Mukherjee, and Gilbert J. Fowler

The first Council of 1924 included President Sir P. C. Ray, Vice-Presidents Gilbert J. Fowler and E. R. Watson, Secretary J. N. Mukherjee, Treasurer P. C. Mitter, and Editors N. R. Dhar and A. N. Meldrum. Other Council members were H. E. Annett, S. S. Bhatnagar, R. L. Datta, B. K. Singh, B. B. Dey, and B. H. Wilsdon.

The Indian Chemical Society started its activity by publishing a quarterly journal. Initially, the Society did not have its own office. It functioned from the office of the Secretary, J. N. Mukherjee, who was then Sir Rashbehary Ghose Professor of Chemistry at the University College of Science, Calcutta. Sir P. C. Ray donated 10,000 Rupees to Calcutta University to adequately accommodate the ICS. The gift allowed the construction of three large rooms in 1933 on the second floor of the south wing of the Sir Taraknath Palit Building of the University College of Science and Technology. Two rooms were allotted to the Society for its use and the third one for the use of the University. The Society still functions from this location in University College of Science and Technology, Kolkata.

Publications

The first issue of the quarterly Journal of the Indian Chemical Society appeared in November 1924 and received appreciation from several leading organizations and personalities from other countries. Professor Wynne, the then President of the Chemical Society, London, cabled to Sir P. C. Ray, congratulating the Indian Chemical Society for this venture. Prof. P C Ray enthusiastically responded to Professor Wynne with thanks. The renowned journal ***Nature*** (London) related to this event:

> The great work in chemistry which has occurred in the Indian Empire during the past ten years, had led to the establishment of an Indian Chemical Society, the first number of the quarterly journal of the Society has now appeared. There are thirteen papers, and only one of these is published under the English names. The remaining papers are published by Indians and come from all parts of the Indian Empire. Four of these emanate from the College of Science, Calcutta, and this is as it should be, because for many years past, this Institution has been the backbone of chemical research in India.

The University College of Science, Calcutta, had been set up by Sir Ashutosh Mookherjee. The significant chemical research centers included Banaras, Lahore, Madras, Agra, Bombay, Dacca, and Bangalore. Everybody agreed that there would always be papers for the continuance of the Journal. The attitude of the provincial governments was not at all encouraging. Only the State of Baroda promised an annual grant. When the prospect of publishing the Journal looked grim, Sir Ashutosh Mookherjee, the then Vice-Chancellor of Calcutta University, came up with the generous offer of publishing the Journal of the Society 15,000 Rupees per year. Soon the Universities of Dacca, Allahabad, and Punjab promised annual grants of 200, 200, and 100 Rupees, respectively. At the meeting of the Watson Committee held at the Medical College, Lucknow, on January 11, 1923, the Committee decided that the funds promised would enable the founding of a Chemical Society and publish a quarterly journal. The Committee meeting at Bangalore in 1924 determined the rules and regulations of the society. Thus, the Indian Chemical Society was officially established and registered on May 9, 1924, with Sir P.C. Ray as the Founding President and J.N. Mukherjee as its Secretary.

Following the ICS foundation and its Journal's publication, the society started its endeavor to build up exchange relations with other such societies around the globe. First, they built links with the ***Journal de Chemie Physique***, Paris, the ***Chemical Abstract***, and the ***Journal of the Chemical Society***. Papers continued to pour in from all over India, and despite extreme financial hardships, the Journal had become a bimonthly by 1928 and a monthly by 1930.

As of January 2021, the Journal of the Indian Chemical Society (JInCS) is published by Elsevier and is part of ScienceDirect (https://www.sciencedirect.com). All back issues (1924-2020) are now available free on the website, http://indianchemicalsociety.com/, financially supported by Xytel India Pvt Ltd., Clean Science & Technology, Ltd., and Meghmani Organics Ltd. A new Editorial Board includes 54 renowned experts from 21 countries. Under its new format, the Journal has six sections: Organic and Biochemistry, Inorganic and Material Chemistry, Physical and Theoretical Chemistry, Analytical and Environmental Chemistry, Industrial and Applied Chemistry, and Engineering Chemistry and Green Technology.

The inaugural issue of the Journal in January 2021 contained articles by invitation. Special issues are published from time to time in consultation with the Editor-in-Chief, Prof. G.D. Yadav. Daily 3-4 articles are submitted online to the Journal from all over the globe.

The activity of the Society was to make an effort to ensure the publication of original research papers and to encourage the enrollment of members and subscribers. In this way, the Society performed a commendable job with its Journal. In collaboration with the Institute of Chemist (India) and the industries, a new Edition was bought as a separate quarterly Journal. Later, in 1950, this Journal was renamed The Indian Journal of Applied Chemistry. Due to the lack of funds, the Journal was discontinued.

The ICS has published a few books and monographs, including the History of Chemistry in Ancient and Medieval India (incorporating P. C. Ray's History of Hindu Chemistry)-Edited by P. Ray, Reflections on Chemical Education - N. R. Dhar, Acharya Prafulla Chandra Ray: Life and Achievements - N. R. Dhar, Glimpses of Acharya P. C. Ray's

Figure 2. From left: photo and bust of Prafulla Chandra Ray, which is placed in the garden of Birla Industrial & Technological Museum, Kolkata; A bust of Sir P. C. Ray at the ICS headquarters; Ray on a 1961 stamp of India; ICS Logo.

Work in Chemical Science by Professor Animesh Chakravorty, Mahakaler Somkhipta Itihas: Prof Anil Kumar Dey, and the periodical (in Bengali), Education in Chemical Science and Technology.

The Society publishes a Bulletin called Chemical Warta, containing news of national and international events, members' achievements, conferences, and academic news.

The Objectives of the Society

The ICS was established with the following objectives as laid down in its Memorandum of Association:

- The cultivation and promotion of Chemistry and of allied branches of science.
- To co-operate with other Organizations having similar Objectives.
- To do and perform all other acts, matters, and things that may assist in, conduce to, or be necessary to fulfill the objects mentioned above and for the Society.
- The Society shall not make any dividend, gift, division, or bonus in money to, or between, any of its members but may pay remuneration to any of its Office-bearers.
- The Council shall have the power to acquire land by purchase or by lease for the fulfillment of the objects of the Society and to create a charge or mortgage on the immovable property of the Society for securing payment of unpaid purchase money or premium.

Society's logo

The ICS logo (Figure 2) contains the image of Sir Prafulla Chandra Ray, who was an eminent Indian chemist, educationist, historian, industrialist, and philanthropist. Ray received a D.Sc. degree from the University of Edinburgh in 1887 and spent 27 years packed with activities in Presidency College, Calcutta. In 1916 he moved to become the first Chair Professor of Chemistry in the College of Science, Calcutta University, at the invitation of the legendary Vice-Chancellor Ashutosh Mookherjee, who later appointed Sir C. V. Raman as the first Chair Professor of Physics.

Ray established the first modern Indian research school in chemistry and is regarded as the father of chemical science in India. He founded the Bengal Chemicals & Pharmaceuticals, India's first pharmaceutical company. His book, A History of Hindu Chemistry from the Earliest Times to the Middle of the Sixteenth Century, was published in 1902.

India commemorated the centenary year of his birth with a postage stamp. His 150th birth centenary coincided with the International Year of Chemistry – 2011. In the same year, the Royal Society of Chemistry honored his life and work with the first ever Chemical Landmark Plaque outside Europe - on Ray in Presidency College, Kolkata, where he started his career (Figure 2).

ICS Branches

The Indian Chemical Society has several branches for the expansion of the activity of the Society. At present, the six active branches include the Allahabad, Bhagalpur, Baroda, Chennai, Raipur, and Mumbai. In 2021-22, a new Industries Branch was created for the benefit of chemists from industry, thus making it as the seventh branch. The Fellows associated with these branches are enthusiastically carrying out various academic activities.

Past ICS Presidents

Many illustrious chemists have served the Indian Chemical Society as the President since its foundation in 1924: Acharya Prafulla Chandra Ray, Gilbert John Fowler, Bawa Kartar Singh, Nil Ratan Dhar, Sir Upendranath Brahmachari, Jnan Chandra Ghosh, Hemendra Kumar Sen, Shanti Swarup Bhatnagar, Biman Behari Dey, Jnanendra Nath Mukherjee, Priyadaranjan Ray, Jnanendra Nath Ray, Prafulla Chandra Guha, Mata Prasad, Bires Chandra Guha, Prafulla Kumar Bose, Krishnaswami Venkataraman, Tiruvenkata Rajendra Seshadri, Ramanlal Chhoganlal Shah, Syed Husain Zaheer, Ranchhodji Dajibhai Desai, Jagdish Shankar, Tuticorin Raghavachari Govindachari, Ram Narayan Chakraborty, Ram Charan Mehrotra, Sukh Dev, and Sailendra Mohan Mukherjee.

The current President, G. D. Yadav, achieved the transfer of the Journal of Indian Chemical Society to Elsevier publishing house and arranged industry support for the digitization of all issues since 1924 (Figure 3).

The Library of the Society

The Society is receiving about 125 Journals in exchange for its own Journal. Some of these Journals are only available in the Eastern Region of India. In addition, there is a relatively large collection of books. The library facilities are open to all interested readers. But due to a shortage of adequate space, the Society cannot extend full facilities to its Fellows and other intending library users.

Memorable Past Events

The Society celebrated some landmark events over the years.

- Silver Jubilee Celebration at University College of Science and Technology, Calcutta, in 1948.
- Golden Jubilee Celebration at University College of Science and Technology, Calcutta, in 1973.
- Diamond Jubilee Celebration at Jadavpur University, Calcutta, in 1984.
- Platinum Jubilee Celebration at Jadavpur University & Indian Association for the Cultivation of Science, Calcutta, in 1999.

Figure 3. ICS President G. D. Yadav at the 2023 IDMA-APA Pharmaceutical Analysis Convention; cover of the Journal of Indian Chemical Society at the Elsevier publishing house; cover of the Chemical Warta bulletin depicting Honorary Fellows.

- Various year programs from May 9, 2023, to August 2, 2024, are planned as part of the Centennial Year.

Membership of the Society

The Indian Chemical Society has provisions for the following classes of Fellowship/ Membership:

1) Life Membership
2) Life Fellowship
3) Institutional Membership
4) Corporate Membership
5) Student Membership

The ICS covers different related disciplines for joining different membership categories and the various industries associated with these disciplines.

Analytical Chemistry	Solid State Chemistry
Inorganic Chemistry	Theoretical Chemistry
Organic Chemistry	Chemical Engineering
Physical Chemistry	Chemical Technology
Green Chemistry	Physics
Industrial Chemistry	Biological Sciences
Polymer Chemistry	Biotechnology
Biochemistry	Materials Chemistry & Engineering
Food Chemistry & Technology	Natural Products Chemistry
Microbiology	Environmental Chemistry
Pharmaceutical Science and Technology	Nuclear Chemistry
Earth Sciences	Oceanography
Marine Chemistry	Chemical Physics
Agro-Chemistry	Biomedical Engineering
Soil Chemistry	Oil Chemistry
Interfacial Science	Dyestuff Chem & Technology
Textile Chemistry & Technology	Any Other

Eligibility Criteria for Fellowship

The ICS uses the following criteria as guidelines to remove subjectivity in recommending applicants for the Fellowship of ICS subject to modifications and approval by the Council.

1. *S.S. Bhatnagar Prize winners*
2. *Fellows of all National and International Academies.*
3. *Full Professors in Centrally Funded Institutes or equivalent grade pay in National Laboratories, CSIR, DAE, DRDO, ISRO, ICMR organizations, State Universities, and deemed to be Universities within the top 200 NIRF rank.*
4. *Vice Presidents and Directors (R and D) of DSIR-recognized laboratories of Industries in the Public or Private sectors.*
5. *Associate Professors in CFI or UGC-recognized universities and colleges who have guided at least 5 Ph.D. publications and patents with a cumulative impact factor of 200. (The I.F. for international patent 20 and national patent*

10). In exceptional cases, Assistant Professors with a cumulative impact factor of 300 will be considered.

6. *General managers and group leaders from industrial R and D with at least 20 scientists having Ph.D. and evidence of patents and technology transfer.*

7. *College Principals or Vice Principals with Ph.D. having full professorship and evidence of producing at least 2 Ph Ds or with publications and patents leading to cumulative I.F. of 50.*

8. *Full Professors in UGC recognized Private Universities with evidence of producing 2 Ph.D. and a cumulative Impact Factor of 200.*

9. *In exceptional cases, those responsible for promoting the chemical sciences through policymaking and whose names have been approved by the Council.*

10. *All others with a degree in Chemical Sciences and Engineering/ Technology, who did not fit into any of the above, will be eligible for Membership.*

Awards and Recognitions

The Society recognizes outstanding achievements in Chemistry and allied sciences and engineering through Lifetime Achievement Awards, Endowment Award Lectures, and Convention Awards (including Young Scientists Awards). The Society has instituted several endowment lectures in the field of chemistry. Some awards are annual, whereas some are biennial.

Annual awards: Acharya P. C. Ray Memorial Award; Professor Priyadaranjan Ray Memorial Award; Acharya J. C. Ghosh Memorial Award; Professor J. N. Mukherjee Memorial Award; Professor P. K. Bose Memorial Award; Professor Dhananjay Nasipuri Memorial Lecture; Professor A. S. R. Anjaneyulu 60th Birthday Commemoration Award; Professor Suresh C Ameta Award; Professor R. D. Desai 80th Birthday Commemoration Medal & Prize; Professor R. S. Varma Memorial Award; Professor A. K. Chandra Memorial Award.

Biennial awards: Dr. Basudev Banerjee Memorial Medal and Prize; Professor B. N. Ghosh 80th Birthday Medal and Prize; Dr. D. S. Bhakuni Prize; Professor D.P. Chakraborty 60th Birth Anniversary Commemoration Award; Rev. Fr. L. M. Yeddanapally Memorial Award; Professor S. S. Sandhu Award; Professor G. V. Bakore Memorial Award; Dr. Ghanshyam Srivastava Memorial Award; Professor U.C. Pant Memorial Award; Professor H.L. Nigam Memorial Award.

The Society has also instituted many Annual Conventions of Chemists Awards for Young Scientists impetus to the young chemists working at different research laboratories. There are several convention awards for young researchers below 32 in several branches of Chemical Sciences. These are:

Analytical Chemistry: Professor V. S. Tripathi Award, and Professor V. Pandu Ranga Rao Award; (Inorganic Chemistry): Professor A. K. Dey Memorial Award, Professor B. C. Halder Memorial Award, and Sri B. M. L. Bhasin Memorial Award; (Industrial & Applied Chemistry): Professor K R Desai Award; (Organic & Biochemistry): Dr. B. N. Mankad Award, Dr. J. M. Dasgupta Award, Dr. D. S. Bhakuni Award, Professor P. Sengupta Memorial Award, and Professor S. K. Talapatra Award; (Physical Chemistry): Professor Santi Ranjan Palit Memorial Award, and Professor S. T. Nandibewoor Award; (Environmental Chemistry): Dr. Upadhyayulu V. Rao Memorial Award, Dr. Upadhyayulu Annapurna and Satyanarayana Memorial Award, and Professor G. Gopalarao Centenary Young Scientist Award

Annual Convention of Chemists

Since 1963 The Indian Chemical Society has been organizing an Annual Convention of Chemists in collaboration with the Institution of Chemists (India). Different funding agencies, such as the Council of Scientific and Industrial Research, University Grants Commission, including DST, and others, sponsor these conventions. At the Annual Convention, the endowment lectures of the Society are delivered by distinguished speakers selected by duly constituted selection committees. In addition, invited lectures are delivered in different sessions of the convention. Oral and poster presentations of communications by younger chemists are also arranged. Some papers published at the Annual Convention of Chemists are selected for Convention Awards.

Honorary Fellows

Several great Scientists and personalities have been honored by the Honorary Fellowships: (Late) Dr. Anji Reddy (India); Prof. W. J. Orville-Thomas (England); Dr. Purnendu Chatterjee (USA); Prof. Helmut Sigel (Switzerland); Prof. M. M. Sharma (India); Dr. R. A. Mashelkar (India); Bharat Ratna Prof. C. N. R. Rao (India); Prof. Animesh Chakravorty (India); Dr. K. L. Mittal (USA); Prof. R. B. Lal (India); (Late) Dr. Srikumar Banerjee (India); Prof. Christopher W. Bielawski (Korea); Mr. Prabir Kumar Ray (India); Padmashri Prof. K. Vijay Raghavan (India); Prof. Ashutosh Sharma (India); Dr. Renu Swarup (India); Prof. Collin Suckling, OBE (UK); Prof. Eric Jacobsen (USA); Dr. Mukesh D. Ambani (India), Shri. Rajjubhai D. Shroff (India); Padma Bhushan Dr. T. Ramasami (India).

Some Nobel Laureates have been honored by the Honorary Fellowships: Prof. M. Eigen (Germany); Prof. Henry Taube (USA); Prof. Jean-Marie Lehn (France); Prof. Sir Richard J. Roberts (USA); Prof. Ryōji Noyori (Japan); Prof. Sir Venki Ramakrishnan (UK); Prof. Sir James Fraser Stoddart (USA), (Late) Prof. Robert H. Grubbs (USA).

Future Perspectives

The Indian Chemical Society is presently involved in various academic activities that have drawn attention from other countries. Its future depends on the sincere, honest, and vigorous efforts of its Fellows. Many industries have supported the Society for propagating chemical sciences and its welfare activities through the efforts of the current president Prof. G.D. Yadav to celebrate the centennial year with grand programs and fund drives. Clean Science and Technology Ltd, UPL Ltd, Meghmani Organics Ltd, Pidilite Industries Ltd and Xytel India have contributed generously, and many others are committed to bolstering the awards. The ICS invites young minds and corporate houses to nurture science for the societal benefits in India.

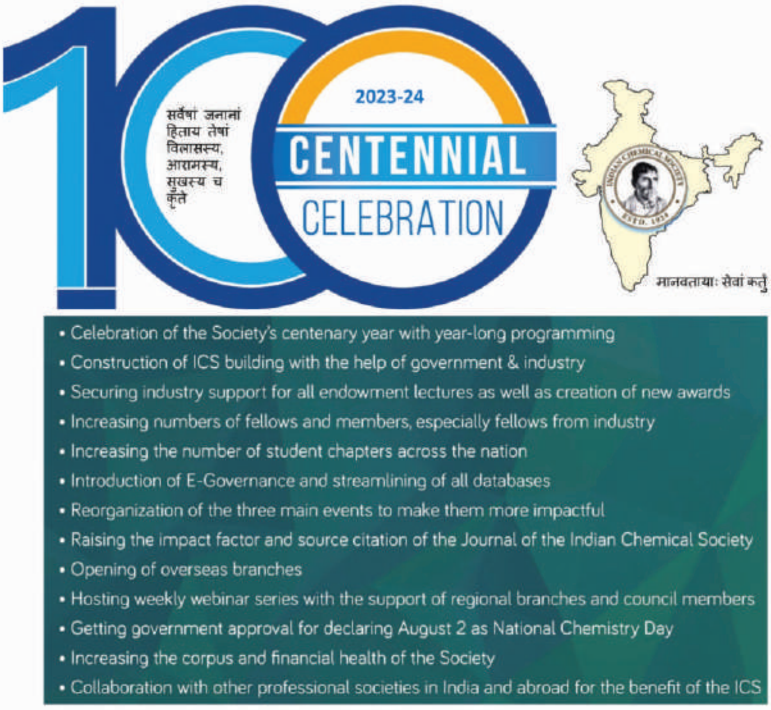
The Kolkata Municipal Corporation had allotted a piece of land within the city in 1967 for the construction of the building of the Society. Unfortunately, the construction could not occur for several reasons, such as a lack of resources and encroachment on the access road to the allotted plot. Despite the sanction of 20 million Rupees for the building about seven years ago by the Department of Science and Technology, Govt. of India, construction could not begin. We need generous donors from industry to complete the building with modern amenities. We intend to use CSR funds for continuing education, seminars, refresher courses, and training of students for the Chemistry Olympiad apart from the regular office and guest house with modern facilities.

Centennial Celebration Year

The Council of the Indian Chemical Society has planned many activities starting from May 9, 2023 until August 2, 2024, unveiled during the Annual General Body Meeting held on December 28, 2022 (Figure 4):

1. Inaugural Function in Delhi which will be graced by a VVIP.

2. Felicitation of achievers, roles models and past presidents responsible for the growth of the profession.
3. Securing Industry Support for All Endowment Awards and creating new awards (100 in number).
4. 5 Fellows from each country (20 countries).
5. Creation of Publication Corpus.
6. Increasing the IF and Cite Score of the Journal of the Indian Chemical Society (Elsevier Publication).
7. Making the Journal Open Access with innovative concepts.
8. 100+ Fellows from Industry.
9. 100 Corporate Members.
10. 100 Institutional members.
11. 100 Student Awards.
12. Encouragement for Lady Scientists by new awards.
13. Chemistry in School: New Initiative for School Children in All Schools to be celebrated on 2nd/3rd August every year.
14. Appeal to all Senior Fellows for Donation as Patrons.
15. Establishment of State Branches.
16. 100 College Chapters.
17. 100 University/IIT/IISERS/ Chapters.
18. Opening of Branches Overseas.
19. Collaboration of Branches with HO.
20. Collaboration with Other Organizations and Societies.
21. Reorganization of three major events across the country.
22. Conference by Foreign Fellows .



- Celebration of the Society's centenary year with year-long programming
- Construction of ICS building with the help of government & industry
- Securing industry support for all endowment lectures as well as creation of new awards
- Increasing numbers of fellows and members, especially fellows from industry
- Increasing the number of student chapters across the nation
- Introduction of E-Governance and streamlining of all databases
- Reorganization of the three main events to make them more impactful
- Raising the impact factor and source citation of the Journal of the Indian Chemical Society
- Opening of overseas branches
- Hosting weekly webinar series with the support of regional branches and council members
- Getting government approval for declaring August 2 as National Chemistry Day
- Increasing the corpus and financial health of the Society
- Collaboration with other professional societies in India and abroad for the benefit of the ICS

Figure 4. Planned activities for the ICS Centennial Year.

The Pledge of the Indian Chemical Society

This is my Society, the Indian Chemical Society. I take deep pride in it, but without vainglory; to it I owe solemn obligations that I am eager to fulfill.

I am privileged to be part of a great tradition, rich culture and ethos built by selfless services of great many individuals and followers of the Founder Acharya Prafulla Chandra Ray, the Sage.

I take great pride in the achievements and eminence of chemical sciences, engineering and technology.

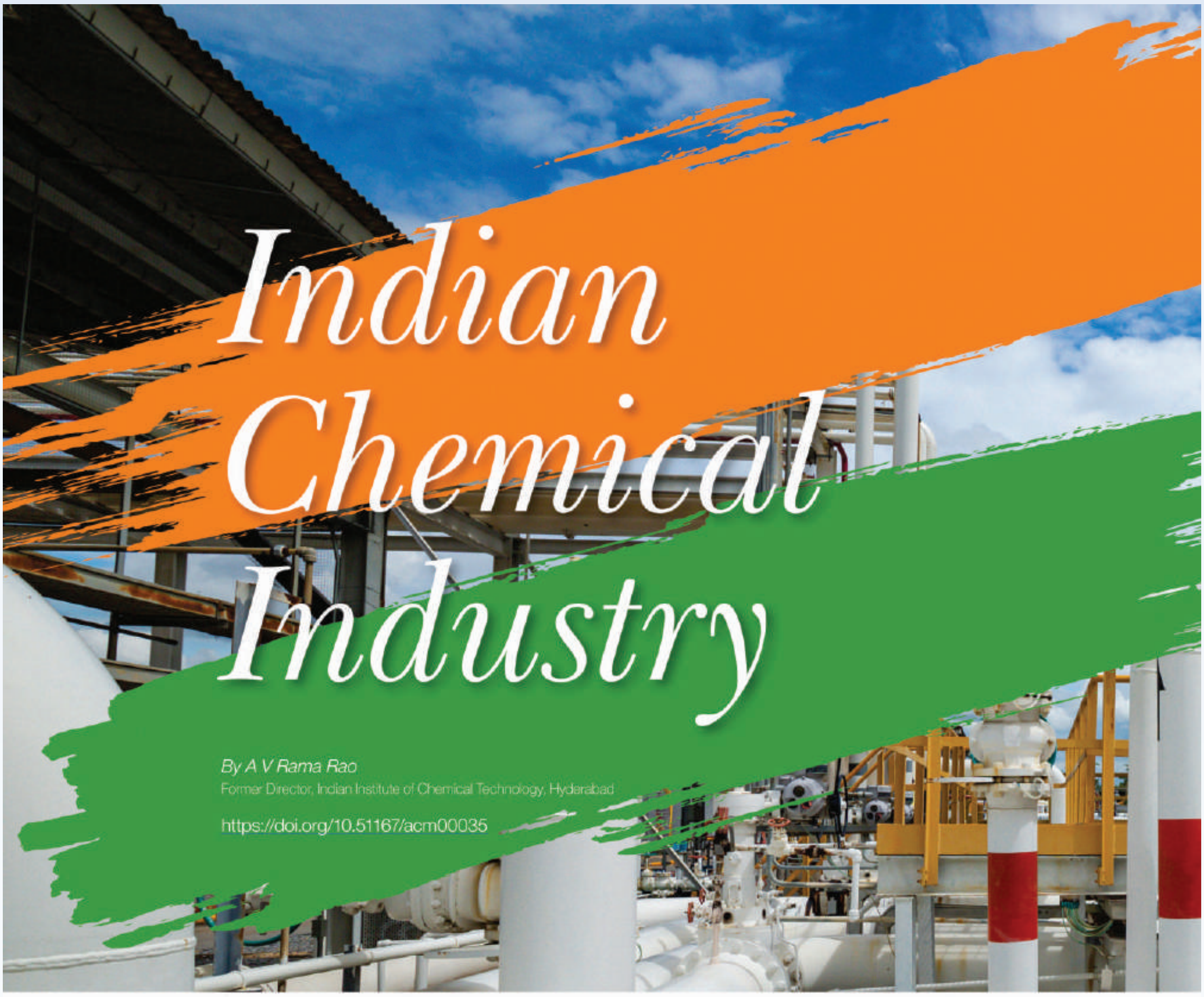
I am fully aware that there is a confluence of chemical sciences with biological sciences in search of better solutions to the pressing problems faced by humanity. I am a beneficiary and benefactor.

Chemistry has been serving all lifeforms since time immemorial; and will continue to serve in achieving the goals of the Net Zero, sustainable development, containing climate change, and lead us towards the path of peace, prosperity, luxury and comfort.

I will be in a company of knowledge seekers, givers and servers associated with the Society. It will be my endeavour to protect its reputation and legacy. I will participate in none but honest enterprise.

I shall shun prejudice of all kinds and perform actions that are deemed righteous morally, ethically, professionally and legally.

To my fellows I pledge, in the same full measure I ask of them, integrity and fair dealing, tolerance and respect, and devotion to the repute and the dignity of our Society; with the consciousness, always, that our special expertness carries with the obligation TO SERVE HUMANITY WITH COMPLETE SINCERITY.



Indian Chemical Industry

By A V Rama Rao

Former Director, Indian Institute of Chemical Technology, Hyderabad

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In early 1940s, I was a young child who suffered several bouts of malaria. The only drug available at the time was quinine which was sold in the local post office. No doubt it helped as a cure, but many also died of malaria. I also realized if anybody contacted TB, they would die in a short time. The other prominent disease was smallpox. If a patient contacts smallpox their survival rate was very slim. People believed that it was due to the curse of the local Goddess, and they would perform rituals, poojas and prayers for eradicating the disease. I can go on mentioning the gamut of the health problems that people were facing during those times. The life expectancy during those years was less than 40 years. Today the situation is totally different. Malaria as well as TB are no more dreadful diseases. They can be cured with proper medication. Smallpox has been almost totally eradicated from the world due to vaccination programs. Thus, the health of humanity has improved, and the life expectancy has gone up well beyond 70 years. How has this happened? This is due to the relentless efforts of chemical and pharmaceutical industries. We now live in a world with lifesaving drugs, where many are available as generics - off patent drugs available at a much affordable price.

Even in India, domestic chemical manufacturers provide various fertilizers, agrochemicals for our food. We use colouring material such as dyes and pigments to colour fabrics and for a variety of other uses. The polymer industry has grown and entered every aspect of our lives, from packing water, milk, and food, for the clothes we wear, furniture, automobiles, machines and electronics we use are made from plastics. The list is long.

Chemical Industry:

Chemistry is at the center of all the action; atoms form molecules which further aggregate to everything in life. The subject has grown, and its allied industries have evolved to deliver everything that supports our lives.

The global chemical market is worth USD 4.73 trillion, and Europe was the largest producer till recent years with China taking over most of the global chemical production. The German company BASF is the world's largest chemical company. The fast-growing Chinese chemical industry is now valued at over 1.5 trillion US dollars and representing 40% of the global chemical industry revenue.

Chemicals can be broadly divided as large volume or bulk chemicals which include petrochemicals, fertilizers, polymers, etc. and specialty chemicals which are also referred to as fine chemicals which have a relatively higher value and used in making pharmaceutical drugs, dyes, agrochemicals, fragrances, and materials

The Indian chemical industry is valued at over USD 200 billion (3% of the world sales) and likely to reach USD 300 billion by 2025. Drugs and Pharmaceuticals normally form a separate class and generally are not included in the chemical sector. India has played a major role in the production of generic drugs (copies of off-patent branded drugs that have the same chemical composition and intended for the same use as the branded drug).

Before any pharmaceutical company introduces a new drug in the market they patent and protect their product to become the sole manufacturer of the drug for the patent duration (life of a patent is normally 20 years). Once the patent expires, other companies can manufacture the same drug with the same chemical composition and purity, these are referred as generic drugs. Today, India had the distinction of being

Dr. A V Rama Rao

Dr. A.V. Rama Rao was born in 1935 in Guntur, Andhra Pradesh, and received his B.Sc. in 1960 from Bombay University and Ph.D. in 1964 from NCL Pune with Dr. K. Venkataraman. While at NCL, he took a sabbatical leave with Prof E.J. Corey at Harvard University (1975-1977). In 1965 he became a Scientist B at NCL Pune and later was Head of the Organic Chemistry Division there, In 1985, He moved to the CSIR in Hyderabad as a Director and transformed the Regional Research Laboratory (RRL) into the Indian Institute of Chemical Technology (IICT). After retirement in 1995, he founded the A. V. Rama Rao Research Foundation, a non-governmental promoting research and doctoral studies in chemistry, and the Avra Laboratories. This multi-million-dollar pharmaceutical company currently has over 600 employees. Dr. Rama Rao has trained 112 Ph.D. students and published more than 260 papers on the isolation and structural elucidation of plant and insect pigments and synthetic dyes, biologically active natural products such as antitumor antibiotics, macrolides, immunosuppressants, and cyclic peptides. He received the Padma Shri (1991), Padma Bhushan (2016), and the technology award from the World Academy of Sciences (TWAS). He is a fellow of all science academies in India and a fellow of the TWAS.

the second largest producer with USFDA approved drug manufacturing units outside the US. The Indian pharmaceutical companies have filed so far more than 1218 ANDAs (abbreviated new drug application) with the USFDA which amounts 45.5% of all applications. The top 20 Indian pharmaceutical companies constitute 80.5% of these applications and 40% of generic drugs used in USA come from Indian manufacturers. The country also has a well-evolved ecosystem of highly skilled professionals to undertake these tasks required for highly regulated manufacturing. Further, 95% of its domestic bulk drug requirements are met by the local industries ensuring drug prices in India are one of the lowest in the world.

Over the last 5 decades, I dealt extensively with the Indian pharma industry and watched it grow from its infancy to its current leadership position.

Earlier History of the Indian drugs and pharmaceutical industry:

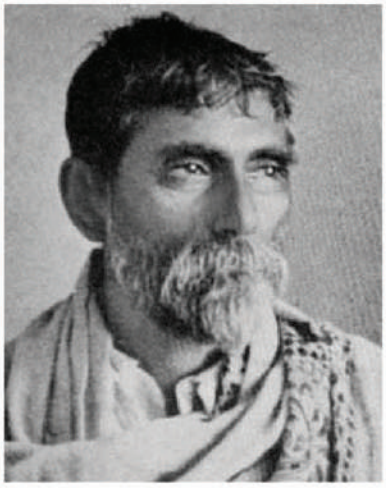
Before the British invaded and took over the country, the Indian medical system relied on traditional Ayurveda and Unani, which were the only indigenous forms that were practiced for the health care and available. The development of the drug industry in India started around a century ago. In 1892, Acharya Prafulla Chandra Ray (P C Ray), started a small manufacturing factory for chemicals and pharmaceuticals named as Bengal Chemicals and Pharmaceuticals in a rented house at "91, Upper Circular Road, Calcutta" with a minimum capital of Indian rupees 700. Ray was keen to exploit the knowledge of ancient Indian medicine by adopting modern methods for manufacturing. The company was converted as a limited company in the name of Bengal Chemicals and Pharmaceutical Works Limited in 1901. It gradually expanded and had undertaken bulk drug production and formulations. In addition, the company was making some perfumes, cosmetics, surgical equipment. Till 1960 the company-maintained leadership in technology after which its sales slowly went down and became sick in 1970. The Government of India nationalized it in December 1980, but it did not recover and once again was declared sick on 14 Jan 1993. Further attempts to revive the company by infusing more money during the Government's 11th five-year plan did not help. Ray also established in 1919 Bengal Immunity Company Limited to produce Sera, vaccines and toxoids, based on their know-how using indigenous raw materials. An important life-saving contribution the company made was the development of an anti-snake venom serum which was effective against the commonly encountered Indian Cobra. The serum was prepared from concentrated and purified plasma obtained from hyper-immunizing horses.

The second major chemical and pharmaceutical company in India was Alembic Chemical Works Company Limited started by B D Amin in 1907 in Baroda with the support of the Maharaja of Baroda. It has grown into a multinational organization and is involved in the manufacture of drugs and intermediates. The company is a leader in macrolide segments of anti-infective drugs and also has expertise in peptide manufacture.

In the US and Europe, modern drug development witnessed a revolution and rapid growth between 1930 to 1960, wherein several breakthroughs were made with the discovery of penicillin and other antibiotics along with the development of synthetic drugs that could treat a gamut of diseases. For example, in early 1930s, Gerhard Domagk of Bayer in Germany tested various azo-dyes against Streptococcal bacteria and discovered Prontosil as an antibacterial agent. In late 1935, he gave it to his dying daughter suffering from a streptococcal infection. She recovered although with a side effect that turned her bright red. Prontosil was not active in Vitro but in Vivo it was converted to Sulphanilamide the main active compound and this discovery gave birth to various sulpha-drugs. He was awarded the the Nobel Prize in 1939.

Another major and accidental discovery was Penicillin. Alexander Fleming working at St. Mary's hospital, London in 1928 discovered Penicillin a life-saving antibiotic drug. Penicillin's curative power and therapeutic action was fully identified by Howard Florey and Ernest Boris Chain and finally the drug was mass produced and commercialized in 1941. During the second world war Penicillin was extensively used to treat the wounded soldiers. Currently, Penicillin is more a starting material for the manufacture of several semi-synthetic antibiotics such as Ampicillin and Amoxicillin. During that period several synthetic drugs also entered the market, which include vitamins, hormones, psychotropic drugs, antihistamines, and anesthetics. However, in India before independence most of these drugs were not made and not easily accessible at affordable prices.

Several multinational companies had formulation facilities in India and were using imported active drug substances, these included- Glaxo, Burrows Welcome, Ciba, Roche, Parke-Davis, Merck, Hoechst, and Wyeth.



Acharya Prafulla Chandra Ray
(1861 – 1944)

(Gerhard Domagk)
Discoverer of sulfa drug

(Alexander Fleming)

These multinational companies operating in India took advantage of the prevailing Indian Patent Act of 1911 and almost all the new drugs introduced in India were priced higher compared to New York or London prices. Realizing the need for affordable health care, the Indian Government encouraged the production of drugs by starting state-owned public-sector units. Thus, Hindustan Antibiotics was started in Pune in 1955 to produce penicillin and streptomycin and their formulations with aid from WHO and UNICEF. Similarly, Indian Drugs and Pharmaceuticals Limited (IDPL) was incorporated in 1961, with the sole objective of creating self-sufficiency through the domestic manufacturing of essential life-saving drugs. IDPL's facility in Hyderabad started manufacturing several synthetic drugs including sulfa drugs and vitamins initially with assistance from the former Soviet Union (USSR) government.

IDPL - Hyderabad played a major role in developing infrastructure for the growth of the Indian drug industry especially the bulk drug industry which involved the mass production of active ingredients. Later some the technical staff left IDPL and started their own companies based on the knowledge that they acquired from IDPL. Several of these former employees went on to become successful entrepreneurs while laying the foundation for the private pharmaceutical industry. Unfortunately, the growth of the private sector led to downfall of the state owned IDPL which was finally liquidated on 9th February 2021 by the Government of India. The city of Hyderabad owes its success and reputation as the pharma capital of India to IDPL. The two states of Andhra Pradesh and Telangana together have 2500 pharma companies with most of them having their headquarters in Hyderabad.

Several Indian companies came together and formed the Indian Drug Manufacturing Association (IDMA) in 1961, with the sole aim of boosting domestic manufacturing. They fought to amend the 1911 Patent Act, a struggle which was culminated in the enactment of the Indian Patent Act of 1970 which was passed by the Indian parliament in September 1972. As a result, "all product patents for drugs and agrochemicals were abolished and only process patents were allowed for a period of 7 years from the date of filing the patent or 5 years from the date of acceptance whichever is earlier". This allowed the Indian pharma industry to begin its journey of drug development and manufacturing. In 1947, the Indian pharma industry had a turnover of Rs.10 crores which had gone up to Rs.360 crores by 1972 but this was just over 1% of the world pharma market value. By 1980's there was phenomenal growth; imports of pharmaceuticals was marginal while India started exporting API's (Generic drugs) and their formulations to various countries.

Indian Institutions and Industry collaboration for developing technologies for lifesaving drugs:

After enacting the new patent law, the then Prime Minister, Mrs. Indira Gandhi who was also the President of the Council for Scientific and Industrial Research (CSIR) instructed all the CSIR Directors, to initiate the development for drugs and agrochemicals and help the Indian chemical industry in technology transfer and commercialization. Dr. B D Tilak, the then Director of National Chemical Laboratory (NCL), Pune, called a meeting of various divisional heads including myself; I happened to be a young project leader in NCL. Dr Tilak stated the Government's intent to initiate work towards the process development for some of the essential drugs. Most of the senior scientists did not take his message seriously and some even refused expressing that they were working in the NCL with a meager salary only for the academic pursuit of fundamental research and if they had to do industrial research, they could as well go to industry and earn a salary at least 10 times higher than what they were being offered in NCL. I was a graduate of Chemical Technology from Bombay University; I realized that the search for innovative solutions to industry related problems could also be done along with basic academic research. I felt finding a new process to produce a drug could be as exciting and gratifying as getting a research article published in a scientific journal. In this quest, I selected Diazepam (Valium, an antianxiety agent produced by Roche) as its sales were growing significantly globally while its production was only in kilo gram quantities per annum. The process that was patented by Roche was tedious for the Indian manufacturers to scale-up. The original Roche process made the key intermediate – "2-methylamino-5-chlorobenzophenone" starting from 4-chloroaniline by reacting with benzoyl chloride in molten zinc chloride and the resultant product was subjected to acid hydrolysis to yield 2-amino-5-chlorobenzophenone. This was then subjected to N-methylation using a classical method and finally converted to Diazepam. I developed a simple process whereby the

Dr. Yusuf K Hamied

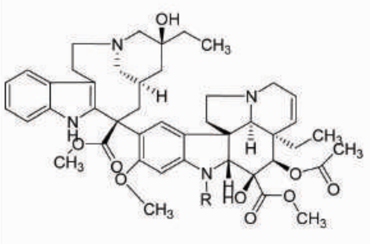
CSIR-Indian Institute of Chemical Technology

same intermediate could be made starting from 4-nitrochlorobenzene using simple operations which made the product drastically cheaper compared to the original patented process. In 1973, I met Dr. Y K Hamied, who was then the Director of R&D in CIPLA and informed him about my work on Diazepam. He was so impressed with my approach that he decided to buy the route of synthesis without waiting for our process scale up. He met Dr. Tilak and told him that he would like to make a one-time payment on nonexclusive basis for the laboratory process developed by Rama Rao. This was the first drug process technology sale from CSIR-NCL that was successfully commercialized by an Indian industry.

Rama Rao's Contributions to Indian Drug Industry - Consultancy and contract research:

After my return from Harvard University working in Prof. E J Corey's group, it was my intention to continue working on important industrial projects. The isolation of Vinblastine and Vincristine, two complex alkaloid molecules from Madagascar periwinkle - *Vinca Rosea* leaves seemed like a colossal challenge to take on. *Vinca Rosea* (*Catharanthus roseus)* was widely grown in India and known for its medicinal properties. In fact, even today some people in Kerala use the dry leaf decoction believing that it cures diabetes. In late 1950's, a delegation from Eli Lilly came to India to look at the Indian medical system and the plant materials that were used as herbal remedies. They carried with them the Vinca dried leaves and looked for antidiabetic agents from the leaf extract. They could not find any active component for the treatment of diabetes but were surprised to realize that the extract contained an anticancer agent. The plant contains nearly 95 alkaloids which were mostly monomers but a small fraction of the alkaloids were dimeric. The Eli Lily team separated the active vinca-alkaloid named Vinblastine using a very tedious alumina column chromatography. Further, they also isolated another minor component named Vincristine which was more active and an effective treatment for pediatric leukemia. Based on these positive results they were importing huge quantities of dried vinca leaves from India. With the growing demand some of the traders who were exporting dried vinca leaves became greedy and started adulterating the vinca leaves. Faced with this problem of getting good quality raw material from India, Eli Lilly started their own plantations near Houston in the southern parts of US where the climate was suitable to grow the Madagascar periwinkle plants. Around the early 1970's, sourcing of the leaves from India was stopped. This led to a political problem with the Maharashtra government having to deal with livelihood of many people who were growing and harvesting this medicinal crop. The state government started procuring these dried leaves and were keenly looking for an institution to develop an indigenous approach to isolate the two valuable dimeric alkaloids. In 1978, I approached the Maharashtra Government for funding to take up this project and was given a grant. My research group quickly worked out a simple process of isolating vinblastine using a solvent extract technique from the vinca dried leaves thereby totally avoiding the tedious chromatography column separation. We then converted it by a simple potassium permanganate oxidation to give Vincristine. We also worked out a way to formulate the drug substance by way of lyophilizing in the form of vials with the help of Hindustan Antibiotics Limited (HAL). For the first time, we demonstrated that the bioavailability of the drug was identical with Eli Lilly's imported vials with assistance from the Head of the Chemotherapy at the Tata Cancer Hospital, Mumbai. The entire technology including its formulation process was passed on to Cipla for commercialization. Cipla introduced both these two natural anticancer agents in 1983 in India and subsequently in 1985 started exporting these two compounds to US and Europe. This was the second example of successfully achieving a solution to a difficult problem where better technology was developed in NCL and commercialized by a domestic company.

Another example which came out from the National Chemical Laboratory was Vitamin-B6. The work on Vitamin-B6 was initiated at NCL in 1958 based on the directive from the Government of India to work on an indigenous process technology and pass it on to the Indian Drugs and Pharmaceuticals Limited (IDPL) in Hyderabad for commercialization. NCL started working on the original twelve step process based on Harris and Folkers method of Merck. When NCL scientists initiated the work in 1958 the cost of vitamin-B6 in international market was 450 USD per kilo but by 1963 the price came down to 80 USD per kilo. This dramatic change happened based on a publication by Kondratyers from USSR stating that substituted hydroxypyridines could be made by a simple Diels Alder reaction involving substituted oxazole with dimethyl acetylene dicarboxylate. Pursuing this new finding, the project was once again taken up by NCL based on Merck process and carried out on pilot plant scale by 1973. But by then the price of vitamin-B6 came down to 30 USD, which the NCL process was not able to meet, and the project was shelved. Later, when I took over as the Head of the Organic Chemistry Department in 1980 at NCL and I was keen to revive the process to work on the vitamin-B6 despite the then Director's reluctance. We realized what went wrong with the earlier process. They used 4-Methy-5-ehtoxyoxazole as the diene, which is very unstable to heat and resulted in lower yields after Diels Alder reaction. Contrary to it, we used 4-methyl-5-cyanooxazole as the diene, which is relatively stable to heat and reacted with cis-1,4-butene diol acetonide as the dienophile. By this way, the process worked out better, successfully carried out on pilot scale and finally commercialized by Lupin Laboratories in their Ankleswar unit in 1985. I continued to associate with Indian industries and taken up several projects under sponsorship or what is referred to as contract research today. I was also an active consultant with several Indian pharmaceutical companies. We worked on developing processes for beta-blockers such as Atenolol and Metoprolol for Cipla and for the first time in India made a chiral drug - Timolol and passed on its technology to FDC, Bombay.



Vinblastine: R=Me
Vincristine: R=CHO

Subsequently, I moved to Hyderabad as Director, Regional Research Laboratories (RRL) in 1985 which was renamed as the Indian Institute of Chemical Technology (IICT) in 1988. Here, I continued to work closely with Indian pharma industry. At IICT, we developed technology for making an anticancer drug, Etoposide and successful transferred the technology to Cipla for its manufacture. We also developed a laboratory process for Norfloxacin and Ciprofloxacin for Cipla. We were also instrumental in developing several other processes for Indian pharma which include Flurbiprofen (for FDC), Astemizole and Gemfibrozil (for Cadila), Mefloquine and Sulbactam (for Unichem).

Dr. Kallam Anji Reddy
(1939 – 2013)

Indian Pharma Revolution after 1972:

Many Indian companies were very keen to take advantage of the new 1972 patent law in India and started copying some of the new and essential drugs which were being made internationally and were keen to introduce them in Indian market. The demand for talented chemists and chemical engineers spiked as more R&D and production units were established. Several entrepreneurs with technical expertise ventured into starting their own companies. One such successful example was Dr. K Anji Reddy, a graduate in chemical technology from UDCT and obtained his Ph.D. in chemical engineering from NCL and joined IDPL as technical officer in 1968.

He was directly involved in taking up R&D projects of IDPL, scaling up on pilot plant and manufacturing. He was very keen to go on his own and set up a company - Uniloids with two other partners in 1974. They started producing Metronidazole which became a big hit in the Indian market. Later he parted ways and founded Standard Organics Limited in 1980 to manufacture Sulfamethoxazole and Trimethoprim. Standard Organics quickly became the leader in the domestic market for these two drugs and also started exporting them to other countries. Anji Reddy started another company named Cheminor in 1981 with Mr. Murali Divi to exclusively manufacture Ibuprofen. Anji Reddy was a family friend, both at UDCT and subsequently at NCL before he left for Hyderabad to work at IDPL. He consulted with me to know more about the Ibuprofen process which we had developed and transferred to Cipla on a non-exclusive basis. I had some new ideas and suggested to use a process starting from 4-isobutylacetophenone, reducing the ketone to alcohol, Dr Reddy's grew into a multinational and today has revenue around USD 2.5 billion manufacturing over 60 API's and is the fifth largest pharma company in India.

The city of Hyderabad continued to produce many great pharma entrepreneurs and is home to majority of the country's top pharmaceutical companies. Aurobindo was founded in 1986 by Mr. P V Ramprasad Reddy; Divi's Laboratories founded in 1990 by Murali Divi; Hetero Drugs founded Dr. B Parthasaradhi Reddy in 1993. All above three were colleagues and associates of Dr. Anji Reddy.

Today, Hyderabad accounts for 40% of total Indian bulk drug production and 50% of them are exported and is regarded as a "Bulk Drug Capital of India".

Cipla was founded by Dr. K A Hamied in 1935 and in the beginning the company confined to formulations and did not manufacture drugs. In 1960, his eldest son Dr. Yusuf K Hamied completed his Ph.D. in chemistry from Cambridge University joined Cipla as its R&D Head. He realized that Cipla would not grow unless it has its own drug manufacturing facilities. Cipla was the first company to introduce steroids in the country and later went on to manufacture almost all the major generic drugs and their formulations. Having had the training in synthetic organic chemistry, Dr. Yusuf Hamied also pioneered the concept of academic and industry interaction and sponsored several projects with my research group at NCL and subsequently at IICT. In 1991, I approached him to commercialize Zidovudine, commonly known as AZT, which at that time

Inaugural function of Cipla Patalganga factory in 1984 (from Right – Dr. A V Rama Rao, Dr. Y K Hamied, Dr. G S Sidhu, DG-CSIR, Hamied's Mother)

was the only drug available for treating HIV and AIDS patients. Initially he was reluctant to introduce this drug as he felt the market was limited. I convinced him that HIV would soon be a major problem in India. Further, I pleaded with the Government of India to waive the import duty on the starting material Beta-Thymidine to help lower the cost of the drug production. I also impressed on the Drug Controller of India on the importance of AZT production by Cipla to facilitate clinical trials to the extent possible within the country. By the combined efforts of the Government and my research group, Cipla commercialized the AZT production in 1993 and marketed the 100 mg capsule formulation at 1/6th of the then prevailing international price. Later Cipla developed several anti-HIV medications and offered the world's first triple single drug cocktail named Triomune at a price of less than one USD per patient per day. Being HIV positive is no longer a death sentence and can be treated as a chronic disease with affordable medicines, thanks to Cipla and several Indian companies that are manufacturing these drugs at low cost.

Future of Indian Drug Industry:

In 1994, India joined the World Trade Organization and accepted the TRIPS mandate. The Indian Patent Act of 1972 was amended on 26th December 2004 and came into effect from January 2005. By this act all product patents were allowed in all sectors, license of right deleted, it also allowed microorganisms to be made patentable while the pre and post grant opposition provision was included in the act. The Government can sanction compulsory licensing wherever required for domestic use. The Indian patent act of 2005 specifically stated that incremental changes will not be regarded as exclusive right. Based on this analogy, drug controller of India did not allow its product patent for Novartis for Imatinib. They appealed to supreme court, even then the court ruled that it was an improved version and not a new invention. India also issued its first compulsory licensing in March 2012 to NATCO Pharma to manufacture Bayer anticancer drug "Nexaver".

After the new patent law, Indian companies invested large sums of money for drug discovery. Dr. K Anji Reddy founder of Dr. Reddy's was a pioneer and made huge investments in the search for new drugs in therapeutic areas such as antidiabetic, cardiovascular and analgesics. These efforts led to development of the two antidiabetic drug candidates which were taken up by multinational companies for further clinical trials. Unfortunately, as is the case with several drug candidates, they could not provide the required results to make it to market.

So far there is only one indigenous drug in the Indian market and this was developed by the Central Drug Research Institute (CDRI), Lucknow. Thanks to the efforts of its former Director, Dr. Nitya Anand, the compound known as Centchroman (Generic name – Ormeloxifene) was introduced in India in 1991 and is a nonsteroidal oral contraceptive. The drug is marketed under the trade name Saheli by Hindustan Latex Limited and used by many women as an oral contraceptive taken one pill per week. This drug is distributed free of cost through government hospitals.

The present global API market is around USD 200 billion while the global pharmaceutical market is valued at USD 1.4 trillion. While these numbers appear attractive, the business itself is very competitive with more than 2000 firms and 5000 manufacturing sites. Currently, India has a reputation in producing high quality and low-cost generic drugs in the world. This industry has been valued at USD 42 billion by 2020. India is the third largest provider of generic medicines by volume and having 20% of global market share. It is also the largest supplier of vaccines to the world by volume and accounting for more than 50% of all vaccines manufacturing in the world. Indian pharmaceutical business is showing an annual average growth of 11% per annum and is expected to reach 60 billion USD in value by 2024. The future of the pharmaceutical business in India is promising and investments into this sector are only increasing, but the area of concern where India needs to achieve self-sufficiency is in the production of raw materials used for making APIs. Most of the Indian companies depend on the import of key starting materials from China and this accounts to 58% by value and 80% by volume. Most of the fermentation products especially antibiotics and almost all steroids are being imported into India from China. Although India is known as the largest producer of Metformin in the world which is used for treating diabetes; two key intermediates for making this drug are imported from China. To counter this dependence on China, in recent years, the Indian government came out with incentives to be given to domestic companies that can produce products without the need for any raw materials being imported.

For the last two decades several entrepreneurs have entered the pharmaceutical business with start-ups offering a gamut of research services along with testing and manufacturing capabilities. I was one of the early entrants who believed in the contract research as a business story. After my retirement at the age of 60 as the Director of CSIR-Indian Institute of Chemical Technology (IICT) in 1995, I started my own venture named Avra Laboratories Private Limited to offer R&D services to multinational companies. Avra grew quickly and built a reputation for being able to work on complex problems and offer low-cost solutions. Our success led many other companies to take notice of the opportunities and join in this space of contract research and manufacturing.

Dr. Nitya Anand

Within a span of a decade, India became a preferred destination for global pharmaceutical companies to source both products and research services. Besides succeeding as a contract research organization, Avra became the first company to produce a complex anticancer drug Irinotecan by total synthesis. Originally, this drug was made from a starting compound Camptothecin, a natural plant alkaloid which has the complex core and is converted to Irinotecan through a semisynthetic approach. Today Avra is a global leader offering advanced intermediates that allow for the facile production of Camptothecin related derivatives.

Dyes & Pigments - Introduction:

Human beings always use colours to decorate themselves, garments, tools, and their surroundings for beautification. Traditionally colours were derived from natural sources. India was known for centuries for producing natural colours derived from plants or insects to dye fabrics. Even during the bronze-age civilization of Mohenjo-Daro, there is evidence of the use of natural colours being applied to fabrics, pottery, and other items. Archaeological data shows evidence of dyeing fabrics with colours derived from plants and insects traced back to about 5000 years in places from the Fertile Crescent, a region in the Middle East considered the cradle of civilization and China.

Natural dyes are derived from plants, invertebrates, or minerals. While most colouring agents are of plant origin others are obtained from biological sources such as insects and fungi. Many natural dyes require the use of chemical compounds called mordents to fix the dye to the fabrics. Mordents are normally inorganic salts such as alum, Ferric sulphate, copper sulphate and other polyvalent metal ions that form a coordination complex with dye and attach to the fabric. Examples of such traditional natural dyes include Tyrion, Crimson, Kermes, Indigo, Saffron, and Madder.

Till the end of the 18th century, Indigo was much sought after from the blue colour it imparts to the fabric. The oldest indigo coloured fabric was discovered in Peru and dates to around 6000 years ago. India was a major center for its production and processing where the plant was cultivated in Bengal.

Cutch is another Asian dye from the wood of Acacia tree, commonly found in India for dyeing cotton to give green, brown colours using an iron-based mordent and an olive brown colour when used with copper salts. Turkey red used for dyeing cotton and was isolated from madder root of the Rubia plant, a process that was developed in India and spread to Turkey. Indian Madder (Rubia cordifolia) is found in the Himalayan regions and still used by craft dyers in Nepal. Besides the spice trade, it was these dyes that brought the Europeans and the East India Company to trade and later colonize parts of India and Asia.

Lac dye is the colouring matter of the lac resin produced by the insect Kerria lacca. The structure of Lac dye eluded the scientists more than five decades after its isolation. The dye known as laccaic acid was first isolated in 1887 and regarded as a single compound. However, efforts to obtain pure laccaic acid eluded scientists for a long time. Renowned Indian chemists, Prof. K Venkataraman, and Prof. T R Sheshadri dedicated a lot of time and effort to identify to its structure and see whether a synthetic alternative could be commercially produced. Prof. K Venkataraman's group spent more than 10 years between 1955 to 1965 and could not elucidate its structure. However, they demonstrated that the dye was a mixture of at least two compounds, one of them having an aliphatic nitrogen in the form of an amine present as the major component. In 1965, I was appointed as a scientist in Venkataraman's group, and he assigned me the task to continue the search for the structure of lac dye. As I worked on this project, I found that the compound was a mixture of two major compounds, one containing a nitrogen as was anticipated along with two more minor components that were named laccaic acid D and laccaic acid E. We were able to determine all the structures based on NMR and mass spectral data. We learnt that one component was missing in the lac dye referred as laccaic acid C derived from tyrosine. We also established a biogenetic synthesis starting from laccaic acid D coupling with tyrosine to yield laccaic acid C, decarboxylation gave laccaic acid E which on acetylation of the amino group gave the major laccaic acid A with its distinct red colour. The pure lac dye was found to be totally non-toxic and could be used as a food colouring agent. Unfortunately, the purification cost is very expensive, and the costs prohibited its use in pure form. In the past the natural resin was used to make gramophone records and telephone equipment, today, its resin is used as a commodity by the paint industry.

The Advent of Synthetic dyes:

The first synthetic dye, Mauve was discovered by W H Parkin while carrying his Ph.D. program to synthesize quinine at the age of 18 years. The compound was bright red and dyed fabric which was not washable. He filed a patent in August 1856 and established the first factory to manufacture synthetic dyes in Greenford, near London. He became rich at a very young age. After this, many major chemical industries such as BASF and Bayer in Germany started working on synthetic dyes in a major way. Indigo which was a most important natural dye from India was first synthesized by Adolf Von Baeyer who reported its synthesis in 1878 and commercialized its manufacturing in 1890. Baeyer received the Nobel prize in chemistry in 1905 for his contribution to the synthesis of Indigo. The synthetic indigo replaced the natural product in 1914 and only 4.1% of the total production of natural dyes came from plants.

The first synthetic dye was made in 1856 and in subsequent years several different classes of dyes entered the market and last class of reactive dyes came from UK from ICI in 1956. Dyes are classified by their method of application to a substrate and placed in categories such as direct dyes, reactive dyes, vat dyes, disperse dyes, azoic dyes, and other types.

Most of the dyes were manufactured using big reactors by utilizing batch operations. With time several improvements were made in the production of synthetic dyes in the form of workup, drying using agitated thin film dryers, and falling film evaporators. Much of the research work was focused on the dye application on cotton, polyester, and polyamide fabrics. Efforts were also made to achieve very high fixations using reactive dyes on cotton and leather, to reduce dye discharges from entering into effluent streams.

Indian Dye Stuff Industry:

The first dye stuff industry unit in India was the Associated Research Laboratories now called ARLab, established in 1941 near Pune, the next big facility in the organized sector was set up by Atul Industries in 1947 in Bulsar where a variety of dyes were produced from 1957. Indian textile industry, which was originally using natural dyes, now totally switched over to synthetic dyes. Two well-known industries in Mumbai in the years between 1960 – 1980, were Amar Dye Limited and the Indian Dyes Industries (IDI). Along with Atic (Atul in collaboration with ICI), was the largest dyestuff industry meeting most of the Indian demand.

The Indian dyes and pigment industries have contributed significantly to the overall growth of the Indian chemical industry. Approximately Rs. 48,000 crores (USD 60 billion) was generated by this industry in the year 2022. This is still a growing sector creating jobs and contributing to exports from India.

In India the top 50 manufacturers of dyes and intermediates have nearly 65% of the total dyestuff market share, the rest of the 35% come from the unorganized sector of small and medium industries of more than several thousand units.

Among the synthetic dyes, the reactive dyes are much in use with a production capacity of around 100,000 tons. For direct dyes the production quantities are nearly 20,000 tons, while disperse dyes, basic, sulphur, and others have a capacity of approximately 10,000 tons per annum. These dye stuffs find several applications in industries where 80% of the dyes are consumed by the textile industry. The growth of the textile and leather industries is a consequence or supplement for the growth of dye industry. In India, nearly 90% of dye stuff manufacturing confined to Gujarat and Maharashtra states. In the year 2017 India exported dyes worth approximately 2.4 billion USD. Among them US constitute 8%, Turkey 7.1%, Bangladesh 6%, China 5.7%, Germany 4.6%, Italy 4.3%, Brazil, 3.9% and rest for other countries.

Although organic chemistry as a subject was popular and research labs were started in most Indian institutions and universities, not much attention was given to the chemistry of dyes. There was only one institute in the country, the Institute of Chemical Technology (ICT) in Mumbai which carried out research devoted to textiles chemistry as well as dyes right from its inception in 1934 and now has the Department of Fibres and Textile Processing Technology.

The first Indian Director of the University Department of Chemical Technology (presently ICT) was Prof. K Venkataraman, he was an expert on synthetic dyes and also the first academic to write two volumes on synthetic dyes and their intermediates in 1952. These two volumes were the main source of information related to the dye stuff technology and were so popular that they were translated into 13 international languages.

Pigments:

Pigments are also colouring matter and different from dyes. Pigments are not soluble in solvents, that they can only be suspended in a medium with the help of a binder, on the contrary dyes are substances that go into solution and can impart colour to the fabric. There are two types of pigments where most of them are inorganic pigments while the rest are organic pigments. Inorganic pigments consist of minerals and metal content that imparts their colour and are primarily based on oxide, hydroxide, silicate, sulphate and carbonate types and classified into four groups: white pigments, black pigments, coloured pigments and specialty pigments. They are manufactured by a simple process involving operations such as washing, drying, powdering, sieving and finally formulating.

Organic pigments are also natural products which change the colour of reflected light because of wavelength-selection absorption. Carotenoids are pigments in plants that produce as variety of red to yellow colours as they absorb violet to green light. The red colour of roses is due to pigments that absorb all colours of normal visible light except red which is reflected giving the rose its red colour. The leaves of plants are green due to the pigment chlorophyl, while the colour of our skin is due to the pigment melamine.

Synthetic pigments are compounds that are made in the laboratory and produced on a commercial scale with a greater control over their production. These pigments are widely used in paints, polymers, synthetic fibers, ink and more recently in electronic devices. A good pigment has the following properties: they mix freely, they show chemical resistance, they are normally brilliant and show resistance to light, wetness, and abrasion. In addition, their particle size range is between 0.2 to 0.4 and have an excellent dispersion property and because of scientific advances in field of synthetic pigments several shades of pigment are available for a variety of uses. The red colour of the Ferrari car is from a pigment based on an organic compound called DPP (diketopyrrolopyrrole) which was first synthesized in 1974 by Donald G Farnum at Michigan State University. Pigment Red 254 aka Ferrari Red was developed and patented by Ciba-Geigy in 1983.

In India dyes and pigments are made by several manufacturers. Among the major dyes and pigments manufacturers in India include: Poddar Pigments, Priya Limited, Sadhana Nitro, Sudharshan Chemicals, Sree Hari Chemicals, Ultramarine, Vidhi Dyes, Vipul Organics and others.

Agrochemicals- Introduction:

In the year 1960, as I started my career as a research fellow at the National Chemical Laboratory (NCL), Pune, working for my Ph.D. degree. Growing up in India, we were familiar with droughts, food shortages and famines in the country. Around that time, Norman Borlaug had become famous for his success in growing high yielding wheat strains in Mexico. Renowned Indian Geneticist, M S Swaminathan wrote a letter to the Director of the Indian Agricultural Research Institute that they should invite Norman Borlaug to learn more about his techniques and if they could be applicable in India. In 1963 Dr. Borlaug visited India and brought with him four promising strains of wheat that were planted in Northern India. These seeds worked perfectly in the Indian climate and were also resistant to rust. A report in the New York Times notes, “In pre-Borlaug 1963, wheat grew there (in India) in sparse, irregular strands, was harvested by hand, and was susceptible to rust disease. The maximum yield was 800 lb per acre. By 1968, thanks to Borlaug's varieties, the wheat grew densely packed, was resistant to rust, and the maximum yield had risen to 6,000 lb per acre.”. It was also during this time, India adopted IR-8, a semi-dwarf rice variety developed by the International Rice Research Institute. Soon the yield of wheat and paddy in the country went up to 5 to 6 times higher per hector. A green revolution had begun in the country. This dramatic increase in wheat and rice production was attributed to new strain of seeds along with the use of fertilizers to promote plant growth, and pesticides for crop protection which was coupled with better irrigation facilities. India was on the path towards self-sufficiency in its food production and in the subsequent years it became a major exporter. Norman Borlaug was awarded Nobel Peace Prize in 1970. Prof. M S Swaminathan was responsible for this transformation and is regarded as the father of Indian green revolution.

In recent years, India's need for food grains is growing steadily due to increase in population (1.3 billion people) and at the same time there is constant decline of the cultivable land as much is lost to growing cities with expanding infrastructure for living and industry. For this reason, the Government of India is being forced to enhance farming methods by the use of fertilizers and crop protecting agents.

The history of Indian fertilizer industry:

Back in 1906, the first fertilizer factory in India was opened at Ranipet (Tamil Nadu). In terms of the scale of investment, the fertilizer industry is regarded next to steel. The present global fertilizer market size is around USD 190 billion and there was a 12% growth from the previous year. also is expected to reach double the requirement. Fertilizers are essential for food security. With the available limited land, farmers must use fertilizers to enhance the nutrients in the soil that were taken up by previous crops.

The top 3 Indian fertilizer companies have a market size of around 57% with Chambal Fertilizers and Chemicals Limited Coromandel International Limited leading and having an installed capacity of 1.5 million tons per annum (MTPA). The state of Gujarat is the top producer of fertilizers, while Pondicherry tops the consumption (in kilos per hector) followed by Telangana and Punjab.

Pesticide industry in India:

Pesticides are compounds used as crop protecting agents and include insecticides, herbicides, rodenticides, and fungicides. 292 pesticides are registered in India and of these 40% are organochlorines. Rice has the highest rate of pesticide usage (29%) followed by cotton (27%), vegetables (9%) and pulses (9%). In India, there are about 125 technical grade manufacturers including 10 multinational companies and 800 formulators with several distributors. The formulations are made from technical grade active ingredients by adding inert carriers, adjuvants, emulsions, solvents, and surface-active agents. The Indian agrochemical market is challenging and suffers from high inventory and long credit periods to farmers, thereby, it requires huge working capital. However, its strength comes from low cost manufacturing and qualified personal making India is the 4th largest exporter of pesticides in the world after China, USA, and France.

The main pesticide manufacturers in India include United Phosphorus Limited (UPL), BASF, PI Industries, Bayer Crop Sciences, Syngenta India, and Rallis India where the top ten companies control almost 80% of the market share. These large players have an extended product portfolio and are regularly introducing new molecules. New global strategic alliances and acquisitions are allowing for greater global reach increasing their market share.

In recent years, the Indian government has been advocating integrated pest management and there is also a demand for organic farming. In addition, the spurious pesticide market in the country is growing steadily along with improper use which impacts the revenue and reputation of the organized sector.

Indian Institutions and Industry Interaction:

After the abolition of the Indian product patent laws in 1972, The government of India directed CSIR laboratories to work on processes for both drugs and agrochemicals. The National Chemical Laboratory (NCL), Pune and the Indian Institute of Chemical Technology (IICT), Hyderabad, initiated technology development programs, performed pilot scale studies and finally helped design chemical plants for pesticide production. NCL worked out on Endosulfan and commercialized the product by transferring technology to industries. IICT initiated a major program on organophosphate pesticides such as Monocrotophos, Chlorpyriphos, Cyhalothrin (pyrethroid) insecticides, and Butachlor herbicides. Chlorpyriphos was much in demand and IICT prepared plant designs to enable the production of 300-400 tons per annum and the technology was transferred to over a dozen Indian companies. In addition, we worked on. IICT also carried out work on developing Neem based biopesticides having Azadiractine (13%) for commercial production. IICT was also involved in developing technology for promoting the use of biopesticide - Bacillus thuringiensis, a soil dwelling bacterium and its spores and insecticidal proteins are used in pest control.

Exports:

The global agrochemical market was around USD 225 billion in 2021 and is projected to reach USD 300 billion by 2030. The Indian agrochemical industries valued at around USD 5.72 billion USD in 2020-2021, with domestic consumption around USD 2.72 billion and exports at USD 3 billion. The forecast was exports is growing and many Indian companies like United Phosphorous, Gharda Chemicals, Excel industries and PI are now increasing their global footprint.

A vast majority of the pesticides that are being used are formulations of generics – products whose patent life has expired. Generic pesticides account for 60% of the global crop protection market. In the next ten years (2021-2030) around 22 patented pesticide compounds will become generic. These are Bixafen, Chlorantraniliprole, Cyantraniliprole, Fenpyrazamine, Flubendiamide, Fluopicolide, Fluopyram, Fluxapyroxad, Isopyrazam, Mandipropamid, Penflufen, Penthiopyrad, Pinoxaden, Pyriofenone, Pyroxsulam, Sedaxane, Thiencarbazone-methyl, Valifenalate, Benzovindiflupyr, Sulfoxaflor, Saflufenacil, and Aminopyralid. This would create a 3 to 5 billion USD opportunity for generic manufactures.

Bhopal Gas Tragedy was considered as the world's worst industrial disaster due to a pesticide industry in India purely by not implementing safety measures and the negligence of the work force.

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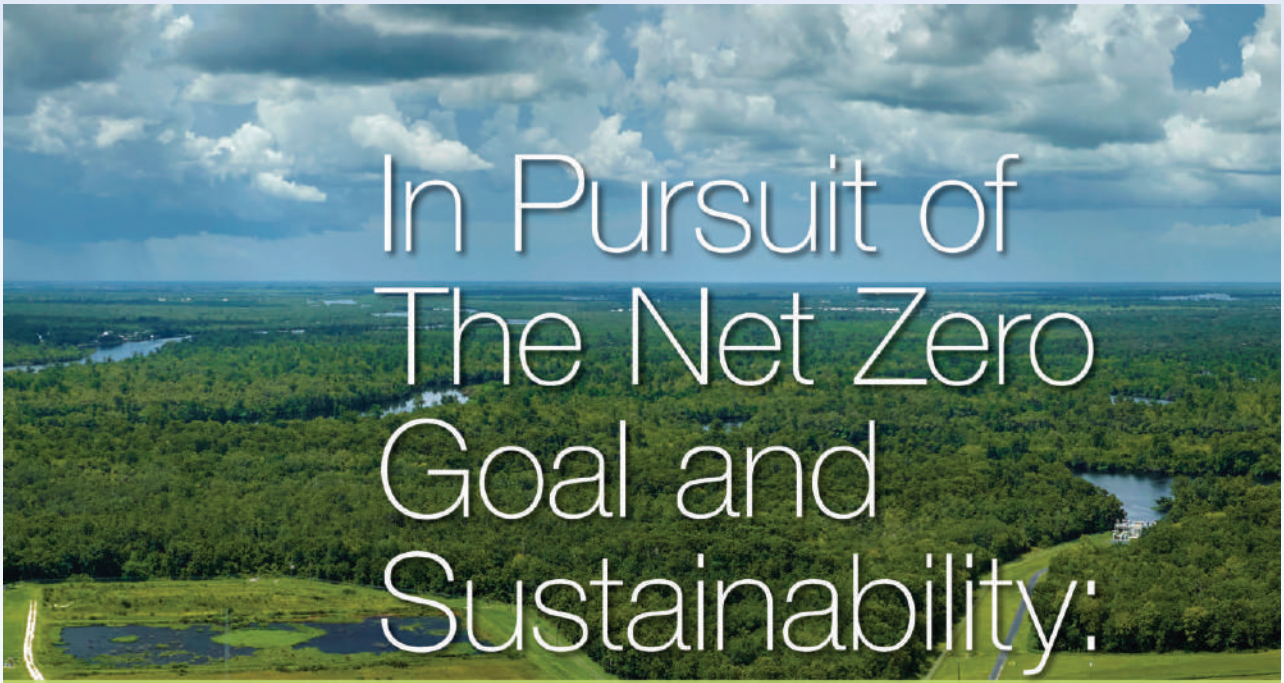

In Pursuit of The Net Zero Goal and Sustainability:

Hydrogen Economy, Carbon Dioxide Refineries, and Valorization of Biomass & Waste Plastic

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COP27 was concluded in Egypt in November 2022 and the world leaders renewed their pledge for the net zero since the world is running out of fossil energy and materials at an alarming rate which was not predicted a few years ago. It is a result of excessive use and waste of energy and materials. The concepts of circular economy and sustainable development were endorsed by all nations of the world and collective efforts and policies were launched. The focus of this article will be how the waste can be converted into wealth be that GHG carbon dioxide, (waste) biomass not used as food, and waste plastic of all kinds by using green hydrogen. Hydrogen will be the savior of the world.

The overuse of fossil carbon including crude oil, coal, and natural gas during the past few decades is primarily responsible for the unprecedented emissions of carbon dioxide leading to climate change, global warming, floods and famines. The fossil carbon will all be exhausted in the foreseeable future bringing into picture the hunt for alternate sustainable resources for energy and materials. Global GHG emissions from fossil fuels and change in land use were responsible for emissions of about 40 Gt CO_2-equivalent 2021. Since the industrial revolution, and particularly after the discovery of petroleum reserves, several billion tons of carbon dioxide have been released into the atmosphere and the concentration stands at 421 ppm (October 2022) with the USA being the topmost and China as the second largest emitters. India is at the third position according to the Global Carbon Project 2021. [1]. However, this scanario will change in the near future as population rises and demand for energy and materials increases disproportionately and no superior technological advances are made. In its pledges - known as Nationally Determined Contributions (NDC) - India has assured that it will take steps to reduce the emissions intensity of its Gross Domestic Product (GDP) by 45% by 2030. The Paris Agreement of 2015 pledged that the nations of the world should restrict the global temperature rise

to less than 2°C and preferably below 1.5°C by adoption of new technologies, energy efficiency and alternate sources, and thus the plan for the net (carbon) zero emissions by 2050 was mooted [2]. In the COP26 held in Glasgow in November 2021, India committed to achieve the net zero goal by 2070 [3]. What is required is to promote carbon negative energy supply to attain the net zero goal at a faster pace.

It would be relevant to mention the Mission Innovation (MI), a global initiative of 23 countries, including the USA, China, Japan, the EU, and Saudi Arabia, which is meant to fast-track the global clean energy innovation to provide an opportunity for CO_2 utilization as Carbon Capture Utilization and Storage (CCUS). The annual rate of rise in atmospheric CO_2 concentration over the past 60 years is about 100 times greater than previous natural increases [4]. Modern societies are all accustomed to the fossil carbon-based economy- luxury, comfort, longevity- which have revolutionized our lifestyle for more than a hundred and fifty years; however, alas, it has and will bring miseries too if we do not tackle the carbon dioxide emissions through technological interventions and innovations. The energy needs of the world are increasing day by day and the use of carbon-based fuels will continue to rise. To follow the requirements of international treaties, the use of renewable resources is advanced. The European Union revised its 2030 targets of reducing carbon dioxide emissions from 40% to 55% below 1990 level to achieve the net zero carbon goal by 2050. Whether the carbon is coming from fossil fuels, waste biomass, or biofuels, there is a dire need to convert carbon dioxide into fuels, chemicals, and materials to make a net-zero economy [5].

The world's economies are heavily dependent on carbon. It is predicted that by the middle of the 21st century, there may not be worthwhile petroleum reservoirs to be exploited economically by using the current methods of production and hence alternate sources must be tapped for chemicals and materials, let alone energy. In the realms of renewable sources in 2050, 73% energy will come from renewables: solar, wind, geothermal, hydro, nuclear, and hydrogen. I believe in the carbon-negative scientific trinity: ***Solar, Wind and Hydrogen*** as green energy sources will be at the forefront, among which hydrogen will be the saviour of the environment and provide of sources chemicals and materials from waste carbon. Both blue and green H_2 will be part of the energy mix which will be about 25% by then [6]. Blue hydrogen is carbon neutral and not carbon negative. The green hydrogen and green ammonia policy declared by the Power Ministry of Govt. of India in February 2022, has envisioned that 50% of India's energy needs will be met by renewable sources by 2030. As regards carbon based chemicals and materials, CO_2 and (waste) biomass will be valuable sources if

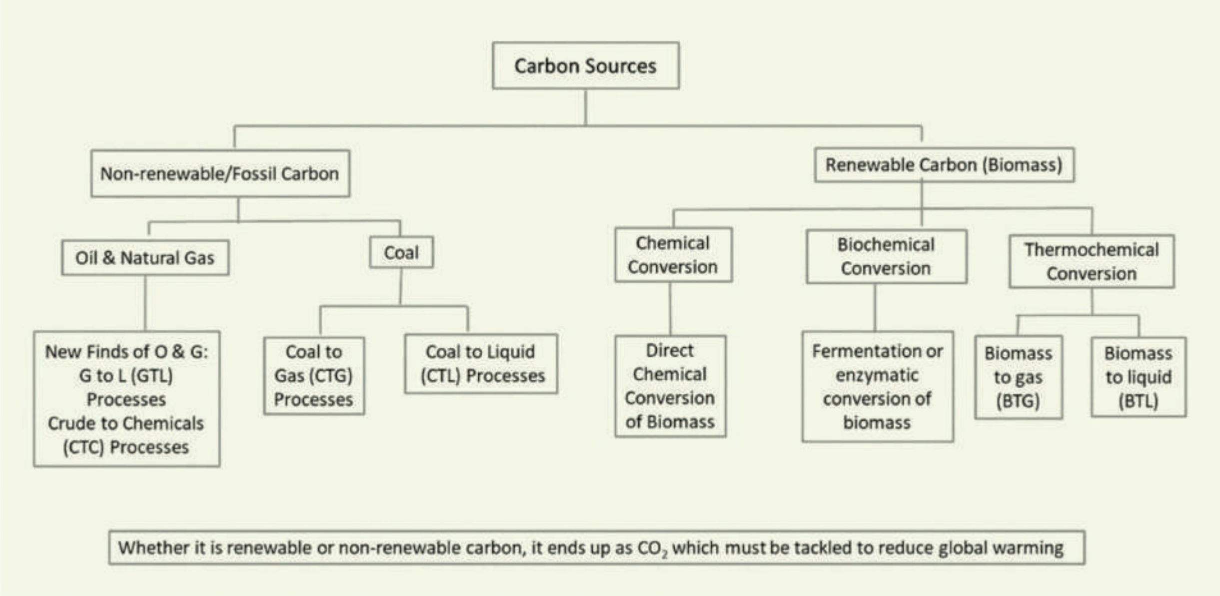


Figure 1. Carbon conversion processes to manufacture useful products. Carbon has been solely responsible for advancement in life style, comfort, luxury, transport, instant communication and longevity [5] (Open access, copy right with author of this article).

the hydrogen economy is adopted [7]. Not many realize that waste plastic is also an important source of energy, chemicals and materials and green technologies should be adopted and policies be in place to reduce the burden on the environment as well as to augment energy and material supply. Whether it is fossil fuel or renewable carbon source the fate of the carbon is ultimately carbon dioxide which must be dealt with to reduce global warming (**Figure 1**).

Hydrogen Production Technologies

Hydrogen can be employed as a fuel in many applications, including fuel cell power generation and fuel cell vehicles. It combusts cleanly, producing only water. The coal and oil-based economy for the manufacture of fuels, chemicals and materials is not sustainable and has done great harm to the environment. It is predicated that we will run out of oil by the mid-2050s and new renewable sources of energy and materials are required. As stated earlier, the renewable energy share will rise to ~73% by 2050 in total of 49000 TWh [6]; however, coal will still play a role meaning thereby the need to hydrogenate CO_2. Thus, hydrogen share could grow from 2% of the global energy mix in 2018 to 13–24% by 2050, at ~ 8% CAGR at the mid-point. An investment of USD 150 billion by 2030 is predicted by the Hydrogen Council [8] and the European Union [9]. In the net-(carbon)-zero economy, green hydrogen will not only achieve the objective of converting CO_2 into fuels and chemicals, but also transforming (waste) biomass and waste plastics into fuels and chemicals. Thus, CO_2 and hydrogen are connected in more than one way for the protection of environment and provision of future stocks of chemicals and energy.

Hydrogen can be produced by water splitting or from any carbon source, fossil or renewable using steam reforming or pyrolysis. Steam reforming is accompanied by CO_2 emissions which will be different per ton of hydrogen depending on the source of carbon. (**Figure 2**).

Hydrogen production technologies are generally categorized into three types (sometimes five) such as grey hydrogen, blue hydrogen, and green hydrogen. Depending on the energy source and method, additional two categories are also mentioned in the literature such as Turquoise and brown hydrogen. The major difference among the grey, blue, and green hydrogen is that the hydrogen is produced using fossil fuels, non-renewable energy, and renewable energy, respectively. Electrolysis of water using clean electricity from wind, solar, hydro, or nuclear energy sources or thermochemical inorganic

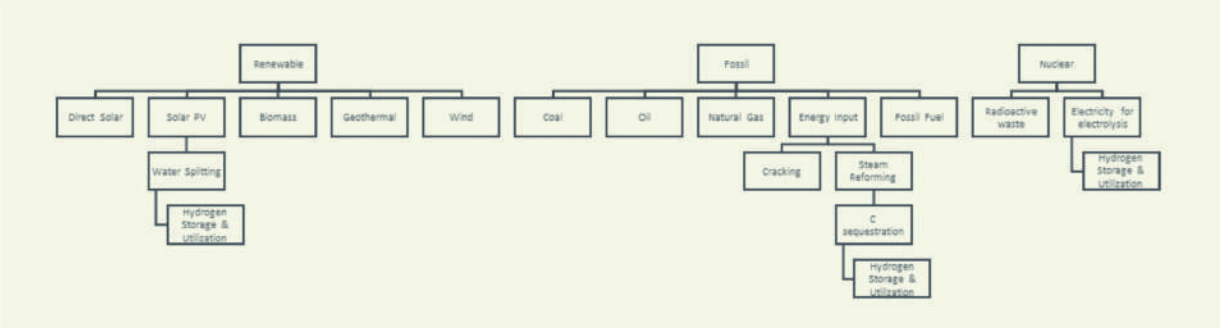


Figure 2. Hydrogen production methods from different sources

water splitting cycles such as copper-chlorine or sulfur-iodine will produce green hydrogen with zero carbon dioxide emissions. Steam reforming of virgin and waste biomass, biogas, bio-oil, or natural gas also gives hydrogen called blue hydrogen utilizing the other carbon portion in the feedstock as carbon dioxide which must be captured, stored and used (the so-called CCUS). It is estimated that blue hydrogen process captures up to 90% of the carbon having low to moderate carbon intensity as given in Table 1. The currently practised grey H_2 is the steam reforming of fossil coupled with co-generation of carbon dioxide; and this method is the most common technology which is increasingly unpalatable because of the emissions of carbon dioxide. In the Turquoise method methane pyrolysis is done to get hydrogen with the carbon being produced as carbon and not CO_2. Brown H_2 is produced from coal without CCUS.

Table 1 presents a comparison and approximate cost of production for 100 TPD of hydrogen production.

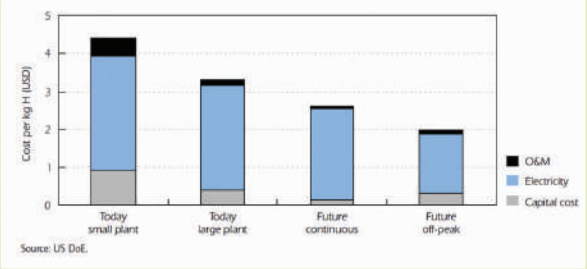
Type of Hydrogen	Brown	Grey	Torquise	Blue	Green	Green (ICT-OEC Process)
Source	Coal	Natural gas	Natural gas	Natural gas	Renewable electricity	Themo-chemical
Process	Steam reforming	Steam reforming	Pyrolysis	Steam reforming	Electrolyzer Water splitting	Cu-Cl water splitting closed loop
Products	No carbon capture & storage	No carbon capture & storage	Hydrogen and carbon as coproducts	Most carbon capture & storage	No GHG O_2 as coproduct	No GHG O_2 as co-product
Ton of CO_2 emitted per ton H_2	19	11	0 (solid C as product)	0.2	0	0
Cost per kg H_2 US$	1.2-2.1	1-2.1	1	1.5-2.9	3-7.5	0.95 (credit of 0.9 for 02 not considered)

Table 1. Merits and demerits of different hydrogen production processes

The green hydrogen production by using electrolysis of water is currently not economical but hotly pursued by major players and governments. Based on the information provided by the Hydrogen Council [8], the International Energy Agency (IEA) [10], and Bloomberg New Energy Fund (BNEF) [11], the following statistics should give an idea of the hydrogen economy.

1. Electrolyser costs: 1100 US$/kW (2020) to 550 USD/kW (2030), 220 USD/kW (2040).
2. The Institute of Chemical Technology (ICT)-ONGC Energy Centre (OEC) Cu-Cl thermochemical process is predicted to produce hydrogen at less than a dollar per kilo for 100 TPD capacity (author's own work on pilot scale).
3. Costs of CCS increases the costs of steam reforming of natural gas from 990 USD/kWh to 1850/kWh.
4. Low-carbon fossil-based hydrogen: Cost in 2030 from 2.5-3.0 USD in the EU,
5. Green hydrogen: USD 1.3-2.9/kg (Figure 3).
6. Target for solar electricity is to be cost competitive with the current fossil-fueled system.
7. If the cost of installed PV power can be reduced from the present cost of about USD 5/W installed to about USD 1/W installed, the cost of solar electricity is predicted to reach USD 0.10/kWh.

The ICT-OEC thermochemical Cu-Cl developed in this author's lab is a closed loop process with energy supply from solar energy stored in molten salts that promises to achieve '111' much before that [5, 7]. On the contrary, the steam reforming of fossil carbon likewise gives grey hydrogen coupled with co-generation of carbon dioxide; and this method is the most common technology used by many industries and it is cheap. However, it is gradually becoming unpalatable because of the CO_2 emissions. All refineries use grey hydrogen in eight of their conversion processes releasing huge quantities of CO_2. Hydrogen and ammonia (which on catalytic splitting gives green hydrogen and nitrogen) are envisioned as the future green fuels to substitute fossil fuels such as crude oil, coal and natural



Source: US DoE.

Figure 3. Hydrogen cost prediction of US Department of Energy [12]

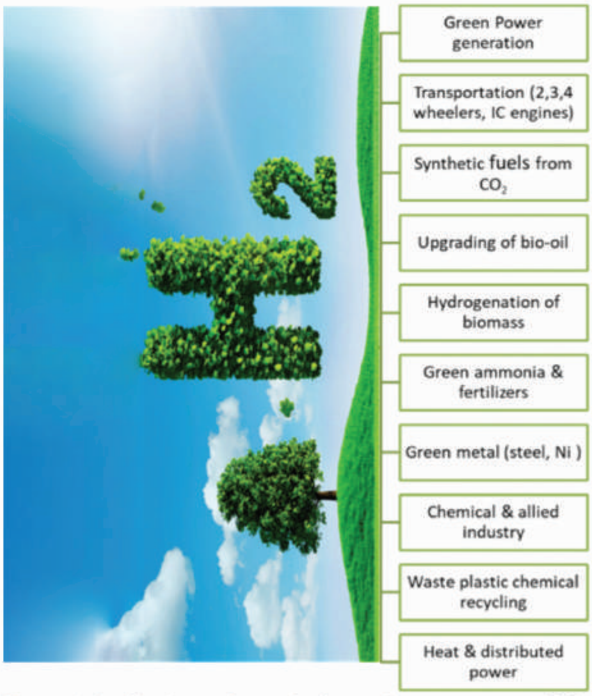


Figure 4. Applications of green hydrogen in energy sector, CO2 and biomass conversion

gas. Hydrogen economy will be a reality if the green hydrogen becomes as cheap as the grey hydrogen (**Figure 3**). Currently the clean hydrogen cost is in the range of ~$2.50 – $6.80/kg. The overall challenge to green hydrogen manufacture is its cost. US DOE's Hydrogen and Fuel Cell Technologies Office (HFCO) is working on developing technologies that will produce green H_2 at $2/kg by 2025 and $1/kg by 2030 via net-zero-carbon routes, in support of the Hydrogen Energy Earthshot goal of reducing the cost of green hydrogen by 80% to $1 per 1 kg in 1 decade ("111") [12]. The various applications of green hydrogen are presented in **Figure 4**.

It is claimed by Haldor Topsoe that their high-temperature solid-oxide electrolysis cell (SOEC) permits to generate carbon-free hydrogen or carbon monoxide using renewable electricity [13].

Green Ammonia

While hydrogen has the benefit of high energy density on a mass basis, huge storage volumes needed for it, and limited existing infrastructure are viewed as a deterrent in the hydrogen economy. Therefore, ammonia is viewed to be a viable solution for transportation and storage of the fuel and crack it back to hydrogen at the user end.

Industrial production of ammonia is done usually by the so-called Haber-Bosch process, in which nitrogen from the atmosphere is catalytically coxed with hydrogen under high temperature and pressure Currently. Ammonia manufacture across the world produces ~420 MMTA of CO_2, which together with hydrogen production, which accounts for 830 MMTA of CO_2; thus it is totally about 2% of GHG emissions per year. Green ammonia could make a substantial contribution to the decarburization of agriculture through additional sustainable production of fertilizers. It can also assist in power generation or as a clean fuel for transportation, largely to power ships. Because of the much higher density of ammonia and its higher energy content, green ammonia lends itself to all applications of green hydrogen (**Figure 5**). The mass energy density of hydrogen is 120 MJ/kg vis-à-vis 18.6 MJ/kg for ammonia, hence its popularity as an alternative fuel. Although hydrogen is an energy carrier, the benefits of green ammonia might overwhelm those of hydrogen because ammonia is denser than hydrogen and needs to be compressed only to 10 atm or cooled to -33°C to store energy. On the contrary, hydrogen must be compressed to 350-700 atm or cryogenically cooled to -253°C as a liquid. Since NH_3 can be stored at lower temperatures, it is an ideal energy carrier. It is also suitable for storing and transporting energy from renewable energy sources [14]. Because ammonia is extensively used for fertilizers, there is already existing distribution network where ammonia is stored in large, refrigerated tanks and then transported by various means, such as pipelines and water which is also an advantage and could be used for green ammonia in the fertilizers sector, or if extended also in other ways (**Figure 5**).

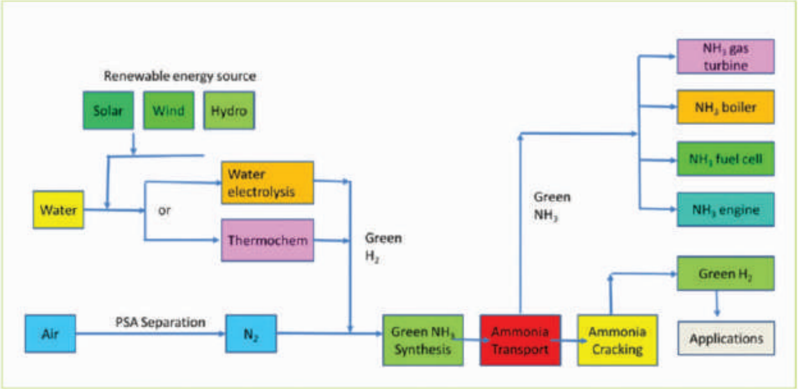


Figure 5. Synthesis and applications of green ammonia. Both water and air will be the feed stocks for green hydrogen and green ammonia.

Pitfalls of Fossil Carbon Based Energy Economy

Among all GHGs, carbon dioxide and methane are the principal constituents which contribute the most to the man-made GHG effect and climate change. Future processes or concepts that undertake this CO_2 reduction must consider the life cycle to assure that additional CO_2 is not released beyond what is already being removed from or going into the atmosphere. CO_2 sequestration is widely documented as an important choice to reduce increasing levels of its concentrations. CCUS technologies are viewed as a practical solution that involves recycling of CO_2 to various important industrial compounds, fuels and feedstock materials bringing to the core the synergism and innovations of catalytic chemistry, chemical engineering and technology, material science and biological sciences to alleviate climate change. However, CCUS technologies are criticized for permitting the continued use of fossil fuels.

In addition to the coal-based power plants, steel industry releases more than 3 billion metric tons of CO_2 each year, having the biggest climate impact. Currently China is the number one producer of steel and India is second; one ton of steel emits 2.3 tons of CO_2. To restrict the global warming, the steel industry must reduce its carbon footprint totally and make use of green hydrogen to produce green steel. The same argument holds for other metal industries. Much attention has fixated on CO_2 but methane is a dominant and dangerous GHG. At the COP 26, over 100 countries signed up to the Global Methane Pledge to reduce global methane emissions by 30% by 2030. This includes six of the world's topmost 10 methane emitting nations like the USA, Brazil, EU, Indonesia, Pakistan, and Argentina and would account to a potential of 46% of global methane emissions and over 70% of global GDP, playing a critical role in keeping the goal of 1.5°C rise within scope [15]. Among all the anthropogenic GHG, CO_2 is largely responsible for global warming and climate change.

The sustainability of extravagant lifestyle of modern society requires gigantic quantities of energy which is primarily satisfied by the fossil resources. The concentration of carbon dioxide in the atmosphere increased from 280 ppm before the industrial revolution to 421 ppm in October 2022 [1]. The increased atmospheric CO_2 concentration is arguably one of the primary causes of accelerated climate change and global warming. This supply chain from fossil feedstock cannot sustain forever as all these energy sources will diminish within three centuries. From the economic point of view importing fossil fuel from foreign countries worth of billion dollars is a waste of foreign exchange for the marginal and developing economies having no oil reservoirs or coal deposits. For instance, a fast growing Indian economy imported 228.6 trillion tons of crude oil at US$ 130 B in 2020 and the government wants to reduce import of oil by developing new technologies including renewable resources such as solar, wind, hydro, coal to fuels and chemicals, 2G ethanol, biodiesel, etc. India accounts for more than a quarter of the net global primary energy demand between 2017-2040 according to BP Energy [6]; 42% of this new energy demand is met through coal, meaning CO_2 emissions will roughly double by 2040. The Paris Agreement 2015 is meant to reduce the risk and impact of global warming by adopting two long term temperature goals, i.e., to check the global average temperature rise well below 2 °C above pre-industrial level, and to take more deliberate actions to limit the rise in temperature to 1.5 °C above pre-industrial levels. To achieve this goal a 20/20/20 strategy was adopted, meaning thereby, 20% decrease in CO_2 emission, rise in renewable energy market share by 20%, and 20% increase in efficiency of current technology which calls for research and innovation. The share of the renewable energy will increase from current ~27% to ~51% by 2035 to ~73% by 2050 totaling 49000 TWh in which both green and blue hydrogen will have a substantial role [16].

Carbon Dioxide as the Future ' New Oil'

Carbon dioxide is nontoxic, nonflammable and highly stable. Since it is produced by a number of power plants, refineries, fermenters, and other industrial processes, which are all contributors to the GHG related problems, CO_2 should not be treated as a liability but a great feedstock for preparing commodity chemicals, fuels, and materials by using innovative cost-effective catalytic processes. Since CO_2 is very stable, its activation is difficult requiring highly active catalysts. Carbon dioxide can be valorized while meeting the net zero goal and it will be the '*new oil*'. The future refiners will use carbon dioxide as a raw material for making fuels, chemicals, and polymers/materials, where green hydrogen will be the most important reactant.

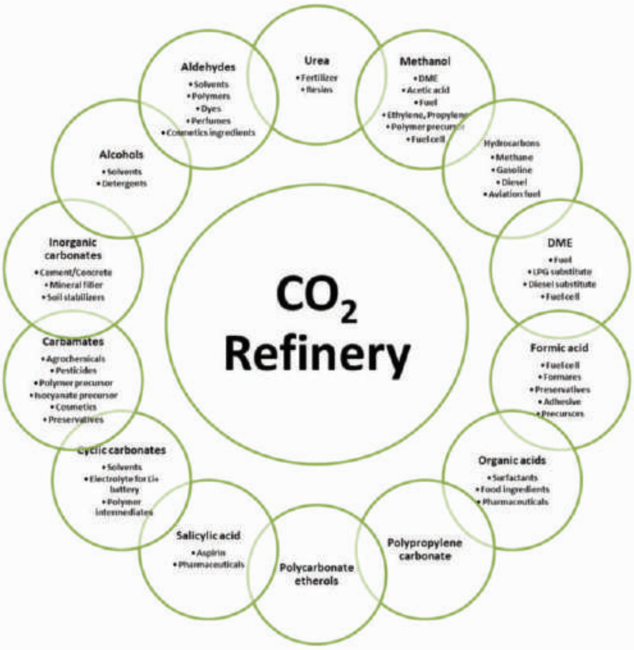


Figure 6. Carbon dioxide refinery: CO_2 as a feedstock for making a variety of products

As an economical, safe, and renewable carbon source, CO_2 turns out to be an attractive C1 chemical building block for making organic chemicals, materials, and carbohydrates (e.g., foods). The utilization of CO_2 as a feedstock for producing chemicals not only contributes to alleviating global climate changes caused by the increasing CO_2 emissions, but also provides a grand challenge in exploring new concepts and opportunities for catalytic and industrial development. Decreasing CO_2 concentration in the atmosphere while meeting the energy demands of an ever increasing population is a formidable task and requires long term planning and implementation of CO_2 mitigation strategies. Reduction of CO_2 production by shifting from fossil to renewable fuels, CO_2 capture and storage (CCS), and CO_2 capture, and utilization (CCU) are the possible areas for systematic control and reduction of atmospheric CO_2. Carbon Capture and Utilization and Storage (CCUS) is one of the key areas that can achieve CO_2 emission targets while simultaneously contributing to the production of energy, fuels, and chemicals to sustain the increasing demands. In CCU concept, CO_2 is captured and separated from emission gases and then converted into valuable products. It is used to produce chemicals such as urea (75 million tons), salicylic acid, cyclic carbonates, and polycarbonates [17-20].

As of now, numerous CO_2 capture technologies related to physisorption, chemisorption, carbamation, amine absorption, amine dry scrubbing, , membrane separation, and mineral carbonation have been practised. Therefore, CO_2 may turn out to be the future 'new oil' by catalytically converting it into synthetic fuels starting from the mixtures of carbon dioxide and hydrogen with specific multiphase reactors. In that way CO_2 appears as one of the possibilities for high level energy storage, including the network regulation from renewable energy production. But, in each case, novel catalytic processes and plants are needed to develop this future industry. Flue gases from fossil fuel-based power plants are the main concentrated CO_2 sources. If CO_2 is to be separated, as much as 100 MW of a typical 500-MW coal-fired power plant would be necessary for today's CCUS based on the alkanolamines absorption technologies [21,22]. Therefore, it would be highly desirable if the flue gas mixtures are used for vehicle CO_2 conversion but without its pre-separation. CO_2 conversion and utilization should be an integral part of CO_2 management, though the amount of

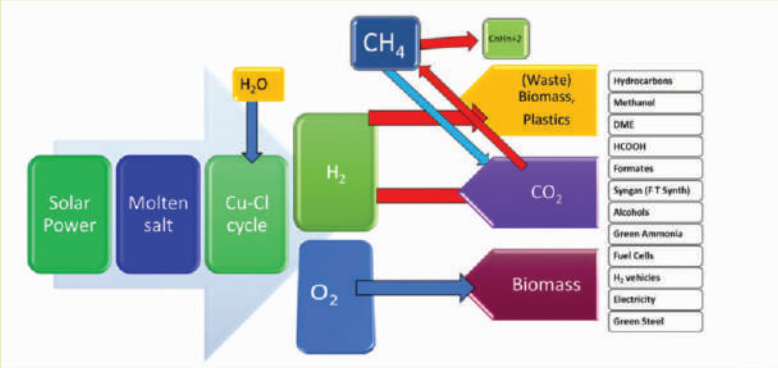


Figure 7. Carbon dioxide conversion to valuable commodity fuels and chemicals using green hydrogen developed in author's lab by ICT-OEC technology [5,7].

CO_2 that can be utilized for making industrial chemicals is small vis-à-vis the amount of flue gas.

Bulk chemicals routinely manufactured from CO_2 include urea to make nitrogen fertilizers, salicylic acid as a pharmaceutical ingredient, and polycarbonate-based plastics (**Figure 6**).

However, carbon dioxide can be catalytically converted into methane and higher hydrocarbons, methanol, dimethyl ether (DME) and formic acid, and other formates as proved in the author's laboratory using hydrogen as also reported by other researchers (**Figure 7**). It forms a part of the hydrogen economy.

CO_2 also could be employed more widely as a solvent; for instance, the use of supercritical CO_2 provides benefits in terms of stereo-chemical control, product purification, and environmental factors for making fine chemicals and pharmaceuticals, for tertiary oil and gas recovery by CO_2 flooding, enhanced agricultural production, and ponds of genetically modified algae that can convert power-plant CO_2 into biodiesel [17,18, 23]. The extraction of CO_2 on gigantic scale including that from the atmosphere is a phenomenal task but it can be achieved by using novel catalytic technologies, process intensification and multi-phase reactor design.

Flue Gas as Source of CO_2

On the basis of the economic and environmental viewpoints, there seems to be a unique benefit of using flue gases directly, rather than the pre-separated and purified CO_2. Typical flue gas composition from natural gas-fired power plants could be around: 8-10 CO_2, 18-20 water, 2-3 oxygen, and 67-72 nitrogen v/v %. Whereas a flue gas from coal-fired plants may contain 12-14 CO_2, 8-10 water, 3-5 oxygen and 72-77 nitrogen v/v %. The furnace outlet temperature of flue gases is normally ~1200 °C which will fall gradually along the pathway of heat transfer, while the temperature of the flue gases exiting to the stack is ~150 °C. Pollution control technologies can eliminate SO_x, NO_x, and particulate matter effectively, but CO_2 and water as well as oxygen remain largely unaffected [24]. Some important chemistries using CO_2 are given in **Figure 8.**

CO_2 conversion into gaseous or liquid hydrocarbon requires high temperature (523-723K) and pressure (20-40 atm), but the conversion is low due to problems in the activation of CO_2. Therefore, currently available technologies are not economically suitable for industrial application. Efficient heterogeneous catalysts can minimize the energy needed for reactions by reducing the activation energy. A lot of literature exists on the utilization of pure CO_2 by different ways such as using plasma, photocatalytic system, electrochemical reduction, heterogeneous catalysis, etc. [26-30]. A few attempts have been made to develop continuous processes for converting carbon dioxide from flue gas to value-added products that are economical and have the potential to meet energy and material needs of the future. However, hydrogen plays an important part in CO_2 valorization and carbon sequestration.

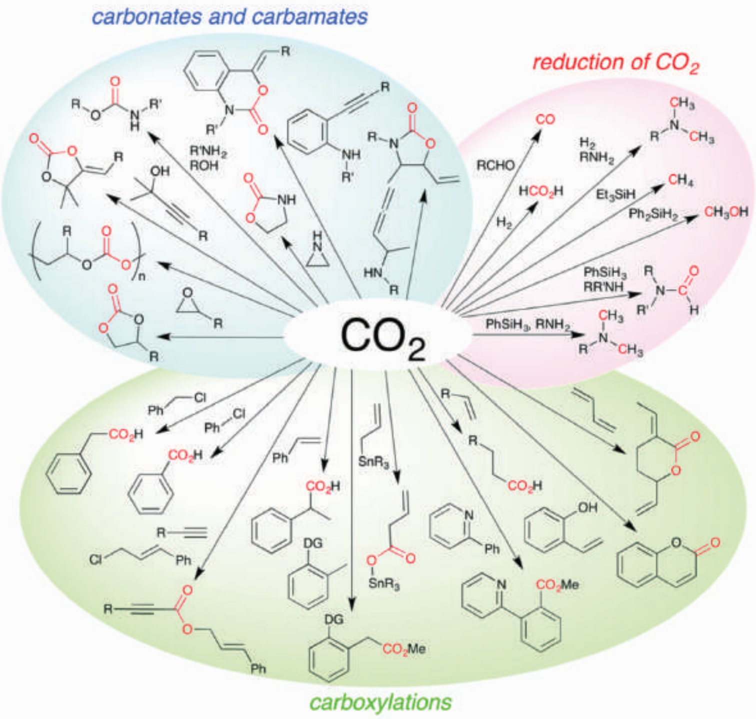


Figure 8. Schematic representation of possible usage of CO_2 for fuel and chemicals [17,18, 25]

The reduction of CO_2 emissions of ~40 Gt in 2021 to ~10 gigatons will contain the global temperature to within 1.5 °C by 2050 [6]. For hydrogen to contribute to mitigate climate change and climate neutrality, it must attain much larger scale of production, totally derived from water splitting using green technologies. The hydrogen economy must overcome many challenges including large-scale infrastructure for refilling stations of hydrogen, akin to those of petrol, diesel and natural gas, and the cost of hydrogen production, transport, and storage must be low. These challenges can be surmounted collectively by multiple partnerships among companies, nations, and research across institutions, and above all local government policies [8]. Green hydrogen must cost below 1.5-2 USD/kg to make the hydrogen economy a reality. As mentioned earlier, the cost of hydrogen production by Institute of Chemical Technology- ONGC Energy Centre (ICT-OEC) hydrogen production technology, developed by this author using water splitting in conjunction with solar energy is less than USD 1/kg [7].

One of the issues of using carbon-based technology, whether renewable or fossil, is the emission of CO_2 which can be valorized by using hydrogen into a few chemical products such as methane and higher hydrocarbons, methanol, dimethyl ether (DME), formic acid, formates, carbonates, ammonia, urea, etc. DME is the cleanest, colorless, non-toxic, non-corrosive, non-carcinogenic and environmentally friendly chemical replacing CFC. DME can be effectively used in diesel engines. Like methanol, it is a clean-burning fuel and produces no soot and black smoke. DME is the best substitute for LPG as a cooking fuel and the well-established LPG industry infrastructure can be used for DME [31-33]. Hydrogen can serve as a vector for renewable energy storage in conjunction with batteries, guaranteeing as a backup for season variation. To help limit global warming, the steel industry will need to shrink its carbon footprint significantly. Thus, hydrogen can substitute fossil fuels in some carbon intensive industrial processes, such as steel, nickel, chemical and allied industries. It can present solutions for difficult to abate parts of the transport system, in addition to what can be accomplished through electrification and other renewable and low-carbon fuels.

Biogas as Source of CO_2

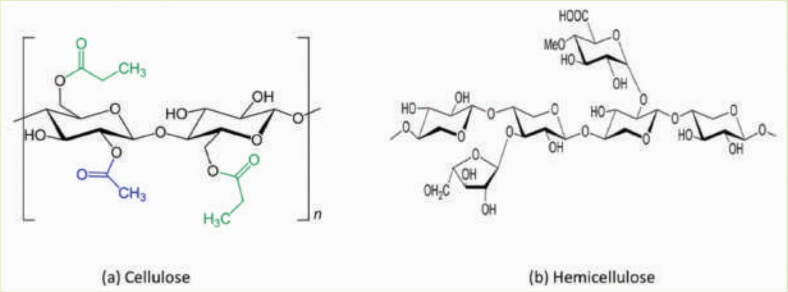
Biogas, typically containing 50-75% methane and 25-50% carbon dioxide is produced by anerobic fermentation from almost all types of biomass, including wet biomass, (which is not usable for most other biofuels), vegetable and animal livestock waste, manure, harvest surplus, oil residues, municipal solid waste (MSW), etc. It is gaining significant industrial attention as a renewable source of carbon. Conventionally, after purification, biogas can be directly combusted for heat and electricity generation, yet the heat value of such combustion processes is low due to the high concentration of CO_2 in the feed gas. From an efficiency point of view, syngas production by biogas reforming with a H_2/CO ratio close to one is an appropriate option for the full utilization of both CH_4 and CO_2 in biogas for several industrial applications. Depending on the molar H_2:CO ratio in the reformed bio-syngas, it can be directly applied as a feedstock for the production of methanol, dimethyl ether (DME), long hydrocarbon chains via Fischer-Tropsch (FT) process, or NH_3 synthesis by the Haber route.

Another incentive for using gaseous biofuels for transport applications is the prospect to diversify feedstock sources. Biomethane, also called renewable natural gas (RNG), or sustainable natural gas (SNG), which is separated from biogas, is the most efficient and clean burning biofuel available today. Biomethane is upgraded to a quality like fossil natural gas, having a methane concentration of 90% or greater, by which it becomes possible to distribute the gas to customers via the existing gas grid within existing applicatiojs. Furthermore, it is very promising to use biogas containing carbon dioxide as the co-reactant for methane conversion in the so-called dry reforming process [34], since carbon dioxide can provide extra carbon atoms for methane conversion, while carbon dioxide also serves as a better oxidant, compared to oxygen or air. The co-feed of carbon dioxide will also increase the methane conversion and the yield of objective product. However, the introduction of carbon dioxide into the feed will lead to a complex product. In addition to syngas, gaseous hydrocarbons (C_2 to C_4), liquid hydrocarbons (C_5 to C_{11+}) and oxygenates can be produced in methane conversion with the co-feed of carbon dioxide. The liquid hydrocarbons are highly branched, representing a high-octane number, while oxygenates mainly consist of a series of alcohols and acids. The development of a production technology for direct conversion of methane and carbon dioxide to higher hydrocarbon and oxygenates using novel catalytic system will probably be more economically desired [35]. It is also important to note that carbon should not be used as a source of fuel but chemicals and materials and all non-carbon sources of energy such as solar, wind, geothermal, tidal, and nuclear and above all hydrogen from water splitting will meet the requirements of the Paris Agreement [5].

(Waste) Biomass as precursor for Chemicals and Materials

Biomass is a renewable energy source having sufficient energy value per unit mass, but which is lower than that of fossil fuels. Hence biomass must be valorized to produce biofuels (in solid, liquid, and gas forms such as methane and hydrogen) for sustainable development and green hydrogen from water splitting will play the most important role.

Worldwide attention is focusing on the use of lignocellulosic biomasses for the sustainable production of biofuels and bio-derived


(a) Cellulose
(b) Hemicellulose

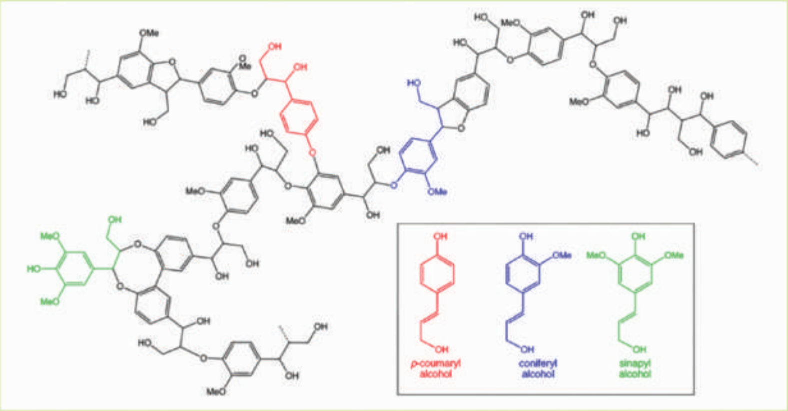


Figure 9. Basic structure of biomass as precursors of different chemicals which can be manipulated through catalytic processes such as hydrogenation/ hydrogenolysis, dehydrogenation, oxidation, condensation, hydrolysis, hydration, isomerization, dehydration, esterification, alkylation, dealkylation, oligomerization and demethoxylation

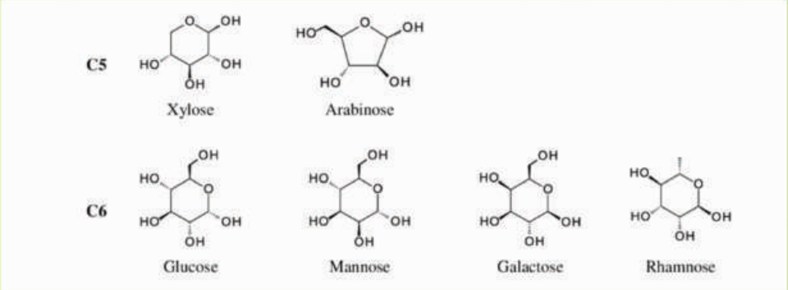


Figure 10. Common C5 and C6 sugars found in hemicellulose which are precursors to a number of chemicals

chemicals. The key components of biomasses (cellulose, hemicellulose and lignin) that have the potential for the sustainable production of several building block intermediates for modern bio-refineries. Cellulose and hemicellulose are mainly formed of C6- and C5-sugars, respectively, while lignin is mainly composed by phenolic units. Such a wealth of chemical functionalities represents, at present, the most promising alternative to petroleum resources.

A variety of chemicals can be derived from lignocellulosic biomass, whether waste or purposely grown, the structures of cellulose, hemicellulose and lignin suggest several catalytic processes can be used to depolymerize and make fuels and chemicals (**Figures 9, 10 and 11**). The importance of green hydrogen is clear since hydrogenation/hydrogenolysis, dehyrogenation and oxidation are needed to make bio-based highly valuable chemicals [5]. Other important chemicals can be derived through condensation, hydrolysis, hydration, isomerization, dehydration, esterification, alkylation, dealkylation, oligomerization and demethoxylation [36, 37]. The 14 top platform

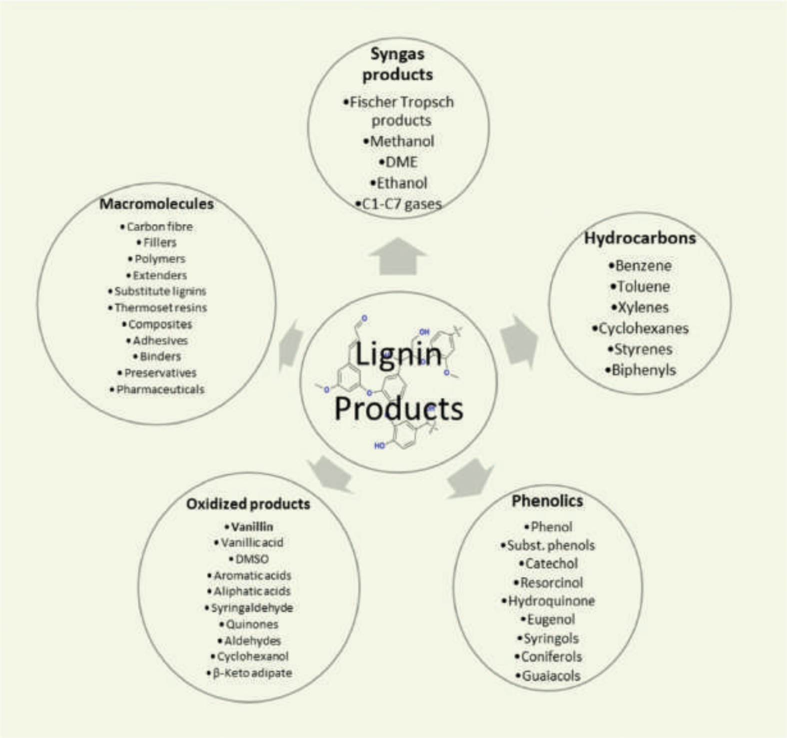
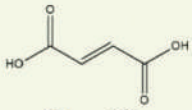
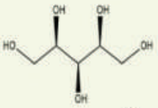
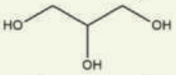
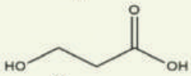
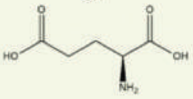
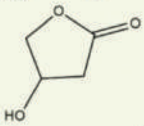
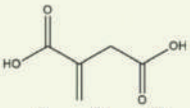
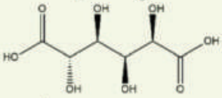
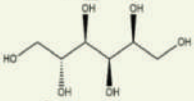
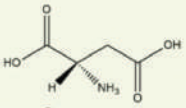
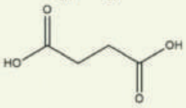
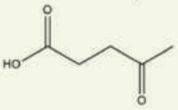
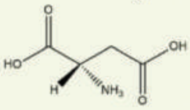


Figure 11. Lignin based valuable products

Table 2. Most important platform chemicals derived from biomass [5,38].

BPM	*Structure*	*BPM*	*Structure*
Fumaric acid		(*S,R,R*)-Xylitol	
Glycerol		3-Hydroxypropionic acid	
L-Glutamic acid		3-Hydroxybutyrolactone	
Itaconic acid		2,5-Furandicarboxylic acid	
Glucaric acid		Sorbitol	
l-Malic acid		Succinic acid	
Levulinic acid		L-Aspartic acid	

chemicals derived from biomass are listed in Table 2.

Many agricultural waste are being produced in all countries that could be converted into biofuels using various treatment and production methods like thermochemical conversion (combustion, gasification, pyrolysis, hydrothermal liquefaction), biochemical conversion (anaerobic digestion, microbial fermentation, enzymatic hydrolysis), and chemical treatment (biodiesel production, transesterification).

Pyrolysis of biomass produces hydrocarbon gases, liquid bio-oils and porous biochar. Biochar could be employed in farms to hold nutrients and water. Biochar can also be used as a green binder to bind urea together to make a fertilizer. Steam reforming of bioethanol will give blue hydrogen. Other biomass derived chemicals like methanol, butanol, ethylene glycol and glycerol (from biodiesel) are important sources of blue hydrogen. Hydrogen production from biomass is a promising bio-energy with carbon capture and storage which is a blue hydrogen that could produce low-carbon hydrogen and generate the carbon dioxide removal envisioned to be required to offset hard-to-abate emissions.

Sustainable biomass feedstocks, namely, agricultural residues and waste will have negligible bearing on food security and biodiversity. The blue hydrogen manufacture from (waste) biomass or bio-derived alcohols represents a neglected near-term opportunity to generate CO_2 removal and low-carbon hydrogen. Hydrogen can aid to decarbonize difficult-to-electrify areas, store energy from irregular renewable power, and be implemented as a chemical feedstock. However, the grey hydrogen is made from fossil natural gas (methane) through steam reforming which is responsible for about 2% of global GHG emissions. Hydrogen production from biomass generates a high purity stream of carbon dioxide well suited for CCUS. Bio-hydrogen is the only hydrogen production route that will lead to the net-negative CO_2 emissions when coupled with CCUS.

Biomass feedstocks for bioenergy are often cultivated in countries like Brazil, India and others in South East Asia in large-scale monoculture plantations like sugarcane that have numerous socio-environmental bearings, including compromising food security, harming biodiversity, increasing competition for natural and agricultural land, manipulating food prices, and aggravating water scarcity. With a rising demand for food production due to ever increasing population, and unprecedented biodiversity loss, biomass feedstocks for blue hydrogen manufacture should have minimal influences on food production, biodiversity, and the natural capital. Thus, purpose-grown bio-energy crops are becoming less appealing and crop residues, household food waste, and livestock manure are considered the most suitable for biogas production through anaerobic fermentation. These feedstocks do not necessitate purpose-grown bio-energy crops, their use does not compete with productive agricultural land and does not harm biodiversity through agricultural enlargement.

In our seminal paper [5] on comparison of crude oil versus bio-refinery, we proved that it makes more environmental and economic sense in using bioethanol as a feedstock than as biofuel. One kg of crude oil gives 32 MJ of energy and 0.2 kg of chemicals whereas 1 kg of biomass gives either 6 MJ energy or 0.8 kg of chemicals. So it is better to convert biomass into chemicals than to refine. Indeed biomass should never be used as a source of fuel but to make value added chemicals and materials; for instance, bioethanol (**Figure 12**).

Both green and blue hydrogen can be utilized in hard-to-electrify segments, namely, cement, steel, refining, ammonia, and glass industries. Biomass needs to be separated into cellulose, hemicellulose, and lignin fractions. Cellulose and hemicellulose are the sources for various platform chemicals like levulinic acid, 5-hydroxymethylfuran (HMF), and furfural. Lignin is a source of hydrocarbon compounds like olefins or aromatic derivatives, jet fuel and ethylene. The catalytic hydrogenation of (hemi)cellulose, hexose, furans, organic acid, lignin, and other bio-derivatives will contribute to the income of agriculturists. Hydrogenation is an efficient method for selective synthesis of combustible fuels and high value-added chemicals. Cellulose can be converted into combustible gases by hydrogenation, and methane is one such gas among them.

The sugars, hexoses and pentoses, can be dehydrogenated into furfural and HMF which are important chemical platform intermediates for tetrahydrofurfuryl alcohol, levulinic acid and its esters, furfuryl alcohol,

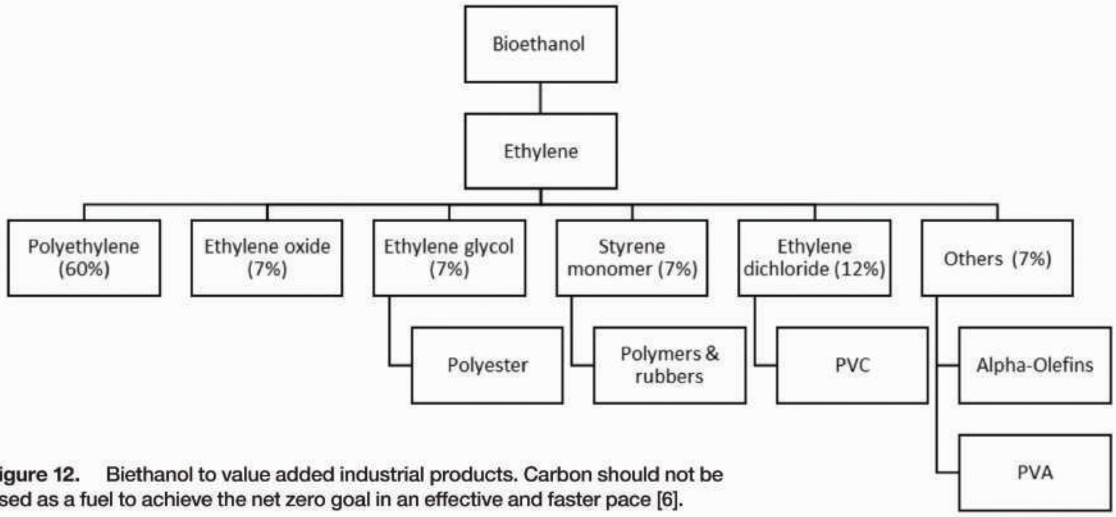


Figure 12. Biethanol to value added industrial products. Carbon should not be used as a fuel to achieve the net zero goal in an effective and faster pace [6].

HMF, γ-valerolactone, etc. The conversion of lignin to benzene, toluene, and xylene which are the major petrochemicals for chemical industry and produce 60% of all aromatic compounds is possible through hydrogenation/hydrogenolysis. Lignin depolymerization is required to produce platform chemicals, upgradation of bio-oils by hydrogenation and biochar. Polyols are definitely among the most appropriate substrates for the production of H_2 or syngas that can be further used as building blocks for the manufacture of methanol and other chemicals, including liquid hydrocarbons through the Fischer Tropsch synthesis.

After cellulose and hemicellulose are broken by acid or reductive catalyzed hydrolysis, glucose and xylose can be straightforwardly hydrogenated into the corresponding C6 and C5 polyols, sorbitol and xylitol, respectively. Thus, C6–C2 polyols, including 1,4-butanediol (1,4-BDO), 1,2- and 1,3-propylene glycol (1,2-PDO and 1,3-PDO) and ethylene glycol (EG), are extensively used as ingredient or additives in food, pharmaceutical and cosmetic industry as well as cheap monomers for the manufacturing of polymers, coatings, adhesives, etc. Xylitol is the most widely used sweetener characterized by a lower calorie-content and reduced glycemic index (GI) with respect to sucrose. Sorbitol has been successfully used for over the years for making polyurethanes. Ethylene glycol is an antifreeze agent which is a main component in the production of bio-PET while other bio-based diols, besides their direct uses, are now used as co-monomers in bio-elastomeric polymers. New catalytic technologies require a cost-effective reduction of the oxygen content in bio-polyols permitting the production of H_2, fuels and other valuable chemicals. Glycerol is the co-product of bio-diesel, typically 10% by weight, that can be used to make more than two dozen chemicals. Unless glycerol is valorized, biodiesel production cannot compete with petro-diesel. Thus, farmers should recognize that there are marvelous opportunities to valorize agricultural waste using green and blue hydrogen to increase their income. Only the growth of grain or fruit production will not enhance their income but making sensible use of all parts of plants and waste thrown or burnt as waste will be part of a circular economy.

Plastic Refining: Chemical Recycling

Plastics refining is a GHG intensive process. Carbon dioxide emissions from ethylene production are projected to increase by ~ 34% over the period 2015-30. For instance, PVC is an extensively used thermoplastic due to its excellent properties such as stability, being cheap, and workability. It is a multipurpose general plastic commonly used in construction, piping and many other consumer goods. PVC is highly polar and possesses a good insulation property, but it is inferior to other non-polar polymers like polypropylene (PP) and polyethylene (PE). PVC, PE and PP are usually used in piping, water sanity, and medical industries, etc. whereas PP is extremely thermally resistant and it can withstand much higher temperatures than PVC. All these polymers including PET, nylon, and PU contribute to carbon footprint and global warming. PVC is demonstrated to have higher energy consumption and CO_2 gas emissions that show its high potential in global warming than other plastics. Likewise, the recycling of PVC has shown substantial contributions in lowering the effect on climate change [84].

About 40% of plastics are used in packaging globally. Typically, packaging is meant for a single use (SUP) and therefore so there is a reckless turnaround for disposal at all places. SUPs are used in many applications such as tires, fabrics, and coatings. Consumers need choices to avoid plastic waste such as legal means to encourage plastic collection through a refundable deposit scheme on SUPs, collection at regular intervals and avoiding plastic waste going as a mixture in municipal solid waste (MSW). The packaging can be dealt with in three different ways including landfill, incineration, or recycling. Waste incineration leads to the largest climate impact of these three options. According to the World Energy Council (WEC), based on the current trend in plastics production and incineration upsurge as anticipated, GHG will rise to 49 MMTA by 2030 and 91 MMTA by 2050. Landfilling has a much lesser impact on climate than incineration. But the landfill sites can be related with similar environmental issues. Recycling is a much better option. With regard to the little costs of virgin plastics, recycled plastics are high cost with low commercial value. It makes recycling lucrative only seldom, and so it calls for substantial subsidies by the government authorities. On the contrary the chemical recycling of polymers including depolymerization and hydrogenation are excellent choices.

Plastic products are an integral part of modern civilization and can be categorized broadly into the following types [39]:

Type 1: polyethylene terephthalate (PET) used in plastic beverage bottles

Type 2: high-density polyethylene (HDPE), used for milk pouches

Type 3: polyvinyl chloride (PVC), used pipes used in plumbing, vinyl tubing, and wire insulation

Type 4: low-density polyethylene (LDPE), used in plastic sheets or packaging

Type 5: polypropylene (PP), used in bottle caps, packaging, and plastic furniture

Type 6: polystyrene (PS), used in Styrofoam, beverage lids, and straws

Type 7: other non-recyclable plastics and all thermoset plastics (acrylics, nylons, polycarbonates, acrylonitrile butadiene styrene, ABS, and polylactic acid).

Type 8: Polyurethanes (PUs): extremely versatile elastomer used in countless such as furniture, bedding, and seating; thermal insulation; elastomers; footware; straps; coatings

According to the survey by the Ellen MacArthur Foundation survey [40] only ~2% of plastics are recycled through chemical conversions into products with the similar functionality. Around 8% are "downcycled" to chemicals of lower quality whereas the remaining is landfilled, goes into the environment, or incinerated. Therefore, cutting down emissions associated with plastics would need the following approaches: reducing waste, retaining materials by restoring or remanufacturing, and recycling. Chemical recycling encompasses three mechanisms by which the polymer is purified from plastics without changing its molecular structure, is depolymerized into the monomer building blocks, which in turn can be repolymerized. It is converted into chemical building blocks that can thus be used to produce new polymers. Polymer upcycling such as SUP conversion into new products is all now worthy of practice. If government-established recycling targets are to be attained, the relationships between consumers, municipalities, and petrochemical production must be enhanced. After all, public opinion is moved by media images of an endangered planet and eco system. Only through the collaboration of people, municipalities, and industry - supported by improved technology along the recycled plastics supply chain, a solution for this global problem can be achieved.

The concept of circular economy for plastics will require many innovative ideas since plastics offer significant benefits to global sustainability, predominantly in transportation, and there are no substitutes readily available for immediate disposition at global scales. Therefore, plastics will be an integral part of in our activities for the foreseeable future. Design of plastic products for circularity involves reuse, recycle, and remanufacturing principles. SUP must be the exemption rather than the rule.

The recycling of plastic is met with additional problems because different additives are used to enhance the performance, functionality, and aging properties of the base polymer. Additives are functional additives (plasticizers, lubricants, slip agents, stabilizers, antistatic agents, flame retardants, , curing agents, nucleators, biocides, foaming agents, catalyst deactivators, etc.), colorants (pigments), fillers (calcium carbonate, barium sulfate, mica, talc, kaolin, clay,) and reinforcements (carbon fibres, glass fibres,). Identification, separation and disposal of additives are a big hindrance to recycling into the virgin resin [39].

Mixed plastics can be incinerated for energy recovery but it frequently creates carcinogenous pollutants. Therefore, only 12% of waste is incinerated in the U.S.A and incineration underestimates the potential that these polymers hold.

Plastic gasification, pyrolysis, and hydrothermal processing (HTP) are all thermolysis processes used to depolymerize plastics using heat). Pyrolysis of plastics into fuel oil is relatively mature technology. HTP takes place in an autoclave using water as a solvent, catalyst, or reactant requiring moderate temperatures (280–450°C) and pressures (70–300 bar). Supercritical water is used to liquefy polyolefins into oil or gas products (**Figure 13**) [42,43].

In solvolysis, xylene and toluene seem to be good solvents, whereas hexane and methanol work well as anti-solvents to recover the common polymers like HDPE, LDPE, and PS in high yields. On the contrary, methylene chloride (MDC) and benzyl alcohol are good solvents to dissolve PVC and PET. Chemolysis is meant to initiate a reverse reaction of the condensation reactions and uses chemicals to depolymerize polymers which only works for condensation polymers like PET and PU. Condensation polymers are equilibrium materials and hence addition of condensation product like ethylene glycol) and heat reverses the polymerization. Thus, chemolysis cannot depolymerize additive polymers like polyethylene (PE) and PP. Chemolysis reactions include aminolysis, glycolysis, and methanolysis. Selective solvent extraction (SSE) and chemolysis are good for sorted plastics and condensation polymers, respectively, which cannot be used to treat mixed plastic [39].

Similar to pyrolysis, HTP favors polyolefins, but it can handle higher quantities of non-polyolefins plastics, including PVC and PET. HTP is used to convert PP into PET, PP, PS, and polycarbonate into fuels and naphtha [44,45], and wax [46].

Hydrogenation of plastic waste to valuable fuels, monomers and chemicals

Hydrocracking using metal catalysts over solid acid supports leads to cracking of heavy hydrocarbon molecules into lighter unsaturated hydrocarbons and the saturation of these newly formed hydrocarbons with hydrogen is a well established refinery technology. It can be used for plastic waste. The advantages of hydrogenation over other methods including incinerations are conversion of waste plastic to high value products while simultaneously handling troublesome atoms (Cl, N, O, S) by hydrodechlorination (HDC), hydrodenitrogenation (HDN), hydrodesulfurization (HDS) and hydrodeoxygenation (HDO) in the hydrotreating processes. The technologies for absorption of HCl, NH_3, H_2O and H_2S are already well established. Dioxin neither survives the hydrogenation process nor does produce super toxic products. The metal impurities remain in present state during the process due to hydrodemetallation (HDM).

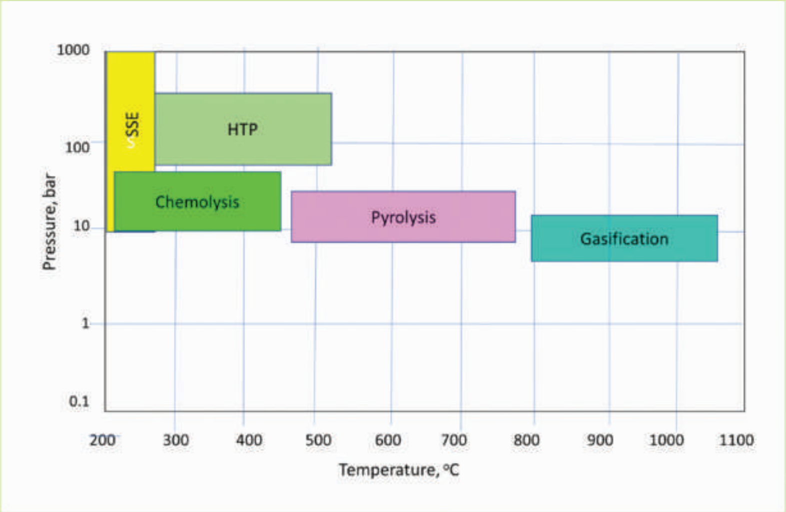


Figure 13. Opportunities abound for technological advancement in the field of chemical recycling; adopted from [39]

A catalytic cascade process where hydropyrolysis can be coupled with downstream vapor-phase hydrotreatment to upcycle mixed plastic waste into fuels. This tandem vapor-phase hydrotreatment technology is feedstock-agnostic and therefore capable of upcycling different kinds of personal protective equipment (PPE) waste [47]. Thus, hydratreating can be used as a favorable chemical upcycling technology for accomplishing a sustainable plastic circular economy.

Future direction

Many challenges exist in producing green hydrogen and to meet the so-called '111' objective as well as using or reusing carbon dioxide in an economical manner. A foremost challenge encompasses determining how best to tap energy sources, since converting carbon dioxide into fuels and chemicals would require large energy input. Another task is to find new reaction routes, including novel heterogeneous chemical and enzyme catalysts, and design and operation of multiphase reactors where process intensification is achieved economically.

Utilization of pure CO_2 by different ways such as using plasma, photocatalytic system, electrochemical reduction, heterogeneous catalysis, etc. has been reported in the literature, most of which is on lab scale. However, scarce attempts have been made to develop continuous processes for converting carbon dioxide from flue gas to value-added products that are economical and have the potential to meet energy and material needs of the future on commercial scale. Over the next two decades, capturing CO_2 from different sectors such as fossil-fuel based power plants, natural-gas processing plants, bioethanol plants, and cement plants could become a important method for mitigating climate change. Most of the captured CO_2 would probably be injected deep into depleted wells and stored, which is known as carbon capture and storage (CCS). One proposed means of reducing the cost of

CCS is to trade some of the CO_2 for subsequent use. Thus, CO_2 is now considered not just a pollutant but a valuable commodity which can be used to produce fuels, chemicals and materials. In the chemical industry, the greatest use of CO_2 (~110–120 MMTA) is to produce urea. However, considering that global CO_2 emissions are around 10 billion MTA, converting it to useful chemicals is not expected to make a big difference in the GHG emissions problem. However, researchers are making progress in developing efficient methods for converting CO_2 into chemicals, so its potential use could be significant.

Decarbonization of the transportation industry is needed most urgently. The new setting trend of the mode of transportation is electric cars and hydrogen driven vehicles, but the question is unresolved as most of the power plants are still using coal and petroleum as the primary source of energy which releases a huge amount of CO_x, SO_x, and NO_x into the environment. However, the current refineries could use green hydrogen in their 8 different processes needing catalytic hydrogenation which will reduce CO_2 emissions from steam reforming of natural gas. It is predicted that by mid-2050s we may not have a viable means of extracting oil from the mother earth using current technologies. These problems along with GHG emissions, commitment to the Paris Agreement of 2015, aiming at net zero carbon by 2050, and containing global temperature rise to below 1.5 °C, have all propelled the development of a new clean energy alternative, which has to be renewable and can be utilized in the industry without any major modification of present infrastructure. For any alternate souce, building new infrastructure in a short period and that too economically, will be horrific. The three main characteristics of the energy supply chain which are essential for any type of energy infrastructure are the energy generation, storage, and distribution about utilization. There are a very few options availabl which can fulfill all the three criteria.

Conclusions

Net (carbon) Zero is a grand plan to restrict the global temperature rise to less than 1.5 °C whereby CO_2 emissions must be reduced from ~40 Gt today to less than 10 Gigatons by using non-carbon renewable energy sources. Green hydrogen will play a massive role in transforming C1 off gases like CO_2 into valuable chemicals and materials. By 2050, almost 49000 TWh of energy will be required among which about 73% will be from renewable resources in which solar energy, wind energy and hydrogen will contribute significantly along with hydro and nuclear. Both blue and green hydrogen will contribute about 24% in the renewables totaling to about 539 MMTA. Hydrogen production will be cheaper than the grey hydrogen cost during a foreseeable future.

The CO_2 conversion into gaseous or liquid hydrocarbons needs reaction conditions of high temperature (250-450 °C) and high pressure (20-40 bar), but the conversion is low due to difficulty in the activation of CO_2. Therefore, currently available technologies are not economically suitable for industrial implementation. Efficient heterogeneous catalysts can reduce the energy needed for reactions by reducing the activation energy. Various catalysts need to be actively investigated to enhance CO_2 conversion and to control selectivity toward the specific desired products. In fact, hydrogen will play an important role in production of all these chemicals. Hydrogen is regarded as energy carrier, and it is only be produced by using energy from other source.

Sustainable methanol economy refers to the combination of captured CO_2 from various waste sources and cheap hydrogen by using renewable energy to produce methanol. It is also referred to as “liquid sunshine” and has a great potential to resolve the energy crises and mitigate climate change. Throughout the last few decades, there is an advanced and viable development of technologies in catalytic hydrogenation of CO_2 for methanol synthesis, leading to a carbon-neutral energy sources by scavenging massive CO_2 released into the environment from various industries.

Most of the hydrogen is produced from hydrocarbon processing in the petrochemical industry, usually by gasification of coal or natural gas reform, which typically costs around at <2 USD/kg. The cost of hydrogen production mainly comes from the energy (heat and electricity) consumed during the process. Renewable energy is the cheapest option for hydrogen production, including geothermal, wind, hydropower, and solar energy. Therefore, the best approach to consider is to produce hydrogen by renewable energy, preferably solar or wind, and use that hydrogen for CO_2 hydrogenation to methanol, DME, and ammonia synthesis. For sustainable hydrogen production for ammonia synthesis, water electrolysis using wind and solar power is used, which provides a clue for methanol synthesis. In the future, thermochemical water splitting cycles such as Cu–Cl could compete for cheap production of green hydrogen if they are

coupled with solar energy as proved in the ICT-OEC (Institute of Chemical Technology-ONGC Energy Centre) hydrogen production technology.

DME is viewed as a ' 2G fuel/bio-fuel' and is a powerful, empowering fuel that can range from being ultra-low carbon to carbon-negative. It can significantly reduce the carbon footprint of the transportation sector and beyond (a) as an energy-dense, cost-effective means to move towards renewable hydrogen, (b) as a blending agent for propane, and (c) as a diesel replacement. DME can also be a clean fuel produced from emitted CO_2 captured from flue gases or directly from power plants.

Carbon dioxide refineries are not far away to be seen and to be believed. Thus, hydrogen can substitute fossil fuels in some carbon intensive industrial processes, such as steel, chemical and allied industries. It can present solutions for difficult to abate parts of the transport system, in addition to what can be accomplished through electrification and other renewable and low-carbon fuels. Net zero should happen much before 2050 during the lifetime of many readers. Biomass including waste and plastic waste will be major sources of chemicals and materials where hydrogenation/hydrogenolysis and oxidation will lead too protection of environment, provision of fuels, materials and energy.

Although bioethanol and other biomass derived chemicals can be used to make blue H_2, it should not be burnt as a fuel if we want to achieve the net zero goal before 2050.

Carbon should be used as a source of chemicals and materials. Bioethanol is more valuable as a feedstock for biorefinery than a fuel as our analysis showed [6]. It makes more economic sense in addition to the net zero target. Chemical recycling of waste plastics will have great benefit. Huge quantities of plastic waste can be converted into fuels and chemicals, and hydrogenation will play a significant role in treating all sorts of polymers and their mixtures. Circular economy must be made mandatory in all sectors and future societies should be taught that material recycling through physical, chemical and biological means and use of green energy will save us from climate change and GHG emissions. Hydrogen will be a true savior in these sectors.

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PIDILITE INDUSTRIES LTD.

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Pidilite Industries Ltd. is a consumer centric company committed to quality and innovation. For decades, Pidilite has been pioneering products for small to large applications, at home and industry, which have forged strong bonds with people from all walks of life.

From adhesives to sealants to waterproofing solutions and construction chemicals to arts & crafts, industrial resins, polymers and more, Pidilite's product portfolio is as diverse as it is ever-evolving. Today, its brands like Fevicol, Fevikwik, Dr. Fixit, Mseal and several other iconic brands are trusted household and industrial names. No wonder it's such a dominant leader in adhesives.

Most people would also know Pidilite for their quirky advertising rooted in Indian earthy humour

A robust and growing network makes its products accessible across demographics and geographies. Pidilite products now sell in over a 100 countries

With all this success, Pidilite is also seen an an organisation with a heart as it embraces responsibility towards the community through social initiatives in rural development, education and healthcare.

Oriental Aromatics

Profile

Brief Profile of Oriental Aromatics Ltd:

Oriental Aromatics Ltd has a rich heritage of experience in manufacturing of flavours, fragrances, specialty aroma chemicals and camphor. Incorporated in the year 1972 and listed on the BSE & NSE, the company today ranks amongst the top 1000 listed entities in India.

The company has evolved into a comprehensive manufacturing conglomerate having its state of the art facilities in Bareilly at Uttar Pradesh, Vadodara at Gujarat, and Ambernath at Maharashtra. The Company has a R&D centre at Powai, Mumbai and a process re-engineering lab at Vadodara facility in Gujarat, both recognised by Department of Scientific & Industrial Research (DSIR).

Oriental Aromatics has a dedicated team of 1400 people across all its areas of operations. Today the Company ranks amongst the top few fully integrated manufacturers of flavours, fragrances as well as speciality aroma chemicals companies and also has its expertise in pharmaceutical grade camphor.

Driven by innovation and excellence the Company reinvests 4% of its profits in Research & Development. The Company focuses on Industry 4.0, sustainability and green chemistry and aspires to become a global sustainable supplier of flavours, fragrances, Camphor and Speciality Aroma Ingredients.

The Company through its CSR activities has been contributing towards areas of education through its extended arm that is Keshavlal V Bodani Education Foundation and undertaking various other projects for empowering communities.

Over the decades the Company has consistently innovated, expanded its portfolio and successfully catered to the evolving needs of customers while winning their appreciation.

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Avra Laboratories Pvt Ltd

Profile

Avra Labs was established in the year 1995 and is among the first in India to focus on providing high-end contract research and manufacturing of advanced intermediates and APIs covering oncology and other therapeutic areas. Today, with our strong team of 600+ employees, we are focused on providing custom synthesis solutions across the value chain, right from developing a cost-effective process to supplying commercial quantities from our facilities, which include USFDA and GMP approved sites. Being founded by one of India's most distinguished scientists, Dr. A. V. Rama Rao, we take pride in our cutting edge chemistry capabilities. We are the only company in the world to develop and successfully commercialize a synthetic process for Irinotecan, and have partnered with some of the largest global innovators to develop advanced intermediates and supply them at a commercial scale post-launch. Our state-of-the-art manufacturing facilities are spread over 30 acres with a total reactor volume over 165.000 liters, located in Hyderabad (USFDA approved) and Vizag. Please visit our website for more information (www.avralab.com) and reach out to us at info@avralab.com for anything you may need.

Meghmani Organics Limited

Profile

We were founded in 1986 as a partnership firm, under the name M/s Gujarat Industries, to manufacture Pigments by our Executive Chairman Mr Jayanti Patel, together with our Managing Directors, Mr Ashish Soparkar and Mr Natwarlal Patel, as well as two of our Executive Directors Mr Ramesh Patel and Mr Anand Patel (collectively the "Founders").

On 2 January 1995, Meghmani Organics Limited, was incorporated as a joint stock company with limited liability and acquired the business and all existing assets and liabilities of the partnership firm M/s Gujarat Industries and the Founders became shareholders of the Company.

We forayed into manufacturing of new and lucrative variant of White Pigment Titanium Dioxide (TiO2) through wholly owned subsidiary with initial capacity of 16,500 metric tons per annum (MTPA) at Dahej, the chemical hub of Gujarat.

We are into the manufacture of Agrochemicals and Pigments in India and have a focus on delivering quality products backed by Research and Development Centre.

We are a leading agro-chemical manufacturing Company with significant presence worldwide. Our strong customer base includes prominent MNC's and extends to more than 75 countries globally. We manufacture three broad categories of Agrochemical products, namely, pesticide intermediates, technical and formulations. Our agrochemical products find primary application in Crop Protection, Veterinary, Public Health and Wood Protection, with over 85% exports. Recently, we have been presented with accreditation of Responsible Care (our Commitment to sustainability) for Agro Division (all units of agrochemicals) by Indian Chemical Council, apex industry body representing chemical industry in India pursuing "Responsible Care Programme".

Within Pigments, we specialize in green and blue pigments, which have varied end use applications in printing inks, paints and coatings and plastics. We have three Pigment manufacturing facilities at Vatva, Panoli and Dahej SEZ in the state of Gujarat. A majority of our Pigments are exported with over 80% exports.

We have 6 multifunctional ISO certified production facilities with a wide range of products and backward integration of key raw materials, located in Gujarat, India's prime Chemical belt and having proximity to key ports.

Our R&D Centre managed by a team of professionals is recognized by the Ministry of Science and Technology. It helps us in continuous process improvement and into introduction of a newer range of pesticides to meet needs of Global customers.

Our in-house fully equipped GLP lab takes care of all data requirements for mandatory registrations of our product in each country.

Safety is the integral part of all our processes and an utmost care is taken by an efficient team of professionals in all the plants.

We grew from Rs. 20 Crore Turn Over Company in 1995 to Rs. 2553 Crore in 2023 with a Net profit earning of Rs. 238 Crore in 2023.

Recently,

we ranked as #1 Fortune Next 500 Company by Fortune India, and,

foray into manufacturing of Nano Urea (Liquid) Fertilizer through Wholly owned subsidiary Company to set up manufacturing facility in Gujarat.

CLEAN SCIENCE AND TECHNOLOGY LIMITED

innovation at work

Profile

Clean Science and Technology Limited ('CSTL'), conceived in 2006, is a first-generation fine and specialty chemical company with a focus towards innovation and value engineering. Aligned to our philosophy, Company was named as Clean Science and Technology.

Our relentless commitment to R&D has enabled us to commercialize novel, unique, innovative, sustainable and cost effective catalytic manufacturing processes. We are among the few global organisations focused on developing ingenious technologies. We identified catalytic chemistry as one of the ways to achieve our goal of devising green chemistries.

We have developed atom efficient technologies underpinned by strong plant engineering capabilities which have enabled us to derive maximum desired product, minimal by-products and effluents, avoid usage of hazardous raw materials and hence increase efficiencies and yields in our processes.

- Our commitment to cleaner processes, help us align to global ESG standards by utilising resources efficiently, reduce waste and minimise emissions.
- Investment in renewable energy to fulfil our power demand and effort towards reducing Greenhouse gas further underscore our commitment to sustainability.

Strong in-house engineering capabilities embellish our R&D commitments. This has helped us commercialize global scale, automated state-of-the-art manufacturing facilities at a very competitive cost. Our engineering capabilities manifests towards setting up plants with high level of safety and compliance with EHS guidelines.

Synergistic collaboration of R&D, engineering team and underlying theme of focus on sustainability has catapulted the Company's success.

- In a short span of 14 years, from being a greenfield company, we have emerged as the globally leading manufacturers of **functionally critical speciality chemicals including Monomethyl ether Hydroquinone (MEHQ), Guaiacol, 4 Methoxy acetophenone (4 MAP) and Butylated hydroxyl anisole (BHA).**
- CSTL has always worked on creating value for our customers and our commitment to the customer first approach is evident from the strong long term relation (10+ years) we share with some of our largest customers. **Majority of our sales come from export to global MNCs across developed nations.**
- Our strong financial performance, robust growth and global scale operations in short span of time is an outcome of innovative approach.

Guidance of our strong and diverse Board ensures high standards of corporate governance and ethics. Visionary and technocrat promoters supported by an experience and committed workforce paves way for long growth runway. We look forward with optimism to continue this exciting journey by creating long term value for all our stakeholders by building a better, sustainable tomorrow.

Thank You
Clean Science and Technology Limited

Aether Industries Limited

Profile

Aether Industries Limited, based out of Surat (Gujarat, India), focuses on producing advanced intermediates and speciality chemicals involving complex and differentiated chemistry and technology core competencies. Aether's products find application in the pharmaceutical, agrochemical, material science, coating, high performance photography, additive, and oil and gas segments of the chemical industry.

Aether's business was started in 2013 with a vision to create a niche in the global chemical industry with a creative approach towards chemistry, technology and systems that would lead to sustainable growth. In the first phase of development through Fiscal 2017, Aether focused on building the team and infrastructure and on R&D centred around building core competencies. Revenue generation operations commenced with the company's second phase in Fiscal 2018. Aether is one of the fastest growing specialty chemical companies in India, growing at a CAGR of nearly 60% between Fiscal 2018 and Fiscal 2021.

Production capacity of more than 9500 MT is available in Aether's state-of-art and DCS automated manufacturing facilities. Aether is also a leading CRAMS (Contract Research and Manufacturing Services) provider and Contract / Exclusive Manufacturing services provider, built upon technology intensive and state-of-art R&D and Pilot Plant facilities. All of Aether's R&D, Pilot Plant (which is one of the largest Pilot Plants in the world), CRAMS, and Large Scale Manufacturing facilities are capable of switching between batch and continuous process technology.

Aether Industries got listed on June 3, 2022 with a valuation of Rs. 8,000 crores plus and currently has a market capitalisation of Rs. 12,000 crores plus. Aether's shares have been trading on both the exchanges – NSE and BSE, wherein the highest share price had been Rs. 1,049 per share.

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Chemical Knowledge of the Hindus of Old.[1]

BY

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An eminent Belgian Indologist, Goblet d'Alviella, has very justly observed that India is a land of paradoxes, that whatever is of ancient origin excites our admiration—her literature including her unrivalled dramas, her transcendental philosophy of the *Upanishads* and the *Geeta* attracted the attention of the West long ago. India was once the cradle of mathematical sciences including arithmetic and algebra; the system of notation, popularly ascribed to the Arabs, is really the product of the Hindu brain.

Max Müller says somewhere that if India had presented no other gift to Europe than that of the numerals, the debt of the latter to the former would have been unrequitable.[2] Ancient Assyria, Babylon and

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[1] Inaugural address delivered by the President, Indian Chemical Society, at its first annual General Meeting held at the chemistry lecture theatre, Hindu University, Benares.

[2] The learned Professor of Sanskrit of Oxford University says "In science too, the debt of Europe to India has been considerable There is, in the first place, the great fact that the Indians invented the numerical figures used all over the world The influence which the decimal system of reckoning dependent on those figures has had not only on mathematics, but on the progress of civilisation in general, can hardly be overestimated During the 8th and 9th centuries the Indians became the teachers in arithmetic and algebra of the Arabs and through them of the nations of the West. Thus, though we call the latter science by an Arabic name, it is a gift we owe to India."—Macdonnell's *History of Sanskrit Literature*, p 424.

Egypt exist only in their monuments, cuneiform inscriptions or hieroglyphs, inscribed on slabs of stone or baked clay. The recent discoveries in Tutankhamen mausoleum have yielded many new specimens of Egyptian art of all kinds. Rome and Greece live in their literature and philosophy, but the Hindu nation persists to-day as she did 2,500 years ago, when Gautama Buddha preached at Benares, the sacred city where we are holding our meeting to-day. Sakya Muni knew that if he could make a breach in the citadel of Hindu religion and culture, the whole of India would readily embrace his new doctrine. For a time Brahminical supremacy must have been shaken to its foundation as is proved by the archæological findings of Sarnath now some five miles from this city. But the tenacious vitality of the Hindu religion is something marvellous and it struck sagacious tourists and observers like Pierre Loti. Even to-day European visitors who find the pious Hindu performing his daily religious practices and ablutions at the bathing ghats of the Ganges can have but little difficulty in coming to the conclusion that impact with the West has scarcely produced any effect on the Hindu. He pursues his daily even tenor of life as his ancestors did twenty-five centuries ago. No wonder that the poet should exclaim :—

> " The East bowed low before the blast
> In patient, deep disdain,
> She let the legions thunder past
> And plunged in thought again."

No doubt the Hindus have been meditating—ever lost in abstruse metaphysical subtleties, but, all the same, in ancient India physical science found her votaries. I have barely time to allude to the atomic theory as propounded in the Vaiseshika System of Kanāda, which anticipates the doctrine of Anaxagoras, Empedocles, etc. I shall limit myself this afternoon to the keen powers of observation as also the necessity of experimental methods enjoined by the Hindus of old, so far as chemical processes are concerned. Indeed, Dhundukanātha, the author of the standard iatro-chemical treatise *Rasendra Chintamani*, (lit. gems of mineral preparations), says—"They are alone to be regarded as real teachers who can show by experiment what they teach. They are the deserving pupils, who, having learnt the experiments from their teachers can actually perform them. The rest, both the teachers and the pupils, are merely stage-actors."[1]

This author, again, acknowledges his indebtedness to the standard work on the subject, *Rasārnava*, in which occurs an elaborate account of the processes of sublimation, distillation, etc., as also of the apparatus required for the process. Indian alchemists are also eloquent in their veneration for and indebtedness to the great adept, Nagārjuna, to whom is ascribed the invention of the above processes. One instance will suffice to give you an idea of the methods adopted for the purification of mercury.

मिश्रितौ चेद्रसे नागवङ्गौ विक्रयहेतुना ।
ताभ्यां स्यात् कृत्रिमो दोषः तन्मुक्तिः पातनत्रयात् ।

[1] अधीत्य बहुविदुषां मुखादपश्यं
शास्त्रेषु दृष्टमखिलं न हि लज्जितानि ।
यत् कर्म व्यरचयमग्रतो गुरूणां
प्रौढानां तदिह वदामि वीतशङ्कः ॥
अध्यापयन्ति यदि दर्शयितुं क्षमन्ते
सूतेन्द्र कर्मगुरवो गुरवस्त एव ।
शिष्यास्त एव रचयन्ति गुरोः पुरो ये
शेषाः पुनस्तदुभयाभिनयं भजन्ते ॥

The above, literally rendered, runs as follows:—"Fraudulent dealers adulterate (alloy) mercury with lead and tin, hence these impurities are to be removed by subjecting the mercury to triple distillation."

The identification of metals by the colouration of their flames is referred to in *Rasārnava*—

"Copper yields a blue flame, that of the tin is pigeon-coloured, that of the lead is pale tinted[1]...... ..... " We are not aware of similar tests being applied anywhere at such an early period as a qualitative test for metals.[2] As regards the high degree of skill in metallurgy attained by the Hindus, it is enough to mention the iron pillar near Delhi.[3] In the ancient Hindu literature only six metals are mentioned, *viz.*, gold, silver, iron, lead, tin and copper. The name of a seventh metal—zinc—occurs in European history for the first time in the works of Paracelsus, who leaves us in the dark as to the nature of his "zincken," which he designates as "semi" or bastard metal.

Libavius was the first to mention the properties of zinc more exactly although he was not aware that the

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[1] *Cf.* "Lead compounds impart a pale tint to the non-luminous gas flame."—Roscoe and Schorlemmer's Chemistry, Ed. 1879.

[2] Cardan (1501-1576) is perhaps the earliest to notice that the colour of the flame varies with different metals—Hoefer's *Hist. d. Chim.* Vol., II, p. 95. Ed. 1869.

[3] Taking A.D. 400 as a mean date—and it certainly is not far from the truth—it opens our eyes to an unsuspected state of affairs to find the Hindus at the age capable of forging a bar of iron larger than any that had been forged even in Europe up to a very late date. As we find them, however, a few centuries afterwards using bars as long as this *lat* in roofing the porch of the temple at Kanaruc, we must now believe that they were much more familiar with the use of this metal than they afterwards became. It is almost equally startling to find that, after exposure to wind and rain for fourteen centuries, it is unrusted, and the capital and inscription are as clear and as sharp now as when put up fourteen centuries ago."

"There is no mistake about the pillar being of pure iron. General Cunningham had a bit analysed in India by Dr. Murray and another portion was analysed in the School of Mines here by Dr. Percy. Both found it pure malleable iron without any alloy."—Fergusson's "*History of Indian and Eastern Architecture*, Ed. 1899, p. 508.

Even now forged masses of such size are exceptional.

metal was derived from the ore known as 'calamine.' He states that "a peculiar kind of tin is found in the East Indies, called 'calaëm.' Some of this was brought to Holland, evidently by the Dutch East India Company, and came into his hands." The extraction of zinc from the ore (calamine) can be followed in every detail from the account left to us in *Rasārnava* and specially *Rasaratnasamuchchaya*. The process as given in the latter work is reproduced below. The literal rendering of it runs thus :

"Rub calamine with turmeric, the chebulic myrabolans, resin, the salts, soot, borax[1].......... Fill the inside of a crucible with the above mixture and dry it in the sun. Close its mouth with a perforated saucer. A vessel filled with water is embedded in the ground, over which the above vessel charged with the mixture is inverted, which is again heated as shown in the figure, by means of a charcoal fire. The operation is stopped when the *flame issuing from the mass changes from blue to white*. The essence of the metal, which drops into the water and has the lustre of tin, is to be collected." Indeed, the process, so elaborately given above, might be quoted almost *verbatim* in any treatise on modern chemistry.[2] It is practically the same as *distillatio per descensum*—the flame of a bluish tint issuing from the mouth of the crucible indicates the combustion of carbon monoxide so often observed in metallurgical operations.

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[1] It is scarcely necessary to point out that highly carbonaceous substances like resin, turmeric, etc., being heated in the absence of air yield carbon in a fine state of division.

[2] *Cf.* "A mixture of two parts of ground roasted ore and one part of coal-dust is brought into the retorts, each holding about 40 pounds of the mixture. As soon as the temperature has risen high enough, the reduction begins and *carbon monoxide* is evolved and burns from the end of the clay adapter with *a blue flame*." (The italics are ours)—Roscoe and Schorlemmer's Chemistry, Ed. 1879, Vol. II, Part I, p. 225.

It is not, of course, claimed that the ancient Hindus knew that the blue colour was due to the combustion of carbon monoxide, but what I should like to lay particular stress upon is the power of keen observation underlying the description.

The ancient Hindus knew the distinction between potassium carbonate and sodium carbonate—the former is called *yavakshāra* (*lit.* ash from the spikes of barley), and the latter *sarjikakshāra*, (equivalent to *natron* from Egypt). The earliest record of this is to be found in the old Hindu work, the *Susruta*. The *Charaka* and the *Susruta* are the two standard and authoritative treatises on *Ayurveda* (*lit.* science of life). The *Charaka* is more concerned with medicine, while the *Susruta* relates more or less to surgery. Here we have a drop of 2,000 years from the *Susruta* to the remarkable discoveries of Joseph Black. In the *Susruta* the two modifications of alkali are referred to as *tikshnakshāra* (*tikshna*, *i.e.*, sharp or caustic; *kshāra*, *i.e.*, alkali), and *mridukshāra* (*i.e.*, mild alkali). The distinction between the two is quite clear. In the days of my boyhood the ashes of the plantain tree (*Musa sapientum*) were used by washermen for cleaning clothes. The reason is that it is very rich in potassium carbonate. In the *Susruta* we have many land plants mentioned which have been botanically classified in Uday Chand Dutt's *Materia Medica of the Hindus.* The *Susruta* says "on an auspicious day cut the plant down, burn it and boil the ashes with water in an iron pan and then filter through cloth folded several times." This, says the *Susruta*, is *mridukshāra*. You know what actually takes place in this process. The clean solution that is obtained is rich in potassium carbonate and is termed mild alkali.

Next comes the description of the preparation of caustic alkali, and this is the most scientific portion.

"Collect several kinds of limestone and shells and burn them strongly and add water to the resulting product. Next mix this slaked lime with the lixiviated liquid obtained above and boil and stir with an iron ladle." The reactions that take place here can be represented in the modern way by the following equations:

$$CaCO_3 = CaO + CO_2$$

$$CaO + H_2O = Ca(OH)_2$$

$$K_2CO_3 + Ca(OH)_2 = 2KOH + CaCO_3.$$

This method, you will look for in vain in any European treatise before the 16th or the 17th century. The process as given in the *Susruta* is so scientific that it can be bodily transferred to any modern text-book on chemistry. Besides recommending the use of an iron vessel for boiling the liquid, the book further says that the *kshāra* so obtained, must be stored in an iron vessel with its mouth closed :

आयसे कुम्भे संहृतमुखे निदध्यात् ।

The *Susruta* cannot, of course, be credited with having known that carbon dioxide was to be excluded from the vessel to prevent the caustic solution from being acted upon. But the physicians of those days must have certainly realised by empirical methods that the causticity would be diminished if these precautions are not taken. Even to-day we keep caustic potash, either in iron or silver vessels. The points to be noted here are that the *Susruta* gives not only a very accurate method of preparation and preservation of the two kinds of alkali but also the distinction between the two varieties, *tikshnakshāra* and *mridukshāra*, is clearly recognised. Davy isolated potassium and he says, "The ancients did not know how to distinguish between potassium carbonate and sodium carbonate." But in our *Ayurveda* this sharp distinction has been clearly stated.

Between the *Susruta* and Joseph Black lies a gap of some 2,000 years. Black was an M.D. of Edinburgh. In his Doctorate thesis (presented in 1755) he gave for the first time the scientific explanation of the difference between caustic and mild alkalis. He heated magnesium carbonate using the balance at each stage of the experiment, and pointed out that on strong heating there was a loss in weight. He also pointed out that a gas was given out which was called "fixed air." Ramsay in his *Life of Black* says "Quicklime is formed by heating lime-stone in the fire; it thereby acquires its burning properties or causticity." Black's essay was an epoch-making one.

M. Berthelot, under whose inspiration I took to writing my *History of Hindu Chemistry*, in reviewing my book says of this portion "that the Hindus possibly got their knowledge of this method from the Portuguese." (*Journal des Savants*, Jan. 1903, p. 34.) But against that I may point out that Chakrapāni, who was the court physician of Nayapāla (1050 A.D.), King of Gour, in the treatise which goes by his name, quotes this mode of preparation verbatim from the *Susruta*. A much older treatise, the *Vagbhata* also does the same. In the course of my studies, I came across a remarkable passage in a Buddhist work which dates as far back as 140 B.C.,—I mean the *Milinda Panho*. Professor Rhys Davids translates the portion as follows: "And when the inflammation had gone down and the wound had become sweet, suppose he were then to cut into it with a lancet, and burn it with caustic. And when he had cauterized it, suppose he were to prescribe an alkaline wash...... . . Now tell me, O King! would it be out of cruelty that the surgeon......... thus cut with the lancet and cauterized with the stick of caustic."[1]

It must be admitted on the other hand that the discovery of Black was quite independent and he showed that the difference between the mild and the caustic alkalis was due to the presence of carbon dioxide in the former. The *Susruta*, of course, does not say anything of this kind.

The use of metallic preparations mentioned in the Hindu Pharmacopœia also dates from a very early period. In Europe Paracelsus was, as we have said, the first to introduce metallic preparations into medicine. But in India, Vrindā who preceded Chakrapāni by at least a century and therefore must have flourished about the 9th Century A.D., or even earlier, was the first to prescribe 'Kajjvali' (black sulphide of mercury) as a medicine. Chakrapāni gives an elaborate description of the process of making 'Kajjvali'. In Europe this preparation was not known before the 17th century.[2]

I need not proceed further. The knowledge of pharmacy which the Arabs brought to Europe was derived from the Hindus. *Er oriente lux*. I shall conclude with the apposite words of that illustrious French Chemist, Jean Baptiste André Dumas: "What an awakening for Europe! After two thousand years she found herself again in the position to which she had been raised by the profound intellect of India and the

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[1] *Sacred Books of the East*—Vol. XXXV, p. 168.

[2] Das Schwarze Schwefelquecksilber lehrte zuerst Turquet de Mayerne, im Anfange des 17 Jahrhunderts, durch Zusammenreiben von warmen Quecksilber mit geschmolzenem Schwefel darstellen "—Kopp: *Gesch. d. Chem*. Vol. IV, 186.

acute genius of Greece." (The first *Faraday Lecture* delivered before the Chemical Society, June 17, 1869).[1]

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[1] Hoefer in his admirable *Histoire de la Chimie* also expresses the same view "L'Inde est le berceau de la filiation des peuples qui marchent à la tête de la civilisation."—Vol., I, Ed. 1866.

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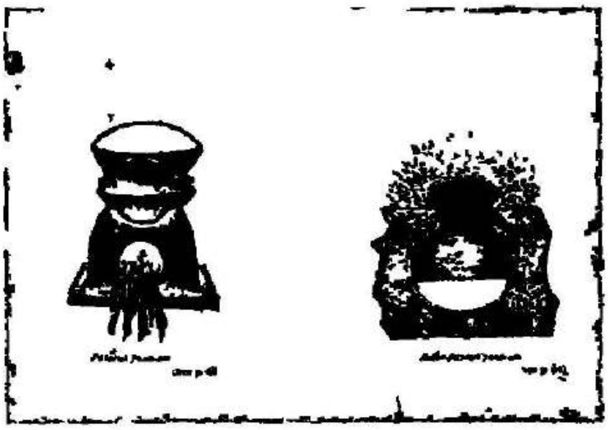
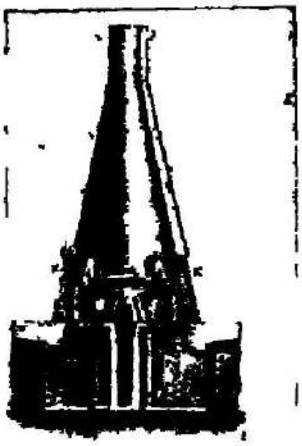


Apparatus for sublimation and
distillatio per descensum.



A modern method of
extraction of zinc.

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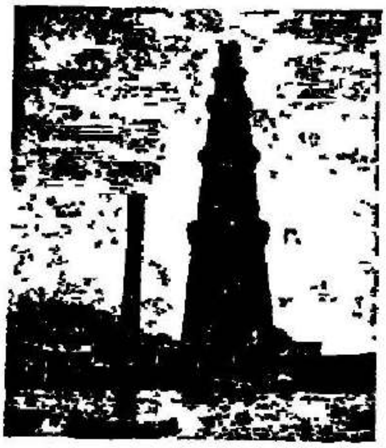

The iron pillar and the
Kutab minar near Delhi.

Fumigating
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Extraction of zinc
from calamine.

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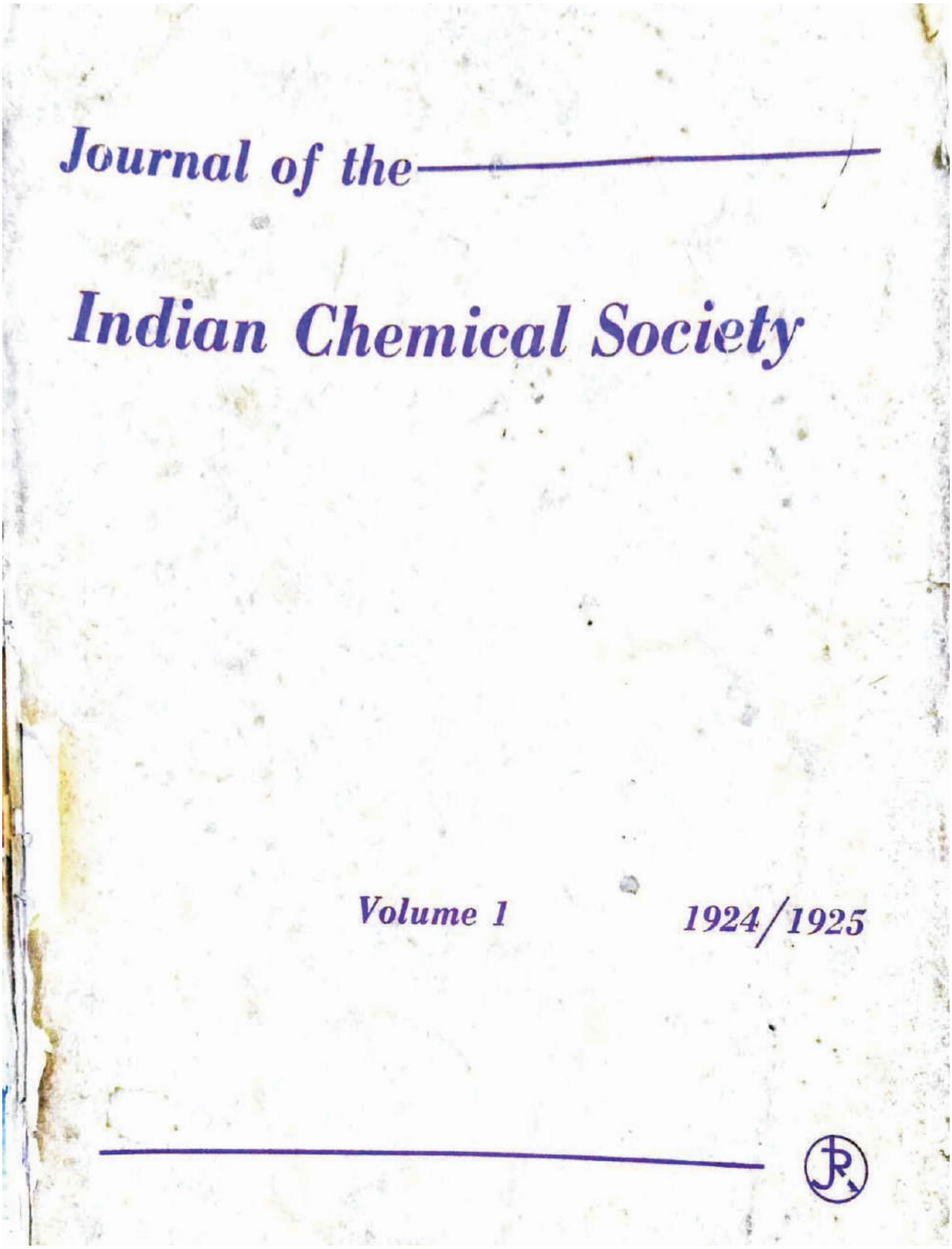
Apparatus for distillation

Apparatus for extraction of mercury from cinnabar



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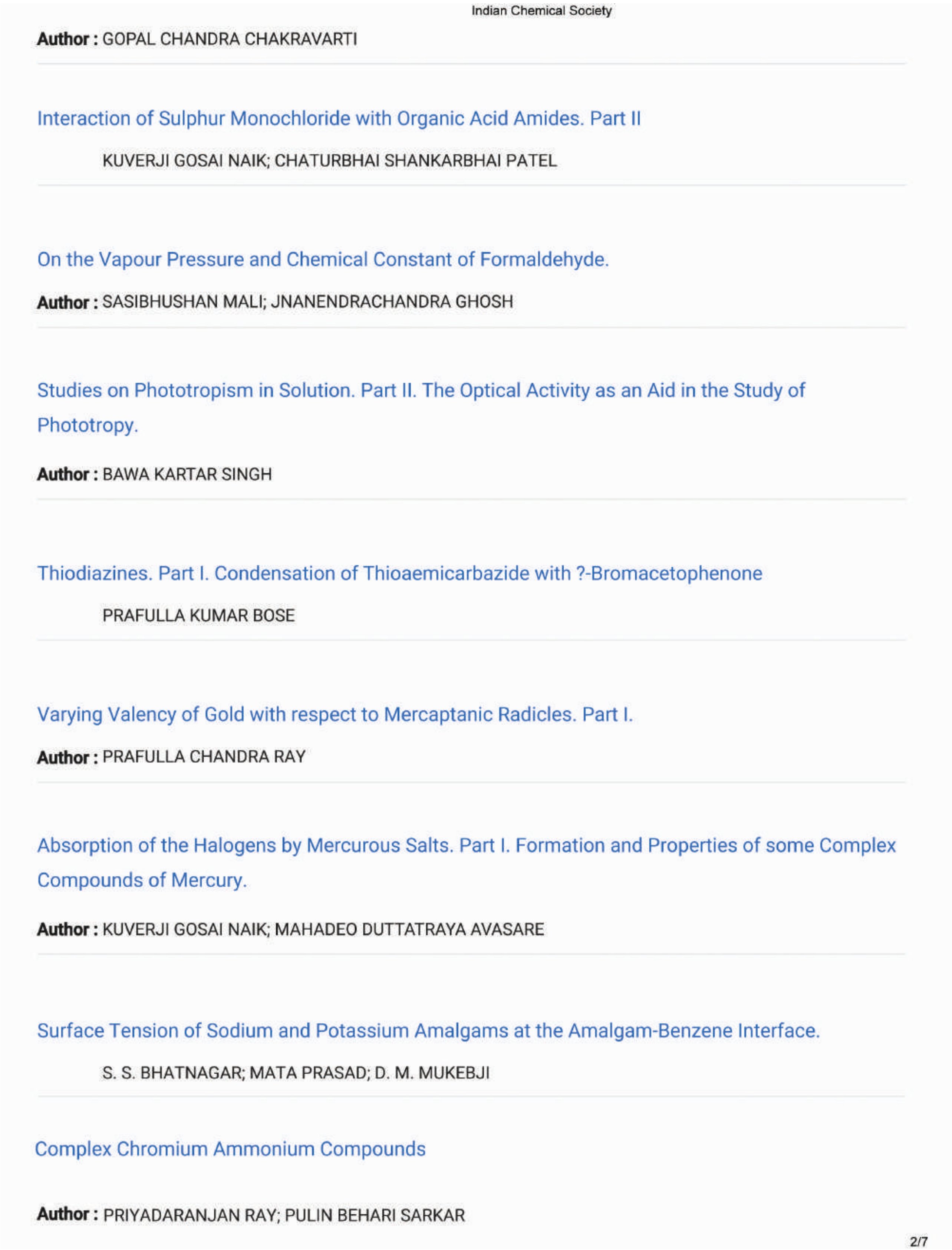

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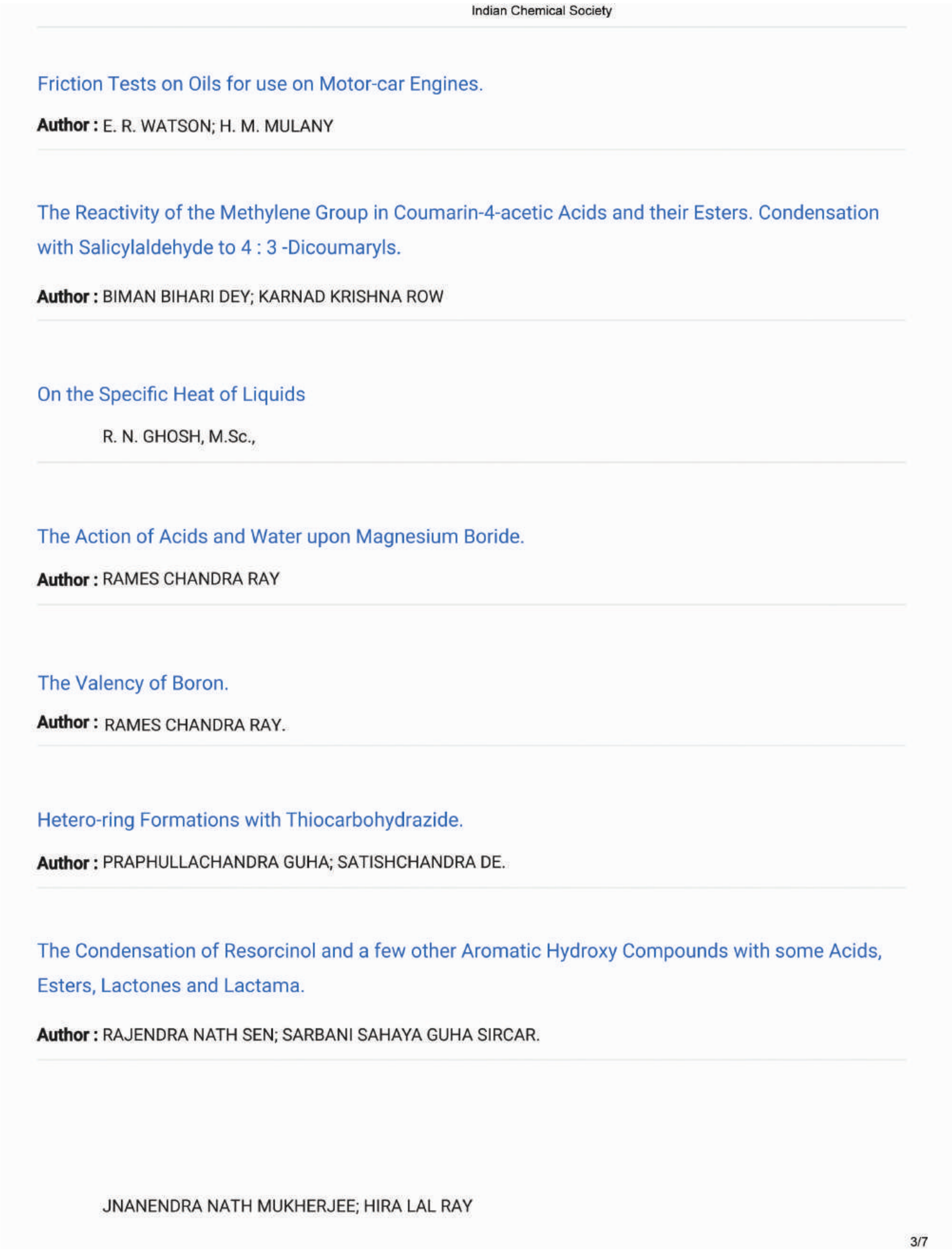

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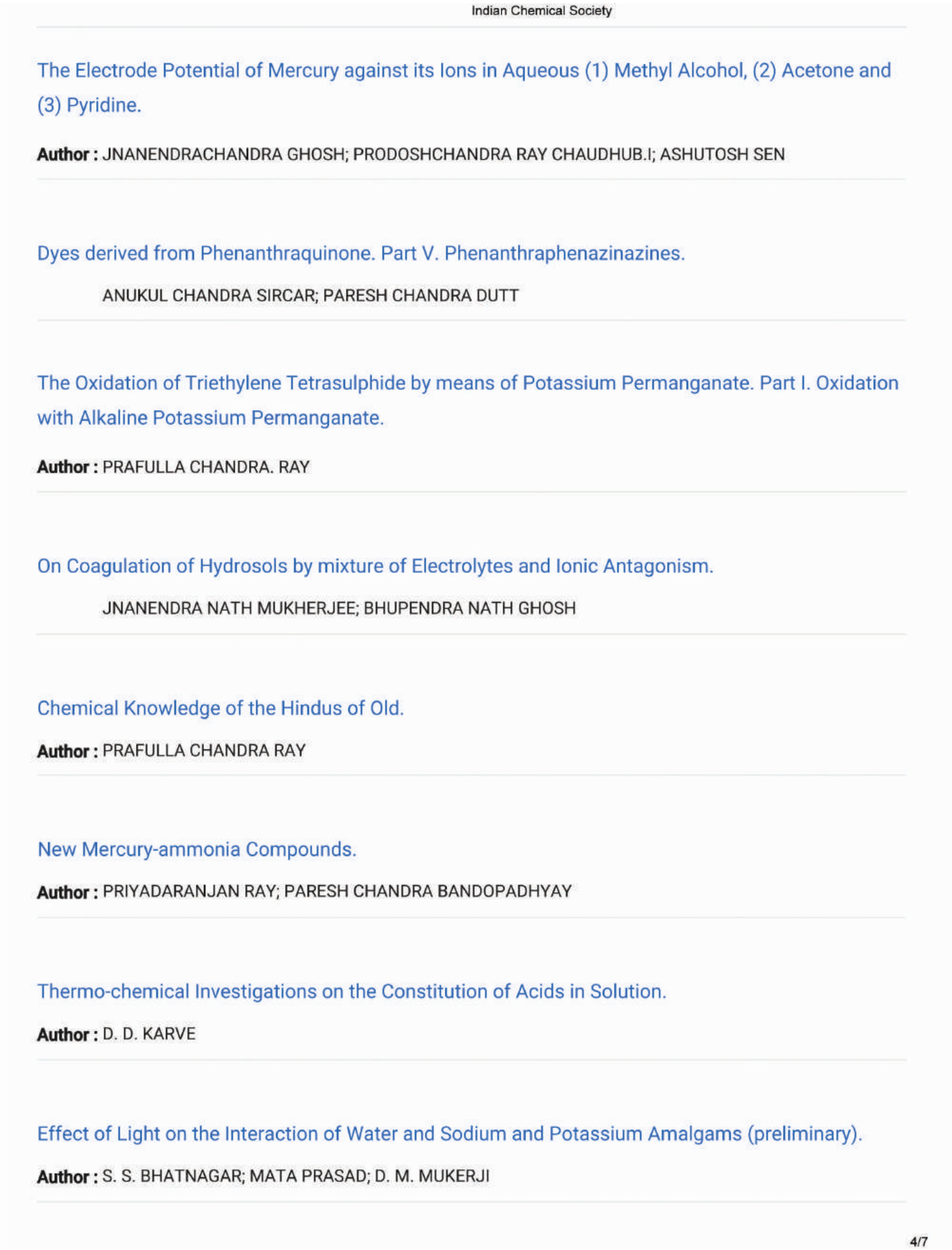

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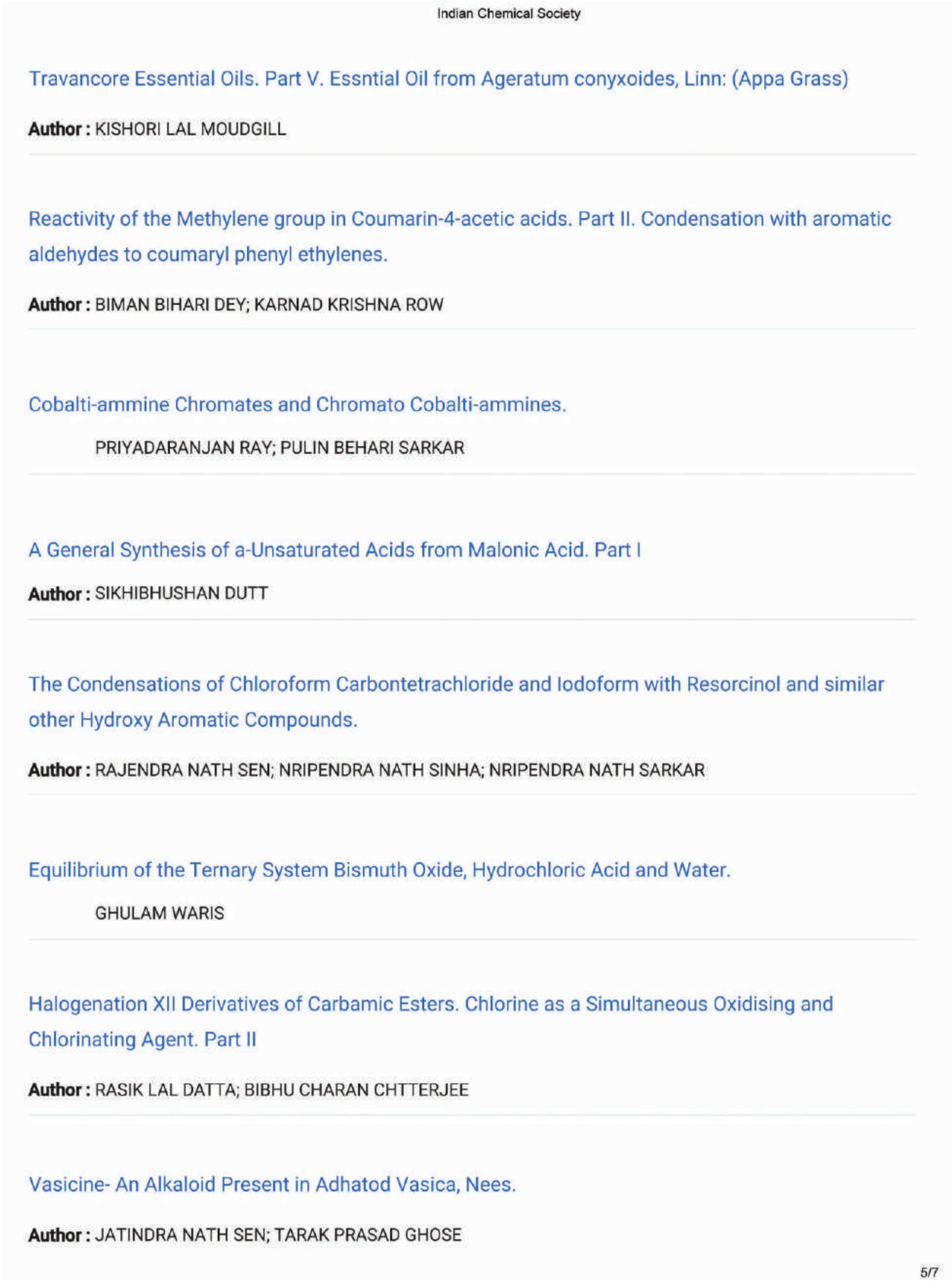

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The Reduction of Unsymmetrical Dichloracetone by Yeast.

BY

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The reduction of chlorinated ketones does not appear to have been studied hitherto, although the reduction of aldehydes and ketones in general by yeast has been the subject of thorough investigation by Neuberg[1] and his co-workers. Their work conclusively proves the value of yeast as a reducing agent, which must play an important part in ordinary fermentation as also in natural syntheses. The first important example of bio-chemical reduction of this nature was furnished by Linter,[2] Liebig, and Lüers who reduced chloral hydrate and made the preparation of trichlorethyl alcohol accessible in the laboratory. The importance of reducing monochloracetone, or indeed, of any of the unsymmetrical chloracetones by means of yeast, lies firstly in the fact that these acetones after reduction give rise to alcohols containing an asymmetric carbon atom as is evident from the following :

$$CHCl_2\cdot CO\cdot CH_3 \xrightarrow{H_2} CHCl_2\cdot \underset{*}{C}HOH\cdot CH_3.$$

Secondly, these chlorinated secondary alcohols would form the basis of urethane derivatives, valuable as soporifics. In ordinary chemical reduction it is the

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[1] C. Neuburg and J. Kerb. Ber. 46, 2225 (1913).

[2] C. J. Lintor and H. J. V. Liebig H. 72, 449 (1911); Linter and Lüers. H. 85, 122 (1913).

racemic form that is invariably obtained, as the chance of formation of the dextro-form is equal to the chance of formation of the laevo-form. In the case of biochemical reduction, the chance of obtaining optically active components is usually great due to the selective action of enzymes, and if in any way the preponderance of one isomer over the other can be secured, the resulting compound should exhibit optical activity (compare Neuberg and Kerb; Neuberg and Nord). An early example of the selective action of ferments or bacteria is to be found in Le Bel's work on the fermentation of inactive propylene glycol by *bacterium termo*. A further example of interest is to be found in the work of Peré,[1] who studied the biochemical oxidation of propylene glycol in contact with *tyrothrix tenuis*. It is significant that this investigator obtained a dextro-rotating propyl glycol, as distinct from the laevo rotatory propyl glycol obtained by Le Bel. The explanation must evidently lie in the use of different bacteria, which would seem to indicate with a degree of certainty that the action of the two bacteria upon racemic propyl glycol is selective.

The particular reaction described in these pages is a case of reduction by yeast in a fermenting solution of sugar. Here also the yeast exerts a selective action and from unsymmetrical dichloracetone gives rise to an optically active dichlorisopropyl alcohol. The rate of this reduction, however, in the case of dichloracetone is relatively rapid as the reduction is probably completed in 24 hours if not in 12 hours. The operation of adding a 20 per cent. alcoholic solution of 10 grams dichloracetone to a fermenting solution of sugar requires 3-4 hours, after which the mixture is allowed to stand

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[1] Annales de Institut Pasteur, 1896, II, 600-8.

overnight in an incubator at 35°C. Next morning the odour of dichloracetone is scarcely to be noticed in the reaction mixture, and the sugar is also found to have disappeared to the extent of 96-97 per cent. The further addition of yeast, or of yeast and sugar, is only to secure certainty of reduction of any dichloracetone that might have remained unacted upon. Dichloracetone does not seem to be appreciably poisonous to beer-yeast and the yield of dichlorisopropyl alcohol is not affected by the rate of addition of the dichloracetone to the fermenting sugar solution. In one experiment in which accidentally the stopper of the dropping funnel was dislodged, about half of the alcoholic solution of dichloracetone fell at once into the fermenting sugar solution without markedly affecting the rate of fermentation of the solution. This non-poisonous character of dichloracetone is convenient and also interesting in view of the fact that Willstätter has recently found bromal very poisonous to yeast and Neuberg (*loc. cit.*) found it necessary to add the aldehydes with which he experimented, very cautiously to the fermenting solution in order to get a good yield of reduction product. Also in some experiments with monochloracetone the rate of addition was found to be very important. The first experiment was conducted with monochloracetone supplied by Messrs. Kahlbaum of Berlin, an alcoholic solution of which had to be very cautiously added in order to maintain the fermentation of the sugar solution. In fact even with the utmost care, it was difficult to maintain a brisk fermentation throughout the addition, and towards the end the addition of monochloracetone had actually to be suspended, in view of the considerably decreased rate of fermentation. It is to be observed here that in course of further investigation, it was found that the monochloracetone supplied by Messrs.

Kahlbaum was not pure, but contained a considerably higher percentage of chlorine than is required by the formula. This may be due either to the presence of some dichloracetone, the boiling point of which closely approaches that of monochloracetone, or to small quantities of higher chlorinated products. The conclusion, therefore, is that either monochloracetone or the very small quantities of tri-, tetra-, or penta-, chlor derivative of acetone, are poisonous towards yeast, dichloracetone itself having scarcely any injurious effect. Experiments with monochloracetone alone could not be completed on account of the difficulty in obtaining a pure specimen of the substance. Its preparation has now been undertaken. In the case of monochloracetone something different occurs, as the peculiar penetrating odour of this compound remains for over a week, and indeed does not then entirely disappear. In our experiments we followed the conversion of monochloracetone into monochlorisopropyl alcohol by the disappearance of this unpleasant and tear-bringing odour. As already mentioned, the poisonous nature of monochloracetone or any component with which it is contaminated, is so marked that a little carelessness in the addition of its alcoholic solution to the fermenting sugar solution speedily stops the fermentation. It is significant that monochloracetone has a fatal action upon yeast, whereas dichloracetone has practically no such injurious action. A careful comparison of the various chloracetones with regard to their action on yeast would be of interest and it is hoped that a future communication may be made thereon.

Whilst in the cases cited above (Neuberg, Pere, Le Bel) the rotation in two experiments was not constant, with dichloracetone however, this has been found to be the same in five separate experiments that have up to now been performed.

An additional interest in obtaining unsymmetrical dichlorisopropyl alcohol by the biochemical method lies in the ease with which a good and cheap yield of this alcohol can be obtained, rendering the process thereby suitable for practical application.

Several experiments have up till now been performed both with the alcohol itself and its urethane derivative, upon rabbits, which justify the expectation that they will be valuable as soporifics. It is to be observed that dichlorisopropyl alcohol is likely to have an advantage over chloral, being poorer in chlorine, and more effective than trichlor ethyl alcohol, being a secondary alcohol. All experiments, that as yet it has been possible to conduct, show that both the alcohol and the urethane derivative are without any injurious effect upon the animal system, and that the difference between the narcotic and toxic doses is fairly considerable. A more detailed report of the investigation in this direction will be shortly communicated.

EXPERIMENTAL.

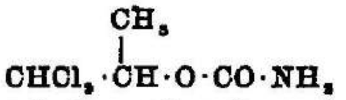
250 grams of starch sugar or ordinary cane sugar were dissolved in 2·5 litres of tap water at 40° in a 5 litre bottle. To the solution 250 grams of pressed beer-yeast were added. In about fifteen minutes the liquid was in brisk fermentation, when a 25 per cent. alcoholic solution of 10 grams dichloracetone was drop by drop added to the fermenting mixture, care being taken not to suppress the vigorous fermentation by too quick addition of the dichloracetone solution. In three to four hours the addition is complete, during which time the bottle is shaken from time to time. The reaction vessel is then allowed to stand over-night in an incubator at 35°C. Next morning the odour of dichloracetone

is found to have practically disappeared, and the sugar also almost fully used up. In order to ensure more complete reduction, about 100 grams more yeast are added and left again in the incubator for two more days, at the end of which the liquid is filtered, the residue washed two or three times and the combined filtrate distilled under vacuum on a boiling water-bath. The ethyl alcohol, dichlorisopropyl alcohol and any unchanged dichloracetone being volatile in steam, collect in the receiver which is constantly kept well-cooled by a rapid current of tap water. The distillate is now shaken up with two litres of ether, the ethereal layer separated, dried over ignited sodium sulphate, and distilled off from a water bath. The residue which now amounts to 8 cc. is fractionated from a small distilling flask, when 5·2 grams of dichlorisopropyl alcohol collect steadily at 146°-148° [compare Wohl and Roth, Ber. 40, 217 (1907)]. The fore-fraction also contains about a gram of the dichlorisopropyl alcohol identified by its optical rotation. From a large scale experiment with 48 grams of dichloracetone, 26 grams of the pure alcohol were obtained, which correspond to a yield of 54 per cent. of the theory.

Dichlorisopropyl alcohol is moderately soluble in water and very soluble in ether and alcohol. It has a burning sweet taste, and a pleasant ethereal odour, having a density of 1·33. The pure liquid in a one decimeter tube rotates the plane of polarisation by $-11·88°$·$[\alpha]D$ is therefore $-9°$.

Found $C=27·83$, $H=4·76$, $Cl=54·0$; $C_3H_6OCl_2$ requires

$C=27·91$, $H=4·65$, $Cl=55·0$ per cent.

The urethane derivative  $CHCl_2·\overset{\overset{\large CH_3}{|}}{C}H·O·CO·NH_2$ is prepared by mixing an ethereal solution of carbamyl chloride with the calculated quantity of dichlorisopropyl alcohol also in ethereal solution. The solution is allowed to stand at room temperature for 15 minutes, after which the ether is expelled on the water-bath. The residual oil soon solidifies on scratching with a glass rod and can then be crystallised either from ether in which it is extremely soluble, or from water in which it is soluble only to the extent of 2 per cent. at ordinary temperature. This is a decided advantage as the loss in crystallising from ether is excessive. The urethane crystallises in white needles, melting at 61°-63° C.

0·1330 gave N = 9·4 cc., at 16°C and 755 mm. press ; N = 8·20 ; $C_4H_7O_2NCl_2$ requries N = 8·14 per cent. 0·75 gram of the urethane dissolved in 25 cc. of water and 2 cc. of glycerine when given to a rabbit weighing 4·5 pounds caused an uninterrupted sleep for 11 hours. The parent alcohol given in 0·5 gram caused an undisturbed sleep in the same animal for a period of one hour, without spasms. The urethane derivative is also optically active. rotating the plane of polarisation to the left. 0·3336 gram dissolved in 2 cc. of absolute alcohol, rotated the plane through −2·226° in a 1 dcm. tube. The reduction of monochloracetone (from Kahlbaum) by a method similar to that adopted in the case of dichloracetone, resulted in a yield of not more than 25° per cent. In fractionating the final product of reduction after extraction with ether, the first part of the distillate, after expulsion of the ether distilled under 100°C and contained mostly ethyl alcohol ; the fraction distilling between 100° and 125° contained unconverted monochloracetone and also a small quantity of monochlorisopropyl alcohol, $CH_2Cl.\ CH(OH).\ CH_3$ the boiling point of which latter is 127°. Then came a fraction boiling between 126° and 132° which may be taken as more or less pure monochlorisopropyl alcohol, but the thermometer then rose rapidly, a product boiling between 138° and 152° was collected which probably marks the boiling point limits of a mixture of mono- and dichlorisopropyl alcohol. After this the thermometer rose steadily up to 180° and a few drops of liquid of unknown composition were obtained.

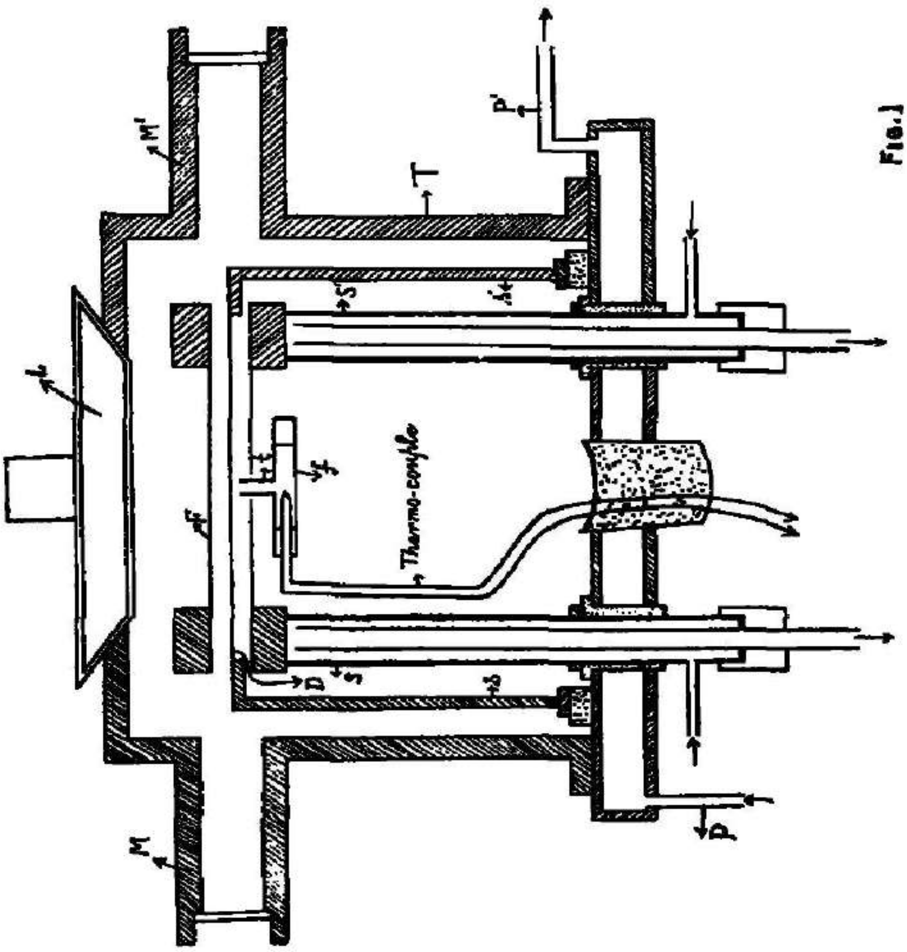


Fig. 1

Surface Tension of Sodium and Potassium Amalgams at the Amalgam-Benzene Interface.

BY

S. S. BHATNAGAR, MATA PRASAD

AND

D. M. MUKERJI.

A systematic study of sodium amalgams containing high percentages of sodium was made by Vanstone who by varying the proportion of sodium and mercury and studying the mixture with respect to thermal diagram (Trans. Faraday Soc., 1911, *7*, 42) and electrical conductivity (Trans. Faraday Soc., 1914, *9*, 291) found out the exact composition which corresponded to the formation of a definite compound.

Comparatively very little is known about the state of sodium-mercury and potassium-mercury mixtures in the liquid state, when only very small quantities of sodium and potassium are present in the mixtures.

Whilst the solid crystalline amalgams of the alkali and alkaline earth metals are regarded as definite chemical compounds, the corresponding liquid amalgams on the other hand have generally been regarded as mercurial solutions of this metal in the monatomic condition. George McP. Smith (Amer. Chem. J., 1907, *37*, 506) does not agree with the latter view and has submitted evidence to show that even in the liquid state chemical compound formation takes place and the liquid amalgam constitutes solution of those salts in mercury. Vanstone (Jour. Chem. Soc., 1914, *105*, 2617) and Maey (Zeit. Phy. Chem., 1899, *29*, 119) have shown that the specific volume in amalgams does not suffer any profound change when combination takes place between the metal sodium and mercury.

It was, therefore, considered desirable to examine such other physical properties, as surface tension, viscosity, etc., of amalgams in order to see if evidence could be accumulated for the views put forward by George McP. Smith (*loc. cit.*). These properties have been shown by Padoa 'Atti. R. Accad. Lincei, 1914, (V), *23*, i, 88—94], Beck (Zeit. Phys. Chem., 1904, *48*, 670) and others to undergo marked deviation from the mixture law when compound formation takes place and can be used with advantage to bring to light the behaviour of the mixtures at various concentrations.

The present investigation deals with the determination of the surface tension of sodium and potassium amalgams at the amalgam-benzene interface. To observe the various stages that amalgams undergo on change of concentration, the composition of amalgams has been varied by very small amounts of sodium and potassium.

EXPERIMENTAL.

Preparation of the Amalgam.

The amalgams were prepared by the electrolytic method of T. W. Richards (J. Amer. Chem. Soc., 1922, *44*, 601). An electric current of about 4½ amperes was passed through a saturated solution of Merck's pure sodium or potassium carbonate contained in a cell consisting of mercury cathode and an anode of platinum foil for a known interval of time. After passing the current for the required time, the electrodes were removed and the supernatant liquid was quickly poured out. The amalgam was then taken out in a beaker and was thoroughly washed 4 or 5 times with distilled water. Subsequently it was taken in a separating funnel and after smart agitations, it was transferred to a vessel containing alcohol. The amalgam, after being washed over twice with alcohol to remove traces of water, was transferred to a flask which was evacuated and was heated for some minutes. Having thus dried the amalgam, it was well shaken in the flask and allowed to cool. When cooled, it was transferred to the storing vessel where it was kept out of contact with air. The amalgams of various concentrations were prepared by passing the same current under the same circumstances for varying intervals of time. In this way the sodium amalgams containing 0·033 % to 0·312 % of sodium and potassium amalgams containing 0·056 % to 0·182 % of potassium were prepared.

Storing of the Amalgam.

The amalgam was stored in a vessel A by an arrangement shown in figure 1. The vessel is set in connection with a large reservoir B of nitrogen through a U-tube C containing calcium chloride and a bottle D containing strong sulphuric acid. The amalgam was quickly poured out of the evacuated flask into the vessel A which was soon after fitted with an air-tight rubber stopper. The taps, 1, 2, 3 and 4 were opened and current of dry nitrogen was passed until the whole system was filled with it (nitrogen). As will be shown later, the amalgams, when kept as above, maintained their composition as such for a period of more than a fortnight.

Analysis of the Amalgams.

After rejecting 8 or 10 drops from the storage vessel, about 10 grams of the amalgam were taken in previously weighed weighing-bottles which were reweighed. The amalgam from the weighing-bottles was transferred to flasks to which a small quantity of water was added and which were kept unexposed to air. The action of water on amalgam appeared to be very vigorous at first but slowed down after a short time. The reaction was allowed to proceed until no evolution of the gas could be noticed even on brisk shaking. The alkali (sodium or potassium hydroxide) formed in the reaction was titrated with standard hydrochloric acid which was prepared nearly of the same strength as the alkali solution.

At first some experiments were performed to see whether the composition of the amalgam remained the same on keeping it for some time in the storing vessel. The results of the above investigation are shown in the following table :—

TABLE I.

Time of standing of the amalgam.	Amount of Na in 100 grams of the amalgam.	No. of estimations.
Immediately after storing ...	0·553 grams.	2
1 day ...	0·554 „	2
2 days ...	0·554 „	4
14 days ...	0·553 „	2
16 days ...	0·553 „	2

It will be seen from the above table that the strength of the amalgam remains constant for all intents and purposes.

By taking fractions of the amalgam from the various parts of the storing vessel, it was also observed that the composition was the same throughout. The above results indicate that the amalgam prepared as above is uniform in composition and does not change by keeping in an atmosphere of an inactive gas like nitrogen.

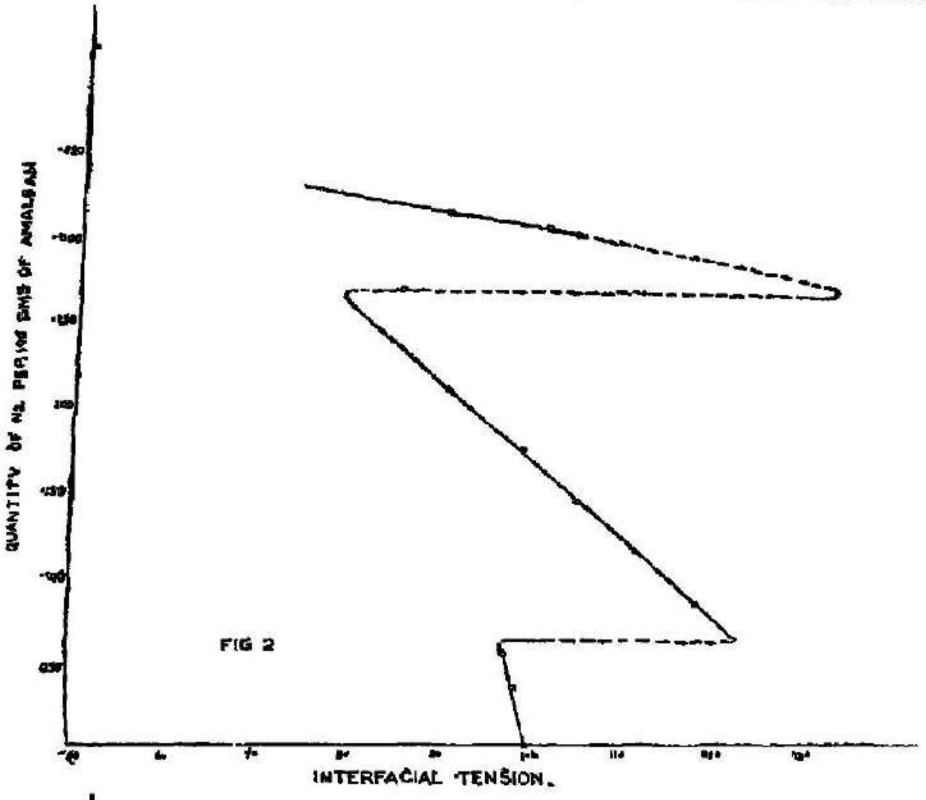

QUANTITY OF NH₄ PER 100 GMS OF AMALGAM
INTERFACIAL TENSION.

FIG 2

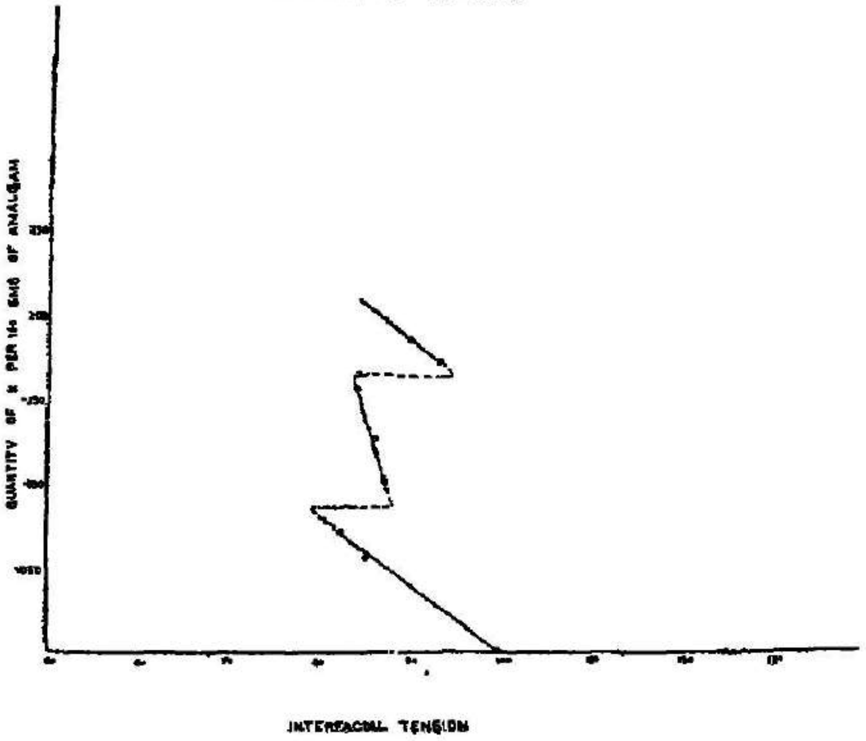

QUANTITY OF K PER 100 GMS OF AMALGAM
INTERFACIAL TENSION

FIG 3

Measurement of the Interfacial Tension.

The interfacial tension between the liquid amalgam and pure benzene was measured by means of a modified form of Donnan's drop-pipette (Zeit Phys. Chem., 1899, *31*, 42) used by Bhatnagar and Garner (Journ. Soc. Chem. Ind., 1920, *39*, No. 13, 185T). The drop-pipette was kept at a constant temperature of 30° C by enclosing the whole apparatus in an incubator. The dropping-tube was so constricted nearly in the middle that a drop of the liquid amalgam took about 15 seconds to fall. The tip of the dropping-tube was made smooth by grinding it very carefully over a razor-hone and was always kept protected from foreign matter. The amalgam was filled in the bulb by means of capillary filters through the side tube up to a definite mark and was kept protected from air exposure by a small quantity of benzene just sufficient to cover the surface. It was found that benzene does not react appreciably with the amalgam. All necessary precautions were taken to prevent the entrance of dust in the apparatus.

It was shown by Lord Rayleigh [Phil. Mag., 1899, (5), *48*, 321] that the surface tension of a liquid can be determined by noting the weight of a drop falling from an orifice of a known diameter. Since then the method has been extended to the measurement of the surface tensions between liquid-liquid surface and liquid-gas surface.

This method has also been extended to the measurement of relative tensions of solutions of different concentrations. By counting the number of drops in a given volume of a liquid A, whose surface tension is required and a liquid B which is being used for comparison, the relative surface tension of A to B can be calculated from the following relation :—

$$\frac{T_1}{T_2} = \frac{n_2 d_1}{n_1 d_2} \qquad \ldots \quad (1)$$

where T_1, d_1 and n_1 are respectively the surface tension, the density and the number of drops of the liquid A in a volume V, and T_2, d_2 and n_2 are the corresponding quantities for the comparing liquid B.

The tip of the dropping-tube was dipped in benzene contained in a small beaker and the number of drops of the amalgam, n_1, and the mercury, n_2, in a given volume were counted. For the sake of greater accuracy, the initial and final coincidence of the level of the liquids in the drop-pipette with the marks were observed through a high-power microscope.

Density of the Amalgam.

The density of the amalgam was measured in benzene by means of a specific gravity bottle. The densities of the amalgams with respect to water were calculated from the density of the benzene which was determined before hand. The values of densities thus obtained are in fair agreement with the values calculated from the specific volume and weights of Maey and Vanstone. The slight deviations which are observable are certainly due to the antiquated and unsatisfactory method used by Maey and Vanstone in preparing these amalgams.

Thus knowing the densities the relative interfacial tensions were calculated from the formula 1.

In the present investigation mercury has been used as a comparing liquid. The values for the interfacial tension of the liquid amalgams have been calculated from the above relative values by assuming the interfacial tension of mercury-benzene to be 100 dynes per cm.

The effect of the increasing quantity of sodium and potassium on the interfacial tension has been brought out in the following tables :—

TABLE II.

Interfacial Tension of Sodium Amalgam at 30°C.

Quantity of Na in 100 gms. of Amalgam.	Drop No.	Density.	$\frac{T_1}{T_2}$	I. T. in dynes per cm.
0·000 gms.	359	13·52	1·00	100
0·033 ,,	361	13·49	0·99	99
0·053 ,,	366	13·47	0·98	98
0·072 ,,	287	13·46	1·24	124
0·084 ,,	299	13·45	1·19	119
0·143 ,,	334	13·40	1·06	106
0·172 ,,	356	13·38	1·00	100
0·207 ,,	384	13·35	0·92	92
0·238 ,,	400	13·31	0·88	88
0·266 ,,	403	13·29	0·87	87
0·299 ,,	332	13·27	1·06	106
0·302 ,,	342	13·26	1·03	103
0·312 ,,	384	13·25	0·92	92

TABLE III.

Interfacial Tension of Potassium Amalgam at 30°C.

Quantity of K in 100 gms. of Amalgam.	Drop No.	Density.	$\frac{T_1}{T_2}$	I. T. in dynes per cm.
0·000 gms.	369	13·52	1·00	100
0·056 ,,	428	13·47	0·86	86
0·068 ,,	442	13·46	0·83	83
0·101 ,,	416	13·43	0·88	88
0·126 ,,	422	13·41	0·87	87
0·156 ,,	432	13·39	0·85	85
0·171 ,,	390	13·37	0·94	94
0·182 ,,	400	13·36	0·91	91

Discussion of Results.

The results of the above investigation are shown in Tables II and III. The interfacial tension of eleven different sodium amalgams containing from 0·033 to

0·312 gms. per cent. of sodium, and of seven different potassium amalgams, containing from 0·056 to 0·182 gms. per cent. of potassium, has been measured. By plotting the interfacial tensions as abscissa against the concentrations of the alkali metals as ordinates, curves as shown in figures 2 and 3, are obtained.

It will be seen from the curves that the interfacial tension decreases as the concentration is increased from pure mercury to amalgams containing 0·06% of sodium and 0·08% of potassium. A discontinuity occurs at these concentrations which probably corresponds to the formation of compounds of sodium and potassium with mercury.

Again from C to D the interfacial tension decreases on further increasing the quantity of sodium or potassium until a second discontinuity is observed at D. This corresponds to the formation of another compound of sodium and potassium with mercury. The remaining portion of the curves also shows a similar behaviour from E to F.

Hine (J. Amer. Chem. Soc., 1917, 39, 882), while determining the electrical conductivities of sodium, potassium and lithium amalgams, also observed similar discontinuities in the case of sodium. The concentration of sodium in the amalgam at which the resistance begins to decrease almost corresponds to the point D on the curve (figure 2).

It will also be observed from the curves that the relation between the interfacial tension and concentration is linear at all concentrations excepting at points where discontinuity occurs. This is similar to the observations of Dorsey (Phil. Mag., 1897), Srebnitsky (J. Russ. Phys. Chem. Soc., 1912, *44*, 145) and of others, namely, that the relation between the surface tension and concentration of solutions is a straight line.

The relation between the interfacial tension and concentration in this case can be expressed by

$$\sigma_A = \sigma(1 - kc)$$

where σ_A is the interfacial tension of the amalgam at the concenration C, σ has the value obtained by producing the curves to the abscissa and K is a constant, which is different for different parts of the curve.

This suggests that compounds of sodium and potassium with mercury are formed in the liquid state even at very low concentration of the alkali metal. At all other concentrations, the amalgam is probably a solution of the compounds and the metal in mercury.

To obtain further evidence of the conclusions already arrived at experiments for the determination of viscosity and other physical properties such as boiling point, etc, of these amalgams are in progress.

The author takes this opportunity of thanking Mr. D. N. Banerji, M.Sc., for the valuable help that he has given in the construction of the apparatus for this investigation.

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Electro-osmotic Experiments on Intensity of Adsorption of a Constituent Ion by an Insoluble Salt.

Part I.

BY

JNANENDRA NATH MUKHERJEE

AND

HIRA LAL RAY.

A heteropolar precipitate like that of an insoluble salt has a tendency to adsorb its constituent ions from aqueous solutions. It seems that this type of adsorption is responsible for several phenomena which do not at first sight appear to be correlated. Lottermoser observed that precipitated silver salts pass into the colloidal state when the solution contains one of the common ions in excess. The charge of the colloid is of the same sign as that of the constituent ion which is present in excess in the solution. Marc from his experiments on the adsorption by crystalline surfaces [Z. phys. Chem., *75*, 710 (1911); *81*, 641 (1913)] concluded that a crystalline substance adsorbs only those dissolved substances which can form isomorphous compounds with the crystal or compounds which have similar crystalline forms. Fajans and Beer [Ber., *46*, 3486 (1913); also *48*, 700 (1915)] pointed out that the separation of a radio-element from its solution by an insoluble salt takes place only when the radio-element itself can form an insoluble precipitate. Paneth and Horowitz [(Z. Phys. Chem. *89*, 513, (1915); also

Phys. Z. *15*, 924 (1914)] recognised in view of Marc's work that the separation of radio-elements, by precipitates is due to the adsorption of the radio-element, and that a radio-element will be adsorbed by an insoluble heteropolar adsorbent only when it can form an insoluble salt. Paneth however, considers that the adsorption of the radio-element consists in an actual exchange of places between ions in the crystal lattice and the radio-elements in solution. Thus barium ions in barium sulphate are replaced by radium ions from solution and the barium ions pass into solution.

It has been pointed out by the writer that in the case of a large number of colloidal suspensoids, the stabilising electrolyte has an ion in common with the colloid, and that the adsorption of a common ion by a precipitate is a simple consequence of the modern view of the structure of crystals of salts. (Far. Soc. Disc. October, 1920; published October, 1921.) The adsorption of an ion imparts a charge to the surface and thus tends to peptise the precipitate. It has been further pointed out (Mukherjee, *loc. cit.*; Phil. Mag., 1922, VI, 44, p. 327) that there is an essential difference in the manner of adsorption as pictured by Paneth and that which must be assumed to account for the stability of colloids. The type of adsorption suggested by Paneth will not impart a charge to the surface and hence cannot account either for the observations on the charge of colloids in the presence of peptising electrolytes or for their stability. The exchange of ions between the crystal lattice and the solution must be a slow process, when the salt is only sparingly soluble, whereas the adsorption of ions by the surface will be much quicker. Both types of adsorption have probably to be taken into account, but it appears from the literature on colloids that the adsorption of ions as such by the surface is more frequent than an actual interchange of ions as conceived by Paneth. Experimental evidence will be adduced in the sequel in support of this view.

Another class of phenomena is also probably closely connected with the adsorption of constituent ions by a precipitate. Bradford [(Biochem. J.; *10*, p. 169 (1916), *11*, p. 14 (1917)] has suggested that the adsorption of the precipitating ions is at least partly responsible for the formation of Liesegang rings. The adsorption of constituent ions may also affect the permeability of the precipitate to the diffusing ions—a factor which also probably plays an important role in the formation of Liesegang rings. (Fischer, Koll. Zeit. *30*. 1920, p. 13.)

The experiments of Debye and Scherrer have shown that colloidal particles have the same crystalline structure as they have in large masses or well-developed crystals. One has, of course, to remember that the surface forces acting on constituent ions existing in the solution are not exactly similar to those acting on the ion in the interior of the lattice. (Madelung, Phys. Z. *20*, 494, 1919). But such considerations do not materially affect the validity of our point of view.

Fajans and Beckerath (Z. Phys. Chem. *97*, 1921, 478) have suggested an explanation similar to ours regarding the adsorption of a constituent ion by a crystal lattice. They have further attempted to consider the energy required to separate an adsorbed ion from the surface in the light of the work necessary to separate the constituent ions from the crystal lattice and the energy change due to hydration. These authors consider that there is a close relationship between the intensity of adsorption of the ions by the surface and the solubility of the corresponding salt (*loc. cit.*, p. 500). Langmuir (J. Amer. Chem. Soc. *38* (1916) 2221; *39*, 1917, 1848), considers the intensity of adsorption to be determined by the energy changes associated with the process. So far no very definite result has been obtained from this treatment as the energy changes associated with the process of adsorption do not admit of easy theoretical calculation and the estimates of the energy change are based on more or less arbitrary assumptions. It would appear from the sequel that Fajans's method of treatment is too simple to account for the intensity of adsorption of ions.

The present investigation deals with the adsorption of ions by precipitated and carefully washed lead chromate. This substance was selected because it has been used in many cases for the investigation of Liesegang rings. Moreover there is a large number of insoluble lead salts and it is of interest to compare the relative intensity of adsorption of different anions by a surface of lead chromate with the solubility products of the corresponding salt.

The amounts of ions adsorbed has been mostly measured from chemical analysis, or from measurements of activity where the sensitive radio-active methods can be used. These methods do not give any indication as to whether the adsorbed ions replace those of the same sign in the crystal lattice thus leaving the crystal and its surface electrically neutral or are adsorbed on the surface with or without exchange of ions and the surface becomes electrically charged, through an excess in the adsorption of ions of one sign. Electro-osmotic measurements can decide between these two possibilities. Moreover, it is more convenient and accurate than analytical methods. It may be noted here that recently several investigators have emphasised the necessity of considering simultaneous adsorption of the solvent and of the solute. The analytical result represents the net effect. One cannot therefore simply say that so much of the solute has been adsorbed. In fact some assumptions about the relative adsorptions of the solute and the solvent have to be made in order that an actual idea of the adsorption of the solute can be made (*cf.* Wo. Ostwald and Izagguire, Koll. Z. *30*, 1919, 279, also previous literature). Of course it is possible that for the dilute solutions with which we are dealing, the adsorption of the solvent can be assumed to be more or less constant. But if there be alterations in hydration, on the adsorption of ions consequent on the variation in the electric charge, then we have a fresh source of disturbance and analytical data do not give a clear idea of the adsorption.

EXPERIMENTAL.

The arrangement used for the electro-osmotic measurements is a modified form of that used by Briggs the straight tube being replaced by a U-tube which does away with the use of porous plugs or glasswool (*cf.* Mukherjee, Nature, Dec. 2, 1922). The method gives results accurate within ±7%. The position of the electrodes in the U-tube did not vary during these experiments. The same U-tube and the glass tube connections were used throughout these experiments. The U-tube was always filled with the precipitated lead chromate between two marks symmetrically placed one on each limb of the U-tube. The precipitate was stirred with water or electrolyte and then poured in the U-tube and allowed to settle for 24 hours. The excess of lead chromate was drawn off with a pipette. The thickness of the layer of the precipitate was 12·8 cm. The preparation and purification of the precipitate requires great care. Chemically pure lead nitrate was further purified by recrystallisations. The crystals were powdered and dried at 102°. Chemically pure potassium chromate was carefully washed in a Buchner funnel. Two solutions of lead nitrate and potassium chromate of equal strength were prepared and lead-chromate was precipitated by addition of equivalent amounts of the two solutions from a burette into a beaker with silver nitrate as outside indicator.

The supernatant liquid was poured out and the precipitate was digested in pure boiling water for half an hour and the supernatant liquid was again poured out. The finer particles were removed along with the supernatant liquid. The process was repeated 10-12 times. It appears that potassium chromate was adsorbed in perceptible quantities during the precipitation, though the supernatant liquid after precipitation showed no trace of chromate with silver nitrate. During the first two digestions, the supernatant liquid assumed a yellow colour after some time, but in subsequent washings remained quite colourless. The substance becomes more free from adsorbed chemicals with repeated digestions. The digested and wet lead chromate was kept in stoppered resistance glass bottles in a place free from fumes.

Differences in the size of the air bubble within fair limits do not influence its velocity for the same experimental arrangement.

Every experiment was carried out under exactly similar conditions. The electric current is switched on for five minutes and the tube is then allowed to rest till the air-bubble becomes stationary, and the distance the bubble has moved is noted. The direction of the current is then reversed, and the mean of the two readings is taken. This was repeated at least five times in each case and their mean was taken. The different readings do not differ by more than ± 5%.

When electrolytes were used, the same amount of the precipitate was washed with the electrolyte solution several times to ensure that the concentration of electrolyte taken remains unchanged after removal of the water and after adsorption. The results are given below. The method is not free from certain sources of error and it is intended to investigate them with a view to modify the experimental arrangements. It may be added that the usual method is sufficiently accurate for our present purpose.

At high electrolyte concentrations the acids set free on electrolysis of the salt solution convert the chromate into dichromate with the consequent change in colour.

The velocity of the bubble is proportional to the density of the electrical charge on the surface. Since

$$v^{*}=\frac{e\cdot H\cdot q\cdot \delta}{\eta}$$

where v=velocity in cms/sec (of the bubble).

H=pot. gradient.

q=sectional area.

e=density of electrical charge; δ=the thickness of the double layer and η= co-efficient of viscosity.

H and q are constant under the conditions of the experiment. η may be taken to be constant for these dilute salt solutions, and δ is assumed to be constant.

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* We have taken the usual form of the equation *cf.* (Freundlich, Kapillarchemie, 1922, p. 328).

TABLE I.

Lead Chromate.

Velocity in cm. per sec. × 300.

Electrolytic conc	Water	KCl	K_2CrO_4	$Pb(NO_3)_2$	KNO_3	K_2SO_4	$BaCl_2$	KI	KIO_3	$CaCl_2$
O	18 2									
N/15000		22 0								
N/5000		23 0	25 1	7 1	20 2	22 6	20 2	22 7	26 6	21 4
N/4000		26 6								
N/2500		28 1								
N/2000		29 8	35 3	−3	31 8	32	20 7	30 5	32 5	25 5
N/1000		32 4	44 9	−7 9	32 8	38 5	17 5	Decomposition sets in	36 8	25 5
N/500		36 8					14 3			
N/250		Decomposition sets in								

DISCUSSION

The readings with water alone show that the substance is negatively charged in contact with water. We are not sure whether the negative charge owes its origin to the adsorption of chromate ions which probably could not be removed even after 13 digestions with pure boiling water, or to the adsorption of hydroxyl ions from water.* It will be seen from the above that of the four cations, K, Ba, Pb and Ca, only $Pb^{\cdot\cdot}$ ions materially affect the velocity of the bubble, diminishing it markedly at as low a concentration as n/5000 and at a higher concentration n/1000, the bubble moves in the opposite direction.

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* The question will be dealt with in a second communication.

These experiments bring out undoubtedly that the adsorption of the positively charged lead ion at first decreases the density of the negative charge on the surface till at a higher concentration, the surface positively becomes charged being covered with an excess of lead ions. It would have been of great interest to follow the the increase in charges still further with increasing concentration, but the transformation of chromate unfortunately prevents further observation.

The marked adsorption of the lead ions in contrast to that of the other cations can be readily understood if we remember that it is a constituent ion of the precipitate (*cf.* Mukherjee, Far. Soc. Disc. Oct. 1922; Phil. Mag., *loc. cit.*).

A comparison of the effects of K, Ba or Ca will show that for the same anion, $Ba^{\cdot\cdot}$ ions are more adsorbed than $Ca^{\cdot\cdot}$ ions and that $K^{\cdot}$ ions are least adsorbed.

On the other hand, of the anions the chromate which is the other constituent ion has a great effect on the charge. In general, on the addition of an electrolyte other than the lead salt, there is an increase in the negative charge to begin with. In the case of $BaCl_2$ the charge at first remains constant up to a concentration of N/2000 and then begins to decrease. This is a very common feature of the curves between the charge and the concentration of the electrolyte, when the oppositely charged ion is weakly adsorbed (*cf.* Mukherjee, Phil. Mag. VI, *44*, 1922, pp. 328 *et. seq.*). In the case of $CaCl_2$ the anion effect predominates within the limits of concentration studied, the density of the charge being always greater than that with pure water. The cation effect is however apparent if we compare the relative effects of calcium chloride, potassium nitrate and potassium chloride.

A quantitative comparison of the relative intensities of adsorption of individual ions is not easy. The observations show that adsorption of both ions at these low concentrations has to be considered. For the different potassium salts it is permissible to compare the relative anion effects, as the cation is the same in each case. In comparing the intensities of the adsorption of the anions, the valency of the anion has to be taken into account. For the same increase in the density of the negative charge, the *amount* of an anion adsorbed is inversely proportional to its valency. Since we know the valency and the increase in the densities of the charge compared to that for pure water, we can compare the relative amounts of the different anions adsorbed. Such a comparison is however not free from objections. First of all, the assumption (*loc. cit.*) of a constant thickness of the double layer is not certainly self-evident. Secondly, we do not know exactly the source of the charge of the surface in contact with water and a replacement of the ions already existing on the surface by the ions of the same charge present in the solution, will not alter the charge and will escape detection. Consequently, even if adsorption takes place there may be no alteration in the charge. The error due to this cause will however be smaller, when the change in charge is great. For this reason, we have taken the values at ·0005N for comparison. Probably the initial charge is due to the adsorption of chromate ions as it is almost impossible to remove the last traces of adsorbed electrolytes by washing or by digestion with boiling water in many cases. The only other source may be the adsorption of hydroxyl ions from water. Lastly the variation in the charge is due to the adsorption of two ions of opposite sign and it is evidently erroneous to refer all of the observed difference to the adsorption of one ion only. These objections are not likely to influence the general nature of the conclusions we have drawn from the comparison outlined above. Since we have at present no idea as to what determines the thickness of the double layer, we might leave it out of account, though it is probable that the thickness of the double layer depends on the density of the electrical charge. This is justifiable to some extent on the ground, that so far conclusions drawn from the assumption, that the velocity of electro-osmosis, or cataphoresis is proportional to the density of the electrical charge on the surface, have helped us consistently to explain colloidal phenomena associated with electrical charge of particles. Regarding the last objection we might neglect the adsorption of the weakly adsorbed ion, in comparison to that of the other as a first approximation, as the great change in the charge shows the preponderating effect of the one over that of the other. In order to form an idea of the relative intensity of adsorption, we must compare the amounts of the anions adsorbed at the same gm. anion concentration. The difference in the velocity is proportional to the net amount of positive or negative charge adsorbed in the form of ions (of both sign) per unit surface. If we compare the potassium salts, we may assume the adsorption of the cation to be constant and the increase in the velocity (*i. e.* of the negative charge) is then proportional to the number of ions adsorbed, multiplied by its valency. The amount of the different anions adsorbed is then given by the increase in velocity (referred to the value for water) divided by the valency of the anion. The following table shows the values for a concentration of ·0005 gm. anion per litre.

Table II.

Potassium Salts.

Anions.	Conc. in gm. ions per litre.	Difference in velocity	Valency	Amount adsorbed
Cl'	·0005	29·8-18·2	1	11·6
NO_3'	·0005	31·3-18·2	1	13·1
SO_4''	·0005	38·5-18·2	2	$\frac{20\cdot3}{2}=10\cdot15$
CrO_4''	·0005	44·9-18·2	2	$\frac{26\cdot7}{2}=13\cdot35$
I'	·0005	30·5-18·2	1	12·3
IO_3'	·0005	32·5-18·2	1	14·3

The anions arrange themselves in the following order:—

$$IO_3' > CrO_4'' > NO_3' > I' > Cl' > SO_4''$$

The order given above does not exactly represent the *relative* intensities of adsorption for anions of different valency. The adsorption of chromate and sulphate ions must be greater than that indicated above for two reasons.

(1) Now the velocity of osmosis indicates the net negative charge being the actual charge due to the adsorbed anions less the charge due to the fixed layer of cations. Since we are comparing equal gram-anion concentrations, the concentration of cation will be double for the divalent anions of what it is for univalent anions. The adsorption of the cations is not negligible and the amount of cation adsorbed at the higher concentration will be greater. So that the same velocity

of movement of the bubble at equal gram-anion concentration would indicate a higher adsorption of divalent anions than of univalent anions, or in other words more chromate and sulphate ions are actually adsorbed than are represented by the figures 13·35 and 10·15.

(2) Secondly the density of the negative charge (44·9) for chromate ion is much greater than that in the case of iodate ions (32·5) and the greater negative charge diminishes to a greater extent the number of collision of the anions on the charge. The adsorption of an ion depends on the intensity of adsorption, *i.e.*, on the energy change associated with the process of adsorption by a neutral surface and on the number of collisions on the surface. In the case where we are dealing with the adsorption of ions, carrying an electrical charge of the same sign as that of the adsorbing surface, the number of collisions evidently do not depend on the concentration of the anion. Only those ions can strike on the surface which have sufficient kinetic energy to overcome the electrical repulsion when it approaches the surface. The greater, the negative charge of the surface, the fewer the collisions of the anion on the surface as compared to the probable number of collisions if the surface were neutral. The greater negative charge of the solid in contact with potassium chromate makes the further adsorption of chromate ions more difficult than in the case of the iodate ions of the same gram-anion concentration. If the electrical conditions were identical, the adsorption of the chromate ions would have been greater than that indicated above. We may therefore take the order to be

$$CrO''_4 > IO'_3 > NO'_3 > I' > SO''_4 > Cl'$$

which is also the order of the increasing solubilities of the lead salts expressed in terms of gr. atomic concentration of lead,

$$CrO_4'' < IO_3' < I' SO_4'' < Cl' < NO_3'$$

with the exception of the nitrate.

A strict comparison between the order of adsorbability and of solubility is therefore not possible. Further solubility of the corresponding salt is not a measure of the change in energy when an ion passes from the adsorbed layer in the surface to the solution. For the same reason, a comparison of the lattice energy and of the intensity of adsorption is also not possible without further assumptions regarding the energy of hydration and regarding the effect of adsorption on the hydration of the ion and on the hydration of the surface (Fajans, *loc. cit.*). We, therefore think that Fajans's conclusions as to the relationship between solubility and intensity of adsorption are untenable. It is however remarkable that the order for the other anions is practically the same as that suggested by Fajans.

SUMMARY AND CONCLUSIONS.

It is possible to draw certain definite conclusions from the experiments recorded here.

(1) A well-digested precipitate of lead chromate is not electrically neutral against water. The negative charge is probably due to the adsorption of chromate ions or in the alternative hydroxyl ions from water or of both. If the latter view were true, we may observe "hydrolytic adsorption" if the hydrogen ions in the second layer can be replaced by a cation from a neutral solution of a salt *e.g.*, sodium chloride we will have an acid extract.

(2) The order of. adsorbability of the cations is

$$\text{Pb}^{\cdot} > \text{Ba}^{\cdot} > \text{Ca}^{\cdot\cdot} > \text{K}.$$

The adsorbability of lead ions is the strongest amongst the cations. It is also very probable that besides the lattice energy of the ions, there are other factors such as the energy of hydration of the surface or of the ion which determine the intensity of adsorption, *i.e.*, the work necessary to separate an ion from the surface to the interior of the solution.

(3) The order of adsorption of anions is probably

$$\text{CrO}''_4 > \text{IO}'_3 > \text{NO}'_3 > \text{I}' > \text{SO}''_4 > \text{Cl}'.$$

The adsorption of chromate is probably the strongest.

(4) The constituent ions of a precipitate are very strongly adsorbed by it. Lead ions being so largely adsorbed as to reverse the charge. This observation suggests the possibility of preparing electrically neutral precipitates. As pointed out above, experiments with electrically neutral lead chromate will enable us to have a better idea of the intensity of adsorption of the different ions. The great intensity of adsorption of the constituent ions is in agreement with the views set forth in a previous paper.

(5) It is of great interest to note that the adsorption of the constituent ions does not consist simply in the exchange of an ion in the crystal lattice with an ion in the solution, as assumed by Paneth. Ions are actually fixed on the surface imparting a charge to it and the type of adsorption considered by Paneth cannot explain the observations recorded here.

(6) Fajans's suggestion that there is a parallelism between the intensity of adsorption of an ion and the solubility of the salt of the adsorbed ion and the ion

with opposite sign in the precipitate is not tenable as the nitrate ion is adsorbed more strongly than the iodide or sulphate.

The method of treatment developed here is capable of other interesting applications.

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(*Recd. Aug.* 2, *1924*)

The Electrode Potential of Mercury against its Ions in Aqueous (1) Methyl Alcohol, (2) Acetone and (3) Pyridine.

BY

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AND

ASHUTCSH SEN.

Numerous investigations have been carried out in aqueous solutions on electrocapillary phenomena since the Lippmann Helmholtz theory was developed; but they are rare in mixed solvents and excepting the researches of Krummreich (Z. F. Electrochem. *19*, 622, 1913) on aqueous ethyl alcohol, not very carefully done either. The importance of finding out how the absolute potential of metals against their ions changes with the nature of the solvent is obvious. The method which gives the most satisfactory results in this field, is the determination of the maximum position of the electrocapillary curve, and in order that the data obtained may be reliable, the conditions postulated in the Lippmann Helmholtz original equations must be fulfilled

$$dU = Edq + \gamma dS \qquad \ldots \quad (1)$$

$$dq = XdS + S\frac{\partial X}{\partial E}\,dE \qquad \ldots \quad (2)$$

$$X = CE$$

Where U=change in internal energy; γ = surface tension, X=density of electrification, S=area of capillary surface, E=potential difference at the boundary, dq=quantity of electricity and c=Capacity of Unit area of the double layer.

Then only a true parabola is obtained represented by the equation

$$\gamma = \gamma_{max} - \tfrac{1}{2}CE^2$$

the maximum of surface tension corresponding to zero value of electrode potential. The experimental conditions in this investigation, were always so determined by trial, that the curves approximated to an ideal parabola, indicating thereby, that the primary processes at the electrode surface contemplated by Lippmann and Helmholtz, have not been accompanied by uncertain disturbing factors.

EXPERIMENTAL PRECAUTIONS.

Clark (Trans. Roy. Soc. Canada, *14*, Ser. 3, Sect. 3, 73, 1921) maintains that the wet surface at the capillary is enormously greater than the cross-sectional area of the capillary due to the electrolyte creeping in between the glass walls of the capillary and the mercury column, and that the area of the wet surface never remains constant. Hence C′ the capacity of the double layer at the capillary surface does not remain constant in course of experiment, and a true parabolic curve is therefore out of the question.

In our experiments the capillary was made perfectly dry and clean, filled completely with mercury and then dipped into the electrolytic solutions. The glass wall beneath the capillary meniscus was therefore completely dry; the motion of the mercury column due to electric charge, and its re-adjustment to final level due to external pressure changes were too slow to leave behind a wet surface, enclosed between glass wall and mercury, which could be observed by the microscope. Only when the applied E. M. F. exceeded 1·6 volts, or the mercury column was, for some reason or other very sticky, a wet film between mercury and glass could be observed. For a capillary electrometer prepared with due precaution and used with care, it may be stated that the area of the capillary surface remains constant.

The nature of the electrocapillary curve depends a good deal on the ions, other than the mercurous ion, introduced into the solution, in order that the liquid may be sufficiently conducting. Thus Kruger and Krumreich (Z. F. Electro chem. *19*, 617, 1913) found that an ideal parabola is obtained very easily when an aqueous solution of normal potassium nitrate and O·IN $Hg_2(NO_3)_2$ was used. It is unfortunate that potassium nitrate is not soluble in non-aqueous solvents, and this important property of potassium nitrate could not be taken advantage of in these investigations. Lithium nitrate, which is soluble in the solvents used by us, did not give a parabolic curve even in pure water, though the maximum obtained was quite sharp. The same difficulty was found in the case of potassium nitrate solutions. An aqueous solution of nitric acid (·0035N) and mercurous nitrate (·002N) gave a fairly good parabolic curve with the maximum at 1·05 volt. The expectation that mixed solvents having similar concentrations of nitric acid and mercurous nitrate would give approximate parabolas has been realised. It appears that the absorption of ions by mercury surface has considerable influence on electrocapillary processes.

It takes a very long time for conditions of equilibrium to be established at the capillary junction in these mixed solvents. In aqueous solution of KNO_3 and $Hg_2(NO_3)_2$, it takes not more than 15 minutes for the mercury meniscus to become absolutely stationary ; but in these experiments, it was discovered, that for half an hour after starting the polarising current, the movement of the mercury meniscus was comparatively rapid, but after that interval there was an imperceptible change which continued for a very long time. The curves given below have been plotted, from readings taken after the polarising current has passed through the capillary electrometer for five to eight hours. An explanation of this long time necessary for the attainment of equilibrium can be attempted from the standpoint of "Reststrom Polarisation." The E. M. F. of a cell of the type—

$$Hg \left| \begin{array}{c} Hg_2(NO_3)_2 \\ KNO_3 \text{ or } HNO_3 \end{array} \right| Hg \text{ is Zero.}$$

If a very slight current is passed through the circuit mercury will dissolve at the anode as $Hg_2^{\cdot\cdot}$ ion and will be deposited at the cathode from the solution. For small values of applied voltage, the back E. M. F. of polarisation will be entirely due to changes in the concentration of the mercurous ion in the liquid layer immediately surrounding the electrodes. If however, the surface of the mercury anode is very large compared with that of the cathode, as in the capillary electrometer, we are justified, in considering that for small current, the anode film does not undergo any change in the concentration of the $Hg_2^{\cdot\cdot}$ ion. In fact, measurements of the anode potential of our capillary electrometers, showed that this was the case. Therefore, the back E. M. F. of polarisation

$$= RT \log \frac{C_a}{C_k}$$

where C_o is the concentration of $Hg_2^{\cdot\cdot}$ ion in the bulk of the solution which is the same as that of the anode, and C_x is the concentration of $Hg_2^{\cdot\cdot}$ ion at cathode film. Obviously when C_x becomes so small, that the osmotic pressure of $Hg_2^{\cdot\cdot}$ ion is equal to the electrolytic solution pressure of mercury, then we have an electrode at zero potential. In the stationary state, where to maintain a definite value of polarisation, a definite residual current is necessary, there must be coming as many $Hg_2^{\cdot\cdot}$ ion from the bulk of the solution into the cathode layer by diffusion, as are being discharged. This number in gram equivalent—

$$N = \frac{1}{86,400} \cdot \frac{D.O.}{a} \cdot \frac{C_o - C_x}{\delta}$$

(Nernst & Merriam Z F Phys. Chem. *53*, 235, 1905.)

D = Velocity of diffusion ; O = area of the cathode surface ; a = electro-chemical equivalent and δ the thickness of the diffusion layer. For the enormous polarisation that we are dealing with in the case of the capillary electrometer, C_x will be infinitely small, and—

$$\frac{i}{96,540} = N = \frac{D.O.}{a.86400} \cdot \frac{C_o}{\delta}$$

In an actual experiment with the capillary electrometer, the residual current was found to be $4 \cdot 2 \times 10^{-8}$ amperes, for an area of capillary surface $= \cdot 0025$. Taking $D = \cdot 0023 \times M$ (M = molecular conductivity of the $Hg_2^{\cdot\cdot}$ ion), δ comes out to be 10^{-3} cm. approximately.

This order of magnitude for δ is the same as that obtained by Nernst and Merriam and thus it is established beyond doubt that we are here dealing with the phenomena of Reststrom Polarisation.

A considerable time might elapse before the concentration gradient across the diffision layer $\frac{C_s - C_k}{\delta}$ attains equilibrium conditions and then again there exist the disturbing effects produced by the movement of the mercury meniscus in response to continuous charge in surface tension. This will specially be the case, when the mercury surface in the capillary, becomes negatively charged, for that condition will correspond to inconceivably low value of C_k.

It is satisfactory to note, that the electrocapillary curves obtained, when these precautions were taken, were approximate parabolas. See Figs. I and II.

EXPERIMENTAL PROCEDURE.

A Wolff Dial Potentiometer standardised by the Reichsantalt was connected to a 4-volt battery, and any required E. M. F. was applied through a galvanometer, the exact value of the E. M. F. being obtained by reference to a standard Weston element. The sensitiveness of the galvanometer in the circuit being known, the strength of the residual current corresponding to a definite polarising voltage can be ascertained. The capillary tube was cleaned before each experiment by washing with strong nitric acid and keeping under chromic acid overnight. It was washed finally with conductivity water, dried in a current of dust-free air, and filled with redistilled mercury. It was then immersed in the electrolytic solution. The U-tube capillary electrometer was found to have an advantage over the vertical tube ending in a capillary, in that, it was more stable. The position of the mercury meniscus was read off as usual with a reading microscope and the difference between the levels of the mercury column in the manometer and in the capillary was measured by means of a travelling microscope capable of reading height to $\frac{1}{1000}$ cm. For capillaries of large bore, an adjustable mercury reservoir was not necessary, the difference in the levels of the mercury columns in the instrument itself was measured directly, the variation in the diameter of the capillary tubing along its length being too small in this case, to be taken into account. A large number of capillary electrometers were prepared, and only those were selected, which gave easily an ideal curve with an aqueous KNO_3, $Hg_2(NO_3)_2$ solution.

The back E. M. F. of the polarised capillary surface is always less than the applied voltage by an amount equal to i × R where R is the resistance of the circuit and i the strength of the residual current. The resistance of the circuit is primarily due to the galvanometer and to the electrolytic solution in the capillary lying above the mercury meniscus. It is impossible to measure directly the magnitude of this resistance, but it is easily calculated from the following data: (1) galvanometer resistance, (2) bore of the capillary and length of the column of electrolyte, and (3) specific resistance of the solution. It was found that in no case, the correction in back E. M. F. due to this factor exceeded 1 millivolt.

Pyridine, acetone and methyl alcohol used in this investigation were obtained from Kahlbaum and distilled in the laboratory until constant boiling points were obtained.

EXPERIMENTAL RESULTS AND DISCUSSION.

The experimental results are given in Figs. I and II and in Tables 2, 3 and 4.

The electrocapillary curve for aqueous solution ought to have been almost identical with that obtained by Kruger and Krumreich (*loc. cit.*). They obtained a maximum at ·8 volt approximately while our experiments give a maximum at 1·005 volt. Ley and Heimbücker (Z. F. Electrochem. *10*, 301, 1904) found that the cell

$$\text{Hg}-\underset{\cdot 05}{\text{Hg}_2}(\text{NO}_3')_2\ \text{KNO}_3-\underset{\frac{N}{10}}{\text{KCl}}.\ \text{HgCl/Hg}$$

had an E. M. F. of ·391 volt. Decinormal calomel element has a value of ·612 volt as obtained from innumerable electrocapillary data. The maximum therefore should lie at (·612+·391) or 1·03 volt in agreement with our results. If Kruger and Krumreich's value were true, decinormal calomel element would have an electrode potential of ·412 volt, which is a move in the direction suggested by Billitzer's data, obtained from the observation of the movement of metal wires dipped in salt solution (Ann. der. Phys. *11*, 902, 1903). Unfortunately their results could not be confirmed.

Tables 2, 3 and 4 give the electromotive forces corresponding to maximum of surface tension in mixed solvents of water-methyl alcohol, water-acetone and water-pyridine, containing mercurous nitrate and nitric acid as electrolytes. The influence of the concentration of the $\ddot{\text{Hg}}_2$ ion on the magnitude of the electrode potential is comparatively small. For the same concentration of mercurous nitrate in the various solvents, it can be shown on the basis of Walden's empirical generalisation,—for the same value of $D\sqrt{v}$, the degree of dissociation is the same,—that the relative concentration of $\ddot{\text{Hg}}_2$ ion in these solvents does not vary beyond the ratio 2 : 1.

The above values may therefore be accepted as the electrode potential of mercury against $\frac{N}{100}$ mercurous ion in the respective solvents. Table 1 reproduces the date of Krumreich (*loc. cit.*) in aqueous ethyl alcohol solution of potassium nitrate and mercurous nitrate The results are, as has been noted before systematically about ·2 volts less than the generally accepted values.

TABLE 1.

Water-Ethyl Alcohol.

Electrode Potential	Composition by weight in per cent	Dielectric constant D	$\frac{E}{D}$
773	0%	81	95
628	10%	75	84
604	30%	60	1 0
479	50%	48 5	97
451	70%	38 1	1 12

TABLE 2.

Water-Methyl Alcohol.

	Composition by vol in per cent		
1 04 (Kruger's value 773)	0%	81	1 20 (95)
719	10%	77	93
611	20%	72	95
636	30%	68	92
581	40%	63 5	92
	50%	58 0	94

TABLE 3.

Water-acetone.

Electrode Potential.	Composition by vol. in per cent.	Dielectric constant	$\frac{E}{D}$
1·05	0%	81	1 2
906	10%	77	1 18
620	20%	72 5	[illegible]
855	30%	67 5	1 25
775	40%	62·0	1 25
751	50%	55·0	1·36
732	60%	48·0	1 51

TABLE 4.

Water-pyridine.

Electrode Potential.	Composition by vol in per cent.	Dielectric constant.	$\frac{E}{D}$
1·05	0%	81	1 25
·550	10%	74	75
·498	20%	68·3	·73
·450	0%	60	·75
·413	40%	53	·77
·363	50%	44	·90

The values of dielectric constants in Tables 1, 2, and 3 are calculated from data given in Landolt's Tabellen. The dielectric constants in aqueous pyridine given above are not very accurate and are taken from the work of Ghosh (J. C. S., *117*, 1390, 1920). The fourth columns in the tables give the ratio of the electrode potential as determined from the maximum of the capillary curve, to the dielectric constant of the solvents. It will be noticed that in aqueous ethyl alcohol solution the electrode potential of mercury is proportional to the dielectric constant of the solvent up to 50% of alcohol. Thereafter the ratio of $\frac{E}{D}$ increases.

In aqueous methyl alcohol, the same constancy in the value of $\frac{E}{D}$ is observed. This ratio varies about the mean value, ·93, and if we accept Kruger's data for pure water as solvent, $\frac{E}{D}$ for water also has approximately the same value, *viz.*, ·95.

In aqueous acetone, results obtained with 20% acetone are very peculiar in that abnormally low value of electrode potentials is obtained. With this exception, the ratio $\frac{E}{D}$ remains constant up to 40% acetone and thereafter increases as in the case of aqueous ethyl alcohol.

There is a very large drop in the value of the electrode potential as pyridine is added to water. Further addition of pyridine beyond 10% by volume, produces a slow gradual change in the value of electrode potential and we find that the ratio $\frac{E}{D}$ remains practically constant within the range 10-40% pyridine. Thereafter $\frac{E}{D}$ increases as in the case of the other mixed solvents.

The electromotive force at the boundary between a metal and its ions in solution is a measure of the free energy A of the process:

Metal atom $\rightleftarrows$ Metal ion in solution.

for $E \cdot \times F = A$.

On the reasonable assumption that the free energy of the atom of an element in the metallic state remains constant at constant temperature, this investigation points to the conclusion, that at 30°, *the free energy of mercurous ion in the above mixed solvents is within a certain range directly proportional to the dielectric constant of the solvent.*

DACCA UNIVERSITY,

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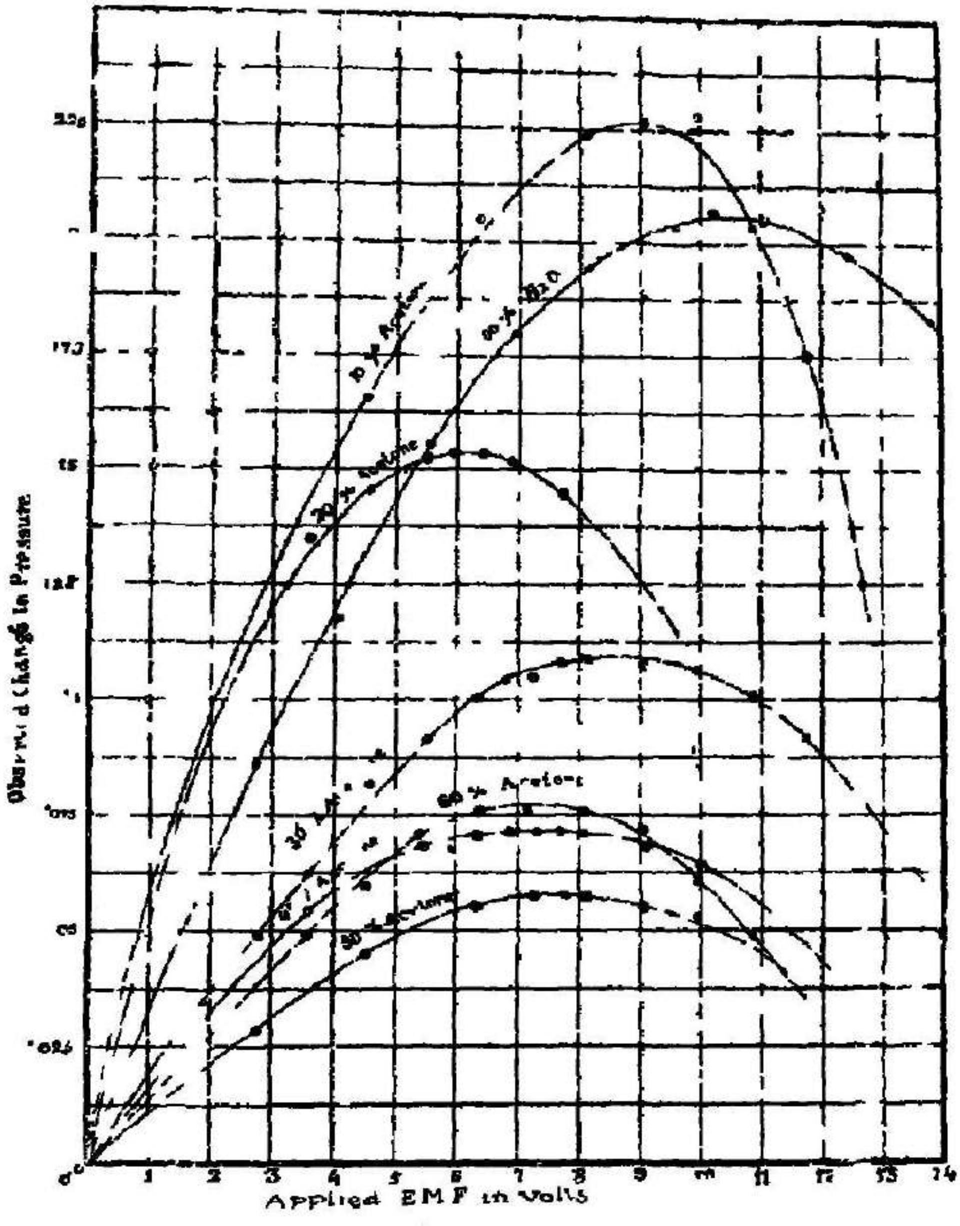

Observed Change in Pressure
·225
·2
·175
·15
·125
·1
·075
·05
·025
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Applied EMF in Volts
% Acetone
60% H₂O
% Acetone
60% Acetone
30% Acetone
30% Acetone

Fig. I.

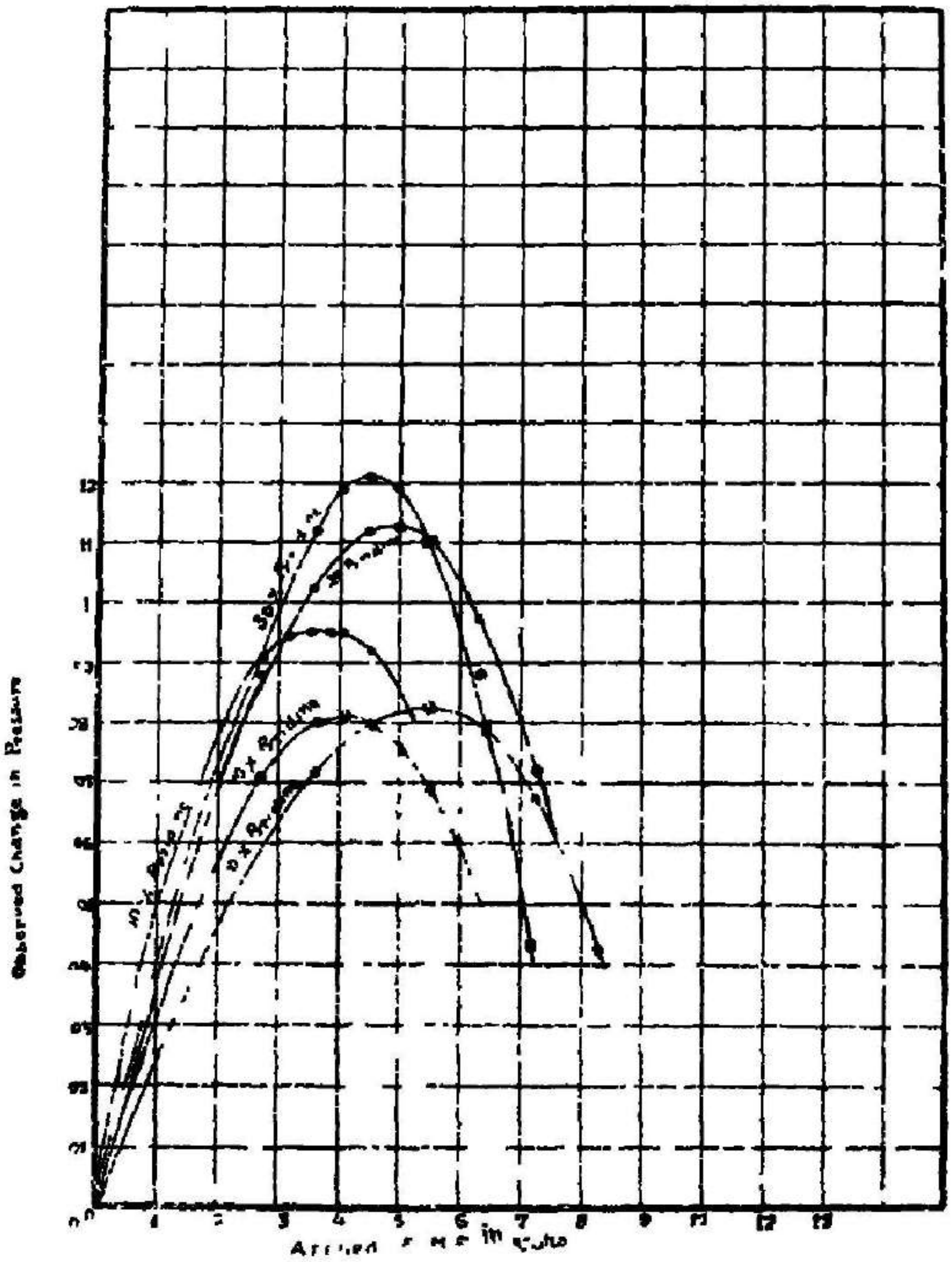

Observed Change in Pressure
12
11
1
0
1
2
3
4
5
6
7
8
9
12
13
Applied E.M.F. in volts

Fig. II.

The Oxidation of Triethylene Tetrasulphide by means of Potassium Permanganate.

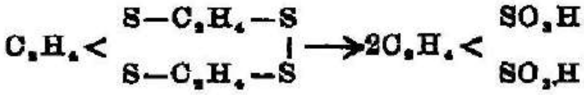
BY

SIR PRAFULLA CHANDRA RÂY.

Part I.

Oxidation with Alkaline Potassium Permanganate.

The oxidation of triethylene tetrasulphide with nitric acid has been shown to result in the break-up of the molecule with the formation of the corresponding disulphonic acid. Each of the sulphur atoms situated between a pair of carbon atoms is converted into a sulphone group while fission takes place between the two contiguous sulphur atoms with the formation of the sulphonic acid (J. C. S. Trans., 1923, *123*, 2176) It seemed desirable to study the action of a less drastic oxidising agent like potassium permanganate which might be expected to yield the corresponding tetrasulphone. This expectation has been realised as will be shown below under Part II. When, however, the tetrasulphide is treated with alkaline potassium permanganate, instead of a tetrasulphone being formed, it breaks up according to the following scheme :



$$C_2H_4<\begin{array}{l}S-C_2H_4-S\\ \qquad\qquad\quad|\\ S-C_2H_4-S\end{array}\longrightarrow 2C_2H_4<\begin{array}{l}SO_3H\\ SO_3H\end{array}$$

EXPERIMENTAL.

The tetrasulphide was suspended in water and treated with about 10 c. c. of a 3% solution of potassium permanganate and a little caustic potash solution. The addition of the permanganate was repeated till there was a distinct excess of it. The temperature was all along kept at about 30°. The reaction was completed by finally heating on the water-bath. The mixture was cooled and the precipitated manganese peroxide brought into solution by passing sulphur dioxide. The solution was concentrated and the potassium and manganese sulphates which crystallised out were filtered off. Alcohol was next added to the concentrated liquid and the precipitate rejected. The alcohol was driven off, the residue dissolved in water and treated with barium carbonate. The precipitate was filtered off and the solution on evaporation gave crystals of the barium salt of ethylene disulphonic acid. The salt was air-dried and was found to be semi-hydrated. (Found: Ba=40·97; S=20·75.* $C_2H_4S_2O_6Ba$, $\frac{1}{2}H_2O$ requires Ba=41·02; S=19·16 per cent.).

Part II.

Oxidation with acid Potassium Permanganate.

On oxidation of the triethylene tetrasulphide with potassium permanganate in dilute sulphuric acid solution, a very interesting result is obtained. The expected sulphone formed during the reaction combines with the manganous sulphate produced and a stable double compound of the formula $[(C_2H_4)_3S_4O_8]$, $MnSO_4$, $6H_2O$ is invariably obtained. It has been found to be very sparingly soluble in the cold but dissolves readily in boiling water from which it crystallises out in the pure state. By adding

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* The sulphonate was converted into sulphate by fusion with a mixture of KNO_3 and Na_2CO_3. The 'melt' was repeatedly evaporated with conc. HCl to convert the excess of the nitrate as far as possible into the chloride. When the solution is treated with $BaCl_2$ a portion of the unconverted nitrate is almost invariably carried down with the $BaSO_4$; hence the p. c. of sulphur generally comes out a little too high.

barium chloride to this boiling solution, the corresponding compound with barium sulphate is at once thrown down. By a similar treatment compounds with the sulphates of calcium and strontium as also of potassium and lead have been obtained. With silver nitrate a double compound of silver sulphate is formed. Corresponding double compounds with the sulphates of nickel, cobalt, and copper have also been obtained by the addition of the respective chlorides. Peculiar interest attachest o some of these compounds, notably the combination of the sulphone with barium sulphate, as on account of its extreme insolubility all attempts to combine it with other compounds have hitherto been unsuccessful. But by following this indirect method, however, an additive compound with barium sulphate has been obtained. The sodium compound could not be isolated in a pure condition by a method analogous to that for the preparation of the potassium compound, a special procedure was therefore adopted.

In all these compounds the proportion of the respective metallic sulphate to the sulphone holds simple integral relationship. In the case of the barium compound alone the components are in the simple ratio of 1 : 1 ; whereas they are in the ratio of 2 : 3 in the manganese, copper, cobalt and nickel compounds. The ratio is as 4 : 5 in the potassium, calcium, strontium, silver and lead double compounds. The sodium compound alone gives a ratio of 4 : 1 between sodium sulphate and the sulphone.

EXPERIMENTAL.

The Oxidation of Triethylene Tetrasulphide with Acid Potassium Permanganate.—The tetrasulphide was treated with a mixture of a concentrated solution of potassium permanganate and dilute sulphuric acid in small quantities at a time and heated on the water-bath. This process was continued till there remained a distinct excess of the permanganate. The oxidation was complete in the course of about 4 to 6 hours. The excess of permanganate was removed by passing a current of sulphur dioxide through the mixture. The solution became hot, leaving a residue of the unacted tetrasulphide, the latter was filtered off and the filtrate concentrated on the water-bath to nearly half its volume. On cooling, a colourless compound crystallised out. This was filtered, washed with cold water, and dried. (Found: Mn = 7·38; S=28·88. $1\frac{1}{2}[(C_2H_4)_3S_4O_8]$, $MnSO_4$, $6H_2O$ requires Mn=7·15; S=29·13 per cent.).

Calcium Compound.—The manganese compound was dissolved in boiling water and a concentrated solution of calcium chloride added to it. A white crystalline calcium compound was at once precipitated, which was filtered and dried. (Found: Ca=7·09; C=16·81. $1\frac{1}{4}[(C_2H_4)_3S_4O_8]$, $CaSO_4$ requires Ca = 7·13; C = 16·04 per cent.).

Strontium Compound.—This compound was prepared by a process similar to that used for the preparation of the calcium compound. (Found: Sr = 14·68; C = 14·66. $1\frac{1}{4}[(C_2H_4)_3\ S_4O_8]$, $SrSO_4$ requires Sr=14·38; C = 14·80 per cent.).

Barium Compound.—This compound was also prepared like the calcium compound. (Found: Ba=23·24; S=26·25. $[(C_2H_4)_3\,S_4O_8]$, $Ba\,SO_4$, H_2O requires Ba = 23·18; S=27·07 per cent.).

Lead Compound.—Lead chloride was dissolved in hot water and added to a solution of the manganese compound in boiling water. The precipitate was filtered, washed with hot water and dried. (Found: Pb=28·35. $1\frac{1}{4}[(C_2H_4)_3\,S_4O_8]$, $Pb\,SO_4$ requires Pb = 28·44 per cent.).

Silver Compound.—On adding a very concentrated solution of silver nitrate to a boiling solution of the manganese compound a white precipitate was at once thrown down. (Found: $Ag=29 \cdot 68$. $1\frac{1}{4}[(C_2H_4)_3 S_4O_8]$, Ag_2SO_4 requires $Ag=29 \cdot 31$ per cent.).

Copper, Cobalt and Nickel Compounds.—These products were obtained by adding a concentrated solution of the respective chlorides to a concentrated solution of the manganese double compound in hot water. The mixture on concentration and cooling gave crystals which were filtered, washed with a little cold water and dried. These compounds are fairly soluble in hot water. The copper compound is slightly bluish in colour. (Found: $Cu=9 \cdot 06$; $S=29 \cdot 55$. $1\frac{1}{2}[(C_2H_4)_3S_4O_8]$, $CuSO_4$, $4H_2O$ requires $Cu=8 \cdot 50$; $S=30 \cdot 23$ per cent.). The nickel compound is slightly greenish in colour. (Found: $Ni=8 \cdot 55$; $S=30 \cdot 03$. $1\frac{1}{2}[(C_2H_4)_3 S_4O_8]$, $NiSO_4$, $4H_2O$ requires $Ni=7 \cdot 97$; $S=30 \cdot 40$ per cent.). The cobalt compound has a slight pink tint. (Found: $Co=8 \cdot 2$[illegible]; $S=29 \cdot 28$. $1\frac{1}{2}[(C_2H_4)_3 S_4O_8]$, $CoSO_4$, $4H_2O$ requires $Co=8 \cdot 00$; $S=30 \cdot 39$ per cent.).

The retention of the characteristic colours of the different metallic double compounds proves that the copper, nickel or cobalt atom does not form a component part of a complex.

Potassium Compound.—This compound was obtained as before by adding a concentrated solution of potassium chloride. There was no precipitate while the solution was hot, but on cooling a crystalline compound separated out. (Found: $K=12 \cdot 79$. $1\frac{1}{4}[(C_2H_4)_3 S_4O_8]$, K_2SO_4 requires $K=13 \cdot 02$ per cent.).

The Sodium Compound.—An aqueous solution of sodium carbonate was gradually added to a solution of of the manganese compound till manganous carbonate was completely precipitated. This was filtered off and the

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filtrate concentrated to a small bulk. On adding alcohol to this concentrated solution a syrup was obtained, which crystallised on keeping in a vacuum desiccator. The crystals were dissolved in water and reprecipitated with alcohol. (Found: Na = 18·26; S = 25·87. $\frac{1}{4}[(C_2H_4)_3S_4O_6]$, Na_2SO_4, H_2O requires Na = 18·77; S = 26·12 per cent.).

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On Coagulation of Hydrosols by mixture of Electrolytes and Ionic Antagonism.

BY

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AND

BHUPENDRA NATH GHOSH.

In a recent paper Freundlich and Scholz (Kolloid. Chem. Beihefte, *16*, 267, 1922) have shown that the precipitating concentration of barium chloride is materially increased if the electrolyte contains in addition lithium chloride in concentrations which are not in themselves sufficient to cause coagulation. This effect has been observed with hydrosols of arsenioussulphide and of sulphur prepared by Oden's method whereas for hydrosols of gold and of sulphur prepared by Weimarn's method the precipitating concentrations remain practically unaffected by such additions. It seems, as it were, the coagulating power of these cations decrease in the presence of a second cation. They found that this antagonism is very pronounced between univalent and divalent cations.

The greatest antagonism was observed between lithium and magnesium, further the effect was absent with gold sol which is not hydrated and they suggested that the effect is due to hydration of these ions and of the colloid.

Apart from considerations of hydration there are other possible factors which might account for the so-called antagonistic action of ions. It is usually assumed (though it rests on rather slender evidence cp. Mukherjee, Thesis of Doctorate of Science, University of London, 1921), that the concentrations of different electrolytes which brings in the same rate of coagulation corresponds to a state of the colloid where the particles have the same density of electrical charge. If that view be correct the observed results might be ascribed to the following causes :—

(1) Difference in the adsorption of the anions and cations present. This is the point of view taken up by Weiser and his collaborators (J. Phys. Chem., *25*, 666, 1921), who consider that in the case of colloidal solutions of arsenious sulphide both the cations and anions are very largely adsorbed. Now in the mixture the anion concentration is higher than in the case of the electrolytes with a divalent cation, and there will be a greater adsorption of the anion. The negative charge on the particles is therefore greater. More cations must therefore be adsorbed to bring down the density of the electrical charge to the value which corresponds to the limiting concentrations. Weiser concludes that the higher coagulating concentration is an index of the greater amount of anion that has been adsorbed.

(2) Freundlich (Z. Phys. Chem., *86*, 458, 1914) has pointed out that the adsorbability of one cation may be influenced by the other that is the presence of the univalent cation in comparatively higher concentrations might interfere with the adsorption of the bivalent cation and diminish its coagulating power.

It would seem that a study of the effect of various anions on coagulation by mixed electrolytes with simultaneous determination of the electrical charge will be most useful. The electrical data are essential for a proper understanding of the nature of the effect we are studying. It is to be regretted that there is very little useful data on this subject. In this laboratory a systematic study of the electrical charge is being carried out.

The present paper deals with the effect of various anions on coagulation of arsenious sulphide hydrosol by mixed electrolytes.*

EXPERIMENTAL.

During the last few years, a number of papers has been published showing that arsenious sulphide sol has different chemical composition, depending on the methods of preparation.

In our work, we have always adhered to the same method of preparation. The following method has been adopted for determining equi-coagulating concentrations. Light from a single filament lamp is allowed to pass through a layer of definite thickness of the coagulating colloid and the time noted when the sharp outline of the filament disappears. The intensity of the light is kept constant by passing a definite current through the filament. Electrolytes are considered to have equi-coagulating concentrations when the time required for reaching the same stage of coalescence is the same in each case. For each pair of electrolytes used the mixtures as well as the individual electrolytes are exactly equi-coagulating. During an experiment the colloid is tested from time to time by determining the coagulating concentration of a particular electrolyte.

TABLE I.

% Concentration of Sodium Benzoate.	% Concentration of Barium Chloride.	Sum.	% Concentration of Calcium Bromide.	Sum.	% Concentration of Calcium Benzoate.	Sum.
0	100	100	100	100	100	100
20	134	154	159	179	175	195
33	138	171	179	212	190	223
50	130	180	170	220	180	230
66	100	166	141	207	146	212

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[*] Since this work was finished Weiser has published another paper on adsorption by precipitates (J. Phys. Chem., 28, 237, 1924).

% Concentration of Sodium benzoate	% Concentration of Magnesium chloride.	Sum.	% Concentration of Barium benzoate.	Sum.
0	100	100	100	100
20	182	202	150	170
33	203	236		
50	195	245	150	200
66	155	221	120	186

Coagulating concentration of Sodium benzoate mean—0·17 N[*] = 100
" " " Barium chloride—0·0015 N = 100
" " " Calcium bromide—0·0017 N = 100
" " " Calcium benzoate—0·0018 N = 100
" " " Magnesium chloride—0·002 N = 100
" " " Barium benzoate—0·0014 N = 100

TABLE II.

% Concentration of Sodium benzoate.	% Concentration of Potassium chloride.	Sum.	% Concentration of Lithium chloride.	Sum.
0	100	100	100	100
20	121	141	181	201
33	114	147	169	202
50	86	136	186	186
66	62	128	98	164

Coagulating concentration of sodium benzoate—0·16 N = 100
" " " Potassium chloride—0·06 N = 100
" " " Lithium chloride -0·08 N = 100

[*] The sum of cations given in the tables is the sum of the percentage concentration of each cation taking the coagulating concentration of each separately to be hundred.

The actual values for different pairs varied respectively from 0·166 N to 0·174 N. The difference in the coagulating concentrations of barium chloride and barium benzoate may be due to experimental errors. But nothing definite can be said until they are more carefully examined. The barium benzoate was prepared from baryta and benzoic acid.

Percentage concentration of sodium benzoate.	Percentage concentration of sodium chloride.	Sum.
0	100	100
20	141	161
33	125	158
50		
66	98	164

Coagulating concentration of sodium benzoate—0·18 N = 100
" " " sodium chloride—0·08 N = 100

TABLE III.

% Concentration of sodium chloride.	% Concentration of barium chloride.	Sum.	% Concentration of calcium bromide.	Sum.	% Concentration. of Magnesium chloride.	Sum.
0	100	100	100	100	100	100
20	134	154	138	158	135	155
33					135	168
50	115	165	125	175	125	175
66	80	146	94	160	104	170

Coagulating concentration of sodium chloride (mean)—0·075 N* = 100
" " " Barium chloride—0·00155 N = 100
" " " Calcium bromide—0·0017 N = 100
" " " Magnesium chloride—0·002 N = 100

TABLE IV.

% Concentration of sodium acetate.	% Concentration of Barium acetate	Sum	% Concentration of Barium chloride.	Sum.	% Concentration of Magnesium chloride.	Sum.
0	100	100	100	100	100	100
20	164	184	156	176	210	230
33	176	209	158	191	233	266
50	170	220	138	188	229	279
66	130	196	125	191	175	241

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* The actual values varied from 0·073 N to 0·078 N for different pairs.

Coagulating concentration of sodium acetate (mean)—0·19 N[*] = 100
" " " Barium chloride—0·0015 N = 100
" " " Barium acetate (approx.)—0 0014 N = 100
" " " Magnesium chloride—0·0019 N = 100

Percentage concentration of sodium acetate.	Percentage concentration of calcium bromide.	Sum.	Percentage concentration of sodium chloride.	Sum.
0	100	100	100	100
20	191	211	178	198
33	208	241	155	188
50	204	254	121	171
66	174	240	85	151

Coagulating concentration of sodium acetate—0·18 N = 100
" " " Calcium bromide—0·0016 N = 100
" " " Sodium chloride—0·07 N = 100

TABLE V.

Percentage concentration of Potassium Trichlor-acetate.	Percentage concentration of Barium Trichlor-acetate.	Sum.	Percentage concentration of Trichlor-acetic acid.	Percentage concentration of Bârium Trichlro-acetate	Sum.
0	100	100	0	100	100
20	123	148	20	108	128
50	100	150	33	104	137
66	85	151	66	65	131

Coagulating concentration of Trichlor-acetic acid—0·04N = 100
" " " Barium Trichlor acetate—0·00156N = 100
" " " Potassium Trichlor-acetate—0·09N = 100

Percentage concentration of Barium benzoate.	Percentage concentration Barium chloride	Sum.	Percentage concentration of $K_4Fe(CN)_6$.	Percentage concentration of KCl.	Sum.
0	100	100	0	100	100
20	78	98	20	105	125
33	64	97	33	93	126
50	49	99	50	81	131
66	33	99	66	53	119

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[*] The actual values varied from 0·187 N to 0·195 N for different pairs.

Coagulating concentration of Barium benzoate—0·0014 N = 100
" , " Barium chloride—0·0015 N = 100
" " " $K_4F.(CN)_6$ —0·2 N = 100
" " " KCl —0·07 N = 100

Percentage coagulating concentration of LiCl.	Percentage coagulating concentration of Mg Cl_2*
0	100
25	200
50	220
73	233

DISCUSSION.

In their experiments neither Freundlich nor Weiser has used electrolytes other than chlorides. The question how far the adsorption of anions is responsible for the increase in the coagulating concentrations of the divalent cations remains open. They have used mixtures of electrolytes containing two cations. It has been shown by Weiser (J. Phys. Chem., *28*, 1924, 241) that there is a displacement of adsorption of one cation by the other. It is therefore not clear whether the observed effect is to be attributed at least in part to the adsorption of anions or to some factor other than the adsorption of anions. If however the mixture of electrolyte contain only one cation and an increased concentration of the cation is necessary for the mixture we must conclude that anion adsorption is responsible for the effect. We have such an instance in the effect of sodium benzoate and sodium acetate on the coagulating concentration of sodium chloride. Displacement of adsorption of one cation by another is impossible since we have got only one cation.

It will be noted that sodiumacetate increases the coagulating concentration of sodium chloride almost to

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* The data for the pair LiCl and $MgCl_2$ are taken from Freundlich's Kapillarchemie, p. 634 (1922), and added for comparison only.

the same extent as it does in the case of barium chloride. Similarly sodium benzoate has almost equal effects on sodium chloride and barium chloride. So we conclude that even in cases where the displacement of adsorption of one cation by another is not possible the effect of the anion is as pronounced as in the case where displacement of adsorption may occur in addition.

TABLE VI.

Percentage concentration of Lithium Chloride.	Percentage * concentration of Barium Chloride	Percentage concentration of Sodium Acetate	Percentage concentration of Barium Chloride	Percentage concentration of Sodium Chloride.
0	100	0	100	100
25	133	20	156	178
50	110	33	158	155
73	110	50	138	121
		66	125	85

It is therefore difficult to say whether the effects of sodium acetate on Barium chloride is due to the displacement of the adsorption of Bä ion or simply due to the adsorption of the anion. In a previous paper (Mukherjee and Chaudhuri, J. Chem. Soc., 1924, Vol. 125, p. 795) reasons have been given which indicate that acetate and benzoate ions are more strongly adsorbed than Cl′ ion. This observation is in agreement with the observed influence of sodiumacetate and sodium benzoate on NaCl. The anion adsorption in these cases is therefore clearly established.

Regarding the effect of LiCl on $BaCl_2$ Weiser has attributed it to the displacement of Bä ion by Li ion as he has actually observed that the precipitate carries with it

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* The result for the pair LiCl and $BaCl_2$ are taken from Freundlich's Kapillarchemie, p. 634 (1922).

less Ba in the presence of LiCl than in its absence. It is however necessary to point out that this observation in itself does not justify Weiser's conclusion. Apart from the difficulties of interpreting analytical data on adsorption (cp. W. O. Ostwald Koll-Z. *30* (1919), 279), Weiser's observation only shows that a smaller number of barium ions are present in the "double layer." It does not follow that there is also a smaller number of barium ions fixed on the surface than in the other case. The distinction between the adsorbed ions which are free to move under an impressed electrical field and those which are not free to move has been overlooked. The relative ratio of the two cations per unit surface in the fixed layer of ions which really determine the diminution in the electrical charge is not necessarily identical with that in the freely moving second sheet of the Helmholtz double layer. Analytical data cannot evidently give an idea of the distribution in either layer. It gives the idea of the total effect due to both layers assuming that the adsorption of the solvent is negligible. Weiser's interpretation will be true if coagulation takes place when the particles are practically neutral as in that case there will be no freely moving ions and all the cations are fixed on the surface. There in no justification for such an assumption.

We would now point out that in all these cases the assumption of a small adsorption of an anion will be sufficient to explain the observed effects * without recourse being had either to considerations of hydration or to displacement of adsorption. If we consider the experiments of Ellis, Powis and Kruyt at low concentrations of the electrolyte we find that there is in most cases a slight rise in the negative charge when the electrolyte is KCl or LiCl. We see that in the case of a chloride with a cation

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* Of course we cannot say that this is actually the case in the absence of relevent data on the electrical charge.

of low coagulating power the increase in the charge may be more pronounced (cp. the curves given by Freundlich Kapillarchemie,* page 354, 2nd edition). In that case there ought to be a gradation in the effects of electrolytes having common anion and cations of same valency but different coagulating power. The coagulating power of lithium is the weakest among the alkali metal ions and that of magnesium among the divalent cations Ba, Sr, Ca, Mg, etc. Both Freundlich and Weiser have observed that lithium and magnesium show the most pronounced effect. Our experiments also support this observation as will appear from the data given above. Where the anions are adsorbed to a marked extent the greater increase in the negative charge is reflected in a greater difference in the coagulating concentrations of different cations of the same valency. We notice that the influence of sodium benzoate is in the order

$$Mg > Ca > Ba, \text{ and } Li > Na > K$$

that is the reverse order of their precipitating power. If we now contrast the effect of mixing sodium chloride instead of sodium acetate or sodium benzoate we find that the individual variations between barium chloride, calcium bromide and magnesium chloride are scarcely perceptible. If the displacement of adsorption of these cations varied from one to another one would then have expected a greater difference between them. Magnesium in no way shows characteristic difference compared to barium or calcium. The anion adsorption in the case of

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* If similarly in the case of arsenious sulphide there is an increase in the charge at low concentration oft hese chlorides then it is not necessary to assume either hydration or the displacement of adsorption. In collaboration with Mr. S. G. Chaudhuri measurements are being made on the variation in the rate of cataphoresis of Arsenious sulphide particles with the change in concentration of acids. So far HCl and H_2So_4 have been studied The variation in charge is very complicated and depends probably on whether we are dealing with an orange or yellow sol. on the concentration of H_2S and probably on the reaction between H ion and the stabilising ion adsorbed on the surface of the colloid.

the chlorides is less pronounced because we are dealing with a relatively less adsorbable anion and cations with fairly strong coagulating power. Our contention is that it is the initial rise in charge at low electrolyte concentration which is to a large extent responsible for all these effects. It does not matter whether the increase in charge is due to a strong adsorption of the anion or to a weak adsorption of the cation as in the case of sodium benzoate and lithium chloride respectively. Recognising that on the addition of a small quantity of an electrolyte (say up to 66% of its coagulating concentration) there is an increase in the charge, the protecting effect of such an increase will of course be more prominent if the coagulating cation has a weaker precipitating power. That is why we find so great an effect of lithium chloride on magnesium chloride or of sodium benzoate or sodium acetate on magnesium chloride. The effect of sodium acetate on calcium bromide is not in any way less pronounced than that of lithium chloride on magnesium chloride and the effect of sodium benzoate on lithium chloride is fairly comparable to that of lithium chloride on magnesium chloride.

Similarly potassium trichloracetate has a greater effect than the acid on the coagulating concentration of the barium salt in keeping with the lower coagulating power of the potassium ion compared to that of the hydrogen ion. The pair barium benzoate and barium chloride show a marked contrast to sodium benzoate and sodium chloride. The total barium ion concentration remains fairly constant. Whereas in the case of sodium acetate and sodium chloride the total sodium ion concentration becomes more than double the coagulating concentration of sodium ions when only sodium chloride is used. The difference is probably due to the low anion concentration of the barium salts and the greater coagulating power of the barium ion. There ought to be from our point of view no increase of charge at low concentration of barium salts. The curves of Ellis and Powis show this peculiarity. Potassium ferrocyanide and potassium chloride on the other hand show a weaker effect than sodium acetate and sodium chloride. This is probably due to the greater coagulating power of potassium ion on the one hand and the weaker adsorption of $Fe(CN)_6$ ion on the other hand in spite of its higher valency as shewn in a previous paper.

We would again repeat that in order to clearly understand the nature of these effects the corresponding measurements of the charge is absolutely necessary and discussion on the displacement of adsorption might be profitably postponed till we have obtained the necessary data.

Lastly we would make a few observations on ionic antagonism as observed in nature. It is rather rash to draw conclusions from a few experiments on coagulation in the laboratory and to conclude from the similarity of effects that there is a similarity in the cause. At the same time we might suggest that at least one of the main causes which is responsible for ionic antagonism as observed by Lillie, Osterhout, Loeb and Clowes (J. Phys. Chem., *20*, 1916) is the effect of the ions on the electrical charge of the dispersed system. The similarity in the effects is probably to be attributed to this common factor. Clowes states "whatever the ultimate theoretical interpretation may be the close correspondence between data accumulated in such widely diversified fields affords substantial evidence of the existence of some heretofore unappreciated fundamental physical principle" and this fundamental physical factor might be the electrical charge.

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3.	*Year of Establishment*	:	
4.	*Manufacturing Sites*	:	
3.	*Annual Turnover (Rs Cr)*	:	
4.	*Name of CMD*	:	
5.	*Name of HR Director or Authorized Official*	:	
	Telephone	:	Email:
6.	*Address of Corporate Office*	:	
		:	
		:	
	Telephones	:	Email:

1

7.	Payment of Fees: The payment is made by one of the means given below. The details are as follows:
	Amount: Date:
8.	(a) We are happy to join the Indian Chemical Society as Corporate Member and would abide by all rules and regulation of the Society and would strive to strengthen the professional activities in the pursuit of chemical sciences.
	(b) We will also subscribe or will not subscribe to the Journal of the Indian Chemical Society published by Elsevier Publishers.
	Authorized Signatory
Date:	Place:

(A) CORPORATE MEMBERSHIP FEES (Including subscription to the Journal)

Type of Industry	**Turn-over of industry**	**Fees for 10 years + Journal**	**Permanent Membership + Journal**
Category A	Above Rs. 1000 Cr	Rs 15.00 Lakh + Rs. 2.00 Lakh	Rs 30 Lakh +Rs. 3.00 Lakh
Category B	Less than Rs. 1000 Cr	Rs 12.00 Lakh +Rs. 2.00 Lakh	Rs 24 Lakh +Rs. 3.00 Lakh
Category C	Less than Rs. 100 Cr	Rs 10 00 Lakh +Rs. 2.00 Lakh	Rs 20 Lakh +Rs. 3.00 Lakh
Category D	Less than Rs. 50 Cr	Rs 5. 00 Lakh +Rs. 2.00 Lakh	Rs 10 Lakh +Rs. 3.00 Lakh
Category E	R and D institutes of CSIR, DRDO, DST, DBT, ICMR,etc.	Rs 5.00 lakh+ Rs. 2.00 Lakh	Rs. 10 Lakh +Rs. 3.00 Lakh

(B) MODE OF PAYMENT

1. Payable by Multicity CTS Cheque in favour of "INDIAN CHEMICAL SOCIETY "
2. Pay online through the Website: www.indianchemicalsociety.com
3. If payment is done electronically, please intimate ICS immediately after the remittance by sending E-mail or FAX as proof of remittance and also mention it in this application form.

(C) IMPORTANT INFORMATION NEFT/RTGS/ECS

i) Bank Name with abbreviated form.	iii) Bank Branch Code
ii) Date of Remittance	iv) TRFFR No. UTR No. etc.

(D) NEFT/RTGS/ECS DETAILS

Name of Vendor	Indian Chemical Society
Bank Account Number	11152790242
Type of Account	Current
Name of Bank	State Bank of India 294/2/1, Acharya Prafulla Chandra Road, Kolkata-700 009
Branch Name	Manicktala, Kolkata
Brach Code	01715
IFSC Code	SBIN0001715
PAN No	AAAAI 1238H
MICR Code	700002062
IBAN No. or International SWIFT	SBININBB492

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FOR OFFICE USE ONLY

Date:

Details of payment received and date of receipt:

Admitted as Corporate Member with effect from ………………………………. for a period of 10 years or as Permanent Corporate Member by the Council of ICS at its meeting held on ……….

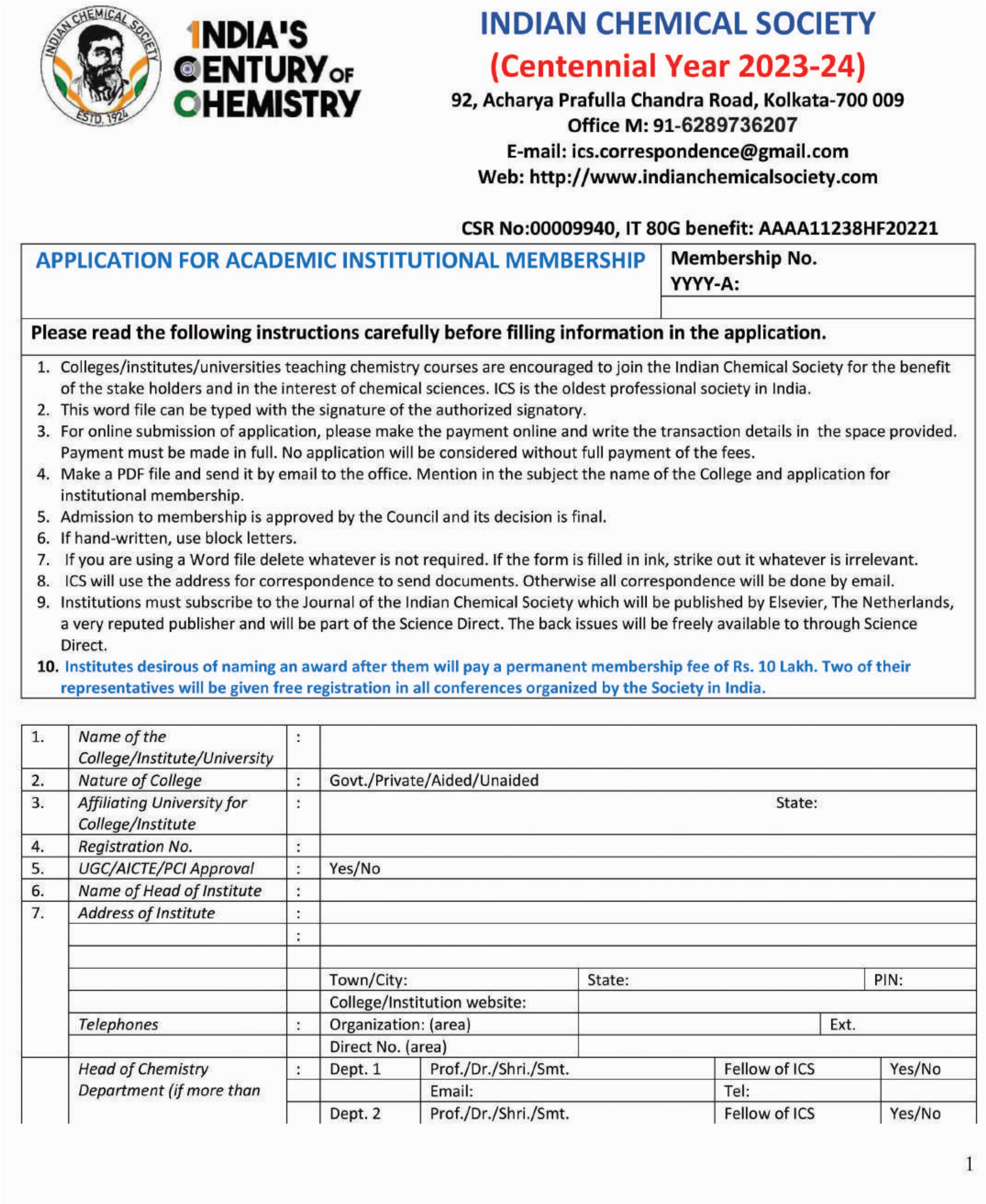
Signature of the Accountant *Signature of the Honorary Treasurer* *Signature of the Honorary Secretary*

The name to be printed on the Certificate

Please print the following name of the organization on the certificate:

The following is the email ID of the responsible person representing the organization. It should be generic and not personal.: e.g. hrd@xyz.com or head@abc.org

N.B.: It will be copy pasted in the certificate and ICS will not be responsible for any mistakes.



INDIAN CHEMICAL SOCIETY
(Centennial Year 2023-24)

92, Acharya Prafulla Chandra Road, Kolkata-700 009
Office M: 91-6289736207
E-mail: ics.correspondence@gmail.com
Web: http://www.indianchemicalsociety.com

CSR No:00009940, IT 80G benefit: AAAA11238HF20221

APPLICATION FOR ACADEMIC INSTITUTIONAL MEMBERSHIP

Membership No.
YYYY-A:

Please read the following instructions carefully before filling information in the application.

1. Colleges/institutes/universities teaching chemistry courses are encouraged to join the Indian Chemical Society for the benefit of the stake holders and in the interest of chemical sciences. ICS is the oldest professional society in India.
2. This word file can be typed with the signature of the authorized signatory.
3. For online submission of application, please make the payment online and write the transaction details in the space provided. Payment must be made in full. No application will be considered without full payment of the fees.
4. Make a PDF file and send it by email to the office. Mention in the subject the name of the College and application for institutional membership.
5. Admission to membership is approved by the Council and its decision is final.
6. If hand-written, use block letters.
7. If you are using a Word file delete whatever is not required. If the form is filled in ink, strike out it whatever is irrelevant.
8. ICS will use the address for correspondence to send documents. Otherwise all correspondence will be done by email.
9. Institutions must subscribe to the Journal of the Indian Chemical Society which will be published by Elsevier, The Netherlands, a very reputed publisher and will be part of the Science Direct. The back issues will be freely available to through Science Direct.
10. **Institutes desirous of naming an award after them will pay a permanent membership fee of Rs. 10 Lakh. Two of their representatives will be given free registration in all conferences organized by the Society in India.**

1.	*Name of the College/Institute/University*	:				
2.	*Nature of College*	:	Govt./Private/Aided/Unaided			
3.	*Affiliating University for College/Institute*	:			State:	
4.	*Registration No.*	:				
5.	*UGC/AICTE/PCI Approval*	:	Yes/No			
6.	*Name of Head of Institute*	:				
7.	*Address of Institute*	:				
		:				
			Town/City:	State:	PIN:	
			College/Institution website:			
	Telephones	:	Organization: (area)		Ext.	
			Direct No. (area)			
	Head of Chemistry Department (if more than	:	Dept. 1	Prof./Dr./Shri./Smt.	Fellow of ICS	Yes/No
				Email:	Tel:	
			Dept. 2	Prof./Dr./Shri./Smt.	Fellow of ICS	Yes/No

	one department, include all departments			Email:	Tel:	
			Dept. 3	Prof./Dr./Shri./Smt.	Fellow of ICS	Yes/No
				Email:	Tel:	
			Dept. 4	Prof./Dr./Shri./Smt.	Fellow of ICS	Yes/No
				Email:	Tel:	
			Dept. 5	Prof./Dr./Shri./Smt.	Fellow of ICS	Yes/No
				Email:	Tel:	
		:	Dept. 6	Prof./Dr./Shri./Smt.	Fellow of ICS	Yes/No
				Email:	Tel:	

8.	*Details of the College/Institute*	:	Affiliated/Constitutional/Autonomous/Department of University/School				
			Year of Establishment		No. of Depts./Schools		
			No. of Science Depts.		No. of Chemistry Depts.		
			No. of Chemistry Programmes	B.Sc.:	M. Sc.:	Ph.D.:	Diploma:
			No. of Chemistry Students	B.Sc.:	M. Sc.:	Ph.D.:	Diploma:

9.	*Name and Designation and Address for Communication*	:			
			Town/City:	State:	PIN:
			Landline #:(country, area):	Email:	

10.	Payment of Fees: The payment is made by one of the means given below. The details are as follows:		
	Amount:	Date:	Proof of Payment: Reference or Snap of Online Payment (Attached)

11. **Certificate by the Principal/Director/ Head or Authorized Person**

(i) We are happy to join the Indian Chemical Society as Academic Institute Member and would abide all rules and regulation of the Society and would strive to strengthen the professional activities in the pursuit of chemical sciences.

(ii) We are interested (or not interested) in naming an annual award after our institute and agree to pay Rs. 10 Lakh as the permanent membership fee.

College Stamp

Principal of College/Institute/Authorized Signatory

(A) INSTITUTIONAL MEMBERSHIP FEES

The Institutional Membership Fee of Rs 1.00 lakh for a period of 10 years. Permanent membership will be for Rs 5.00 lakhs. The Journal subscription fee is Rs 10,000/- per annum which should be sent along with the application fee. An award will be named after them if they pay Rs. 10 lakh.

(B) MODE OF PAYMENT

1. Payable by Multicity CTS Cheque in favour of "INDIAN CHEMICAL SOCIETY "
2. Pay online through the Website: www.indianchemicalsociety.com
3. If payment is done electronically, please intimate ICS immediately after the remittance by sending E-mail or FAX as proof of remittance and also mention it in this application form.

(C) IMPORTANT INFORMATION NEFT/RTGS/ECS

i) Bank Name with abbreviated form.	iii) Bank Branch Code
ii) Date of Remittance	iv) TRFFR No. UTR No. etc.

(D) NEFT/RTGS/ECS DETAILS

Name of Vendor	Indian Chemical Society
Bank Account Number	11152790242
Type of Account	Current
Name of Bank	State Bank of India 294/2/1, Acharya Prafulla Chandra Road, Kolkata-700 009
Branch Name	Manicktala, Kolkata
Brach Code	01715
IFSC Code	SBIN0001715
PAN No	AAAAI 1238H
MICR Code	700002062
IBAN No. or International SWIFT	SBININBB492

****

FOR OFFICE USE ONLY

Recommended /Not recommended for admission as Institutional Member.

Date: *Signature of the Membership Officer*

Details of payment received and date of receipt:

Admitted as Life Fellow/Member with effect from .... by the Council of ICS at its meeting held on ....

Signature of the Accountant *Signature of the Honorary Treasurer* *Signature of the Honorary Secretary*

The name to be printed on the Certificate

Please print the following institutional name on the certificate:

The following is the email ID of the responsible person representing the organization. It should be generic and not personal.: e.g. principal@xyz.com or director@abc.org, vc@abc.org

N.B.: It will be copy pasted in the certificate and ICS will not be responsible for any mistakes.

INDIAN CHEMICAL SOCIETY

(Centennial Year 2023-24)

92, Acharya Prafulla Chandra Road, Kolkata-700 009

Office M: 91-6289736207

E-mail: ics.correspondence@gmail.com
Web: http://www.indianchemicalsociety.com

Paste a photo or image in JPEG, TIFF format (less than 500 KB)

Membership No.
YYYY-LF

APPLICATION FOR LIFE FELLOWSHIP

Please read the instructions and eligibility criteria on page 6 before filling information in the application.

1. This word file can be typed with the signature of the applicant. The fellowship is for life.
2. The names and complete addresses including email and mobile number (if any) of the proposer and seconder should be mentioned if their signatures could not be obtained. In that case, write they have agreed to support.
3. For online submission of application, make the payment in appropriate currency (depending on affiliation address) online or give DD number and write the transaction details in the space provided. Payment must be made in full otherwise the application will be treated invalid.
4. While uploading the signed form on the website or sending by email, a c.c. should be marked to them. The office will contact them for verification of their support.
5. Make a PDF file and send it by email to the office. Mention in the subject your name and category of membership.
6. Admission to membership is made by the Council and its decision is final.
7. If hand-written, use block letters and furnish documentary evidence of all the information.
8. Attach your CV including employment record, list of publications (if applicable), etc. and use more pages if the space is insufficient. For applicants from industry or industrial organizations, some portion may not be relevant
9. Only life fellowship or membership is accepted by the Society and for members wishing to be upgraded there will be fresh fee which will be revised from time to time.
10. If you are using a Word file delete whatever is not required. If the form is filled in ink, strike out it.
11. ICS will use the address for correspondence to send documents. Otherwise, all correspondence will be done by email.
12. The Journal of Indian Chemical Society is published by Elsevier from 2021 and all members of different type are required to subscribe to it. It will be part of the Science Direct. The back issues will be freely available through Science Direct.

1.	*Name of applicant*	:	First Name (F)	Middle name (M)		Surname/family name (S), if any	
		:					
2.	*Name to be addressed in correspondence*	:	Prof/Dr/Shri/Smt.				
3.	*ORCID id (for academics and researchers)*	:	0000-0000-0000-0000				
			If you do not have ORCID id, visit www.orcid.org and create it. It is a unique ID used globally for scientific writing and to avoid confusion in similarity of names. It is a sixteen-digit number with a hyphen after each 4 digits.				
4.	*Personal Information*	:	(a) Date of Birth: DD-MM-YYYY		(b)Sex: M/F/T		
			(c) Nationality:	Passport #		Validity:	Yr.
			(d) OCI: Yes/No	OCI #			
5.	*Official Designation*	:					
6.	*(i) Name of Organization*	:					
	(ii) Address	:					

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			Town/City:	State &Country:	PIN:
			Institution website:		
			Personal website:		
	Telephones	:	Organization: (country, area)		Ext.
			Direct: (country, area)		
	Official Email	:		Official M: (country)	
	Personal Email id	:		Personal M: (country)	
7.	*Permanent address (please inform the office of change of address on relocation).*	:			
			Town/City:	State & Country:	PIN:
			Landline #:(country, area)		
8.	*Address for Communication (Valid upto DD/MM/YYYY)*	:			
			Town/City:	State & Country:	PIN:
			Landline #:(country, area)		
9.	*Previous Membership*	:	Yes/No	Type of Membership:	Membership No.
10.	*Academic Qualifications (Attach a PDF file of the certificate with self-attestation.) If the applicant is professionally known to the President/Advisor/Patron and has a verified ORCID, this requirement may be waived by the office.*				

#	Name of Degree	College/Institute	State	University	Year of Passing
1.	B.Sc./B.Tech./B.E./Eqvt.				
2.	M.Sc./M. Tech./M.E./Eqvt.				
3.	M. Phil.				
4.	Ph.D.				
5.	Post-Doc. Fellow				
6.	Any other (name)				
7.	Any other (name)				

11. *Subject Expertise and Contributions* : Please provide the following information which is needed to create a database of reviewers and experts. Many of you work at the interface between Chemistry and other sciences. You may have expertise in more than one area but basic degree (number 1) in one discipline. Order them according to your interest.

Specialization	Order	Specialization	Order
• Analytical Chemistry		• Solid State Chemistry	
• Inorganic Chemistry		• Theoretical Chemistry	
• Organic Chemistry		• Chemical Engineering	
• Physical Chemistry		• Chemical Technology	
• Green Chemistry		• Physics	
• Industrial Chemistry		• Biological Sciences	
• Polymer Chemistry		• Biotechnology	
• Biochemistry		• Materials Chemistry & Engineering	
• Food Chemistry & Tech		• Natural Products Chemistry	
• Microbiology		• Environmental Chemistry	
• Pharma. Sci & Tech		• Nuclear Chemistry	
• Earth Sciences		• Oceanography	
• Marine Chemistry		• Chemical Physics	
• Agro-chemistry		• Biomedical Engineering	

		• Soil Chemistry		• Oil Chemistry	
		• Interfacial Science		• Dyestuff Chem & Technology	
		• Textile Chemistry & Tech		• Any other (name)	
12.	**Contributions to Profession**	**Research/Innovation/Leadership/Manufacturing/Business**			
12a	**Applicants based in Academia/Research Institutes/Govt. Labs engaged in research and publication, guidance of research students (Fill in part 12a)**				
.	**Research Contributions Statistics on Research and Innovation Productivity (Only numbers)**	• International Papers:		• International Patents:	
		• National Papers:		• National Patents:	
		• Conferences Presentations:		• Ph.D. Guided:	
		• Masters' Thesis Guided:		• PDF guided :	
		• Current Masters Students:		• Current Ph.D. Students:	
		• Current PDF:		• Current Project Staff:	
		• Patents:		• Technology Transfer	
		• h index:		• i10 index:	
		• No. of citations:		• Citations per paper:	
12b	**Applicants based in Industry/Business/Ministries/Policy Making Bodies/Entrepreneurs/Industrialists (Fill in part 12b only)**				
	Name of industry			Year of Estab.	
	Name of Govt. Ministry/ Council/Autonomous Body				
	Whether Public Ltd or Private Ltd. company				
	Website				
	Whether manufacturing or consulting firm or import/export firm or policy making body				
	Your current title				
	Whether entrepreneur/ promoter/majority share holder/proprietor				
	No. of years in service so far (altogether; not in one company)				
	Approximate Annual Turnover (for companies)				
	Number of employees under your supervision				
	No. of inhouse technologies developed (R & D & I)				
	No. of inhouse technologies transferred to plant				
	Name of CEO/CTO/Head to whom you report			Tel No. and Email ID	
13.	*Membership and Fellowships of National & International Academies, and Professional Societies. List positions as office bearers of any such bodies (last 5 years)*	1.		8.	
		2.		9.	
		3.		10.	
		4.		11.	
		5.		12.	
		6.		13.	
		7.		14.	
14.	*Membership of Committees of UGC, AICTE, DST,DBT,*	1.		5.	
		2.		6.	

	SERB, etc. (last 5 years) or membership of industry associations	3.		7.	
		4.		8.	
15.	*Awards & Recognitions (last 5 years)*	1.		4.	
		2.		5.	
		3.		6.	

16. *List of Ten Most Important Publications (Not applicable to Industry based applicants, unless relevant)*

#	Authors (same order)	Title	Journal	Vol.	Year	Pages	DOI	I.F.	Citations
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									

16. Accomplishments: Give a brief outline in an annexure within 200 words stating therein the most significant contribution in the field of specialization and its impact.

17. Payment of Fees: I have made payment by one of the means given below. The details are as follows:

Amount:

Date:

Proof of Payment: Reference or Snap of Online Payment (Attached)

18a. List of Fellows Supporting the Application. If the President/Patraon/ Branch Chair/Past President/Hon. Fellow/Current Council Member invited you to apply then only one name should be written as the supporter. A c.c. of the form should be sent to them for their consent. Please ask them to be a supporter. The office may verify it.

Whether invited by the President of ICS	Yes/No	Name			
Whether invited by the Chairman of ICS Branch	Yes/No	Name			
Whether invited by the Past President or Adviser of ICS	Yes/No	Name			
Whether invited by the Hon. Fellow of ICS	Yes/No	Name			
Whether invited by the Current Council Member of ICS	Yes/No	Name			

For others two supporters are needed. The consent to support the applicant can be in the form of a letter or email by the fellow in which case there is no need of any physical signature. The applicant must ensure that s/he has taken the necessary permission from the concerned fellows. The list should be provided as follows:

	Name	Affiliation	Fellowship No. (if known)	Consent taken	Email	Mobile No.
1.						
2.						

(A) LIFE FELLOWSHIP FEES

1. Life Fellowship: Rs. 11000/- for Indian fellows Plus Rs. 4000/- for subscription to the Journal for 5 years (Total Rs 15000) should be enclosed with the application form (effective from January 1, 2023).
2. Life Fellowship: US$ 500 for Foreign fellows Plus US$ 45 for subscription to the Journal for 5 years (Total US$ 545). This has to be provided in INR by making online payment. The current amount is: Rs. 45000/- It includes subscription to the journal will be for life.

MODE OF PAYMENT

1. Payable by Multicity CTS Cheque in favour of "INDIAN CHEMICAL SOCIETY "
2. Pay online through the Website: http://www.indianchemicalsociety.com/UserPanel/payment-gateway.aspx
3. Payment by credit/debit card is also possible as given on the website.
4. If payment is done electronically, please intimate ICS immediately after the remittance by sending E-mail or FAX as proof of remittance, and also mention it in this application form.

(B) IMPORTANT INFORMATION NEFT/RTGS/ECS

i) Bank Name with abbreviated form.	iii) Bank Branch Code:
ii) Date of Remittance:	iv) TRFFR No. or UTR No.

(C) NEFT/RTGS/ECS DETAILS

Name of Payee	Indian Chemical Society
Bank Account Number	11152790242
Type of Account	Current
Name of Bank	State Bank of India 294/2/1, Acharya Prafulla Chandra Road, Kolkata-700 009
Branch Name	Manicktala, Kolkata
Brach Code	01715
IFSC Code	SBIN0001715
PAN No	AAAAI 1238H
MICR Code	700002062
IBAN No. or International SWIFT	SBININBB492

* * *

I, the undersigned, do hereby engage that, if elected as a Fellow, I will endeavour to promote the interests and welfare of the Indian Chemical Society and I will uphold its Constitution and observe its laws, rules and regulations, and to the utmost of my power maintain its dignity as long as I shall continue as a Fellow thereof. If my qualifications fall short in any way, I agree to accept the life membership. I have made the payment of all appropriate dues by one of the means given above. After approval of my admission I shall be entitled to avail of the privileges of fellowship as provided in the Constitution and the Bye-laws of the Society. I have filled in the template of the Fellowship online and there is no spelling mistake of any kind in it.

Place:
Date: *Signature and full name of the applicant*

……

FOR OFFICE USE ONLY

Recommended /Not recommended for admission as Life Fellow/Member.

Date: *Signature of the Membership Officer*
Details of payment received and date of receipt:
Admitted as Life Fellow/Member with effect from .... by the Council of ICS at its meeting held on ....

Signature of the Accountant *Signature of the Honorary Treasurer* *Signature of the Honorary Secretary*

Eligibility Criteria for Fellowship of Indian Chemical Society

1. S.S. Bhatnagar Prize winners/Infosys awards or similar national/international honour/recognition
2. Fellows of all National and International Academics, RSC and ACS, Commonwealth Chemistry, other associations of which ICS is a member or the like
3. Full Professors in Centrally Funded Institutes or equivalent grade pay in National Laboratories such as CSIR, DAE, DRDO, ISRO, ICMR, ICAR or such Central or State organizations, State Universities and Deemed to be Universities (within top 200 NIRF rank).
4. General Managers/Vice Presidents and Directors (R and D) of DSIR recognized laboratories of Industries in Public Sector or Private Sector.
5. Associate Professors in CFI or UGC recognized universities and colleges who have guided at least 2 Ph Ds with publications and patents with cumulative impact factor of 50. (The I.F. for international patent 20 and national patent 10). In exceptional cases, Assistant Professors with a cumulative impact factor of 200 will be considered.
6. Group Heads in related Central or State Ministries with Ph.D.s (in one of the subjects given above), having experience of 15 years. In exceptional cases, those with master's degree but relevant experience can also be considered.
7. General managers and group leaders for industrial R and D with supervision of at least 5 scientists having M.Sc./Ph.D. and evidence of patents and technology transfer.
8. Vice Presidents, Presidents, Directors, Managing Directors of Industries with a turnover of Rs 10 Cr or above.
9. College Principals or Vice Principals with Ph D having full professorship and evidence of producing at least 2 Ph Ds or those with publications and patents leading to cumulative I.F. of 50.
10. Full Professors in UGC recognized Private Universities with evidence of producing 2 Ph.D.s and cumulative Impact Factor of 200.
11. In exceptional cases, those who have been responsible for promotion of chemical sciences through policy making and whose names have been approved by the Council at the recommendation of the President/Patron/Advisor.
12. All others with a degree in Chemical Sciences and Engineering/Technology, Physics, Biological Sciences, Earth Sciences, Environmental Sciences, or the subjects mentioned above, who did not fit into any of the above, will be eligible for Membership.

The name to be printed on the Certificate (to be provided by the applicant)

Please print the following name on my certificate (first name, middle name, last name):

Professor/Dr./Shri./Smt.	
ORCID (if any)	
Membership Number	YYYY-LF

N.B.: It will be copy pasted in the certificate and ICS will not be responsible for any mistakes. All membership numbers will precede by the year of election. That will help ICS to create a proper database.

INDIAN CHEMICAL SOCIETY

(Centennial Year 2023-24)

92, Acharya Prafulla Chandra Road, Kolkata-700 009

Office M: 91-6289736207

E-mail: ics.correspondence@gmail.com
Web: http://www.indianchemicalsociety.com

Paste a photo or image in JPEG, TIFF format (less than 500 KB)

Membership No.
YYYY-LM

APPLICATION FOR LIFE MEMBERSHIP

1. This word file can be typed with the signature of the applicant. The membership is for life.
2. The names and complete addresses including email and mobile number (if any) of the proposer and seconder should be mentioned if their signatures could not be obtained. In that case, write they have agreed to support. Only one consent is needed in certain cases
3. For online submission of application, make the payment in appropriate currency (depending on affiliation address) online or give DD number and write the transaction details in the space provided. Payment must be made in full otherwise the application will be treated invalid.
4. While uploading the signed form on the website or sending by email, a c.c. should be marked to them. The office will contact them for verification of their support.
5. Make a PDF file and send it by email to the office. Mention in the subject your name and category of membership.
6. Admission to membership is made by the Council and its decision is final.
7. If hand-written, use block letters and furnish documentary evidence of all the information.
8. Attach your CV including employment record, list of publications (if applicable), etc. and use more pages if the space is insufficient. For applicants from industry or industrial organizations, some portion may not be relevant
9. Only life fellowship or membership is accepted by the Society and for members wishing to be upgraded to the fellowship category, there will be a fresh fee which will be revised from time to time.
10. If you are using a Word file delete whatever is not required. If the form is filled in ink, strike out it.
11. ICS will use the address for correspondence to send documents. Otherwise, all correspondence will be done by email.
12. The Journal of Indian Chemical Society is published by Elsevier from 2021 and all members of different type are required to subscribe to it. It will be part of the Science Direct. The back issues will be freely available through Science Direct.

1.	*Name of applicant*	:	First Name (F)	Middle name (M)	Surname/family name (S), if any		
		:					
2.	*Name to be addressed in correspondence*	:	Prof/Dr/Shri/Smt .				
3.	*ORCID id (for academics and researchers)*	:	0000-0000-0000-0000				
			If you do not have ORCID id, visit www.orcid.org and create it. It is a unique ID used globally for scientific writing and to avoid confusion in similarity of names. It is a sixteen-digit number with a hyphen after each 4 digits.				
4.	*Personal Information*	:	(a) Date of Birth: DD-MM-YYYY		(b)Sex: M/F/T		
			(c) Nationality:	Passport #		Validity:	Yr.
			(d) OCI: Yes/No	OCI #			
5.	*Official Designation*	:					
6.	*(i) Name of Organization*	:					
	(ii) Address	:					

1

			Town/City:	State &Country:		PIN:
			Institution website:			
			Personal website:			
	Telephones	:	Organization: (country, area)			Ext.
			Direct: (country, area)			
	Official Email	:		Official M: (country)		
	Personal Email id	:		Personal M: (country)		
7.	*Permanent address (please inform the office of change of address on relocation).*	:				
			Town/City:	State & Country:		PIN:
			Landline #:(country, area)			
8.	*Address for Communication (Valid upto DD/MM/YYYY)*	:				
			Town/City:	State & Country:		PIN:
			Landline #:(country, area)			
9.	*Previous Membership*	:	Yes/No	Type of Membership:		Membership No.

10. *Academic Qualifications (Attach a PDF file of the certificate with self-attestation.)*

#	Name of Degree	College/Institute	State	University	Year of Passing
1.	B.Sc./B.Tech./B.E./Eqvt.				
2.	M.Sc./M. Tech./M.E./Eqvt.				
3.	M. Phil.				
4.	Ph.D.				
5.	Post-Doc. Fellow				
6.	Any other (name)				
7.	Any other (name)				

11. *Subject Expertise and Contributions* : Please provide the following information which is needed to create a database of reviewers and experts. Many of you work at the interface between Chemistry and other sciences. You may have expertise in more than one area but basic degree (number 1) in one discipline. Order them according to your interest.

Specialization	Order	Specialization	Order
• Analytical Chemistry		• Solid State Chemistry	
• Inorganic Chemistry		• Theoretical Chemistry	
• Organic Chemistry		• Chemical Engineering	
• Physical Chemistry		• Chemical Technology	
• Green Chemistry		• Physics	
• Industrial Chemistry		• Biological Sciences	
• Polymer Chemistry		• Biotechnology	
• Biochemistry		• Materials Chemistry & Engineering	
• Food Chemistry & Tech		• Natural Products Chemistry	
• Microbiology		• Environmental Chemistry	
• Pharma. Sci & Tech		• Nuclear Chemistry	
• Earth Sciences		• Oceanography	
• Marine Chemistry		• Chemical Physics	
• Agro-chemistry		• Biomedical Engineering	
• Soil Chemistry		• Oil Chemistry	
• Interfacial Science		• Dyestuff Chem & Technology	

			• Textile Chemistry & Tech		• Any other (name)	
12.	**Contributions to Profession**					
12a	**Applicants based in Academia/Research Institutes/Govt. Labs engaged in research and publication, guidance of research students (Fill in part 12a)**					
.	**Research Contributions Statistics on Research and Innovation Productivity (Only numbers, If relevant)**		• International Papers:		• International Patents:	
			• National Papers:		• National Patents:	
			• Conferences Presentations:		• Ph.D. Guided:	
			• Masters' Thesis Guided:		• PDF guided :	
			• Current Masters Students:		• Current Ph.D. Students:	
			• Current PDF:		• Current Project Staff:	
			• Patents:		• Technology Transfer	
			• h index:		• i10 index:	
			• No. of citations:		• Citations per paper:	
12b	**Applicants based in Industry/Business/Ministries/Policy Making Bodies (Fill in part 12b only)**					
	Name of industry				Year of Estab.	
	Name of Govt. Ministry/ Council/Autonomous Body					
	Your current title					
13.	*Membership of professional body, if any*	1.			8.	
		2.			9.	
14.	*Awards & Recognitions, if any*	1.			4.	
		2.			5.	
		3.			6.	

15. *List of Important Publications, if any*

#	Authors (same order)	Title	Journal	Vol.	Year	Pages	DOI	I.F.	Citations
1.									
2.									
3.									
4.									
5.									

16. Payment of Fees: I have made payment by one of the means given below. The details are as follows:

Amount: Date: Proof of Payment: Reference or Snap of Online Payment (Attached)

17a List of Fellows Supporting the Application. If the President/Patraon/ Branch Chair/Past President/Hon. Fellow/Current Council Member invited you to apply then only one name should be written as the supporter. A c.c. of the form should be sent to them for their consent. Please ask them to be a supporter. The office may verify it.

	Whether invited by the President of ICS	Yes/No	Name			
	Whether invited by the Chairman of ICS Branch	Yes/No	Name			
	Whether invited by the Past President or Adviser of ICS	Yes/No	Name			
	Whether invited by the Hon. Fellow of ICS	Yes/No	Name			
	Whether invited by the Current Council Member of ICS	Yes/No	Name			

17b	For others two supporters are needed. The consent to support the applicant can be in the form of a letter or email by the fellow in which case there is no need of any physical signature. The applicant must ensure that s/he has taken the necessary permission from the concerned fellows. The list should be provided as follows:					
	Name	Affiliation	Fellowship No. (if known)	Consent taken	Email	Mobile No.
1.						
2.						

(A) LIFE MEMBERSHIP FEES

1. Life Fellowship: Rs. 6000/- for Indian fellows Plus Rs. 4000/- for subscription to the Journal for 5 years (Total Rs 10000) should be enclosed with the application form (effective from January 1, 2023).
2. Life Membership for Foreign Applicant: US$ 250 for Foreign fellows Plus US$ 50 for subscription to the Journal for 5 years (Total US$ 300). This has to be provided in INR by making online payment. The current amount is: Rs. 25000/- It includes subscription to the journal will be for life.

MODE OF PAYMENT

1. Payable by Multicity CTS Cheque in favour of "INDIAN CHEMICAL SOCIETY "
2. Pay online through the Website: http://www.indianchemicalsociety.com/UserPanel/payment-gateway.aspx
3. Payment by credit/debit card is also possible as given on the website.
4. If payment is done electronically, please intimate ICS immediately after the remittance by sending E-mail or FAX as proof of remittance, and mention it in this application form.

(B) IMPORTANT INFORMATION NEFT/RTGS/ECS

i) Bank Name with abbreviated form.	iii) IFSC Code:
ii) Date of Remittance:	iv) TRFFR No. or UTR No.

(C) NEFT/RTGS/ECS DETAILS

Name of Payee	Indian Chemical Society
Bank Account Number	11152790242
Type of Account	Current
Name of Bank	State Bank of India 294/2/1, Acharya Prafulla Chandra Road, Kolkata-700 009
Branch Name	Manicktala, Kolkata
Brach Code	01715
IFSC Code	SBIN0001715
PAN No	AAAAI 1238H
MICR Code	700002062
IBAN No. or International SWIFT	SBININBB492

****

DECLARATION

I, the undersigned, do hereby engage that, if elected as a Member, I will endeavour to promote the interests and welfare of the Indian Chemical Society and I will uphold its Constitution and observe its laws, rules and regulations, and to the utmost of my power maintain its dignity as long as I shall continue as a Member thereof. After approval of my admission I shall be entitled to avail of the privileges of fellowship as provided in the Constitution and the Bye-laws of the Society. I have filled in the template of the Membership online and there is no spelling mistake of any kind in it.

Place:
Date: *Signature and full name of the applicant*

FOR OFFICE USE ONLY

Recommended /Not recommended for admission as Life Fellow/Member.

Date: *Signature of the Membership Officer*
Details of payment received and date of receipt:
Admitted as Life Fellow/Member with effect from .... by the Council of ICS at its meeting held on ....

Signature of the Accountant *Signature of the Honorary Treasurer* *Signature of the Honorary Secretary*

The name to be printed on the Certificate (to be provided by the applicant)

Please print the following name on my certificate (first name, middle name, last name):

Professor/Dr./Shri./Smt.	
ORCID (if any)	
Membership Number	YYYY-LM

N.B.: It will be copy pasted in the certificate and ICS will not be responsible for any mistakes. . All membership numbers will precede by the year of election. That will help ICS to create a proper database.

INDIAN CHEMICAL SOCIETY

(Centennial Year 2023-24)

92, Acharya Prafulla Chandra Road, Kolkata-700 009

Office M: 91-6289736207

E-mail: ics.correspondence@gmail.com
Web: http://www.indianchemicalsociety.com

Paste a photo or image in JPEG, TIFF format (less than 500 KB)

APPLICATION FOR STUDENT MEMBERSHIP

Membership No.
YYYY-S:

Please read the following instructions carefully before filling information in the application.

1. Student membership is available to any UG, PG or Ph D student of a recognized college or institute in India. The fee is for the entire duration of the programme.
2. This word file can be typed with the signature of the applicant.
3. For online submission of application, make the payment in appropriate currency (depending on affiliation address) online or give DD number and write the transaction details in the space provided. Payment must be made in full otherwise the application will be treated invalid. No application will be considered without full payment of the fees.
4. While uploading the signed form on the website or sending by email, a c.c. should be marked to them. The office will contact them for verification of their support.
5. Make a PDF file and send it by email to the office. Mention in the subject your name and application for the category of student membership.
6. Admission to membership is made by the Council and its decision is final.
7. If hand-written, use block letters and furnish documentary evidence of all the information.
8. If you are using a Word file delete whatever is not required. If the form is filled in ink, strike out it.
9. ICS will use the address for correspondence to send documents. Otherwise all correspondence will be done by email.
10. A student member can subscribe to the Journal of the Indian Chemical Society which will be published by Elsevier, The Netherlands from 2021 and it will be part of the Science Direct. All back issues since 1924 will also be available free.

1.	*Name of applicant*	:	First Name (F)	Middle name (M)	Surname/family name (S), if any		
		:					
2.	*Name to be addressed in correspondence*	:	Shri/Smt				
3.	*ORCID id (Provide it if you would like to publish research articles during your studies). Otherwise it is not mandatory.*	:	0000-0000-0000-0000				
			If you do not have ORCID id, visit www.orcid.org and create it. It is a unique ID used globally for scientific writing and to avoid confusion in similarity of names. It is a sixteen-digit number with a hyphen after each 4 digits.				
4.	*Personal Information*	:	(a) Date of Birth: DD-MM-YYYY		(b)Sex: M/F/T		
			(c) Nationality:	Passport #		Validity :	Yr.
			(d) OCI: Yes/No	OCI #		Validity :	Yr.
5.	*Name of the College/Institute/University*	:					
	Name of the Principal/Director/VC	:					
6.	*Address of College*	:					

1

		:			
			Town/City:	State:	PIN:
			College/Institution website:		
	Telephones	:	Organization: (area)		Ext.
			Direct No. (area)		
	Head of Department to which student belongs:	:	Prof./Dr./Shri./Smt.		
		:	Email:	Tel:	M:
			If the HOD is Fellow of ICS. Yes/No	Membership No.	
7.	*Permanent address of the Student Member*	:			
			Town/City:	State & Country:	PIN:
			Email:	M:	
8.	*Address for Communication*	:			
			Town/City:	State:	PIN:
			Landline #:(country, area)		

10\. *Academic Qualifications (Attach a PDF file of the certificate with self-attestation.)*

#	Name of Degree	Year I	Year II	Year III	Year IV	Projected Year of Graduation
1.	B.Sc.					
2.	M. Sc.					
3.	Ph.D.					

11\. *Specialization* : Tick mark your degree specialization

Specialization		Specialization	
• Analytical Chemistry		• Inorganic Chemistry	
• Organic Chemistry		• Physical Chemistry	
• Industrial Chemistry		• Green Chemistry	
• Polymer Chemistry		• Biochemistry	
• Food Chemistry		• Nuclear Chemistry	
• Environmental Chemistry		• Any other	

12\. Research Publications (if any)

• International Papers:		• International Patents:	
• National Papers:		• Conferences Presentations	

15\. *Awards, Scholarships/Research Fellowships (if any)*

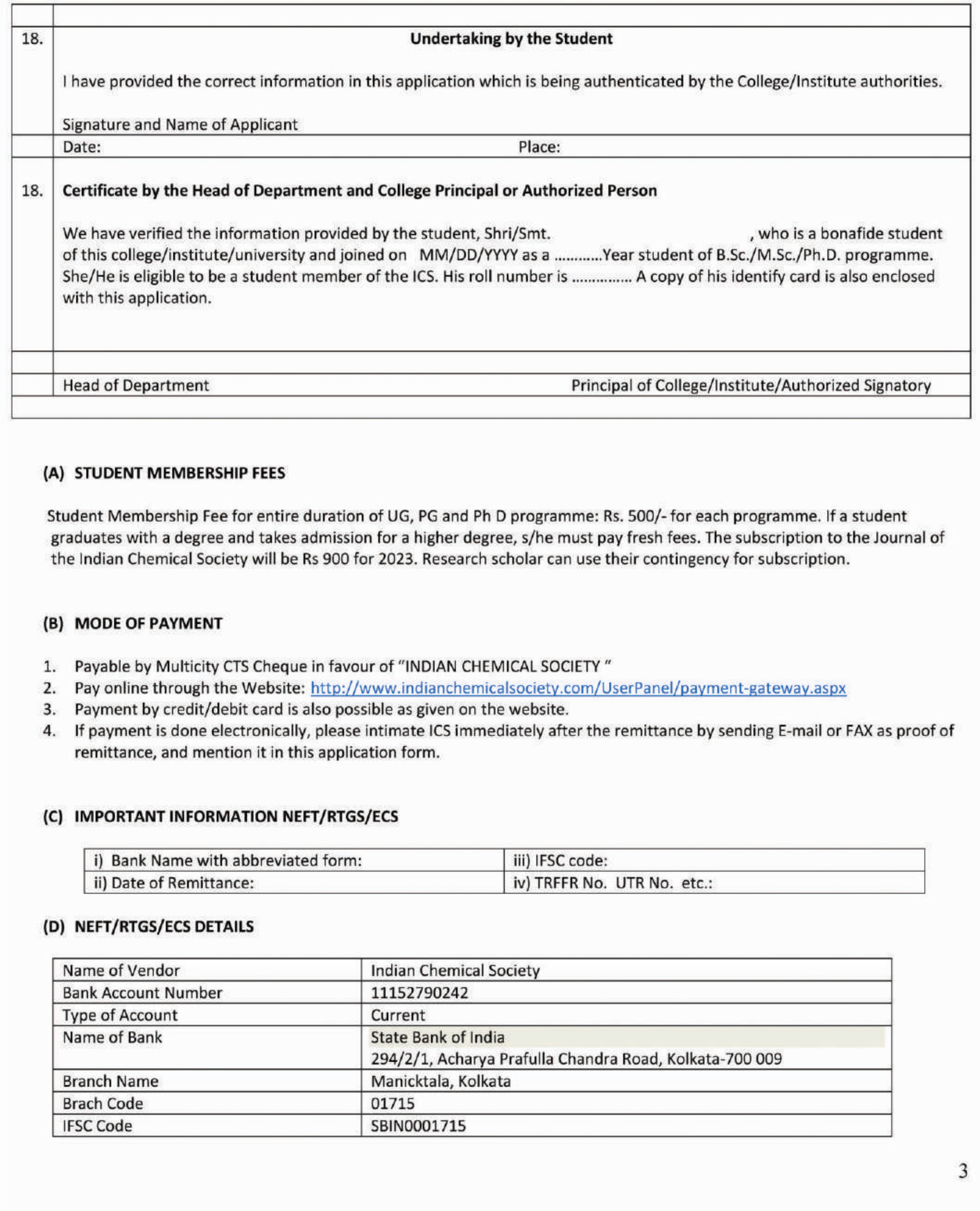
1.		4.	
2.		5.	
3.		6.	

16\. *List of Publications, i*

#	Authors (same order)	Title	Journal	Vol.	Year	Pages	DOI	I.F.	Citations
1.									
2.									
3.									
4.									
5.									

17\. Payment of Fees: I have made payment by one of the means given below. The details are as follows:

Amount: Date: Proof of Payment: Reference or Snap of Online Payment (Attached)



18. **Undertaking by the Student**

I have provided the correct information in this application which is being authenticated by the College/Institute authorities.

Signature and Name of Applicant

Date: Place:

18. **Certificate by the Head of Department and College Principal or Authorized Person**

We have verified the information provided by the student, Shri/Smt. , who is a bonafide student of this college/institute/university and joined on MM/DD/YYYY as a ....Year student of B.Sc./M.Sc./Ph.D. programme. She/He is eligible to be a student member of the ICS. His roll number is .... A copy of his identify card is also enclosed with this application.

Head of Department Principal of College/Institute/Authorized Signatory

(A) STUDENT MEMBERSHIP FEES

Student Membership Fee for entire duration of UG, PG and Ph D programme: Rs. 500/- for each programme. If a student graduates with a degree and takes admission for a higher degree, s/he must pay fresh fees. The subscription to the Journal of the Indian Chemical Society will be Rs 900 for 2023. Research scholar can use their contingency for subscription.

(B) MODE OF PAYMENT

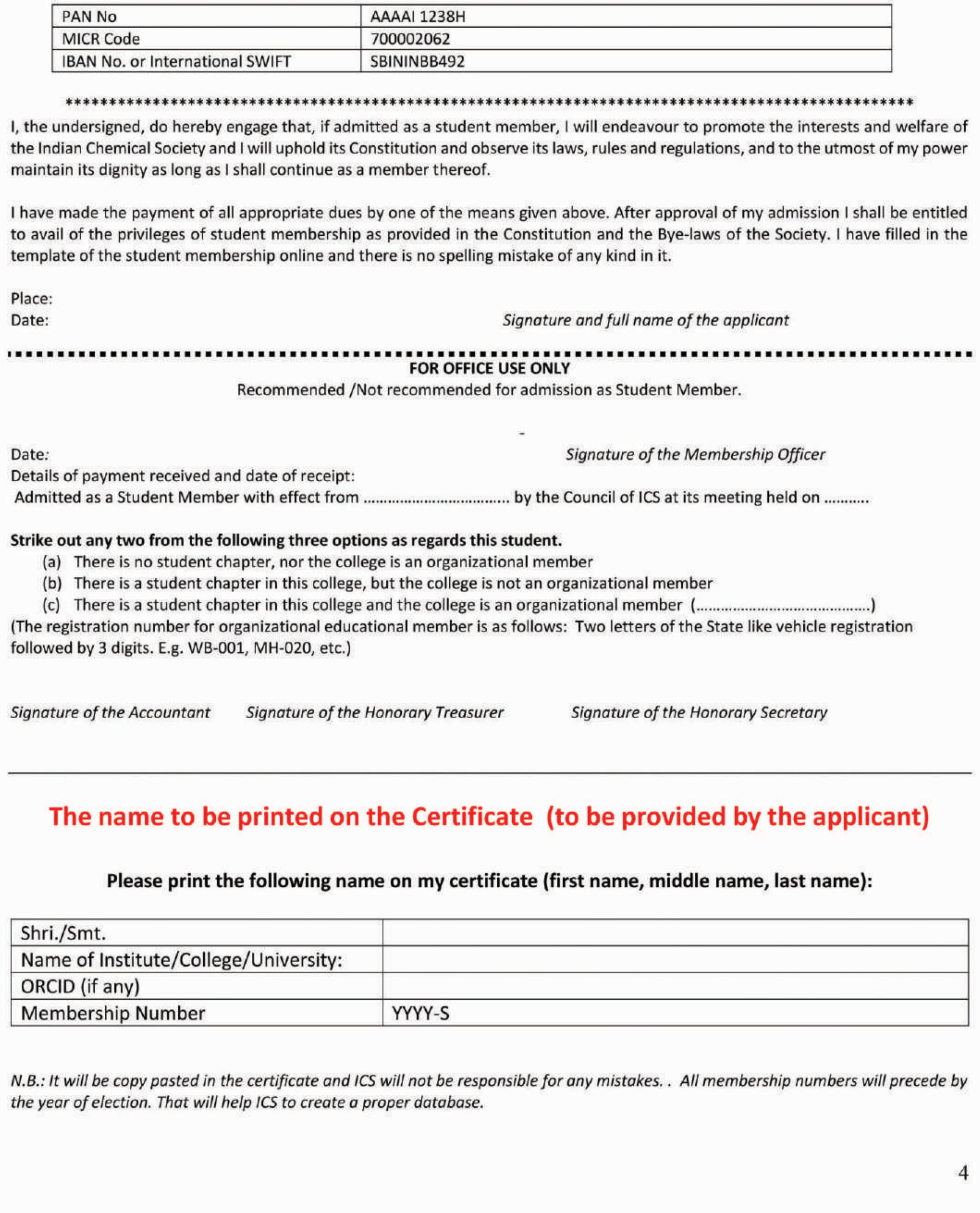
1. Payable by Multicity CTS Cheque in favour of "INDIAN CHEMICAL SOCIETY "
2. Pay online through the Website: http://www.indianchemicalsociety.com/UserPanel/payment-gateway.aspx
3. Payment by credit/debit card is also possible as given on the website.
4. If payment is done electronically, please intimate ICS immediately after the remittance by sending E-mail or FAX as proof of remittance, and mention it in this application form.

(C) IMPORTANT INFORMATION NEFT/RTGS/ECS

i) Bank Name with abbreviated form:	iii) IFSC code:
ii) Date of Remittance:	iv) TRFFR No. UTR No. etc.:

(D) NEFT/RTGS/ECS DETAILS

Name of Vendor	Indian Chemical Society
Bank Account Number	11152790242
Type of Account	Current
Name of Bank	State Bank of India 294/2/1, Acharya Prafulla Chandra Road, Kolkata-700 009
Branch Name	Manicktala, Kolkata
Brach Code	01715
IFSC Code	SBIN0001715



PAN No	AAAAI 1238H
MICR Code	700002062
IBAN No. or International SWIFT	SBININBB492

****

I, the undersigned, do hereby engage that, if admitted as a student member, I will endeavour to promote the interests and welfare of the Indian Chemical Society and I will uphold its Constitution and observe its laws, rules and regulations, and to the utmost of my power maintain its dignity as long as I shall continue as a member thereof.

I have made the payment of all appropriate dues by one of the means given above. After approval of my admission I shall be entitled to avail of the privileges of student membership as provided in the Constitution and the Bye-laws of the Society. I have filled in the template of the student membership online and there is no spelling mistake of any kind in it.

Place:
Date: *Signature and full name of the applicant*

FOR OFFICE USE ONLY

Recommended /Not recommended for admission as Student Member.

Date: *Signature of the Membership Officer*

Details of payment received and date of receipt:

Admitted as a Student Member with effect from .... by the Council of ICS at its meeting held on ....

Strike out any two from the following three options as regards this student.

(a) There is no student chapter, nor the college is an organizational member
(b) There is a student chapter in this college, but the college is not an organizational member
(c) There is a student chapter in this college and the college is an organizational member (..)

(The registration number for organizational educational member is as follows: Two letters of the State like vehicle registration followed by 3 digits. E.g. WB-001, MH-020, etc.)

Signature of the Accountant *Signature of the Honorary Treasurer* *Signature of the Honorary Secretary*

The name to be printed on the Certificate (to be provided by the applicant)

Please print the following name on my certificate (first name, middle name, last name):

Shri./Smt.	
Name of Institute/College/University:	
ORCID (if any)	
Membership Number	YYYY-S

N.B.: It will be copy pasted in the certificate and ICS will not be responsible for any mistakes. . All membership numbers will precede by the year of election. That will help ICS to create a proper database.

4

THE CENTENNIAL FOUNDATION DAY *Celebrations*

of

Indian Chemical Society