THE VISION OF NEP 2020

Integrating Bharatiya Knowledge
System in Chemistry Textbooks

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Vidya Bharati Uchcha Shiksha Sansthan

Vidya Bharati
Uchcha Shiksha Sansthan

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The Vision of NEP 2020: Integrating Bharatiya Knowledge System in Chemistry Textbooks

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PREFACE

Department of Chemistry, University of Delhi organized a two-day offline workshop on "Indian Contribution to Chemical Sciences" jointly with Vidya Bharati Uchcha Shiksha Sansthan and Samvit Foundation as the Knowledge Partner. This workshop was organized on May 6 and 7, 2022. The program was attended by Professors, PGTs and Research Scholars from the discipline "Chemical Sciences". The general idea of this workshop was to make recommendations updating the National Curriculum Framework in tune with the National Education Policy 2020 and simultaneously to bring out the thoroughly deliberated, authentic information of ancient Indian Chemical Practices and knowledge. This workshop was envisioned to deliberate upon the school curriculum for the Holistic Development of Chemistry Students for their Physical, Mental and Spiritual Well-being.

It is no secret that India has the world's most extensive collection of written texts with one of the most vibrant cultures. A piece of literature often functions as both written text and an oral tradition. Indian tradition has permanently attached the highest value to knowledge; all knowledge is constituted in languages. The Indian Knowledge System and languages inspire societies, intellectuals, and philosophers worldwide. However, over the years, there has been systemic neglect of this excellent knowledge repository from the curriculum and textbooks; as a result, young adults are nowhere connected to the roots of this great country. The National Education Policy 2020 has laid a roadmap for 21st-Century India and emphasizes our traditional knowledge systems. By taking Indian knowledge traditions forward, we can fulfil the aspirations of our country.

It is of utmost importance to develop the Indian Knowledge System, cultural awareness and competencies among children and young adults to inculcate a sense of positive cultural identity, pride and belongingness towards this rich reservoir of Indian knowledge wealth. Thus, there is an urgent need for smooth assimilation of the Indian Knowledge System and refocusing on traditions and values in the course curriculum for conservation, promotion and dissemination of this tremendous hidden wealth of India.

ACKNOWLEDGEMENT

We gratefully acknowledge the support and guidance from Sh. K. N. Raghunandan ji, Sanghatan Mantri, Vidya Bharti Uchcha Shiksha Sansthan (VBUSS). His visionary approach in higher education landscape was of great help. We would also like to express our eternal gratitude to the Hon'ble Vice Chancellor Delhi University Prof. Yogesh Singh ji, for his keen interest and support in organising this event. His motivational guidance helped in achieving desired deliberations. Thanks to Prof. K. C. Sharma ji, President VBUSS and Sh. Govind Mohenty Ji (Organising Secretary, VBUSS) for gracing the occasion and motivating the participants by their presence. Grateful acknowledgement to Sh. Prakash Chand ji, Vice President VBUSS, Prof Gurmeet Singh, VC Pondicherry University and Prof. Ramesh C. Bhardwaj, VC Maharashi Valmiki Sanskrit Vishvidyalaya, Kaithal for their inspiring words and presence. Thanks to Prof Shri Prakash Singh, Director South Campus, Prof. Balaram Pani Dean of Colleges and Prof A.K. Prasad, HoD Chemistry for helping and guiding us all through. Thanks to the all the faculty members and Scholars of Chemistry Department for their support and participation in this event.

Thanks to all the resource persons and participants to make this event a meaningful one. We thank Prof. Ruchir Gupta (JNU) and Prof. Lokesh Jindal (JNU) for their constant support and guidance. Time to time help of Prof. V Ramanathan IIT BHU is gratefully acknowledged. We would like to express our cordial thanks to all who helped make this conference a success. The success of this conference was first of all a result of the quality and the motivation of its participants. So, we would like to thank all participants for their presence and contribution to a friendly atmosphere during this event. Our thanks are also due to all the session chairmen, who directed the programme. We are also very grateful to the reporters of each session, whose very consistent reviewing of lectures was of great help. We have much pleasure in thanking Delhi University for financial support and VBUSS for support in travel cost of the resource persons. We are very grateful to the staff of the international guest house for creating hospitable atmosphere for the Resource Persons and offering very good services. Our very special thanks go to all who so graciously accepted our invitation to participate at the workshop. Last, but not least, we would like to thank all chairmen of the respective sessions and all members of the Scientific and the Organizing committees. Without their tireless efforts the workshop would not have been possible. Our Sincere thanks to Sh. Ankit Suri and Sh. Abhishek Saxena for their constant support all through this planning and program. I thank the organizing committee members for making this event a reality.

The organizing committee on behalf of University of Delhi and VBUSS wishes to acknowledge the motivation, support and encouragement that we have received and from many other individuals, who helped in organizing this workshop. Samvit Foundation is also acknowledged for guiding and giving this workshop a desired shape. The advice received from Sh. Gajanan Ji was of great help in organizing the academic program in the workshop.

Finally, I, on behalf of the organizers and on my own behalf thanks the participants and the respected guests for making this event a meaningful workshop of Ancient Chemistry.

Prof. Raj Kishor Sharma
Prof Subho Mozumadar
Prof. Rakesh Kumar Sharma
Prof Saroj Shukla
Prof. R.K. Soni
Sh. Sandeep Kumar
Dr. Ankita Singh
Dr. Mansi
Dr. Bhaskar
Dr. Anamika
Mr. Deepak Kumar
Ms. Diksha

Eminent Resource Persons of the Workshop

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4.	Prof. V. Ramanathan	Professor	Department of Chemistry, IIT BHU, Varanasi
5.	Dr. Geetha Sudheer	MD (Pediatrics)	MS, MD (Pediatrics), M Sc, PhD
6.	Prof. Ramesh Gardas	Professor	Department of Chemistry, IIT Madras
7.	Prof. Raj Sharma	Professor	Chemistry Department, University of Delhi
8.	Prof. Anil Bhalekar	Professor	R T M University, Nagpur, Maharashtra
9.	Prof. S. K. Shukla	Professor	Department of Polymer Science, Bhaskaracharaya College of Applied Science
10.	Prof. R.K. Soni	Professor	Head Chemistry, Ch. Charan Singh University Meerut
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Chapter 1

NATIONAL EDUCATION POLICY (NEP) AND INDIAN KNOWLEDGE SYSTEM

This workshop was planned to include Indian contributions in chemistry containing materials and metallurgy in the school textbooks. Under NEP-2020, the educational framework is revised as 5+3+3+4, where chemistry exclusively features in the last stage, which includes classes 9, 10, 11 and 12 in the current system. The recent exposition of chemistry content in the NCERT textbooks has almost no historical range. Be that as it may, what is more, worrisome is that these textbooks fail to convey even an iota of the scientific achievement of our ancient Indians, particularly in chemistry. It is a brainer that the chemistry we study and teach is modern chemistry having European origin.

Nevertheless, if the textbooks fail to inform the scientific achievements of our forefathers, it will be highly detrimental to the cause of NEP 2020, which espouses rootedness in a big way in several instances of the document. To achieve this rootedness and to instil genuine pride in the scientific achievements of our forefathers, it is envisaged that wherever possible, we will try to educate our children about the accomplishments in chemistry. Therefore, in this workshop, attention was given to neither pandering to jingoism/tokenism by alluding to simple hearsay nor relegating valuable contributions as sporadic acts of accidental instances. Authenticated results from our rich past are given credence and recommended for the textbooks.

The idea behind introducing India's knowledge system in NEP is to implant in students a rootedness and pride in India and its "rich, diverse, ancient and modern culture and knowledge systems and traditions". Students/learners should take a deep-rooted pride in being Indian, not only in thought but also in spirit, intellect, and deeds. They must develop knowledge, skills, values, and dispositions that support responsible commitment to human rights, sustainable development and living, and global well-being, thereby reflecting a truly global citizen. The most important pillar of the Indian Knowledge System is its rich heritage of ancient and eternal scientific knowledge. The workshop discussed the possibility of adding curated Indian scientific expertise to the NCERT Chemistry books. Thus, the young minds would understand the contribution of Indians and their tradition to Chemistry.

Until and unless we generate curiosity amongst our students about chemistry, we will not be able to achieve the objective of NEP 2020. Eventually, chemistry's role in day-to-day life should be incorporated into our books with illustrations and examples, preferably from the Indian context. At the same time, unsubstantiated content must not find its way into textbooks to pay tokenism to Indian contributions, which will be highly counterproductive. Only authentic, scientific and well-established facts, which are aplenty, must be included in the chemistry textbook, which will arouse curiosity in the impressionable minds but will also adequately root them to the Indian contributions in chemistry.

Thematic Area

India has a long history of scientific thought. It has a fair share of enriching the world's material culture. There are enough shreds of evidence of knowledge and practices of chemical sciences. Early literature has plenty of data on mines and minerals (ores of gold, silver, iron, copper, lead and tin). Besides, Information on various characteristics of precious stones like pearls, rubies, etc., is also available.

Further, the details of fermented juices such as honey, jambu, sugarcane, jaggery, jackfruit, mango, etc. and techniques for oil extraction have been discussed in early text with their uses and characteristics. Dated a few centuries CE, the information provided in Caraka Saṃhitā and the Suśruta Saṃhitā details the broader use of chemicals for medical/pharmaceutical use. Different alkalis (kṣāra) are described as among the 'ten arts' (kalā). Alkalis were defined as mild, caustic or average and had a herbal origin. Varāhamihira's Bṛhat Saṃhitā (6th century CE) describes the perfumes prepared from 16 essential substances mixed in a different ratios. Perfume & cosmetics making was the primary chemical practices in classical & medieval India. Bṛhat Saṃhitā has numerous recipes, for example, the fabrication of glutinous material for building construction. Several texts are available on traditional 64 arts. Among them are the techniques of gold and silver coins making, jewellery and gem; mineral and metallurgy, Metallic colours, flames, coatings etc. are described. The Ancient literature suggests several exciting practices of value in today's advanced world.

Indian custom has permanently attached to the knowledge, constituted in different languages. The world is greatly inspired by the Indian knowledge System practices and beliefs. But, over the years, this excellent knowledge has not received due consideration in the curriculum and school textbooks, leading to a disconnection of our young adults from the origins of our society. This workshop attempts to recreate our traditional knowledge to connect our past with the present youth.

Therefore, this workshop aimed at inviting experts knowing ancient Indian chemistry to deliberate on the ancient literature. To authenticate and give credence to the valuable information and bring recommendations text for inclusion of Indian Ancient knowledge in NCERT Chemistry books.

The workshop was attended by more than 150 chemistry Professors, PGTs and Research Scholars. Many unknown ancient works were discussed to bring out the knowledge of the chemical community. Participants learnt that much text material is available as a collection of ancient Indian knowledge of chemical sciences. Many professors and teachers were enlightened to see the literature available in the field. Participants presented their ideas during the discussion hours/ interacted with the resource persons, took note of the literature material and requested that this kind of workshop be organised frequently after a period of interval. They should be allowed to present their research in ancient Indian contributions.

Another impact of this workshop is that other subjects in our university have also started planning to organise such events and write recommendations for the Indian Knowledge System. The Chemistry Department, Delhi University is organising an international conference to discuss the contribution of Acharya P.C. Ray on his birthday, i.e. August 2nd. The Physics Department of Delhi University is planning to organise a similar conference to discuss the works of ancient physics.

Besides highlighting authentic and technically correct ancient texts on Chemistry, these efforts have also motivated to instil a sense of pride in Chemistry teachers and students to teach Indian academic values to the coming generation.

CHAPTER – 2

EXTRACTS OF 331st REPORT: REFORMS IN CONTENT AND DESIGN OF SCHOOL TEXT BOOKS[1]

Department-Related Parliamentary Standing Committee on Education, Women, Children, Youth and Sports has presented the "Three Hundred and Thirty First Report of the Committee on "Reforms in Content and Design of School Text books". The report focuses on:

- Removing references to un-historical facts and distortions about our national heroes from the text books;
- Ensuring equal or proportionate references to all periods of Indian History;
- Highlighting the role of great historic women achievers.

The relevant highlights of the report are given below

- The report elaborates upon National Curriculum Framework that will provide roadmap for the development of new generation of textbooks providing more space to experiential learning for bringing in students the conceptual clarity and motivate students

1 This report was presented by Dr. Vinay P. Sahasrabuddhe, Chairman Department-related Parliamentary Standing Committee on Education, Women, Children, Youth and Sports on 26th November, 2021

for self-learning and self-assessment to improve not only cognitive skills but also the social -personal qualities.

- New NCF for School Education will guide the development of new generation textbooks across the subject areas. The new generation textbooks across subject areas will take care of the thematic, inter-disciplinary and multi-disciplinary approaches to highlight Indian culture and traditions, national heroes including women achievers and great regional personalities besides providing coverage to different phases of Indian history.
- NCF must focus on restructuring of stages of curriculum and pedagogy as 5+3+3+4, more focus is on Early Childhood Care and Education and Foundational Literacy and Numeracy, Integration of Pre-vocational Education from classes 6 to 8, Integration of Knowledge of India across the stages, focus on the holistic development through experiential learning, flexibility in choice of subjects etc.
- The report further informs about new ways for promotion of experiential learning, art integrated learning, sports integrated learning and competency-based learning, including internships, 10 bag less days, peer tutoring, interdisciplinary and multidisciplinary projects and development of fun-based student appropriate learning tools to promote and popularize Indian arts and culture etc.
- It also highlights different pedagogies such as group discussions, mock drills, excursion trips, visits to various places, such as zoo, museum, local store or restaurant; field study, classroom interactions, etc. were also being used to support experiential learning. Also, opportunities were provided to break subject boundaries by integration of art forms (visual or performing arts, such as dance, design, painting, photography, theatre, writing, etc.), stories, pictures, fun activities or games, sports,

etc. for holistic learning of concepts of science and mathematics without burden.

- It further states that the future syllabi and textbooks will be based on goals and competencies which will lead towards mapping of core essentials with competencies hence lessening the curriculum burden and focusing on holistic learning and development. The curriculum and syllabi should provide lots of space for experiential learning and textbooks will be based on competencies rather than content.
- NEP, 2020 recommends integration of knowledge of India across the stages and subject areas in the curriculum. Under this concern, as per the directions of new National Curriculum Framework for school education, various activities including development of digital and audio-video materials will be taken up.
- Thematic, interdisciplinary and multidisciplinary approaches to highlight Indian Culture and Traditions, our National Heroes including women achievers and great personalities from different regions of the country and perspective of equity, integrity, gender parity, constitutional values and concern for environment and other sustainable development goals.
- Experiential Learning through projects and age-appropriate activities, simple language, glossary, more in-text and end-text assessment questions and reduction of curriculum load to core essentials.
- All textbooks will be visually rich with illustrations, photographs, maps, etc., the illustrations and activities will be age/class appropriate. Local flavor will be added to the core essentials in textbooks of the States, to showcase the diversity of the country.
- Local flavor will be added to the core essentials in textbooks of the States, to showcase the diversity of the country. NCERT

has been working towards bringing dictionary on Indian sign language, which will help in developing material in sign language. The upcoming books and other materials based on the new NCFSC will follow the same pursuit in future.

- More emphasis on role of women: Role of women as rulers, their role in knowledge sector, social reforms, Bhakti movement, art and culture, freedom struggle **(Jnana Prabodhini, Pune)**. Coverage of great historic women heroes belonging to different periods of Indian History including Gargi, Maitreyi, rulers like Rani of Jhansi, Rani Channamma, Chand Bibi, Zalkari Bai etc. will be taken up in the new textbooks, supplementary materials and e-content.
- National initiatives such as Swachh Bharat, Digital India, 'Beti Bachao Beti Padhao', 'Demonetization', GST etc. were integrated in the new textbooks in the review of syllabi and textbooks in 2017-18. Contents were added in history textbooks regarding knowledge, traditions and practices of India. For example, addition of material on Vikram Samvat, Metallurgy, Shivaji Maharaj, Paika revolt, Subhash Chandra Bose, Swami Vivekanand, Ranjeet Singh, Rani Avantibai Lodhi and Sri Aurbindo Ghosh.
- The objective of teaching history was to instil high self-esteem in students, National Renaissance, National unity, Social Inclusion and establish links with cultural roots. Thus following points are to be kept in mind while writing text books:
    - Depicting cultural unity
    - Linguistic heritage- importance of Sanskrit, Prakrit and Pali for national unity and international spread.
    - Linking Indian languages.
    - Civilization development -Vedic to present.

- ○ Comparison of scientific temper with other civilizations on scientific and objective ground.
- ○ History of sacrifices of various segments of Indian society for saving cultural values.
- ○ Social inclusion.
- ○ India and its cultural boundaries.
- ○ Civilization proofs of India in other countries of the world.
- ○ Religio-cultural emissaries from India should have proper place.
- ○ Local, national as well as international influence of any event or thought should be highlighted. **(Bharatiya Shikshan Mandal, New Delhi)**

- The representatives of **Vidya Bharti** also put forth their views on the subject and pointed out certain factual distortions about vedic tradition, incompatibility of certain facts with constitutional ideals and values in the school textbooks. They suggested a thorough review and removing of such distortions/ discrepancies from the school textbooks. They also mentioned about 'My NEP' programme launched to reach non-academic people and to make them learn about the things in the National Education Policy in a nutshell.
- Inclusion of History of North East India: Bhakti and social movements in Assam and Manipur, tribal heroes who fought against British, contribution of Arunachal and Manipur with reference to Azad Hind Fauj and 1962 war, dynasties in Assam, Manipur, Tripura, Meghalaya. **(Jnana Prabodhini, Pune)**
- Post-independence History of Indian pride also needs to be stressed: Story of ISRO, story of BARC, story of cooperative movement (Story of Amul), story of restorations (Somnath, Hampi, archaeological sites such as Lothal) etc. **(Jnana Prabodhini, Pune)**

- The Design of textbooks should be:
  - Curriculum of history can be organized in an ascending order. The scope of curriculum grows with the growth of experience sphere of students from local to global.
  - Digitization of textbooks to make them attractive and dynamic document to go beyond text/ printed form: need to add audio-visuals with QR codes.
  - Inclusion of intellectual games, simulations. VR Games modeled to let students experience the historical times (for example 'Real lives') **(Jnana Prabodhini, Pune)**
- As far as the Modern period is concerned, some leaders have received more weightage as compared to others. The role of Subhash Chandra Bose, Sardar Patel, Bhagat Singh, Ram Prasad Bismil, Lala Lajpat Rai, Khudiram Bose, Surya Sen, and even the women revolutionaries must be highlighted. The contribution of Veer Savarkar needs to be given enough weightage. **(Public Policy Research Centre, New Delhi)**
- The representatives pointed out that proportionate representation across Region, Time Period, and Events should be given in the Textbooks. South and East Indian dynasties have been highly under-represented. The history of great kingdoms like the Marāṭhas, Coḷas, and Vijayanagara as well as the early Kāśmīra dynasties, Kaliṅgas, Gaṅgas, Gajapatis, Kākatiyas, Ahoms, Ceras, Pallavas, Pāṇḍyas, Pālas, Senas, and Pratihāras either get a passing mention or not even that. The crucial role they played in our history must be elaborated. They further added that we must include these dynasties, which represent the very spirit of Bhāratīya Civilization that the Radhakrishnan Committee wanted every student to imbibe. **(Samvit Research Foundation, Bengaluru).** The following points were further added:

- Bhāratīya saṃskṛti has been widespread from Mesopotamia in the West to Japan in the East, from the Himalayas in the North to Indonesia in the South
- The Zend Avesta has significant relationship with the late Ṛigvedic period
- Our Itihāsas and Purāṇas, particularly the Rāmāyaṇa, have been an integral part of the culture of many regions of Southeast Asia.

• The representatives also added that the history curriculum hardly emphasizes the role played by women in our history. It is important for students to learn –
  - the importance our civilization has given to women and how women participated in all aspects of life over the centuries
  - the freedom and opportunities available to women in public life
  - the great achievements of women from ancient times until the present day
  - the temporary changes in status of women in the wake of invasions
  - to progressively appreciate that our paramparā has a beautiful and holistic perspective of strītva that is far beyond modern formulations.

• They further suggested that this can best be accomplished by exposing the children to factual information from the past:-
  - Introduce the three great goddesses of the Vedas – Bhāratī, Ilā, Sarasvatī. Introduce a few Veda-suktas for which women are the mantra-draṣṭāriṇīs. In the Vedic period, mention woman scholars, brahmavādinīs, and mantra-draṣṭāriṇīs, including instances of where women learnt the Vedas.

- ○ Present the dynamic role played by women in the Rāmāyaṇa and Mahābhārata. Give a complete picture of women-related references in the smṛtis.
- ○ Portrayal of women in various classical literary accounts (e.g. Kālidāsa's Mālavikāgnimitra) that indirectly shows how the society was shaping up at that time.
- ○ The critical contributions of queens in every century and every region across communities. Prominent rājamātas who played a role in shaping their children as rulers; important women warriors, scholars, poetesses, philanthropists, public personalities, sanyāsinīs, philosophers, saints, and freedom fighters

- The Committee is of the view that there should be an appropriate comparison of the portrayal of women heroes like Rani Laxmi Bai, Zalkari Bai, Chand Bibi etc vis-a-vis their male counterparts. The Committee observes that the women heroes from different regions and eras should be given equal weightage highlighting their contributions in the history textbooks.
- The Committee also observes that notable women in all fields, and their contributions, like that of Ahilyabai Holkar, Abala Bose, Anandi Gopal Joshi, Anasuya Sarabhai, Arati Saha, Aruna Asaf Ali, Kanaklata Deka, Rani Ma Guidinglu, Asima Chatterjee, Captain Prem Mathur, Chandraprabha Saikini, Cornelia Sorabji, Durgavati Devi, Janaki Ammal, Mahasweta Devi, Kalpana Chawla, Kamaladevi Chattopadhyay, Kittur Chennamma, M. S. Subbulakshmi, Madam Bhikaiji Cama, Rukmini Devi Arundale, Savitribai Phule and many others have not found adequate mention in NCERT textbooks.
- The Committee observes that generally Women are underrepresented in school textbooks, many a times shown through images in traditional and voluntary roles, leading to

formation of gender stereotypes in the impressionistic minds of students and feels that there is a need to undertake an analysis of the textbooks from the Gender perspective as well.

- The Committee observes that in the suggestions received regarding updation of NCERT books, emphasis was laid on providing equal representation to the North-East Indian States and the History. It was suggested that developmental models and economic policies should have sections dealing with and talking about the complex realities and demographics of the North-East along with the history of civilizations and tribal communities of the North-eastern region. Furthermore, the textbook content should also ensure adequate balance in representing Hill areas and Plains areas so as to recognise both communities adequately.

Subject Experts

Prof. J.S. Rajput, Former Director, NCERT in his submission before the Committee stated that Reforms in the content and design of Textbooks should focus on the following aspects:

a. Distortion of historical facts where one ruler is remembered and other equally prominent one's finds no mention.

b. Not only periods, history must be just and objective to considerations of regional imbalances, historical contributions of the communities, people and practices.

c. Social and cultural distortions must not be presented by those bound by prejudices and biases.

He stated that the content and design of textbooks is a product of Policy on Education, Curriculum Framework to be developed after its sensitive comprehension, followed by the process of preparing detailed syllabus for each textbook; for each grade /class. The quality and content of the textbook shall depend on the quality of the authors; that include depth, seriousness, professional competence and commitment of individuals and institutions assigned the task. A good textbook can be authored only by those who are lifelong learners.

It was emphasized that National level textbooks are essential for several reasons, but it must be remembered that local element of curriculum also cannot be ignored. A class three textbook on environmental education just cannot be same in Tripura and Thiruvananthapuram. Hence, it is necessary to strengthen expertise and institutions at the State level. We need high level experts in textbook writing, evaluation, assessment, growing up, guidance, and all that children could need. now education is not only about/through textbooks, but textual materials for online learning, self-learning, digital learning, open and distance learning, and a couple of other terms that are in vogue. It has to be hybrid teaching and learning in future. Things have changed drastically in 2020, and some of the impacts shall continue in future as well.

New discoveries are taking place, new facts are coming up, and textbooks just cannot remain the same. This is worsened if the history is written with certain pre-conceived biases resulting out of politically-constrained ideological bindings. History writing in India has suffered on these unacceptable considerations, and it must be extracted - and liberated -out of gross subjectivity and ideological bias to transparent objectivity, and openness of mind, willingness to enter into dialogue with those holding diametrically opposite views. New facts have emerged around us; say; Aryan Invasion theory, Saraswati River, Ram Setu, and so many more solely because of new scientific advancements and new tools that have led to new researches. These just cannot be ignored in preparing new textbooks. ndian history writing needs a thorough professional review. As it was determined to highlight certain individuals, regimes and eras, it suffers from serious imbalances of every possible type. He further pointed out the British tried to downgrade the great contributions of ancient India in philosophy, science, mathematics, spirituality, medicine and other fields and it was continued to be neglected in our textbooks. While considerable initiatives were taken for removing gender bias and caste discriminations, history writing remained confined to the hegemony of a select group of few academics for over five decades. The post- independence history books are deficient on 'linking Indians to India'; and this includes history, heritage and culture. In fact, this aspect needs serious informed and scholarly deliberations before textbooks are prepared in response to the NEP-2020.

The second most important aspect that no textbook writer could ignore pertains to the need for strengthening social cohesion and religious amity. Racial discrimination and caste considerations - in varied connotations – have not vanished fully even in what are known as most advanced societies. We must accept that these challenges still exist even before us; and these require an attitudinal transformation. Our Children must know that different religions are a reality, that no religion could claim superiority over any other.

Shri Hukmdev Narayan Yadav, Ex-MP, Lok Sabha emphasized the importance of the subject and suggested for detailed discussion with more stakeholders and eminent educationists. The focus should not 'be only on facts and figures while writing Indian history but it should focus on the deep essence of the nature of Indian history in order to make it more understandable.

Shri Shankar Sharan, Eminent Educationistal so deposed before the Committeeon the above subject and highlighted various topics for inclusion/ exclusion in NCERT text-books. He drew the attention of the Committee Members as to why the text-books had references to unhistorical/ distorted facts and why a section of intellectuals insisted on keeping it. Focusing on this will only help in removing such discrepancies.

Recommendations

In view of the evidences gathered throughout the process, the Committee strongly recommends that:

- While creating the content for textbooks, inputs from experts from multiple disciplines should be sought. This will ensure balance and diversity of views. It should also be ensured that books are free of biases. The textbooks should instill commitment to values enshrined in the constitution and should further promote national integration and unity.
- There is a pressing need to develop high-quality textbooks and effective teaching methods. Thus mandatory standards related to text-book content, graphics and layout, supplementary materials, and pedagogical approaches should be developed. Such standards are needed for printed as well as digital textbooks.
- There is a need to have more child-friendly textbooks. This is possible through enhanced use of pictures, graphics, QR codes, and other audio-visual materials. Children should be taught through enhanced used of games, plays, dramas, workshops, visits to places of historical importance, museums etc. as such approaches will ignite their inquisitiveness and analytical abilities.
- The initiative of Maharashtra State Bureau of Textbook Production & Curriculum Research known as Ekatmik Pathya Pustak conceived in 2018-19 to lighten the school bag is appreciable. Towards this, the Bureau has created quarter-specific integrated material for Marathi, English, Mathematics and ‘Play, Do, Learn’ for Class I students into a single book. A similar approach may be adopted by others. Such initiative will be aligned to the School Bag Policy of New Education Policy (NEP), 2020 as laid out in Section 4.33.

- Education must be provided in the light of values enshrined in the constitution which cannot be taught by mere delivery of information. The pedagogy woven around textbooks has a lasting impact on the minds of the student and hence learning-by-experiment methodology should be compulsorily used by all teachers. Such an approach will enhance positive attitude towards learning amongst students.
- The prioritization of development of foundational skills amongst primary students is required by the NEP-2020, and therefore necessitates the use of information technology and digital devices. Therefore, digital content should be created and disseminated using satellite technology to enhance our students' capabilities and potentials. Such approaches will further curriculum reform and will also help develop more effective operational models for content delivery, and learning. Introduction of modern technologies/ methodologies for the dissemination of information as part of teaching strategies should be undertaken preferably after enabling the possibility of the same uniformly in every part of the country. Schools in remote corners of the country should be suitably equipped for the same.
- The primary school textbooks should serve two purposes; provide strong foundation in core areas such as reading, writing and arithmetic, and provoke curiosity so that students can rapidly expand their knowledge in later years. This is also in alignment with NEP 2020's goal of promoting competency-based learning.
- The NCERT and SCERTs should primarily focus on providing core content through their textbooks. Detailed information and supplementary materials may be provided

through other texts, videos, reference books, A/V files, etc. Further, textbooks should be anchored in facticity. Any presentation of data or survey results should be appropriately referenced. Textbooks should be designed to provoke curiosity and analytical abilities, should be tuned to cognitive capability of the student, and should employ simple language. Further, efforts should be made to design textbooks in ways such that project-based, art-integrated, and experiential learning models can be deployed for effective education. In this way, our textbooks will promote scientific temper, innovation, and also the four Cs; Communication, Collaboration, Creativity, and Critical Thinking.

- The Ministry should explore the possibility of developing a core class-wise common syllabus for various subjects for implementation by CBSE, CICSE and various other State education Boards as this will go a long way in maintaining uniformity in educational standards of school students across the country.
- Our textbooks should highlight the lives of hitherto unknown men and women from different states and districts who have positively influenced our national history, honour, and one-ness. This may require content production teams to dig deeper into local sources of knowledge, including oral ones, and identify linkages between the local and the national. In this way, our textbooks should elicit "Unity in Diversity" of India emphasizing that diversity in India is in fact diverse manifestation of the innate one-ness or intrinsic unity.
- The textbooks should include content on world history and India's place in the same. In this regard, special emphasis must be placed on the histories of other countries of the

world. This is aligned with international guidelines which argue for study of history through a multi-perspective approach. Further, sufficient emphasis must also be placed on the connects between histories of South-East Asia and India. This would be very useful in the context of India's Look East policy.

- Our history textbooks should be continually updated, and account for post-1947 history as well. In addition, an option of conducting review of National Curricular Framework at regular intervals should be kept.
- The Department of School Education & Literacy and NCERT should carefully study how other ancient civilizations/ countries teach their own histories to their respective citizens through textbook content, and areas of emphasis. The results of such a study should be used to improve our own history textbooks and teaching methods taking into consideration history at the grassroots level preferably at the district levels. Further, the State Boards may prepare district-wise history books that will impart knowledge about local historical figures to the students.
- The NCERT should consider the suggestions received by this Committee, while framing the NCF and syllabus of the textbooks. For avoiding content overload on students, NCERT in collaboration with SCERT should identify State-specific historical figures for inclusion in respective SCFs. Efforts may also be made to incorporate and highlight the contributions of the numerous local personalities in various fields in State curriculum.
- The NCERT and SCERT should incorporate the ancient wisdom, knowledge and teachings about life and society from Vedas and other great Indian Texts/ Books in the school

curriculum. Also, educational methodologies adopted in the ancient Universities like Nalanda, Vikramshila and Takshila should be studied and suitably modified to serve as a model reference for teachers so as to benefit them in improving their pedagogical skills for imparting education in the present day context.

- Contributions of ancient India in the fields of Philosophy, Science, Mathematics, Medicine, Ayurveda, Epistemology, Natural sciences, Politics, Economy, Ethics, Linguistics, Arts, etc may also be included in the textbooks. The traditional Indian knowledge systems should be linked with modern science and presented in the contemporary context in NCERT textbooks.
- New technologies should be adopted for better pedagogy for the education of History. Further a permanent mechanism to make suitable rectifications through additions or deletions in the textbooks in a structured manner needs to be established.
- All books especially history books other than published by Government agencies used for supplementary reading may be in consonance with the structure/ content of NCERT books to avoid discrepancies. Also, Ministry of Education should develop a monitoring mechanism for ensuring the same.
- There is a need for discussing and reviewing, with leading historians, the manner in which Indian freedom fighters, from various regions/parts of the country and their contributions get place in History textbooks. This will result in more balanced and judicious perception of the Indian freedom struggle. This will go a long way in giving due and proper space to the freedom fighters hitherto

unknown and oblivious in the freedom movement. Review of representation of community identity based history as of Sikh and Maratha history and others and their adequate incorporation in the textbooks will help in a more judicious perspective of their contribution.

- In order to address the underrepresentation of Women and girls in school textbooks or them being depicted only in traditional roles, a thorough analysis from the view point of gender bias and stereotypes should be undertaken by NCERT and efforts be made to make content portrayal and visual depiction gender inclusive. The textbooks should have greater portrayal of women in new and emerging professions, as role models with a focus on their contributions and pathway of achieving the same. This will help in instilling self-esteem and self confidence among all, particularly girls. Also, while examining the textbooks, other issues like environment sensitivity, human values, issues of children with special needs etc can also be looked up for adequate inclusion in the School textbooks.
- The significant role played by women in the freedom movement and in various other fields needs adequate representation in the textbooks as it would go a long way in understanding the issues in a better way for the next generation of students.
- One of the major social ills afflicting our society in the present times is the malaise of drug addiction cutting across the class divide. It has far-reaching adverse effects on the socio-economic structure of the country, and that concerted efforts are required to be made by the government agencies as well as the civil society to combat this menace. As part of these efforts, the ill effects of such addiction must be

adequately and suitably highlighted in strong words, in the content of school text books to caution the impressionable young minds of students against falling prey to luring tactics of anti-social elements and resulting in waywardness. Similarly, the textbooks should have separate elements spreading awareness against internet addiction and other such aspects that are harmful to the society.

- Taking into account the voluminous number of suggestions received from teachers, students, Institutions for updating the syllabus of NCERT textbooks incorporating various subjects, an internal Committee be set up by Ministry of Education and NCERT to examine the suggestions so received and incorporate the same in curriculum as deem fit.
- All NCERT and SCERT textbooks must be published in all Eighth Schedule languages of the Constitution of India, besides Hindi and English. Further, efforts for developing textbooks in local languages (those not part of the Eighth Schedule) be also made. These will help the children in understanding the subjects better as the content will be in their mother tongue.
- To supplement the textbook content, field visits/ excursions should be introduced as a compulsory part of learning experience. As an initiative in this regard, textbooks can introduce a “Box Format” near the name of the place being mentioned stating the importance of that place whether religious, historical, etc. promoting the readers to visit it. This would further promote North-South and East-West integration.

Chapter–3

NEP & DEVELOPING NEW TEXT BOOKS[1]

Prof. Chand Kiran Saluja
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Prof. Chand Kiran Saluja emphasizes upon the various aspects of New Education Policy- 2020 such as building a culture of reading across the country. NEP-2020 has focused upon the development of curriculum, syllabus and textbook and it envisions a new way of learning which is not merely text book focused. Earlier, NCF 2005 had also mentioned that learning should be active rather than textbook centric only. Textbooks as a single source of education are not enough; they are important but are not only a teaching material. Therefore, a large number of packages should be developed at State and District levels with adequate provision for cluster and school level modifications and supplementary materials. To understand a textbook one needs to understand the curriculum and the aims of education. The present-day classroom practices

1 Based on the Keynote Address delivered by Prof. Chand Kiran Saluja in the Prparatory Workshop on Textbooks: Indian Knowledge System and Languages organized by VBUSS on 3rd & 4th February, 2022 and Keynote Lecture in the Two-day National Workshop on Sanskrit in the light of NEP 2020 & Indian Knowledege Systems organized by Central Sanskrit University, Delhi and Shri Lal Bahadur Shastri National Sanskrit University, Delhi on 4th & 5th June 2022.

are, in almost all schools of the country, totally dominated by the textbook. As a result, it has acquired an aura and a standard format. What is needed is not a single textbook but package of teaching learning method and material that could be used to engage the child in active learning. The textbook thus becomes a part of this package and not just a teaching learning material e.g., it connects the past with the present and should lead to experiential learning which means taking classroom to the field and vice versa. Therefore, a large number of packages should be developed at state and district levels with adequate provision for cluster and school level modifications and supplementary materials. This essentially means establishing proper coordination between the textbook designing committees at national and regional levels. The establishment of NCERT and SCERT are the part of this purpose only. The cluster system envisaged in the NEP, 2020 is also a part of this exercise. The availability of a number of alternative TLM packages of approved quality to the increased choice of the teachers may go a long way in introduction of IKS. To understand the textbook, one must understand the relationship between the curriculum and aims of education. There is a difference between curriculum and syllabus. The syllabus is something that is taught to the student in the classroom but curriculum involves vast level of activities including the syllabus. In simple terms, the curriculum starts from the moment a student enters the school environment and continues to be involved into till the end of the school hours and thereafter too in the form of doing various activities given by the teachers. Part I of the NEP, 2020 document outlays various objectives of education.

Textbooks are to be prepared based on certain pre-suppositions in relation to imparting of education and these presuppositions are guided by social, physical and psychological aspects of learners.

- The presentation of the textbook should be organized keeping certain things in mind such as what should be the topic of a lesson, how should study be conducted, how should vocabulary related to the lesson be organized etc.
- The objective of the textbook should not aim at merely addressing the curiosity in the minds students alone but also to create more curiosity among them. Therefore, the preparation of the textbooks should aim at invoking curiosity in the minds of learners.
- Textbook is an instructional material. It is not only for teaching but for learning as well. Therefore, textbooks should be designed keeping teaching-learning textual material based on a teaching model in mind.
- We must collect material for the preparation of textbooks first. As envisaged in the NEP, 2020, such material useful for the preparation of textbooks should be able to establish proper explanation of the idea to be taught, should be able to invoke thinking process among children, the textbook should be able to develop critical faculty among students and they should highlight Indianness or Indian values embedded in them.
- A Teaching Model essentially means designing educational activities and situations (classroom situations to learn).
- Constructive Teaching Learning Situation: NEP 2020 in its part 4 maintains that textbooks should not be an exercise of merely providing answers to the questions but students should be enabled to find out answers to the questions in their minds. Constructive approach used in NEP document means students should be equipped to find out answers that are already in their minds through the means of textbooks. NEP document says education should move towards less content and more towards learning about how to think critically and solve problems, how

to be creative and multidisciplinary, and how to innovate, adapt and absorb new material in novel and changing fields.

- Pedagogy must evolve to make education more experiential, holistic, integrated, inquiry driven, discovery oriented, learner-centric, discussion based, flexible and of course, enjoyable.
- Education should evolve into a process that recognizes, accepts and develops the potential of the learner.
- This must also be born in mind that while teaching, a teacher is not merely teaching in the classroom but he/she is also learning from the experiences of his/her students which he/she can bring in use for teaching the next batch of students. Part 4 of the NEP 2020 also emphasizes on art oriented and play oriented ways of teaching-learning process. Art cannot be understood only in terms of narrow understanding like drawing but seeing and perceiving things with different aspects associated with a particular issue is also an art.
- Textbooks should be prepared by drawing connections between cause and effect related to a particular issue as well.
- Activities prescribed for students should not be merely individual student centric but they should also develop group behavior among them. The NEP too has said that such activities will help students to keep in tune with the developments of the 21st century and should imbibe constitutional values among students, e.g., fundamental duties, environmental concerns etc.
- Approach to preparing textbooks should not be followed in isolation but must have an inter-disciplinary approach for example, textbook preparing committees on science, social sciences and languages should come together and device strategies in this regard.

- Textbooks for students should enable them not to learn what's being taught in the classroom for that moment or year alone but they should develop the sense of learning things continually.
- Thus, textbook should inculcate the thoughts and ideas on social justice, equality, scientific development, and national unity, cultural preservation of India, developing wholesome personality, developing resources to their fullest and using them in sustainable ways.
- Section 4.31 of the NEP provides for developing textbooks at national level keeping local issues and local aspects in the center stage. It lays emphasis on the constructive approach based on the discussions, explanations and utility of the learnt knowledge in practical life. It also talks of including supplementary material in the textbooks. It also talks of including bunch of books derived from the national and local sources.
- The reduction in content and increased flexibility of school curriculum renewed emphasis on constructive rather than rote learning. This must be accompanied by parallel changes in school textbooks. All textbooks shall aim to contain the essential core material (together with discussion, analysis, examples and applications) deemed important on a national level, but at the same time contain any desired nuances and supplementary material as per local contexts and needs. Wherever possible schools and teachers will also have choices in the textbooks they employ from among a set of textbooks that contain the requisite national and local material - so that they may teach in a manner that is best suited to their own pedagogical styles as well as to their students and communities' needs.
- Section 4.32 of the NEP provides for coordination between NCERT and SCERT to develop textbooks in various

languages spoken in India. They must derive from the sources across regions in India. "The aim will be to provide such quality textbooks at the lowest possible cost -namely, at the cost of production/printing - in order to mitigate the burden of textbook prices on the students and on the educational system. This may be accomplished by using high-quality textbook materials developed by NCERT in conjunction with the SCERTs; additional textbook materials could be funded by public-philanthropic partnerships and crowd sourcing that incentivize experts to write such high-quality textbooks at cost price.

- States will prepare their own curricula (which may be based on the NCFSE prepared by NCERT to the extent possible) and prepare textbooks (which may be based on the NCERT textbook materials to the extent possible), incorporating State flavour and material as needed. While doing so, it must be borne in mind that NCERT curriculum would be taken as the nationally acceptable criterion. The availability of such textbooks in all regional languages will be a top priority so that all students have access to high-quality learning. All efforts will be made to ensure timely availability of textbooks in schools. Access to downloadable and printable versions of all textbooks will be provided by all States/UTs and NCERT to help conserve the environment and reduce the logistical burden."
- Section 4.33 provides for "Concerted efforts, through suitable changes in curriculum and pedagogy, will be made by NCERT, SCERTs, schools, and educators to significantly reduce the weight of school bags and textbooks.
- In this regard, it's important to look at 1992 Committee Recommendations on how should the textbooks be also the 2005 NCF recommendation on the curriculum.

- Textbooks should include topic, role of the concerned topic, syllabus, self-study material, pictorial representations, structuralism, experiential learning, communication, students' participation, empowering teachers, culture, constitutional values, skills required for the 21st century, research aptitude, supplementary books etc.
- Education should be the process of humane learning presupposing a specific social nature and a process by which children grow into the intellectual life for those around them.
- Education should enable the child to look at the environment around her/ his in a holistic manner and does not compartmentalize any topic into science and social science.
- Therefore, an attempt should be made in the textbook so that it will help a child to locate every theme in physical, social and cultural contexts critically so that the child can make informed choices in his/her life.
- The challenge in relation to writing a textbook at national level lies in the fact that it should reflect the multicultural dimensions of the Indian society. Every effort should be made to include every community in the country giving due space to their culture and way of life so that all of them feel important.
- The position paper by the textbook preparation committees previously constituted had observed that- While writing textbooks…..“who is the child we are addressing was the big question. Does a child study in the big of school of the metro city or the school in the slums, a small-town child, one in village school or one in the remote mountainous areas? One also needed to tackle the difference of gender, class, culture, religion, language, geographical locations etc. These are some of the issues addressed in the book, which the teacher will also

have to handle sensitively in her own ways." While preparing textbooks these issues of concern must be deliberated over.

- There is need to inculcate the habit of reading among our students and for that to happen the books must be prepared in a way that they become attractive for them.
- We need to pay attention to the section 4.35 of the NEP in this regard. It says, "The progress card of all students for school-based assessment, which is communicated by schools to parents, will be completely redesigned by States/UTs under guidance from the proposed National Assessment Centre, NCERT, and SCERTs. The progress card will be a holistic, 360-degree, multidimensional report that reflects in great detail the progress as well as the uniqueness of each learner in the cognitive, affective, and psychomotor domains. It will include self-assessment and peer assessment, and progress of the child in project-based and inquiry- based learning, quizzes, role plays, group work, portfolios, etc., along with teacher assessment. The holistic progress card will form an important link between home and school and will be accompanied by parent-teacher meetings in order to actively involve parents in their children's holistic education and development. The progress card would also provide teachers and parents with valuable information on how to support each student in and out of the classroom. AI-based software could be developed and used by students to help track their growth through their school years based on learning data and interactive questionnaires for parents, students, and teachers, in order to provide students with valuable information on their strengths, areas of interest, and needed areas of focus, and to thereby help them make optimal career choices." These issues must be kept in mind while preparing textbooks.

- The interdisciplinary approach of seeking knowledge is not new to us in India. The Sushrutsamhita has quite elaborately spoken about it in the following words-

एकंशास्त्रमधियानो न विद्र्याछास्त्रनिश्चयं
तस्माद बहुश्रुताः शास्त्रंविजनीयचिकित्स्काः
शास्त्रंगुरुमुखोदीर्णमादायोपास्य चासकृत
यः कर्मकुरुतेवैद्र्यः स वैद्र्योन्य तू तस्कराः
(सुश्रुत संहिता सूत्रस्थानम4. 6-8)

- Our education should make students competent, experienced and capable enough to expand their knowledge on their own. While writing books, the interests of all students of society belonging to different gender, class, culture, religion and geographic locations should be kept in mind.
- The textbooks should be structured primarily in the five parts, viz. 1. Curriculum or syllabus as per our educational needs and objectives. 2. Collection of the material and its sequencing or sorting for the intended purpose, for example, the collected material can used for designing syllabus of various classes. 3. Evaluation of the utility of the syllabus or curriculum. 4. Presentation of the collected material in the textbooks and 5. background checking meaning whether there is any need for further improvement in the designed books and its syllabus (**पतिपृष्ठि**). It has been very beautifully said in the Indian knowledge traditions in the following shloka of Shukarhasyopanishad-

श्रवणंतु गुरोः पूर्वं मननंतदनन्तरम्।
निदिध्यासनमित्येतत् पूर्णबोधस्य कारणम्।।
(शुकरहस्योपनिषद्)
श्रवण > मनन > निधिध्यासन

Chapter–4

CHEMISTRY IN ANCIENT INDIA

Chemistry was known as Rasayan Shastra, Rastantra, Rasa Vidya and Rasakriya, all of which imply "Liquids Science". Rasakriya Shala was the name given to chemical laboratories, and a chemist was known as Rasayana. In India, the chemistry was developed in stages through experimentation, and the areas of application of chemistry were:

- Metallurgy (smelting of metals)
- Distillation of Perfumes.
- Making of dyes and pigments.
- Extraction of sugar
- Production of paper
- Production of gun powder
- The casting of Canons, etc

India has a long history of scientific thought. It has a fair share of enriching the world's material culture. The materials on Earth have been categorized into *panchbhootas* since Vedic times. The *panchbhootas* were linked to human perceptual senses: Earth (Prithvi) with smell, Fire (Agni) with vision, Air (Maya) with feeling, Water (Ap) with taste and Ether (Akash) with sound. These five elements have been thought to make up the material world. Besides ether, philosophers believed that the other four were physically tangible and made up of minute particles of a substance. The last minuscule matter which could not be further subdivided was called Parmanu. For each of the five elements, there are five different types of paramanu. As a result, it's safe to assume that Indian thinkers came up with the concept of splitting an atom.

From the Bronze Age onwards, India was the birthplace of metallurgy. Indeed, metallurgy has played a significant role in the progression from the Bronze Age through the Iron Age to the present. In metal smelting, Indians were skilled in extracting and casting from ore. Mesopotamia probably inspired this idea in India. The Iron Pillar of Mehrauli in Delhi and a Gautama Buddha figure in Sultanganj, Bihar, are outstanding examples of Indian metallurgy. They have not caught rust even thousands of years later after their manufacture.

Nagarjuna was a great metallurgist and alchemist in ancient times. Rasaratnakara is another work that focuses on liquid preparation (primary mercury). The survey of metallurgy and alchemy was also emphasized in the text. Another treatise Rasarnava is a Sanskrit literature about *Tantrism* composed in the medieval era (12^{th} century). Its tantric research focuses on metallic preparations and alchemy in the context of chemistry.

The usage of paper dates back to the Middle Ages. The manufacturing of gun powder and its use in cannons began in India after the arrival of the Mughals. Different ratios of saltpetre, sulphur, and charcoal were used to make different types of gunpowder. *Tujuk-i- Baburi* explicitly mentions the casting of cannons.

Alchemy attracted the attention of the people of almost all cultural areas for over two thousand years in the ancient and medieval periods. It can be said that alchemy in India evolved into petrochemical practices much earlier, probably in the 11^{th} and 12^{th} centuries A.D. It would seem that alchemy in its twin aspects (transmutation of base metals into gold or silver and the preparation of the elixir of life to attain immortality) made its appearance in India by about the sixth or the seventh century A.D. The Sanskrit equivalent of the term alchemy is *rasa-vidya* and that of the alchemist, *rasasiddha*. The word *rasa,* as used in the alchemical literature, generally means mercury which, together with sulphur and mica, is central to the whole of Indian chemical thought. The Indian alchemical ideas seem to have grown around male-female symbolism in indigenous imagery. Mercury is regarded as Siva's principle and sulphur that of his consort [1].

The beginnings of Indian alchemy are obscure. Though ideas of rejuvenation and methods of bodily treatment to live for a long time in a youthful state are to be found in the classical texts of Ayurveda [2], the alchemical ideas characterized by the twin aspects and mysterious ways based on mercury and male-female symbolism, It should be emphasized that in a century or two, the followers of alchemy in India formulated their practices into an organized knowledge, characteristically Indian. The result was that alchemy came to be recognized as *Rasaśästra* and even *Raseśvaradarsana*. The *Rasasastra* texts are noted for their presentation of a wide variety of alchemical knowledge possessed by the Bhartiya *rasavadins*, including the *maharasas*, *uparasas, navaratnas*, *dhātus* [3] and several medicinal plants and substances used in alchemical preparations in general and the elixir of life in particular. The Indian alchemists were skilled in performing several purificatory processes with metals. They had evolved many apparatuses for this purpose, and some of them were of a complicated type. In them, they used to prepare alchemical compositions with far-reaching effects.

Significantly, some of the purification processes and substances of alchemical significance are common to both Arabic and Indian alchemy. Interestingly there are several alchemical texts in the Tamil language. One of Tamilnadu's reputed alchemists, Ramadevar, says in one of his works that he visited Arabia, assumed the name of Yakub [4] and taught alchemy there. The Tamilian alchemy has as its central theme the preparation of what is known as *muppu* (generally recognized as the union of three salts), which is like the Philosopher's Stone-a concept which appeared in Europe much later. In the fifteenth century A.D., Paracelsus in Rome gave alchemy a new meaning and direction. Instead of the two fundamental alchemical principles-mercury and sulphur-Paracelsus, enunciated three-including salt, Mercury, sulphur and salt constituted the tria prima of Paracelsus [5]. Salt is of prime importance in Tamilian alchemy, which also accords place to mercury and sulphur in its scheme.

However, it seems to be reasonably sure that the use of alchemy for bringing succour to disease-afflicted humanity was recognized in India much earlier than the Iatro-chemists of the West led by Paracelsus. Paracelsus thought that the human body was to be recognized as a chemical system composed of mercury, sulphur and salt. A derangement among them would give rise to pathological states. The exposition of Paracelsus eventually led to the use of mineral medicines more and more. According to Paracelsus, alchemy was to engage itself in the noble task of transforming naturally occurring minerals into products beneficial to humanity.

Interestingly, mineral medicines using mercury, sulphur, and salt were used in India even in the eleventh or the twelfth century A.D. The reason is not far to seek. Alchemy in India was concerned more with life-prolonging compositions than with the transmutation of base metals into noble ones.

Chemical Practices in ancient India

It is now known that the artisans of the Harappa civilization had an intimate knowledge of the processing and properties of naturally occurring minerals and were well-versed in the art of pottery-making and metal-working. E. Mackay believes that the glazed pottery found at Mohenjodaro was probably the earliest specimen [6]. Interestingly, the practice of glazing pottery appeared in Mesopotamia about 1500 years later than in the Harappa civilization. The Harappan metalsmiths knew the technique of making beads, soldering, sheet-making, rivetting, coiling and *cire perdue casting* (wax metal-casting process). There was a flourishing trade in metals and metallic ores between India and neighbouring countries like Afghanistan, Persia and Mesopotamia.

The advent of Iron technology in India is of particular significance. It is generally believed that Asia Minor or the Caucasus was the region where the first smelting operations of iron were carried out, and the Hittites knew the smelting of iron between 1800-1200 B.C. By about 1000 B.C., there was extensive use of iron in the Near East, even though it could not replace copper and bronze, which had established themselves as metals in the service of man. Possibly, the Indian iron metal-workers might have become familiar with the iron metallurgical practices of the Near East and adapted them to suit the local conditions and the nature of the indigenous ore. But, historically of great significance is the fact that even though the iron smelting operations were just in vogue in India by about 1000-800 B.C., in the course of four to five centuries, the Indian iron and steel objects earned the admiration of the people in other parts of the then known world. The Greek historian Herodotus (5th cent. B.C.) indicates that the Indians in the Persian army used arrows tipped with iron. Ktesias (5th cent. B.C.) speaks of two swords of Indian steel presented to him in the Persian Court. It has been recorded that Alexander received from Porus of Taxila (320 B.C.) thirty pounds of steel. Later, Indian iron and steel became famous in Rome for fashioning them into fancy cutleries and armours [7].

Historical relics like the Iron Pillar at Delhi and the copper statue of the Buddha found at Sultanganj in Bihar (now in the Birmingham Museum in England) bear eloquent testimony to the metallurgical practices in the Classical Age of India. The Iron Pillar has a height of 24' (with 1' 8" below ground), and its diameter diminishes from 16.4" below to 12.05" above. The specific gravity of the metal is over 7.6, and the Pillar weighs more than six tons. It is made of wrought or malleable iron (99.72%) and is still without any signs of rust, even though it is about 1500 years old [8]. As V. Ball says: "It is not many years since the production years of such a pillar would be an impossibility, and even now, there are comparatively few places where a similar mass of metals could be turned out" [9]. In addition to this Pillar, a colossal iron pillar of a later date (about 12th cent. A.D.) in two pieces has been found at Dhar in the Malwa region. The enormous statue of the Buddha = about seven feet six inches in height and nearly a ton in weight - probably belonging to the fifth century A.D. has been cast in two layers, the outer layer by the *cire perdue* process and the inner layer in segments on a mould composed of sand, clay, charcoal and paddy husk using iron bands for holding the components together [10]. Apart from the excellent metallurgical skill for which India was well known in the ancient period, the chemical knowledge that the Indians possessed in the use of alkalis, acids and salts, preparation of cosmetics and perfumes, pyrotechnics and the like was undoubtedly at a high level. However, chemical practices remained more valuable branches of a developing chemical knowledge.

Indian contribution to Chemistry through the ages:

(For Integration in IKS)

Chemistry in India through the ages

1) Pre-vedic stage up to 1500 BCE

2) The Vedic and the Ayurvedic period up to 700 CE

3) The transitional period from 700 CE to 1100 CE

4) The Tantric period from 700 CE to 1300 CE

5) Iatro Chemical period' from 1300 CE to 1600 CE

The Historic Period (pre-Vedic stage) (1000-400 BCE)

According to *Rigveda*, the tanning of leather and dyeing of cotton was practised during this period. During the period c.1000-400 BC, they made a particular kind of polished grey pottery known as Painted Grey Ware. Other varieties of ceramics, for example, red or Northern Black-Polished (N.B.P.) Ware (600-200 BC) were also made later. These Wares indicate their mastery of control of kiln temperatures and the reducing atmosphere. Kautilya's *Arthasastra* (KA) was a scientific landmark of this period. KA described the production of salt from the sea and the collection of shells, diamonds, pearls and corals. *Charaka Samhita* and *Susruta Samhita* were two celebrated Ayurvedic treatises on medicine and surgery. Chemical knowledge of the times, especially treatment-related, was compiled in them.

Indus Valley Civilization (2600-1900 BCE)

The Indus valley civilization was the earliest society, which had developed an elaborate urban system depicted in streets, public baths, temples and granaries etc. They also had the means of mass production of pottery, houses of backed bricks and a script of their own. So, we can say that the story of early chemistry in India begins from here.

Pottery could be regarded as the earliest chemical process in which materials were mixed, moulded and fired to achieve desirable qualities. Thousands of pottery in the Rajasthan desert varied in shape, size and colour. They show prehistoric people knew the art of making pottery using burnt clay. Coloured and wheel-made pottery were found at Harappa. The pottery was decorated with geometric and floral patterns and human and animal figures. Remains of glazed pottery were also found at Mohenjodaro.

Cement: Gypsum cement was used to construct a well in Mohenjodaro. It was light grey and contained sand, clay, traces of calcium carbonate and lime.

Minerals: The Indus valley people used several minerals for various valuable products such as medicinal preparations, plasters, hair washes etc. Faience, a sort of proto-glass, was quite popular with the Harappans and was used for ornaments. They also smelted and forged various objects from lead, silver, gold, and copper; and used tin and arsenic to improve the hardness of copper for making artefacts.

Medieval Alchemy (AD 800-1300)

Alchemy in India flourished in the medieval period. Indian alchemy had two characteristic streams: gold making and elixir synthesis. The two faces of the alchemical practice, the metallurgical and the physico-religious, were superimposed to get a single picture. Wherein mercury and its elixirs were used to transmute the base metals into noble ones and for internal administration to purify the body, rejuvenating it and taking it to an imperishable and immortal state.

Importance of Mercury: The texts of Indian alchemy (*rasavidya*) reveal that many inorganic and organic substances were used as plant and animal products, but more of the former. The essential minerals are generally referred to as *rasas*, and in later texts, they are classified into *maha* (superior) and *upa* (subsidiary) *rasas*. Mercury, though a metal, is extolled as the king of *rasas*, the *maharas*, and has several names in the *rasa sastra* texts: *parada, sita, rasendra, svarnakaraka* (maker of gold), *sarvadhatupati*. More than two hundred names of plants have been mentioned in the texts. Still, many of them have not been appropriately identified from the point of view of modern botanical nomenclature—generally, their roots, leaves or seeds aid digestion processes. As for the animal products, their excreta, flesh or other parts of their bodies were diligently processed and used.

The texts, written in the medieval period, dealt with gold-making and elixir syntheses. Elixir or *Rasayana* was a substance that could transform other base metals into gold and silver and confer longevity and immortality when taken internally. If an elixir proved successful in transmuting metals, it was supposed to be safe for internal administration. Mercury was considered the most potent of all imports and possessed divine properties due to its heavy weight, silvery white and shiny appearance, fluidity, and its property of readily combining with other substances. The potions containing mercury were supposed to give longevity and immortality, thus making it the main ingredient of the powders used in the transmutation and as elixirs. Mercury had to undergo 18 processes before it could be used for transforming either metals or the human body. These processes were as follows:

1. ***Svedana*****:** steaming or heating using a water bath
2. ***Mardana***: grinding
3. ***Murchana***: swooning or making mercury lose its form
4. ***Utthapana***: revival of form
5. ***Patana***: sublimation or distillation
6. ***Rodhana***: potentiation
7. ***Niyamana***: restraining
8. ***Sandipana***: stimulation or kindling
9. ***Gaganabhaksana***: consumption of essence of mica
10. ***Carana***: amalgamation
11. ***Garbhadruti***: liquefaction (internal)
12. ***Bahyadruti***: liquefaction (external)
13. ***Jarana***: calcinations
14. ***Ranjana***: dyeing
15. ***Sarana***: blending for transformation
16. ***Sankramana***: acquiring power of transformation or penetration
17. ***Vedhana***: transmutation
18. ***Sevana***: becoming fit for internal use

These were known as the *samskaras*. Briefly, the processes are as follows:

Svedana consists in streaming mercury with a number of vegetables and mineral substances; *mardana* involves rubbing the streamed mercury in a mortar with vegetable and acidic substances to remove some more impurities; in *murchanam* mercury is rubbed in a mortar with another set of vegetable substances, till it loses its own character and form; in *utthapana* the mercury is steamed again in alkalis, salts, the three myrobalans, alum, etc.; *patana* involves distillation (3 types: *urdhva, adah* and *tiyak*); *rodhana* consists in mixing the distilled mercury with saline water in a closed pot; in niyamana the process is continued by streaming mercury for 3 days with a number of plant products, alum borax, etc.; *sandipana* involves steaming with alum, black pepper, sour gruel, some alkalis and some plant substances; *ganganagrasa* requires fixation of the desired degree of the essence of mica for its consumption; in *carana* mercury is boiled with sour gruel and leaves of some kinds of cereal plants, alum etc.; *garbhardrti* involves treating mercury with other metallic substances; in bahyadrti the essences of the minerals or metallic substances are utilized in the molten or liquid state; *jarana* involves heating mercury with the desired minerals or metals, alkalis and salts; *ranjana* involves colouring by a complex process; in *sarana* mercury is digested with gold, silver etc. in an oil base; *kramana* requires smearing mercury with a number of plant extracts, mineral substances, human milk etc. and then heating them ; *vedhana* consists in rubbing the treated mercury with oil and a few other materials so that it acquires the power of transmutation; and finally *sarayoga* it is available for internal use.

Modern Chemistry (Iatrochemistry): 1300-1600 BCE

Chemistry developed mainly through alchemy and iatrochemistry during BCE 1300-1600. But from the early seventeenth century onward, a marked decline in alchemical writings was observed. The alchemy practised with full enthusiasm started to fade from the beginning of the Tantric period. This was possible because of the realization that alchemy could not deliver the goods it promised. Now it was a period of the ascendance of iatrochemistry. After the decline of alchemy, iatrochemistry probably reached a steady state over the next 150-200 years. Still, it declined due to the introduction and practice of western medicine in the 20th century. During this period of stagnation, the pharmaceutical industry based on Ayurveda continued to exist but gradually declined. There was a considerable time gap between giving up old methods of production of certain chemicals and the adoption of newer approaches based on modern chemical ideas. When the old ones became out-fashioned, it took about 100-150 years for the Indians to learn and adopt new techniques, and during this time, foreign products poured in. As a result, the indigenous units using traditional methods gradually declined due to the adverse policies of the rulers. A decline in demand was the other main reason for this.

The Indian dyes were superior in quality and low price, bringing a considerable return to the European trading companies. Therefore, the East India Company, till the beginning of the nineteenth century, supported the indigo plantation. But, when Huemann discovered synthetic indigo in 1890, indigo cultivation in India suffered and finally stopped. Thus the synthetic dyes completely overtook the natural dyes. Modern science appeared late on the Indian scene, i.e., only in the later part of the nineteenth century. By the mid-nineteenth century, European scientists started coming to India. A science college was established in Calcutta in 1814. The study of chemistry was first introduced in the Presidency College of Calcutta in 1872, followed by post-graduate teaching in chemistry in 1886. The Indian Association For Cultivation of Sciences was established in 1876. Early chemists like P.C. Ray and Chuni Lal Bose were actively associated with it. P.C. Ray was well aware and proud that Indians had made considerable progress in chemistry during the ancient and medieval periods, as was evident from his two volumes on the *History of Hindu Chemistry*. After Ray, Chandra Bhusan Bhaduri and Jyoti Bhusan Bhaduri were the ones who conducted significant research in the field of inorganic chemistry. R.D. Phookan sowed seeds of research in physical chemistry. Thus many young scientists started taking a keen interest in modern scientific research activities. P.C. Ray established the Bengal Chemical of Pharmaceutical Works Ltd. in Calcutta; J.K.Gajjar with the help of Kotibhaskar and Amin, established the Alembic Chemical Works in 1905 at Baroda, and Vakil in 1937 established the alkali industry under Tata's patronage, and Tata Chemicals Ltd. came into existence. The Indian chemical industry was thus established, and it continued to grow at a slow but steady pace in the 20th century. It is interesting to note that the western world is now veering around to alternative medicines based on traditional Indian recipes and iatrochemistry, so much so that the global annual trade in herbal products has reached $60 billion [11-13].

Metalworks in ancient India

Wootz Steel: The Rise and Fall of a Great Indian Technology

Swords were frequently made in the eastern Mediterranean region using wootz steel, an exclusive Indian method of creating steel. Simply put, it was impossible to find steel of such high grade elsewhere. Around 700 BCE, Wootz steel was developed in India and traded throughout ancient Europe and the Arab world. It was widely used to make Damascus swords in the Middle East. These sword metals' characteristics include hardness, which contributes to the edge's sharpness, flexibility, strength, and the usual surface structure found on a sword. The Tamil root word for the alloy, *urukku*, *wook*, is likely where the word wootz came from. Dravidian languages also have steel name pronunciations that are comparable.

In the 12th century CE, Arab Edrisi said that Indians had outdone ancient Hindus in producing iron and that it was impossible to match their accomplishments in making steel. Arabs brought wootz steel to Damascus, where a booming industry used steel to create weapons and armour. Wootz steel manufacturing in India reached practically industrial levels by the end of the 17th century CE, predating the Industrial Revolution in Europe.

Indians followed oral tradition without written literature and documentation, and few records were accessible to record the wootz-making process. Most passengers who left thorough descriptions were from Europe, including Buchanan in 1807, Heyne in 1818, HW Voysey in 1832, and Josiah Marshall Heath in 1840. However, experts in England, France, and Russia were interested in Wootz steel.

Due to England's colonisation of India, wootz steel was the subject of intense research. Electricity's creator, Michael Faraday, was enthralled by wootz steel and eagerly researched it. Together with the cutler Stoddart, Faraday tried to learn how to create Damascus steel. They came to the mistaken conclusion that the additions of aluminium oxide and silica contributed to the steel's qualities, and they published their findings in 1820. Faraday is credited as the father of alloy steel even though he could not duplicate the wootz steel. Western scientists made this discovery after thorough research into the composition, microstructure, and relationship between the mechanical characteristics of steel. These investigations on wootz steel laid the groundwork for contemporary materials science, and they still motivate scientists today.

Recent studies on the ultra-high carbon wootz steel's qualities, such as its super plasticity, support the claim that it was a sophisticated material in the ancient world having not just a history but a future.

On the other side, however, the British Raj imposed mining restrictions and manufacturing levies. Mining and steel production must have been disrupted in part as a result. In the end, it might have contributed to India's knowledge loss during the previous 150 years.

Source: Based on Ranganathan, S. and Srinivasan, S. (2006). "A Tale of Wootz steel" Resonance (June 2006), pp. 67-77 and Prakash, B. (1977). "Metals and Metallurgy", Chapter 3 (3.2] in History of Technology in India Vol. I, A.K Bag (Ed.), Indian National Science Academy, New Delhi, pp. 80-174, and other published material.

Mining and Ore Extraction

In terms of technology, the ancient Indians made significant contributions to metallurgy, material science, and metalworking. Indian metalsmiths made several noteworthy advancements, particularly in mining and working with iron, steel, copper and its alloys, and zinc, where they acquired particular expertise. An intriguing picture emerges from an archaeological investigation of the area around the main mining hubs of contemporary India, including Zawar, Rajpura Dariba, Rampura-Agucha, Khetri, Chamba, Deri-Ambaji, Singhbhum, Chitradurga, and Cudappah. In addition to large amounts of slag and retorts, these places contain actual historic mine workings and waste. The extent to which mining and metalworking have grown in ancient India is further supported by an examination of the ruins of temples and townships in various locations around the country of India. One can determine the skill and technical superiority displayed by an analysis of the gathered archaeological specimens.

An examination of the site's metallurgical technology was prompted by the excavation of an ancient historic iron smelting site close to Dhatwa in the Tapti valley of Gujarat's Surat District. Iron items, piles of iron metallurgical tap slag, and fragments of iron ore in layers 3, 2, 1, and on the mound's surface were all discovered as a result, providing proof of an iron-smelting industry. Layers 1 and 2 included significant amounts of iron items and slag, indicating that the sector must have grown over time [14].

Similar technology was used in the ancient mining and ore extraction processes. Inevitably, fissures in the rock had to be made by lighting a fire and quenching it with water. The ore was then removed using hammers, chisels, and scrapers. The excavations were supported by timber, and the mining operations left a succession of open cuts at the top. Wooden trolleys moved the ore, while earthen pitchers were utilised to transport water.

The ancient Indians acquired the knowledge and abilities necessary to explore profitable ore resources and mine them. Studies went into great depth about how the ancient Indians mined copper in the Khetri mines in Rajasthan. They knew how to remove the ore using hammers and chisels after first burning and quenching the ore to crack it. Additionally, they created a few techniques for further processing the ore to produce molten metal.

In numerous places in these hill regions, there are visible underground excavations down to a depth of almost 500 feet. Various tunnels are 5 feet by 4 feet in size and have several features that help the atmosphere. There were several steps in the mining process. The ore was first moved by lighting the fire. It was also quenched in water. And it was removed with the use of a chisel and hammer. The miners' workers carried these extracted ores out of the mines on their heads for further processing.

Large quantities (about 6-7 tonnes) are stacked to crack the ore and set fire. The workers immediately leave the mines, only to return after three days. The studies on the mining process suggest that each worker proceeded into the mine with a chisel, lamp, and a small basket. The lamp on his head not only illumined but also helped him identify the glittering particles of ore. While at work, the miner sat upon his heels with the lamp upon his head, the hammer in his right hand, the chisel in his left hand, and the small basket upon his knee, in which he received all the fragments of ore that were struck off by the chisel. The basket was passed through a chain of workers, and in this manner, the ore was cascaded to the surface eventually.

Once the ore is brought to the surface, they are finely powdered using heavy hammers to be conducive for roasting. The powdered ore was mixed with cow dung and made into rolls about four inches long which were dried first in the Sun and then roasted in the open air in a fire of cow-dung cake. The ore was then ready for smelting. There is enough evidence to show the smelting of the ore using locally built furnaces, cemented with clay having nozzles and bellows. The bellow valve was created using a pair of sticks, and they were opened when the bag was raised to blow the air. The molten metal was stirred and drawn out through a hole at the bottom of the furnace. After lighting the furnace, the ore was gradually introduced alternatively with charcoal and flux (refuse from the old iron furnaces).

Metals and Metalworking Technology

Base metals and alloys have been used by the ancient Indians for various purposes, including the creation of weapons, decorations, vessels, tools, artefacts, statues, and coins, to name a few. Indians were particularly advanced in iron, steel, and zinc. Artefacts made of gold, silver, copper, and bronze have been found at Mohenjo-Daro, Harappa, and South Indian burial grounds. The bronze figure of a dancing girl discovered at Mohenjo-Daro proves the ancient artisans' technological power. The statue demonstrates the artisans' ability to drill small holes and use the lost wax casting process to cast the statue (known in modern times as the cire-perdue process). There are numerous references to gold, silver, iron, copper, and alloys throughout the Vedic writings [15]. It is therefore not surprising to discover that mining. They were familiar with ore processing, metal extraction, metalworking techniques, and alloying. This section will cover the elements above of Indian metalwork and metallurgical concepts [16].

A detailed study of the archaeological remains and the repository of literary works from the 5th century CE to the 12th century CE, in addition to numerous references in the Vedic texts, clearly point to certain unique aspects of metalworking and metallurgy in India during ancient and medieval times.

Gold Extraction Process

Bharat Gold Mines Ltd. has examined and documented the method used to extract gold in ancient times. According to the information that is currently accessible, mercury was added to a mixture of black sand and gold ore before being rubbed with a small amount of table salt. The gold and mercury would eventually combine to produce an amalgam. Water is added to the mixture and then squeezed off to separate the amalgam. It was ultimately burned in the fire to remove the gold. If silver or other base metals were discovered alloyed with the gold, it was hammered into a thin sheet between two stones. The plate was burnt in two-layered cow dung. The cow dung absorbed the base metals separating the pure gold. This shows that Hg (Mercury) amalgamation and gilding techniques were known to the Indian artisans from early times.

However, panning, a straightforward gravity separation method, is most frequently used to separate native gold from sand and quartz rock. In this method, the gold particle is extracted from the quartz by crushing it to an acceptable size, and it is then separated by suspending the resulting mixture in water. Sand and soil are washed away when the suspension's pan is shaken under water. Gold particles then settle at the pan's bottom. For larger-scale operations, enormous pans were suspended through a sling in the river water so the mixture could be stirred easily.

Coins and jewellery were the primary products of gold extraction. Additionally, it was utilised in Ayurvedic preparations as "Suvarna Bhasma." The purified gold metal bar may be worked with by ancient artisans using forging, punching, embossing, and other metallurgical processes to create ornaments with complex designs. Metal forming methods like rolling and wire drawing were also available to ancient artisans. Either punch marking or die casting in clay moulds was used to create gold coins.

Zinc Production

Perhaps the final metal to be discovered and utilised before the birth of Christ was zinc. In their 1984 study, Hegde, Craddock, and Sonawala concluded that between 600 and 200 BCE, India was the first to introduce zinc to the rest of the world. Rajasthan distinguishes itself geographically as a significant mining region that dates back to around 1000 BCE. According to studies based on the debris and slag pile in Rajasthan's Zawar district, 15,000 tonnes of zinc should have been extracted and processed. In ancient India, mining for zinc was exported. Before the start of modern mining operations, it is estimated that around 2.5 million tonnes of ore in the mined region had been extracted.

Extensive archaeological excavations conducted in several parts of Rajasthan clearly show that the earliest artefact containing an appreciable amount of zinc anywhere in the world is from India. A pioneering contribution of the Indian subcontinent in the history of science and technology was the mastery of the metallurgy of zinc production. In the Aravalli ranges of northwestern India, amongst rich polymetallic mineral deposits, one can see several mining galleries, slag heaps, and retorts which bear testimony to the early extraction of lead and silver at Dariba and Agucha and, most uniquely, of zinc, at Zawar. The Zawar area near Udaipur has yielded extraordinary evidence suggesting that the extraction of metallic zinc flourished on an almost semi-industrial scale by the mid-14th century CE, as indicated by some carbon dates from the analysis of archaeo-metallurgical debris. Surveys and excavations revealed the extensive presence of furnaces or koşthis, intended for a creative process of zinc extraction by downward distillation [17].

Ancient Indians developed a novel methodology of downward drift reduction distillation process for Zinc purification, which is a precursor to the modern techniques adopted all over the globe. As we know, Zinc has a melting point of 410°C and a boiling point of 930°C. Moreover, in the open air, at about 550°C, Zinc gets oxidized to ZnO (Zinc Oxide). Therefore, the only viable method to extract Zinc is to rapidly cool the Zinc vapour to around 500°C to produce the liquid metal, thereby preventing its reoxidation. The ingenuity of the ancient Indians made this possible using the downward drift reduction distillation process. Some studies suggest that in India, the process of distillation of water, wine, and probably mercury was known even in the Vedic period (Yajurveda). The distillation apparatus near the ancient Takṣasila (Needham) was unique and advanced. This system uses a separate condenser tube fitted to the mouth of the distil to carry the vapours to the water. A similar apparatus called Damru-yantra was used for the preparation of Ayurvedic formulations.

The principle of the downward drift distillation process can be explained in simple terms using the description of a yantra available in Rasa-Ratna-Samuccaya (RRS) for extraction of Zinc, Mercury, etc. Imagine having a pair of pots placed one over the other with their mouths aligned. It means that the lower pot is in the normal position, and the upper pot is set upside down over the lower pot. The upper inverted pot has a solid charge and is sealed with clay. It has a reed stick at the centre for the escape of gases. The upper pot is heated by building a firing platform around it. Once it reaches 600°C, the reed is charred and burnt off, paving the way for less metal vapour to flow downwards. The lower pot acts as a condenser and converts the vapour into liquid metal. Figure 5.1 is a simple Yantra Used for the Downward Drift Distillation Process.

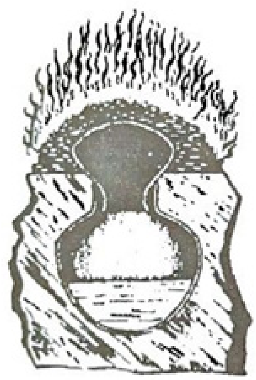


Figure 2.1. A Simple Illustration of the is simple illustration of the yantra for the downward distillation process

Source: Sen, S.N. and Subbarayappa, B.V. (2009). "A by the Zawar smelters. The process used by Concise History of Science in India", Indian National, consisted of the following steps. Zinc is Science Academy, 2nd ed., p. 429. It is reproduced with extracted by smelting Zinc Sulphide ore. After permission.

Copper Mining and Extraction Process

Copper artefacts from antiquity are abundant in India. Due to the unusual holiness that ancient Indians attached to copper, copper utensils have been utilised in religious rites in India for a long time. Wires, copper, and brass have been used to manufacture stringed musical instruments—for which India is renowned—since ancient times. The following archaeological finds suggest that the copper industry had a long and prosperous history in ancient India. [18]:

- In one area measuring roughly three feet in length, three feet in width, and four feet in depth, up to 424 copper tools and weapons and 102 thin silver plates were found in the village of Gungeria in the Nagpur Division of the former Central Provinces in 1870 CE. Most copper tools were spades, axes, shovels, and celts made for residential, agricultural, and military use. These have been preserved in the Indian Museum's archaeological section in Kolkata.

- Near the boundaries of the Kingdom of Nepal, a large solid copper bolt was discovered in the Rampurwa Ashoka pillar. The bolt appears like a barrel and tapers slightly at both ends. It measures 14 inches in diameter in the middle and is 242 inches long. The bolt's two ends are about 12 inches apart in circumference. This bolt should have been created as far back as the third century BCE, demonstrating the high level of metallurgical expertise of the ancient Indians.
- In the ruins of a former Buddhist monastery in Sultanganj, in the district of Bhagalpur, a massive copper statue of Buddha was found. It was almost one tonne in weight and stood 7 feet 6 inches tall. Its construction method and the discovery of a Chandragupta II coin close to the monastery have led to an estimate of its construction date of the fifth century CE. Additionally, copper ore lumps were discovered, indicating that the smelting and casting processes were carried out on the spot. It has been removed and is now on display in the Birmingham Museum.
- The Chinese traveller Hieun Tsang purportedly saw another monument, 80 feet high, built by King Siläditya (also known as King Harşavardhan, who ruled from 606 to 647 CE), close to Nalanda, in a brass Vihara. As stated by Hiuen-Tsang, "This enormous copper needs to be covered by a pavilion with six tiers. It was created by Raja Purnavarman,

the final ancestor of King Aoka, a monarch from the 7th century CE ".

- The rulers primarily used copper to make their coins. Copper coins with punch marks from numerous Northern Indian monarchs from the first century BCE, Kanishka copper coins from the first century CE, and Gupta kings have all been discovered. The Andhra and Khatrapa empires produced some of the oldest copper coins in Central and Southern India. Various other dynasties' brass coins from that era have also been gathered.
- Inscribed with Maurya Brähmi characters, one of the earliest copper plates was found in the village of Sohgaura, Gorakhpur district (320-230 BCE). Among the earliest copper plates found in Northern India are the Takşaila plates and the Sue Vihar inscriptions of Kanişka.
- Major Hay discovered a beautiful antique copper ghoti or lota in the Punjabi village of Kundla in the Kangra area in 1857. A scene depicting Prince Siddhartha, afterwards known as Buddha, riding in a chariot driven by four horses in a regal procession is etched all around the vessel. The manufacture of the utensil is dated between the first century BCE and the third century CE based on the writing style and the usage of copper in the item.

Extraction of Copper for Ayurvedic Purposes

RRS provides a vivid description of the methods used to extract copper and how it is used to create various Ayurvedic medicines. There are two types of copper, one of which is impure or black copper, and it comes from Nepal, according to RRS (Mleccha). The impure copper comprised copper oxides and other impurities like Pb, Sn, As, Zn, etc., making it hard and brittle. The Nepal copper was high quality (99.5%), brick red, and exceedingly ductile. By melting small charges in crucibles, RRS has described numerous procedures for extracting pure copper from chalcopyrite. Copper is employed in Ayurvedic therapeutic formulations in powder form (bhasma). As a result, specific methods are laid forth for the copper extraction process that uses lemon juice as a reductant. Following chalcopyrite purification, the ore material is roasted at 750–900°C and supplemented with 100 cc of lemon juice for every 100 g of ore. Cu (Copper) and Fe (Iron) are transformed into citrates during roasting. More lemon juice and 25% borax (flux) are added to the roasted ore, and the mixture is then squeezed into 20–30 mm balls. These balls are melted at 1250°C utilising a 4-stage process after being sun-dried. The extracted copper is sulphide free at the end of the procedure.

Another procedure stated in the RRS is based on the cementation process, which precipitates copper from blue vitriol solution ($CuSO_4$). In this process, concentrated $CuSO_4$ solution was kept in an iron bowl, where on the surface, a copper layer was formed following the reaction given below:

$$CuSO_4 + Fe \rightarrow FeSO_4 + Cu$$

After a while, a thick layer of pure copper particles is left on the surface of the iron. The copper is retrieved by scraping it off the surface of the iron after the solution has been removed. Finally, this pure copper is cleaned with water devoid of sulphur oxide and utilised to make copper *bhasma.*

Copper Alloys

During the excavation of certain ancient stupas at Manikyalaya in 1830, brass objects dating from the first century BCE to the first century CE were discovered. A second brass urn with an inscription from the same year as the first was found in a tope in the Wardak district, roughly 30 miles west of Kabul. This urn was originally thickly gilded, so the surface has survived in good condition. Its shape and size are similar to standard water jars in India. Another Harappan site of Ross (also in Gujarat) has produced a few samples of the chisel, cell, rod, and bangle, made of brass and assaying up to 1.54% zinc. Lothal (2200–1500 BCE) revealed one severely oxidised ancient artefact. According to the Chinese traveller Hiuen Tsang, Indians knew how to make brass by combining copper with calamine. In the time of Siladitya (Harşavardhan), Hiuen Tsang wrote about an unfinished brass "vihar" (convent) at Nälandă that had brass walls, doors, and windowsills. On the other hand, massive brass cannons and firearms from the Moghul era are evidence of the mediaeval metalworkers' prowess.

Mercury

The Ayurvedic text Caraka-samhită refers to the substance HgS (Mercury (II) sulphide) as Rasa-sindur. HgS and Hg (Mercury) have been employed extensively in creating Ayurvedic remedies. The usage of Cinnebar (Hingula) to generate Mercury (Hingulakrasta-rasa) has been recorded in RRS and other writings on the Rasa-ästra. Additionally, a detailed description of the extraction and distillation equipment is provided. HgS decomposes quickly on heating in air or with lime to red hot temperature. The reactions are as follows:

$$HgS + O_2 \rightarrow Hg + SO_2$$

$$3HgS + 2CaO \rightarrow 2Cas + 3Hg + SO_2$$

The procedure of this metal's purification and its conversion back to HgS for Mercurial medicines are both covered in the Ayurvedic literature. As mentioned, Hg is utilised in the amalgamation process to extract silver and gold.

Lead and Silver

A straightforward roasting procedure can transform PbS into PbO, which can be further reduced to molten lead at 500°C. This technology was employed in the roasting and reduction processes in open pit furnaces in areas like Zawar in ancient India. Temperatures of up to 1000°C are easily attained in such a furnace, and the reduced metal quickly flows out and collects in the front pit. Ag_2S (Silver Sulphide) decomposes and reduces at this temperature, forming an alloy with molten lead. The Pb-Ag alloy was heated in a shallow hearth furnace with bone charcoal at the bottom to produce silver metal. Excess air is blown during the alloy's remelting process to cause the lead to oxidise into PbO. Due to its extremely low melting point, this is skimmed off, leaving the pure liquid silver behind. It is extracted and then forged into ingots.

The Silver-Copper alloys and the methods used to produce silver coins with a specific weight are described in Kautilya's Arthasästra. A high level of craftsmanship was evident in the creation of the punching dies, according to research on the punch marks on ancient coins.

Iron and Steel in India

India has many ancient examples of iron, which will persuade anyone that it has always been a wealthy producer of iron. Numerous archaeological digs have conclusively shown that ancient Indians knew how to use iron. During Christ, Indians produced significant iron artefacts far ahead of their time. The iron pillar at Qutub Minar, which weighs around 6,000 kg and is located in South Delhi's Mehrauli neighbourhood, is well-known. Less well-known iron pillars include one on Mount Abu and one at Dhar, which weighs 7,000 kg and is located in the 12th century CE.

Another noteworthy example is the 29 iron beams of the Konark temple in Odisha Additionally, the enormous iron beams at Konark that had been buried for several millennia in the sea sand were just recently discovered. These, along with a large number of iron beams in Puri and Bhubaneswar, including up to 239 pieces found in the Puri Gunduchibari temple, provide compelling proof of the superiority of iron in prehistoric Indian civilisation [19]. These artefacts' incredible size and resilience to corrosion suggest highly developed iron metalworking techniques. The presence of multiple Aoka pillars, which were flawlessly carved out of single blocks of enormous stone in the fourth century BCE, further suggests that the best steel saws and steel chisels were used in India.

Swords, daggers, tridents, spears, javelins, arrows, spades, hangers, saucer lamps, beam rods, and tripods are just a few archaic iron tools that have been discovered during the excavation of numerous burial sites in the Tuticorin area of Tamil Nadu. The Bodh Gaya stupa dates back to the Ashokan era. A chunk of iron slag discovered during the excavation of the stupa's foundations is now kept in the Kolkata Museum. The first known archaeological proof of iron production in India is a sliver of iron dating to the third century BCE. Along with the iron slag, many iron clamps that measure five to six inches long and one inch wide have also been discovered in the main temple and in various stupas in Bodh Gaya, which are preserved in the Indian Museum.

The ability to produce corrosion-resistant iron seems to have been known to the ancient Indians, especially from the Gupta era. Using more modern terminology necessitates a solid grasp of metallurgy and material science. The 1500 years old wrought iron pillar in the Qutub complex weighing ten tonnes, the enormous iron girders at Puri, the ornamental gates of Somnath, and the feet wrought-iron gun at Nurvar are monuments of ancient art and bear silent but eloquent testimony to the marvellous metallurgical skill attained by the Hindus [20]. Numerous prominent iron artefacts, such as forge-welded cannons, were produced and used in ancient and mediaeval India, demonstrating the high standing of iron and steel technology in those periods. These cannons, discovered at Nurwar, Mushirabad, Dhaka (in Bangladesh), Bishnupur, Bijapur, Gulbarga, and Thanjavur, provide ample proof of the mediaeval

Indian blacksmith's aptitude for designing, engineering, and building enormous forge-welded iron objects. The cannon in Thanjavur must be considered one of the largest forge-welded iron cannons in the world based on its size and weight. The gun was created in Thanjavur during the rule of Raghunatha Nayak, according to a recent, reliable history of the ancient city (1600-1645 CE) [21].

The Delhi iron pillar dates to the fifth century CE, is topped with a beautiful capital, and is made of nearly pure iron (99.72%). The pillar is unmatched since it has endured the effects of weather for such a long time without rusting. According to the Sanskrit inscriptions discovered on the pillar, it was built during the Gupta dynasty's reign of Chandragupta Vikramaditya II (375–414). The ornamented capital, which is 3 feet and 5 inches tall, adds 3 feet and 6 inches to the pillar's overall length of 23 feet 6 inches. According to legend, the pillar's top was once embellished with an idol of the Garuda (eagle), but this was taken away when it came under the control of Muslim monarchs. As the only process known to the ancient Indians, forge welding should have been used to create the pillar. On the other hand, such massive iron artefacts started to be forged in the West in the 19th century [22].

More than 100 surgical instruments constructed of iron-carbon alloys have been produced, according to the Sushruta Samhita. They have undergone heat treatment to give them a razor-sharp edge that can split a thin hair in half longitudinally. According to the literature, a surgical knife can be made razor-sharp to the point that it can split a hair longitudinally by applying a carbonaceous paste to its edge, heating it to a red-hot temperature, and then putting it through hardening and tempering processes.

Smelting of Iron

India possesses one of the largest and richest deposits of hematite, magnetite, and hydrated forms like limonite, etc., dispersed throughout the country. This is why India is considered an expert in iron. Using a variety of furnaces, the ancient Indians extracted iron from these sources and produced sponge or wrought iron. Indian furnaces were built differently than those in Western Asia and Europe during the same period. The other furnaces were constructed by excavating a hole in the ground and fitting the stone pieces into the proper shape. In contrast, the Indian furnaces were built using prefabricated clay blocks. While Western furnaces had to be thrown out after only one use, Indian furnaces could be repaired and used again.

In the past, a specific caste within each tribe was responsible for the iron-smelting process, and they all prayed to the god Asura. These "Asuras" smelted iron in Bihar, Odisha, and the eastern portion of Karnataka, while "Agarias" did it in Central India. Studies have been conducted on the "Agaria" tribe's iron smelting practices in the central Indian districts of Rewa, Udaipur, Ranchi, and Koraput. The "Lohars" or "Loharins" are another groups related to ironworking (blacksmiths). While Lohars worked on the wrought iron to build various tools and objects using adequate heat treatment procedures. Agarias were involved in the smelting of the iron ore to create wrought iron blooms.

Table 2.1
Classification of Fe-C Steel Alloys as per Rasa-ratna-samuccaya Properties

Type of Iron	*Name*	*Properties*
Kanta-loha (Soft Iron)	Bhramaka	Very soft, magnetic iron Mildly magnetic, sticks to iron pieces
	Cumbaka	
	Karsaka	Attracts iron objects
	Drávaka	Strong magnetic iron
	Romaka	Permanent magnet, develops magnetic field around it

Type of Iron	*Name*	*Properties*
Tiksna-loha (Carbon Steel)	Khara	Develops good cutting edge, breaks on bonding
	Sara	Softer iron, it has fibrous fracture
	Hranala	Hard and inflexible, has fibrous fracture
	Täravatta	Develops good cutting edge
	Vajira	Good hardening and tempering property, bluish in colour, hard cutting edge
	Kala	Develops hard cutting edge after tempering
Munda-loha (Cast Iron)	Mrdu	Soft, brittle, low melting point
	Kuntha	Grey iron
	Kadara	White cast iron

Source: Bag, A.K. (1977). History of Technology in India, Vol. I, Indian National Science Academy, New Delhi, p. 125

Extraction of Iron from Biotite by Ayurvedic Method

Several methods for removing iron from Biotite and other iron-bearing minerals to create medicine have been described in RRS and other Ayurvedic books. Three steps make up this procedure, known as Satvapatana: Sodhana (purification), Bhavana (maceration and trituration), and Dhamana (Heating and smelting). The mineral must first be purified by being heated and quenched seven times in certain extracts. The suggested liquids used for the purification of biotite are [23]:

1. Käñji (Acidic fermentative liquid)
2. Triphala (Decoction of a mixture of Terminienelia chebula, Terminalia belerica, and Emblica Officinalis)
3. Cow's urine
4. Cow's milk

This procedure is followed by an intermediate step called Bhavana, and then the treated mineral, mixed with a few other substances, is pelletized. According to RRS, the charge materials must include the following percentage: 200 g of pure mica. 50 g each of borax (for flux) and musali powder (for reductant). Water is added to this mixture, pelletized into 25–30 mm balls and dried in the sun. The pellets are loaded into a crucible and fired in a furnace to high temperatures. The RRS literature describes a furnace design that can reach 1400 °C. Varahamihira (550 CE) in Brhat-samhită discussed the following processes for carburisation and hardening of iron swords in Chapter 50 (verses 23-26) [24]:

i) Make a paste of the gelatin from the sheep's horn and excreta of the pigeon and mouse with the juice of the plant Arka (Caletropis Gigantica) and smear this to the steel after rubbing it with sesame oil. After heating the sword to red hot condition, sprinkle on It any of the following: water, milk of horse, camel or goat, ghee, blood, fat, or bile. Then sharpen the edge.
ii) Plunge the steel, red hot into a solution of plantain ashes in whey, keep it for twenty hours, and then sharpen the edge.

Manufacture of Steel

In manufacturing steel, the initial step in making wrought iron is to create cast iron directly, which is accomplished by heating iron ores with charcoal in small blast furnaces (the blast is admittedly created using hand bellows). Each piece is divided into three parts and placed in a crucible with fresh leaves of vonangady and dried branches of "tangedu" (Cassia auriculata) (convolvulus laurifolia) to transform wrought iron into steel. The crucible's mouth is then carefully sealed with a handful of red mud before being placed in a hole dug in the ground and arranged in a circle with their bottoms facing the centre. After six hours of continuous blowing from massive bellows, the procedure is complete. The hole is subsequently filled with charcoal. The crucibles are then taken out of the furnace, laid out in rows on wet mud, and hot water is thrown on them. At the bottom of the crucibles, when it has assumed this form, the steel is discovered in conical bits [25].

According to certain research, the chemical reaction when heat is applied to the closed crucible causes the dry wood and green leaves to produce charcoal and a plentiful supply of hydrocarbons. The rapid production of steel is substantially accelerated by the combined action of carbon and hydrocarbons on iron.

The European method of cementation using charcoal alone used to take six or seven days and even fourteen to twenty days, while the Indian process takes only four to six hours.

One can carburize a hot sponge or apply a carburising paste selectively to the instruments' cutting edges and then reheat them to 950–1000°C. As we've already seen, the ancient Indians used this technique to create sharp cutting edges, like those on swords and surgical knives. However, the iron subjected to the carburising process had low fracture strength, structural heterogeneity, and inconsistent quality. These issues were resolved with the advent of the Wootz steel production technique, a legendary invention of the ancient Indians.

Yuktikalpataru, an 11th-century CE work, mentions the relative properties of iron-carbon alloys produced in different regions of India and provides a comparative metric for their relative superiority as given below [26]:

- Kraufica-iron is supposed to be two times better than Samanya (probably Munda-loha).
- Kalinga (Odisha)-8 times better than Crouńca iron.
- Bhadra-100 times better than Kalinga iron..
- Vajra-1000 times better than Bhadra iron.
- Pändi-6 times better than Vajra iron.
- Niravi-10 times better than Pandi iron.

- Kanta-Ten billion times as good as Niravi iron.

Lost Wax Casting of Idols and Artefacts

This method has been used to create metal sculptures based on original sculptures. The metal sculpture is constructed of bronze, brass, silver, or gold. This method produced exquisite bronze statues and icons created during the Chola era. A bronze idol of Siva-Parvati made in the 11th century CE utilising the lost wax casting method is seen in Figure 5.2. The lost-wax casting method is also employed in the Indian tradition to create paca Loha idols, which combine five metals: gold, silver, lead, copper, and zinc. This technique allows for the creation of intricate works and a high-quality post-casting finish. These paca-Loha idols are so unique, old, and grand that many have been stolen, smuggled, or taken outside the nation. The Sindhu Sarasvati Civilization's 6,000-year-old amulet has the first known use of this method. Other instances are from Mesopotamia in the third millennium BCE and relatively later times.

In this procedure, a pattern of the required shape is initially created using beeswax (thus, the name Madhücchista Vidhanam translates to "process employing beehive residues"). The next step is to prepare a mould by coating it with prepared clay slurry. Wax is later removed by baking the refractory shell once the clay slurry has dried. The refractory shell is typically embedded in a box filled with the sand-clay mixture before casting the molten metal to provide additional support for the refractory wall. The metal casting is carefully removed from the mould once the metal has been poured and solidified. Filing, chiselling, engraving, and polishing are used as additional refinements and finishing touches.

Apparatuses Used for Extraction of Metallic Components

Figure 2.2. An 11th Century CE Bronze Idol of Siva-Pãrvati

Source: https://upload.wikimedia.org/wikipedia/commons/9/94/Bronze_siva.png

A closer examination of the alchemical works from the Common early era reveals that they created the equipment used to extract different chemicals and metallic elements. The alchemists used a variety of tools and gadgets called yantras. For example, RRS has provided descriptions of multiple crucibles (Müşa) and furnaces used to produce Ayurvedic drugs. Additionally, it lists 36 types of tools (yantras), 17 types of crucibles, and 9 types of furnaces, for a total of 51 kinds of metallurgical tools. The Ayurvedic specialist, the metallurgical engineer, and the alchemist appear to be utilising each other's expertise and using similar devices, but in different sizes, to meet their needs.

The alchemists' go-to tool is the crucible, or müşa-yantra, which acts as a general-purpose container for numerous processes. Earth made up the mûsa-yantra. The crucibles combine goat's milk with anthill dirt, rice husk, iron rust, chalk, human hair, and a few other components in a specific ratio. The mixture is worked into a mass that resembles dough, which is then moulded into the required shapes and dried in the sun. For diverse tasks, there were numerous crucible types. A crucible in the shape of brinjal (Solanum melongena) is used to extract zinc from calamine. A tubular end is placed on this crucible, expanding like a flower as it approaches its mouth. We will quickly review a few of the instruments discovered in the ancient Indian laboratory [27].

The device is straightforward and constructed of earthy materials bent into various shapes. In every instance, either wood or cow dung was used as a heat source. As we all know, this might not produce a high temperature. Therefore the chemicals are heated for a few days to a few weeks, depending on the situation.

Dola-yantra uses a suspension mechanism using which the ingredient to be subjected to some treatment is kept in a piece of cloth, tied, and suspended using a rod. This is immersed in a pot half-filled with the desired liquid. The liquid is then heated from the outside.

Svedani-yantra is used for steaming purposes. The mouth of a pot is covered with a piece of cloth, and the substance to be steamed is placed on the fabric. Water is kept in the pot and is protected using another pot. The substance is steamed by boiling the water.

Patana-yantra is used whenever a sublimation or distillation process is involved. It consists of a well-baked pot of suitable dimensions. This pot is filled with water up to the neck and is supported by a larger pot that is turned upside down. The pots' two necks are securely fastened together using an adamantine consisting of lime, unrefined sugar, and buffalo milk. The following is how a downward sublimation method is used. The substance vaporises and gathers in the water in the bottom pot when it is smeared inside the upper vessel and heated from the outside by burning cow-dung cakes. However, the substance can also be heated in the lower pot while moist cloths are used to keep the upper pot cold. The upper pot's interior is filled with sublimate deposits.

Dheki-yantra is also used for the distillation of substances such as mercury. One bamboo tube's end is inserted into a hole drilled below a pot's neck. The other end is inserted into a water-filled brass jar. This device exposes mercury to distillation together with the other necessary compounds.

Väluka-yantra is a type of sand bath for heating substances uniformly and for usually a long time. The item to be heated is kept in a long-necked bottle partially submerged in the sand in an earthen pot. The device is slowly heated from underneath until a straw set on the sand's surface starts to burn. Salt is occasionally used in place of sand.

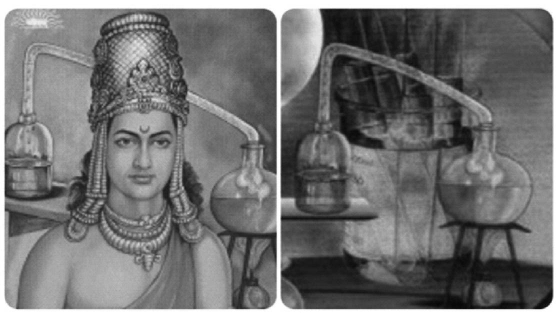
Dhupa-yantra is used for fumigation purposes. This equipment is used to fumigate the leaves of gold or silver with sulphur or arsenic vapours. This is accomplished by using two vessels. Iron bars are positioned in the lower vessel's mouth at an angle, and gold or silver leaves are placed on them. The lower vessel is used to hold sulphur or the arsenic compound, and the upper vessel is used to cover it. The fumigation occurs after heating.

The Rasarnava [28] provides information regarding a müşa-yantra used to heat mercury and sulphur together. Two crucibles make up the equipment, one of which has a small hole. Sulfur and mercury are placed in two crucibles. Filtered garlic juice is to be used to wet mercury and sulphur. The mercury crucible is to be inserted into the sulphide crucible. Then the apparatus is to be carefully dropped into an earthen pot over another earthen pot, with the rims being luted with the cloth. For three days, a fire made of cow dung heats it from the outside.

Chapter–5

SOME OF THE ANCIENT INDIAN CHEMISTS

Acharya Nagarjuna



Nagarjuna is believed to have contributed to philosophy, alchemy, medicine and Tantra. At Srisailam, he experimented on metals, especially mercury (parad). In 1923, Max Walleser concluded his survey as: "The systematic development of the thought of voidness laid down in prajnaparamita sutras is brought into junction with a name of a man of whom we can't even positively say that he is the author of the works ascribed to him: this name is Nagarjuna" [29]. The main reason for accepting more than one Nagarjuna is that historians believe Vajrayana can be traced only from the sixth century onward. Therefore, Tantric works attributed to Nagarjuna are also from the Time of Nagarjuna. Nagarjuna's two epistles (Ratnavali and Suhrllekha) were written to his patron, a Satavahana king [30].

Acharya Kanada

Acharya Kanada was born in 600 BC in Prabhas Kshetra (near Dwaraka) in Gujarat, Eastern India. His real name was Kashyap. He is an ancient natural scientist and philosopher and has said to formulated the theory of atoms 2500 years before John Dalton's discovery (still needed to be referred to). He founded the Vaisheseka school of Indian philosophy. He used this to explain the creation and existence of the universe by proposing an atomistic theory, applying logic and realism, which made his school one of the earliest known systematic realist ontologies in human history.

The Vedic Atomic Theory

It is said that Kanada believed that the atom was eternal and had the tendency to bind with other particles. Vaisesika atomists posited the four elemental atom types.

The ancient Indian school system is known as "Gurukul".
***Source:* dreamstime.com**

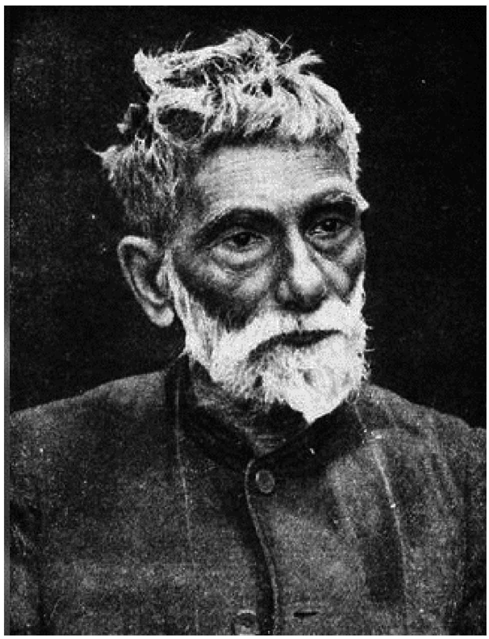
The union of two atoms forms a double or binary molecule called "Dwinuka". According to the theory proposed by Kanada, Dwinuka would have similar properties to the original parmanu (atoms). He also stated that the combinations of different types of atoms result in a non-identical molecule that could chemically change a component in the presence of specific factors such as heat — for example, a change in the colour of utensils made of mud when they are heated. Kanada's book, called Vaisheshik Darshan (also called Kannada sutras), captured his atomic theory, which states the following:

- Everything can be partitioned
- Subdivision leads to the creation of parmanu (atom) after a while
- Parmanu is indivisible; that is, it cannot be divided further
- A subsection of any particle has an end and cannot be carried infinitely.
- Atom is indestructible
- It is the foundation for all material existence
- Parmanu has a specific property which is the same as the class of substance to which it belongs
- It cannot be seen through the naked eye
- Atoms can be combined to produce chemical changes by heating them or using other measures.
- Paramanu or atoms can have a state of motion and a state of absolute rest.

"Paramanu" in today's measurements: Paramanu ("atom") is the unit of measure for any being. A single Paramāṇu represents the smallest unit possible. Combining 8 Paramāṇu units will form a single Rathadhūli unit and so on.

Acharya Kanada defined life as an organized form of atoms and molecules and death as an unorganized form of those atoms. His discovery was not without controversy and has been in dispute since the earliest days. The earliest significant finding of the atom that survives today was made in the 5th century by Greek philosophers Leucippus and Democritus. Scholars such as McEvilley (2002) assume that such similarities are due to extensive cultural contact and diffusion, probably in either direction.

Prof P.C. Ray (CIE, FNI, FRASB, FIAS, FCS)



P. C. Ray was a chemist, a historian and sociologist of science and an industrial entrepreneur. Following his education in Calcutta, he won a Gilchrist Scholarship to study in Britain in the 1880s.

Ray studied chemistry, physics and zoology for a BSc and was awarded a D.Sc. in inorganic chemistry in 1887. He was elected Vice-President of the University Chemical Society in 1887. Ray wished to apply for a position within the Indian Educational Service, although the higher posts in education were all but closed off to Indians. He returned to India in 1888 and tried to enter the service armed with various letters of recommendation. He was unemployed for a year until he got a temporary teaching post in Calcutta.

P. C. Ray eventually set up the Bengal Chemical and Pharmaceutical Works in Calcutta, India's first pharmaceutical company. In 1904 he toured Europe and was given a warm reception by Indian students at Edinburgh. In 1912, the University of Durham conferred an honorary DSc degree. Ray was awarded the Companionship of the Indian Empire (CIE) in 1912 and a knighthood in 1919. In 1916 he took up a position at the University College of Science in Calcutta, where he remained until retirement.

Chapter–6

EXECUTIVE SUMMARY AND RECOMMENDATIONS

The current school education system presents various challenges to the students in their academic progress concerning understanding the curriculum, teacher's expectations, family pressure and many other socio-psychological issues. This workshop was organised in collaboration with Vidya Bharti Uchcha Siksha Sansthan (VBUSS) and Samvit Foundation to recommend the Chemistry curriculum. This workshop was planned to include Indian contributions in chemistry, which also contains materials and metallurgy, in the school textbooks. Under NEP 2020, the academic framework is revised as 5+3+3+4, where chemistry exclusively features in the last stage, including classes 9, 10, 11 and 12 in the current system.

The current exposition of chemistry content in the NCERT textbooks has almost no historical range. The more worrisome is that these textbooks fail to convey even an iota of the scientific achievement of our ancient Indians, particularly in chemistry. It is a brainer that the chemistry we study and teach is modern chemistry having European origin. Nevertheless, if the textbooks fail to inform the scientific achievements of our forefathers, it will be highly detrimental to the cause of NEP 2020, which espouses rootedness in a big way in several instances of the document. It is envisaged that wherever possible, we will try to educate our children about the accomplishments in chemistry to achieve this rootedness and instil genuine pride in our forefathers,

To address the issues mentioned above and for their holistic education, experts from various specializations in Chemical Sciences from different reputed institutions were invited to deliberate on "Indian Contribution to Chemical Sciences" during 6-7 June 2022, Conference Center, Delhi University. The inaugural session was attended by about 150 participants, including Professors, School Teachers (PGT) and Research Scholars, along with 12 Resource Persons. The presence and motivation by of Hon'ble Vice Chancellor, Delhi University, Professor Yogesh Singh, Sh. K. Raghunandan Ji, Prof Kailash C. Sharma, Prof Ramesh C Bhardwaj and Prof Gurmeet Singh was phenomenal. The workshop began with Ma Saraswati Vandana, followed by Dr. Mansi welcoming the guests on behalf of the organizers DU, VBUSS and Samvit and introducing the workshop's theme. It was followed by Prof. Ashok Prasad, HoD Chemistry, felicitating the guest and briefly describing the programme. He spoke about the Department of Chemistry's achievements and how this can assist in integrating Ancient Chemical Knowledge into the Indian Knowledge system and the chemistry test books. In his opening remarks, Prof K. C. Sharma, President VBUSS and former VC Kurukshetra University, mentioned the objectives of the meeting and its importance for the workshop theme "Indian Contribution to Chemical Sciences" and the possible implementation strategies. He spoke about the information available in our ancient system – a few non-tested or scientifically evidenced and time-tested ones currently performed by a few organizations. He also mentioned the unawareness of our own findings/ assets/ancient literature in our school children and the need for including some unified, standardized practices from our ancient system specifically for accepting, practising and taking this further with pride on the knowledge of our forefathers/gurus and rishis. He concluded by saying that the outcome of such a workshop should lead to recommendations to the Indian Knowledge System and Education Ministry for implementation in the NCERT Chemistry textbooks.

Prof. R.C. Bhardwaj VC, Maharshi Valmiki Sanskrit Vishvidyalaya, Kaithal, emphasized the value of ancient literature and extended full support in translation and discussion involving Sanskrit Literature. Prof Gurmeet Singh, Vice Chancellor of Pondicherry University, expressed his happiness in taking up a very well-needed subject of the workshop and awareness of our ancient contribution to Science. Vice Chancellor of Delhi University, Prof. Yogesh Singh, addressed the participants about our heritage of Ancient Knowledge and advised on what is expected from the meeting. He spoke about the importance of the holistic development of students and future scientists. His message was to consolidate past knowledge with a forward-looking approach. While presenting a vote of thanks, Prof. Raj Kishore Sharma requested the participants that care must be taken to neither pander to jingoism/tokenism by alluding to simple hearsay nor relegate valuable contributions as sporadic acts of accidental instances. Authenticated results from our rich past must only be given credence and recommended for the textbooks. Any lapse in this direction would prove counterproductive to our collective effort and completely derail the mission to educate impressionable minds with genuine Indian accomplishments. There is no need for hyperboles and opinionated excesses, as there are more than enough instances from our rich scientific past to boast about.

The first technical session started with a Keynote lecture by Prof Gurmeet Singh, VC Pondicherry University, followed by an orientation by Prof. Raj K Sharma about the need for the workshop. He insisted on integrating ancient knowledge with the Indian Knowledge System and implementing the deliberated and authenticated contribution to textbooks. M.Sc. Students of

Chemistry and Research Scholars presented an overview of ancient Indian chemical Knowledge in different domains of science.

The First Resource lecture was presented by Prof. Nand Kishore, who opened technical session II with his talk on “Contributions of Indian Scientists in Chemical Thermodynamics”. He discussed the 18th and 19th centuries when scientists abandoned the idea of a physical caloric, understood heat as a manifestation of a system’s internal energy and related it with Vedic philosophy. Today Isothermal Calorimetry has made it possible to understand the biologically important system.

Another term which comes into play is partial molar volume; from our country (India), many scientists have used this property to understand intramolecular interaction. Boyle’s law, Henry’s law, then the deviation of ideality, all these deviations (given in NCERT book) can be calculated from and measured from the partial volume, which can be calculated from the DMS series densitometer. Partial molar volume at infinite dilution can be shown by V^0. Professor Ramesh Gardas also presented his talk in thermodynamics and agreed to combine his talk summary with Prof Nand Kishore.

Prof. Rajiv Gupta delivered a talk titled “Luminaries of Indian Science” on biographies of some Indian scientists. He tried to highlight the achievements of Indian scientists even under British rule. He discussed modern science awakening in the last decades of the nineteenth and early decades of the twentieth century about P.C Ray, J.C Bose and C.V. Raman, starting from their early education to becoming renowned scientists. He emphasized that the Nation needs well-qualified, trained human resources, which would be future leaders with good qualities such as faith in values, self-esteem, national identity, perseverance etc., which modern education invariably lacks. Suggested that to re-establish the ancient glory, Indian knowledge and tradition must be reinstated and re-established in the school educational system.

Prof. N.B. Singh presented the concept of the atom in the context of ancient India. He emphasized the theory of atoms formulated approximately 2500 years before by an Indian sage and philosopher named Acharya Kanada. This idea came to Kanada's mind while walking with rice grains in his hand. He nibbled at the food in his hand, throwing away the small particles one by one until he could not break them down anymore, and it left a smell on his hands. He realized that he could not divide the food into different parts, and the realization of a *matter which cannot be divided* further came into existence. He called this indivisible matter *"anu,"* which means atom. Kanada also proposed that atoms could be combined in various ways to produce *chemical changes* in the presence of other factors, such as heat.

Prof. V. Ramanathan discussed "Indian contributions in chemistry, metallurgy and material science: Bringing them to school textbook". This talk relates how the names of many minerals and elements we find in European languages are derived initially from Sanskrit. He mentioned knowledge possessed by ancient Indians from the Indus Valley Civilization and how it is lost. According to him, chemistry's role in day-to-day life should be incorporated in our books with illustrations and examples, preferably from the Indian context. At the same time, unsubstantiated content must not find their tokenism to Indian contributions, which will be counterproductive. Only authentic, scientific and well-established facts, which are aplenty, must be included in the chemistry textbook, which will arouse curiosity in the impressionable minds and adequately root them to the Indian contributions in chemistry.

Dr. Anil Bhalekar explained the laws of thermodynamics from the Shrimad Bhagwat Gita. He explained the *ordered evolution* of chemical and biological systems and the entire Universe in terms of a mathematical equation, where the first term maintains irreversibility with increasing disorder and the second term simultaneously produces order within the system. According to him, there are shlokas in the ancient Indian literature for this equation, which is an expression of the Law of ageing and is the base of the *Law of probability* for describing the evolution in biological systems.

Dr. R. Geetha Sudheer presented the "Contribution of Siddha system of medicine to chemical sciences". The Siddha system of medicine is among the AYUSH systems recognised by the Government of India. He cited many examples to emphasize that ancient Indians developed this traditional medicinal system. Noticeable is the use of turmeric and paan as natural indicators. Siddha system also discusses making sulphur biocompatible before adding to the formulation by using traditional techniques commonly called "cutting muṟai" for producing monoclinic sulphur at room temperature. He also mentioned using plant extracts for multiple disorders described in the Siddha system.

Prof. S.K. Shukla's talk on "Indian Prospective for Processing of Materials" is a great effort to highlight the ancient Indian contribution. He explained the processing of pure and mixed metal in the context of old India for developing weapons, agricultural tools and construction purposes after using different processing conditions and furnaces. Some basic examples in class are the iron pillar of Delhi, which is protected from atmospheric corrosion and the grilled wrought iron Buddha image lying in the Lucknow State Museum. He believes this knowledge will not only encourage students about our past glory but also help start a small-scale materials processing industry using different furnaces and vernacular heating technology.

Dr. A.K. Mishra's presentation on "Copper in ancient India" included the metallurgy of this metal in ancient India. He explained the uses and importance of copper concerning Atharvaveda, followed by the metallurgical processing mentioned in Rigveda. The modern blast furnace method of smelting copper, which was first described by Agricola in the middle of the sixteenth century when writing about the operation of the Mansfield copper works, is conceptually similar to the traditional Indian method of extracting copper. He also explained some copper compounds used by ancient Indians, again indicating the knowledge of metallurgy.

In the same line, Prof. R.K. Soni presented the "Extraction and use of Iron, Gold and Silver during Ancient Period". He emphasized that the Extraction and use of Iron, Gold and Silver were found in their advanced state in the ancient period. Three significant areas of our ancient rishis: (i) Intellectual thinking about nature, (ii) Development of Professional skills for livelihood, (iii) Welfare measures like health Care of Society are relevant. While describing the Iron extraction procedure and furnace designs talked about the Death of Indian Iron during British Empire. Therefore, the disappearance of ancient technology during the seventeenth to nineteenth centuries was aggravated by the discovery of new alchemical principles and the development of a new industrial process of metal production in Europe. He also discussed the purification of Gold and Silver by Ancient Indians.

Prof. Raj Kishor Sharma's presented a topic away from metallurgy and materials. He spoke about "Energy: understanding and usage in ancient India" and highlighted the origin and applications of electricity from Agastya Samhita. He explained the Vedas as a source of knowledge and skills. The battery description from Agastya Samhita was discussed, and its similarities with modern-day batteries were highlighted. Sage Agastya is known as the father of science. As per his Samhita, he is believed to know or had invented the Electrical cell (Battery) much before the European reports. His timelines are considered to be before 2000 BC. In his book Agastya Samhita, he mentioned numerous scientific aspects of how to make an electric cell. Agastya was also named Kumbhodbhava as he invented an electric cell made of the earthen pot, as described in the sloka. Shlokas about electrolysis of water producing hydrogen and oxygen and the properties of these gases were presented. Agastya Samhita also includes electroplating, similar to modern-day technologies. Finally, the concept and uses of electricity concerning Atharvaveda and Rigveda were briefly explained.

The last session on 7th May 2022 evidenced an energetic valedictory function with enthusiastic and motivated participants with requests and suggestions to hold more discussions over some time. Sh. Govind Mohanty Ji National Organising Secretary Vidya Bharti graced the session as Guest of Honour, and Prof V.S. Parmar, former Head Chemistry Department, was the Chief Guest. Sh. Govind Mohanti emphasised the importance of integrating ancient knowledge with our current education system for the holistic development of future youth. Professor Parmar congratulated the department for holding a significant discussion in the workshop and highlighted the importance of self-reliance in nation-building.

Based on the lectures delivered by resource persons, the following points about ancient Indian chemistry emerged:

- Indian civilization has a long history that goes back at least two millennia in recorded history. Numerous additional archaeological and literary findings support the ancient notion of a thriving society in ancient times.
- Ancient Indians made significant advances in metallurgy, material science, and metalworking, among other fields of technology.
- Numerous prominent iron artefacts, such as forge-welded cannons, were produced and used in ancient and mediaeval India, demonstrating the high standing of iron and steel technology in those periods.
- Numerous archaeological artefacts suggest that the copper industry had a long and thriving history in ancient India.

- The oldest artefact in the world to contain a significant amount of zinc comes from India, as demonstrated by extensive archaeological digs in regions of Rajasthan.
- The purified gold metal bar could be worked with using ancient metalworking methods like forging, punching, embossing, etc., to create ornaments with complex designs.
- Research on the Zawar zinc mines offers fascinating details about zinc production in ancient India. Ancient Indians used a revolutionary technology called downward drift reduction distillation, a forerunner of the current procedures.
- In the classic Ayurvedic Caraka Samhita, the compound HgS is called Rasa Sindura. Both Hg and HgS have been widely used in creating Ayurvedic medications.
- Iron has been extracted from ore sources and produced as a sponge or wrought iron by ancient Indians using a variety of furnaces. One can carburise a hot sponge or bloom by carburising paste selectively to the tool's cutting edge and warming it to temperatures between 950°C and 1000°C.
- Ancient Indians used this technique to create sharp cutting edges for things like surgical blades and swords.
- There are several references to iron, copper, gold, silver, and tin in the Vedic corpus. A few significant treatises on metallurgy and metalworking date from the fifth century CE to the thirteenth century CE are also found.
- The ancient Indians acquired the knowledge and abilities necessary to explore profitable ore resources and mine them.
- Rasa-Ratna-Samuccaya described various procedures for extracting pure copper from chalcopyrite. Copper is employed in Ayurvedic therapeutic formulations in powder form (bhasma).

- A closer study of the early Common Era alchemy works offers a solid idea of what a scientist's laboratory would have looked like and what kind of equipment they created and utilised to extract different chemicals and metal components.
- Bronze was used in the lost wax casting process to create exquisite idols and icons made during the Chola era.

Recommendations for Designing New Textbooks

The two days "Indian Contribution to Ancient Chemistry" workshop was organised on May 6^{th} and 7^{th}, 2022, and many participants attended the event. The resource persons from different areas of Chemistry deliberated and presented their research. The workshop was planned for class 8^{th} -12^{th} chemistry students; therefore, the text matter under discussion was the NCERT books, and the authentic knowledge from the ancient texts was under discussion. Although Ancient Indians worked in many areas of Chemistry known as Alchemy, the vital information available is from Materials and Metallurgy. However, the historical legacy of India in the advancements related to chemistry, processing metals, minerals, gunpowder, ceramics, medicine, cosmetics, and paint, among others, are well recorded and readily accessible. Unfortunately, they have never got highlighted in our textbooks. Therefore, the ancient Indian contribution to chemistry must be taught to students, not as the "History of Indian Chemistry" but lucidly as the "Indian contribution" to the particular area while discussing Modern Chemistry. For Example

The names of many minerals and elements that we find in European languages are derived initially from Sanskrit; like the term 'corundum', a mineral is derived from Sanskrit Kuruvinda, while the word 'sulphur' is derived from Sanskrit 'sulvari' and beryl is derived from the Sanskrit word 'veluri'. Ayurveda played a significant role in processing metals and minerals, making our ancestors contribute to the field of Chemistry. Science and technology in ancient and medieval India covered all the major branches of human knowledge and activities. In early civilization, metallurgy has remained an activity central to all civilizations from the Bronze Age and the Iron Age. It may be taught that during the Indus Valley Civilization, Cement traces were discovered during the Mohenjo-Daro period. During this time, leather tanning and cotton dyeing were practised, according to Rigveda.

Glass, paper, soap, dyeing, cosmetics and perfumes, alcoholic lacquers, pharmaceuticals, gunpowder, and saltpetre were the most crucial chemical products. Nagarjuna (a metallurgist) and Kanada were famous ancient Indian chemists.

In Siddha system, sulphur is made biocompatible before adding to the formulation using various traditional techniques commonly called “cutti mu̱rai”. Among the different methods of cutti mu̱rai for sulphur mentioned in Siddha texts, melting with butter followed by quenching in fresh cow’s milk is the most popular. This process produces a stable form of monoclinic sulphur at room temperature. The monoclinic clinic sulphur formed by heating orthorhombic sulphur is believed to be maintained in the same allotropic form by incorporating the organic substances in the milk. Similarly, the sulphur prepared by quenching molten sulphur in a mixture of curd and ground leaves of Lawsonia inermis gives plastic sulphur that is stable at room temperature. This indicates the knowledge of various allotropes of Sulphur in Siddha system.

A prehistoric element named after the old English word ‘coper’ and the Latin word ‘Cypriumaes’ means a metal from Cyprus. Copper is considered the first metal utilized by ancient cultures dating back to the Neolithic period. The shiny red-brown metal was used for tools, sculpture, jewellery, bells, lamps, containers, amulets, death masks etc. The copper-tin alloy was commonly utilized in the ancient world as bronze. Copper is the first metal found by humankind, dating back 10,000 years. In the history of the Indian subcontinent, copper has been one of the most significant metals.

Copper appears to have been known in India during the later Vedic period, particularly during the Brahman period. It does not appear to have been stated in the Rig-Veda, the oldest Veda However, it is listed as loha (from lohita or red) in the White Yajurveda list of six metals. These examples can be given to students to instil pride among students about their own country. Similarly, the date of the copper age in India can be taught, and a model can be given as the Colossal copper statues of Buddha. While discussing the metallurgy, the Metallurgical practices in Ancient India can be discussed well documented. Similarly, the Iron metallurgy in ancient India and the death and reason for the end of Indian Iron can be taught.

Many Laws of current science find their origin or similar description in our Vedas and other texts as Bhagwat Gita. For example, energy and electricity have been extensively discussed in Atharvana Veda, Rik Veda and Agastya Samhita. Inevitably, more research and deliberations are needed to relate these with the current science correctly; however, the understanding of the knowledge that we had in ancient times can be given to the students. The laws of thermodynamics can relate to the verses from many ancient Hindu texts.

Science is a subject of interest due to logic, calculations and concepts; therefore, the Ancient Indian Contributions cannot be taught as "History of Chemistry". If we attempt this, it takes the students' interest away from the subject. And students might start memorizing it in the place of understanding it. Thus, if chemistry teaching is not done with students actively engaged in class, the concept will not be embedded in the students' minds. Examples may be given from their daily life, for example, the formation of vinegar use of iron pieces in the process. The use of vinegar as an electrolyte in an electrochemical cell as an acidic electrolyte etc. pH indicators are commonly used to demonstrate the acid and base reactions in conventional teaching. This simple mechanism has been utilised to authenticate the process completion of ancient chemical processes. The authentication procedure for Chunnam (one among the 32 types of internal formulations) involves mixing the finished product (chunnam) with turmeric. If the product turns red, it will be deemed a complete drug. Or else the entire process has to be repeated from scratch. In this process, calcium carbonate in Chunnam changes the pH when mixed with turmeric dissolved in water, resulting in red colour. Here, turmeric acts as a pH indicator and calcium carbonate in chunnam acts as an alkalinizing agent.

Another example is the reactions noted in paan, where green-coloured betel leaf, mixed with white-coloured calcium carbonate and brown-coloured araeca-nut, gives a red colour. In this, the organic substances (catechin, gallic acid, anthocyanin, Epigallocatechin, gallate's, epicatechin and tannic acid) acts as pH indicator, and calcium carbonate acts as an alkalinizing agent. Similarly, Wax loss technology is a unique metal casting technique used in ancient for making metal parts like statues and other features like dancing girls. This process is referred to in books of historical science, but its inclusion in chemistry books will be effective light the students as well as faculty. "Lost-wax technique is a materials process technique used for casting of metal articles like solid and hollow statues of different metals. This process is comprised of sequential thermos chemical steps of materials processing. The initial stage is made of wax, which is then covered with clay and allowed to dry. In the consecutive stage, a tiny hole was made in the clay cover and heated further. Thus, the molten wax was drained out through the hole, leaving a negative image of the sculpture inside the hardened clay. Then the molten metal was poured into that hard clay through the hole. The clay cover was carefully removed when the metal cooled and solidified, and the image was cleaned and polished. One variation is that the clay is left to dry without being heated. The wax melts and runs out when the molten metal is poured into the mould. Then, create the image you want to make; the external surface of the wax is finely carved. The clay core is left inside. When the molten metal is poured into the mould metal casting, the wax melts away. The exact process was applied in making statues of Buddha in Nepal and Tibet with several advantageous features like surface finishing and cost-effectiveness.

What needs to be done

Besides leaving out the Indian contribution to Chemistry, the current problem plaguing chemistry education in India is the lack of creative teaching in a chemistry classroom coupled with a lack of exploration in learning experiences that could engage students in realistic, thought-provoking problems where they work with each other's, apply their knowledge, skills, and creativity to find solutions to real-world issues ultimately. Chemistry is tricky because it is characterised by abstract concepts and an abject lack of relating these to students' daily lives. By and significant for the JEE aspirant and those who cleared it, chemistry is the least preferred subject compared to mathematics and physics. The reason often cited is the relatively higher content in chemistry demanding memorization. Thus, if chemistry teaching is not done with students actively engaged in class, the concept will not be embedded in the students' minds.

Industry 4.0 has made governments and employers recognise creative thinking as an essential skill. Much of what is routine in the workplace is being automated due to the digital revolution, but creative thinking remains (for the time being, at least) a uniquely human domain. It is high time for chemistry education to recognize this significance so that "creative chemistry" is as widely accepted and understood as the term "creative arts."

With the lack of prior research on creative teaching in chemistry, it is essential to cultivate innovative teaching among chemistry teachers to make a meaningful lessons for students.

One of the fundamental challenges in schools is the developing interest in Chemistry students right from their early classes. There is a significantly lesser inclination for chemistry because while very little in chemistry is taught till the 8th standard, the leap in 9th standard chapters is too much, forcing the students to memorise the formulae in chemistry, resulting in hate for the subject. Textbooks play a significant role in arousing the students' interest and guiding them to desired intellectual levels, say in chemistry.

Until and unless we generate curiosity amongst our students about chemistry, we will not be able to achieve the objective of NEP 2020. Chemistry's role in day-to-day life should be incorporated into our books with illustrations and examples, preferably from an Indian context. At the same time, unsubstantiated contents must not find their way into the textbook to pay tokenism to Indian contributions, which will be highly counterproductive. Only authentic, scientific and well-established facts, which are aplenty, must be included in the chemistry textbook, which will not only arouse curiosity in the impressionable minds but will also adequately root them to the Indian contributions in chemistry.

Chapter–7

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24. The process is described in the following two verses of Rasa-ratna-samuccaya: प्रसप्रकाराणि निक्षिप्तं काज्जिकेऽभ्रकम् निर्दोष जायते नूनं प्रक्षिप्तं वाऽपि गोजले।। prataptam saptavarani niksiptam kāñjike'bhrakam nirdosam jāyate nunam praksiptam vip gojale || RRS 2.16 विनकथिते चापि गवा दुग्धे विशेषतः ततो धान्याभ्रकं कृत्वा पिष्टा मत्स्याक्षिकारसैः।।

triphalakvathite căpi gavā dugdhe visesatah tato dhanyābhrakam kṛtvå pisṭvā matsyäksikä RRS 2.17

25. The two processes for sharpening the sword are given in the following verses of Brhat-sambiti

इदमीशनसंच शखपानं रुधिरेण श्रियमिच्छतः प्रदीप्ताम्।

इतिया गुणवत्ताभिलिप्सोः सलिलेनाक्षयमिच्छतश्च वित्तम्।।23।।

बडवौष्ट्रकरेणुदुग्धपानं यदि पापेन समीहतेऽर्थसिद्धिम् झषपित्तमृगान्वबस्तदुग्धैः करिहस्ताच्छ्दिये सतानगर्भः ।।24।।

आके पयो हुदुविषाणमग्रीसमेत पारावताखुशकृता च युतः प्रलेपः।

शस्त्रस्य तैलमथितस्य ततोऽस्य पानं पच्जाच्छितस्य न शिलानु भवेद्विघातः।।25।।

क्षारे कदल्या मथितेन युक्ते दिनोषिते पायितमायसं यत्। सम्यक् शितं चाश्मनि नति भड्ग न चान्यलोहेष्वपि लस्य कौण्ठयम्।।26।। idamausanasam ca sastrapānam rudhirena śriyamicchataḥ pradiptam |

26. ivisa gunavatsutábhilipsob salilenaksayamicchataśca vittam ||23|| vadavauştrakareṇudugdhapanam yadi pápena samihate'rthasiddhim

27. |hasapittamrgaśvabastadugdhath karihastacchidaye satālagarbhaih ||24|| arkam payo huduviṣaṇamarṣisametam pārāvatakhušakṛtā ca yutah pralepah |

28. Sastrasya tailamathitasya tato'sya panam paścācchitasya na śilāsu bhavedvighataḥ ||25||

29. ksåre kadalya mathitena yukte dinoşite payitamayasam yat | samyak Sitam casmani naiti bhangam na cānyalohesvapi tasya kaunthyam || 26 ||

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    सामान्यादिगुणोक्तं कनिदेशगुणस्ततः। कलेः शतगुणं भई भद्रा सहसा || 85.31 का गुण परिनिभिर्गुणेः। ततः कोटिसहस्रेण स्वान्तः प्रशस्यते 85.32

    samanyad dvigunańcoktam kalirdadagunastatab | kaleh šatagunam bhadrambhadradvajramvajratsastigunahpandirniravirdaśabhirgunaib tatab kotisahasrena hyayaskantab pradasyate || 85.32

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