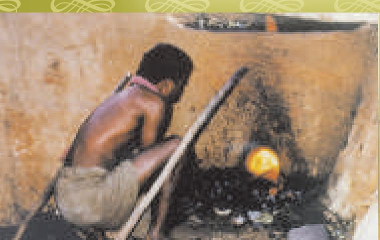
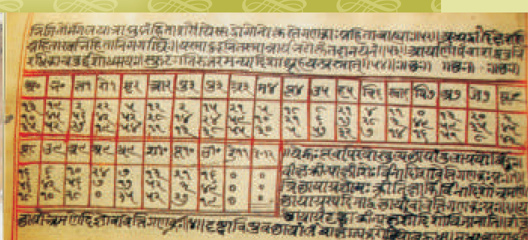
Knowledge TRADITIONS & PRACTICES OF INDIA

Textbook for Class XI

Statue of Kannagi, Chennai

Module 2
Chemistry in India

CENTRAL BOARD OF SECONDARY EDUCATION
Shiksha Kendra, 2, Community Centre, Preet Vihar,
Delhi-110 092 India

नया आगाज़

आज समय की माँग पर
आगाज़ नया इक होगा
निरंतर योग्यता के निर्णय से
परिणाम आकलन होगा।

परिवर्तन नियम जीवन का
नियम अब नया बनेगा
अब परिणामों के भय से
नहीं बालक कोई डरेगा

निरंतर योग्यता के निर्णय से
परिणाम आकलन होगा।

बदले शिक्षा का स्वरूप
नई खिले आशा की धूप
अब किसी कोमल-से मन पर
कोई बोझ न होगा

निरंतर योग्यता के निर्णय से
परिणाम आकलन होगा।
नई राह पर चलकर मंज़िल को हमें पाना है
इस नए प्रयास को हमने सफल बनाना है
बेहतर शिक्षा से बदले देश, ऐसे इसे अपनाए
शिक्षक, शिक्षा और शिक्षित
बस आगे बढते जाएँ
बस आगे बढते जाएँ
बस आगे बढते जाएँ.........

CBSE
CONTINUOUS AND COMPREHENSIVE EVALUATION
KNOW - AS YOU GROW

Knowledge TRADITIONS & PRACTICES OF INDIA

Textbook for Class XI

Module 2
Chemistry in India

CENTRAL BOARD OF SECONDARY EDUCATION
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Preface

India has a rich tradition of intellectual inquiry and a textual heritage that goes back to several hundreds of years. India was magnificently advanced in knowledge traditions and practices during the ancient and medieval times. The intellectual achievements of Indian thought are found across several fields of study in ancient Indian texts ranging from the Vedas and the Upanishads to a whole range of scriptural, philosophical, scientific, technical and artistic sources.

As knowledge of India's traditions and practices has become restricted to a few erudite scholars who have worked in isolation, CBSE seeks to introduce a course in which an effort is made to make it common knowledge once again. Moreover, during its academic interactions and debates at key meetings with scholars and experts, it was decided that CBSE may introduce a course titled 'Knowledge Traditions and Practices of India' as a new Elective for classes XI - XII from the year 2012-13. It has been felt that there are many advantages of introducing such a course in our education system. As such in India, there is a wide variety and multiplicity of thoughts, languages, lifestyles and scientific, artistic and philosophical perceptions. The rich classical and regional languages of India, which are repositories of much of the ancient wisdom, emerge from the large stock of the shared wealth of a collective folklore imagination. A few advantages given below are self explanatory.

- India is a land of knowledge and traditions and through this course the students will become aware of our ancient land and culture.
- Learning about any culture particularly one's own culture - whatever it may be - builds immense pride and self-esteem. That builds a community and communities build harmony.
- The students will be learning from the rich knowledge and culture and will get an objective insight into the traditions and practices of India. They will delve deeply to ascertain how these teachings may inform and benefit them in future.
- The textbook has extracts and translations that will develop better appreciation and understanding of not only the knowledge, traditions and practices of India but also contemporary questions and issues that are a part of every discipline and field in some form or another.

This course once adopted in schools across India can become central to student learning: each student brings a unique culture, tradition and practice to the classroom. The content is devised in a way that the educator becomes knowledgeable about his/her students' distinctive cultural background. This can be translated into effective instruction and can enrich the curriculum thereby benefitting one and all. This insight has close approximation with the pedagogy of CCE.

The course is designed in a way that it embodies various disciplines and fields of study ranging from Language and Grammar, Literature, Fine Arts, Agriculture, Trade and Commerce, Philosophy and Yoga to Mathematics, Astronomy, Chemistry, Metallurgy, Medicine and Surgery, Life Sciences, Environment and Cosmology. This can serve as a good foundation for excellence in any discipline pursued by the student in her/his academic, personal and professional life.

This book aims at providing a broad overview of Indian thought in a multidisciplinary and interdisciplinary mode. It does not seek to impart masses of data, but highlights concepts and major achievements while engaging the student with a sense of exploration and discovery. There is an introduction of topics so that students who take this are prepared for a related field in higher studies in the universities.

The examination reforms brought in by CBSE have strengthened the Continuous and Comprehensive Evaluation System. It has to be ascertained that the teaching and learning methodology of CCE is adopted by the affiliated schools when they adopt this course. The contents have to cultivate critical appreciation of the thought and provide insights relevant for promoting cognitive ability, health and well-being, good governance, aesthetic appreciation, value education and appropriate worldview.

This document has been prepared by a special committee of convenors and material developers under the direction of Dr. Sadhana Parashar, Director (Academic & Training) and co-ordinated by Mrs. Neelima Sharma, Consultant, CBSE.

The Board owes a wealth of gratitude to Professor Jagbir Singh, Professor Kapil Kapoor, Professor Michel Danino, and all those who contributed to the extensive work of conceptualizing and developing the contents. I sincerely hope that our affiliated schools will adopt this new initiative of the Board and assist us in our endeavour to nurture our intellectual heritage.

Vineet Joshi
Chairman

Convenor's Note by Professor Jagbir Singh

In 2012, CBSE decided to introduce an Elective Course 'Knowledge Traditions and Practices of India' for classes XI and XII and an Advisory Committee was constituted to reflect on the themes and possible content of the proposed course. Subsequently Module-Preparation Committees were constituted to prepare ten modules for the first year of the programme to include the following Astronomy, Ayurveda (Medicine and Surgery), Chemistry, Drama, Environment, Literature, Mathematics, Metallurgy, Music and Philosophy.

Each module has;

I. A Survey article

ii. Extracts from primary texts

iii. Suitably interspersed activities to enable interactive study and class work

iv. Appropriate visuals to engender reading interest, and

v. Further e- and hard copy readings.

Each module in the course has kept in mind what would be a viable amount of reading and workload, given all that the class IX students have to do in the given amount of time, and controlled the word-length and also provided, where needed, choices in the reading materials.

Each Module consists of:

I. A Survey Essay (about 1500-2000 words) that introduces and shows the growth of ideas, texts and thinkers and gives examples of actual practice and production.

ii. A survey-related selection of extracts (in all about 2000 words) from primary sources (in English translation, though for first hand recognition, in some cases, where feasible, the extracts are also reproduced in the original language and script).

iii. Three kinds of interactive work are incorporated, both in the survey article and the extracts - comprehension questions, individual and collective activities and projects (that connect the reading material and the student to the actual practice and the environment).

iv. Visuals of thinkers, texts, concepts (as in Mathematics), practices.

v. Internet audiovisual resources in the form of URLs.

vi. List of further questions, and readings.

The objective of each module, as of the whole course, is to re-connect the young minds with the large body of intellectual activity that has always happened in India and, more importantly, to enable them (i) to relate the knowledge available to the contemporary life, theories and practices, (ii) to develop, wherever feasible, a comparative view on a level ground of the contemporary Western ideas and the Indian theories and practices, and (iii) to extend their horizons beyond what is presented or is available and contemplate on possible new meanings, extensions and uses of the ideas - in other words to make them think.

We have taken care to be objective and factual and have carefully eschewed any needless claims or comparisons with western thought. Such things are best left to the readers' judgement.

This pedagogical approach clearly approximates CBSE's now established activity-oriented interactive work inviting the students' critical responses.

It is proposed to upload the first year's modular programme to be downloaded and used by schools, teachers and students.

As a first exercise, we are aware that the content selection, a major difficult task, can be critically reviewed from several standpoints. We do not claim perfection and invite suggestions and concrete proposals to develop the content. We are eagerly looking forward to receiving the feedback from both teachers and students. That would help us refining the content choice, the length and the activities. We will also thankfully acknowledge any inadvertent errors that are pointed out by readers.

The finalisation of this course is thus envisaged as a collective exercise and only over a period of time, the Course will mature. We know that perfection belongs only to God.

If our students enjoy reading these materials, that would be our true reward.

Prof. Jagbir Singh
Convenor

Acknowledgement

CBSE ADVISORS

- Shri Vineet Joshi, *Chairman*
- Dr. Sadhana Parashar, *Director (Academic & Training)*

CONVENOR

Prof. Jagbir Singh
Convenor, Former Head Department of Punjabi Delhi University

MATERIAL PRODUCTION TEAM

Prof. Kapil Kapoor
Prof. of English & Former Pro Vice Chancellor, Jawahar Lal Nehru University

Prof. Michel Danino
Guest Professor, IIT Gandhinagar, & Visiting Faculty, IIM Ranchi

Prof. Avadhesh Kumar Singh
Professor & Director School of Translation IGNOU

Dr. P. Ram Manohar, MD (Ayurveda)
Director and CSO, AVP Research Foundation, 36/137, Trichy Road, Ramanathapuram P.O., Coimbatore-641045, Tamil Nadu, India

Dr. J. Sreenivasa Murthy
(Sanskrit/Philosophy) Head, Department of Sanskrit, M.E.S College, Bangalore - 560 003

Prof. Bharat Gupt
(Retd) Associate Professor, Delhi University, Founder member and Trustee International Forum for India's Heritage. PO Box 8518, Ashok Vihar, Delhi 110052.

Dr. Vipul Singh
MLNC, University of Delhi, South Campus, New Delhi

Prof. Shrawan Kumar Sharma
Head Dept. of English Director, Centre for Canadian Studies Gurukul Kangri University Haridwar, Uttarakhand

Ms. Kiran Bhatt
(Retd.) Head of Dept. (English), Modern School, Vasant Vihar, New Delhi

Ms. Heemal Handoo Bhat
Shaheed Rajpal DAV Dayanand Vihar, New Delhi

Mr. Pundrikakash
Vice Principal, Physics, RPVV, DoE, Kishan Ganj, New Delhi

Ms. Rashmi Kathuria
Maths, Kulachi Hansraj Model School, Ashok Vihar, New Delhi

Dr. Sanjay Kumar
K.V., SPG Complex, Sector - 8, Dwarka, New Delhi

Ms. Bindia Rajpal
The Air Force School, Subroto Park, New Delhi

Ms. Reeta Khera
VVDAV Public School, D- Block, Vikaspuri, New Delhi

Ms. Uma Sharma
Ex Craft Coordinator CCRT, Ex TGT, RPVV, Vasant Kunj, New Delhi.

Ms. Archana Sharma
Freelancer: Content Developer, Resource Person - SCERT, DIET (RN) New Delhi.

Ms. Anjali Shukla
DAV Public School, Sector - 7, Rohini, New Delhi - 110085

Dr. Sandhya S. Tarafdar
PGT History, K.V. Vikaspuri, New Delhi

Dr. B. S. Dashora
ELT Group (Retd. Principal), Bhopal, Madhya Pradesh.

Ms. Shubhika Lal
Modern School, Vasant Vihar, New Delhi

Ms. Kusum Singh
DAV Public School, Sector-14, Gurgaon

Ms. Gayatri Khanna
ELT, Free Lancer, New Delhi

Grateful Thanks to:

Dr. Rajnish Kumar Mishra, JNU

Dr. Santosh Kumar Shukla, JNU

Mr. Albert Abraham
Former Report Writer, CBSE

CO-ORDINATOR

Ms. Neelima Sharma
Consultant (ELT), CBSE New Delhi

EDITORS

Prof. Kapil Kapoor, *Prof. of English & Former Pro Vice- Chancellor Jawahar Lal Nehru University*

Prof. Michel Danino, *Guest Professor, IIT Gandhinagar & Visiting Faculty, IIM Ranchi*

SUPPORTING MEMBERS (CBSE)

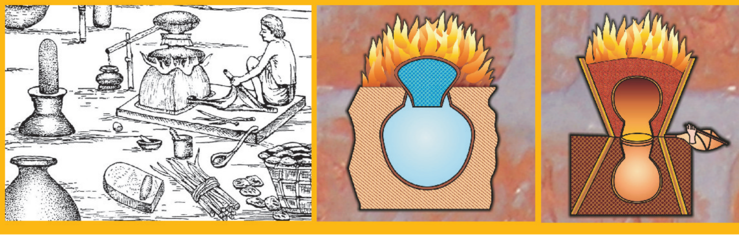
Mr. Yogeshwar
Asstt. Record Keeper

Mr. Abhimanyu Kumar Gupta
Computer Assistant

Ms. Prabha Sharma
Computer Assistant

Content of Module 2

Chemistry in India 1



Chemistry in India: A Survey

Chemistry, as we understand it today, is a relatively young discipline; it took shape in 18th-century Europe, after a few centuries of alchemical tradition, which was partly borrowed from the Arabs. (Alchemy was a semi-esoteric practice whose ultimate goal was to turn base metals into gold and discover an 'elixir of life' that would grant immortality.) Other cultures — especially the Chinese and the Indian — had alchemical traditions of their own, which included much knowledge of chemical processes and techniques.

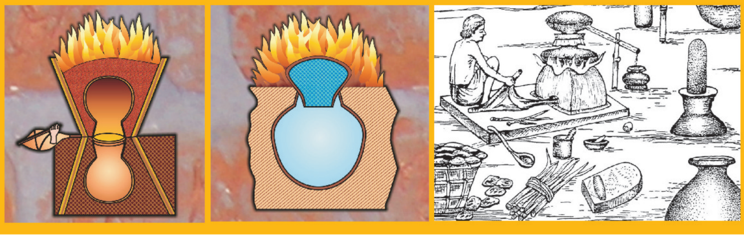
Define alchemy with regard to chemistry.

Early Chemical Techniques

In India, we can trace such techniques all the way to the Indus civilization (3rd millennium BCE) and its antecedents. The Harappans' metallurgical skills have been described in the module on **Metallurgy in India**. Pottery called for a control of processes such as heating, fusion and evaporation. Bead-making involved complex treatments of minerals, including bleaching a bead with a solution of calcium carbonate, then heating it in a kiln, so as to leave permanent white designs on it.

Explain the role and place of metallurgy in the emergence of civilization.

A bleached bead from Harappa (courtesy: J.M. Kenoyer).



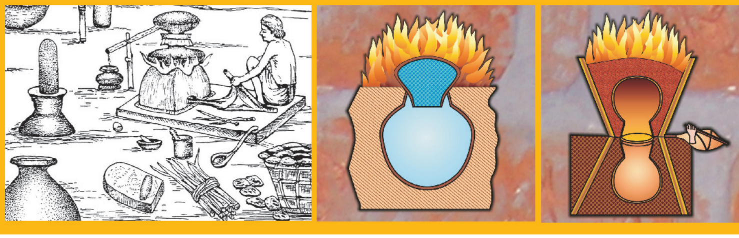
Harappans also experimented with various mortars and cements made of burnt limestone and gypsum, among other components. Finely crushed quartz, once fired, produced faience, a synthetic material; it was then coated with silica (perhaps fused with soda) to which copper oxide was added to give it a shiny turquoise glaze. Faience was then shaped into various ornaments or figurines. The addition of iron oxide gave a greenish blue tint to glazed pottery, while manganese oxide resulted in a maroon colour.

A Harappan bangle made of faience (courtesy: J.M. Kenoyer).

Such techniques survived the end of the Indus civilization and found their way to the later Ganges civilization (1st millennium BCE), often with innovations — glass manufacture, for instance: numerous glass beads and other artefacts have been unearthed from Taxila in the Northwest to Nalanda in the East and Arikamedu in the South. (More technologies will be discussed in the module on **Other Technologies in India**.)

What uses was glass initially put to?

Pigments were another area for skilled chemical practices, and were required for painting (witness the famous Ajanta murals) as well as dyeing of cotton and other

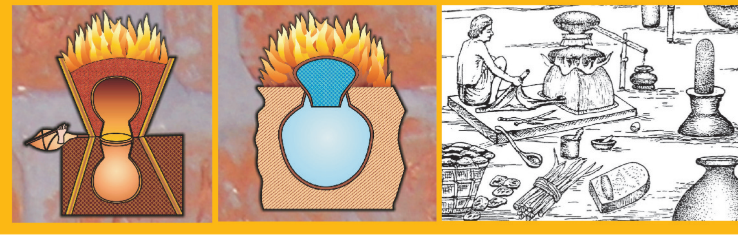


textiles. Interestingly, sources of pigments were not limited to organic materials (such as extracts of specific flowers or fruits) but included mineral sources, from carbon (lamp black) to arsenic sulphide (yellow ochre) or copper acetate (verdigris, greenish-blue in colour).

Atomism in *Vaiśeṣika*

Although it did not translate into actual chemistry, the Indian notion of atomism deserves a brief mention (this will be developed in the module on **Perceptions of the Physical Universe**). Atomism, or the concept that matter is ultimately made of indivisible building blocks, appeared in India a few centuries BCE as part of philosophical speculations, in particular in the *Vaiśeṣika*, one of the six philosophical systems of ancient India (see the module on **Indian Philosophical Systems**). The author of the *Vaiśeṣika Sūtras* came to be known as Kaṇāda (literally 'eater of particles') and may have lived any time after 500 BCE.

In this system, all substance was seen as an aggregated form of smaller units called atoms (*aṇu* or *paramāṇu*), which were eternal, indestructible, spherical, supra-sensible and in motion at the primordial state; they could form pairs or triplets, among other combinations, and unseen forces caused interactions between them. The *Vaiśeṣika* system identified nine types of substance (*dravya*): (1 to 5) the five elements (earth or *prithvi,* water or *ap,* fire or *tejas,* wind or *vāyu,* ether or *ākāśa*), (6) time (*kāla*), (7) space or direction (*dik*), (8) the mind (*manas*), and (9) the spirit or knower (*ātman*). Besides, substance had twenty-four different qualities (*guṇas*), including fluidity, viscosity, elasticity and gravity. While fluidity was related to water, earth and fire, viscosity was unique to water, and gravity to earth. Distinctive characteristics of sound, heat and light were also discussed, which often came close to later discoveries of physics, although, lacking a mathematical apparatus, they did not evolve into scientific theories.



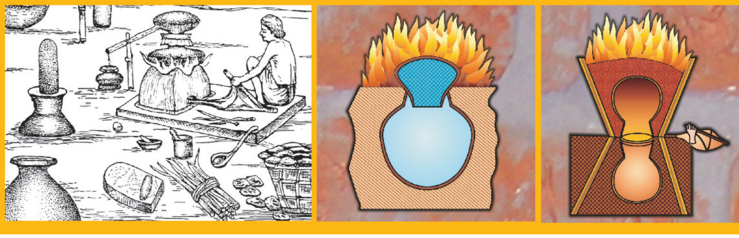
Chemistry in Early Literature

We find plentiful evidence of knowledge of chemical practices in some of India's early literature.

Kauṭilya's *Arthaśāstra* is a well-known text of governance and administration authored probably in the 3rd or 4th century BCE, during the Mauryan era. It has much data on prevailing chemical practices, in particular a long section on mines and minerals (including metal ores of gold, silver, copper, lead, tin and iron). It also discusses the various characteristics of precious stones (pearl, ruby, beryl, etc.), details of fermented juices (from sugarcane, jaggery, honey, *jambu,* jackfruit, mango, etc.), and oil extraction.

The fundamental two texts of Ayurveda are the *Caraka Saṃhitā* and the *Suśruta Saṃhitā,* both dated a few centuries CE (see module on **Life Sciences: Historical evolution of India's medical tradition**). Not only do they turn to a wide range of chemicals for medical use — metals, minerals, salts, juices — but they also discuss the preparation of various alkalis (*kṣāra*), which is regarded as one of the 'ten arts' (*kalā*). Alkalis are described as mild, caustic or average and are prepared from specific plants: after the plants have been burnt together with some limestone, their ashes are then stirred in water, filtered, and the resulting solution is concentrated by boiling, to which burnt limestone and conch shells are added. Such alkalis were used to treat surgical instruments as well as thin sheets of metals like iron, gold or silver intended for the preparation of drugs. These texts also speak of organic acids extracted from plants such as citrus or tamarind (an awareness of mineral acids came much later).

Varāhamihira's *Bṛhat Saṃhitā,* an encyclopaedia of sorts composed in the 6th century CE, has a chapter on the preparation of numerous perfumes out of sixteen fundamental substances mixed in different proportions. Indeed, perfumery and cosmetics formed a major branch of chemical practices in classical and medieval India.



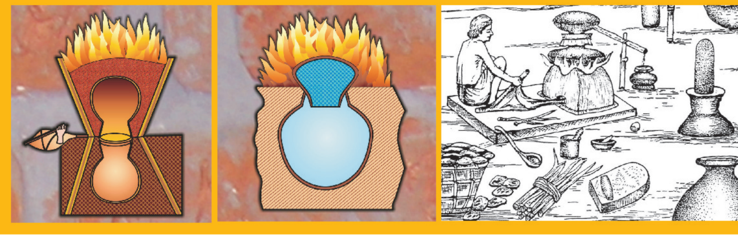
The *Bṛhat Saṃhitā* also includes various recipes, for instance for the preparation of a glutinous material to be applied on the roofs and walls of houses and temples; it was prepared entirely from extracts from various plants, fruits, seeds and barks which, after being boiled and concentrated, were then treated with various resins. It would be interesting to test and scientifically assess such recipes.

Several texts (such as the *Kāmasūtra*) contain a list of the traditional sixty-four arts which an accomplished person was supposed to master. Among them, interestingly, we find, 'Knowledge of gold and silver coins, jewels and gems; chemistry and mineralogy; coloured jewels, gems and beads; knowledge of mines and quarries,' which testifies to the attention paid to such fields.

Why should the knowledge of precious stones and metals be regarded as so important that it was included in this list of sixty-four arts?

The Classical Age

Alchemy in India emerged around the mid-first millennium CE, during the Gupta empire. Its origins remain hard to trace, and scholars have proposed that it received inputs from China, where the discipline is well attested as early as in the 2nd century CE. Whatever its beginnings, Indian alchemy soon took a stamp of its own. It was variously called *rasaśāstra, rasavidyā* or *dhātuvāda*; the word *rasa* has many meanings, such as essence, taste, sap, juice or semen, but in this context refers to mercury, seen as one of the most important elements. Mercury was identified with the male principle (Shiva), while sulphur (*gandhaka*) was associated with the female principle (Shakti), and most alchemical texts were presented as a dialogue between Shiva and Shakti. (Intriguingly, the genders of mercury and sulphur are the other way round in Chinese alchemy!) This is in tune with the Tantra philosophy, and indeed, in alchemical practices, preparations



and processes, mercury was regarded as divine and assumed to be potent enough to confer not only longevity but also occult powers, including invisibility and levitation.

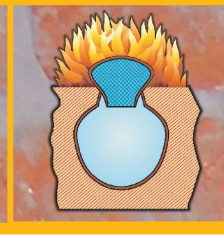
There is a vast alchemical literature, authored by savants such as Nāgārjuna, Govinda Bhāgavat, Vāgbhata, Somadeva, Yaśodhara, among many others. The *rasaśāstra* texts discuss many chemical substances and their interactions. They were categorized as follows (with some variations):

- *mahārasas* or eight major substances: mica, tourmaline, copper pyrite, iron pyrite, bitumen, copper sulphate, zinc carbonate, and mercury (sometimes lapis lazuli and magnetite or lodestone are included);
- *uparasas* or eight minor substances: sulphur, red ochre, iron sulphate, alum, orpiment (arsenic trisulphide), realgar (arsenic sulphide), collyrium (compounds of antimony), and tintstone or cassiterite (tin dioxide).
- *navaratnas or* nine gems, including pearl, topaz, emerald, ruby, sapphire and diamond;
- *dhātus* or seven metals: gold, silver, copper, iron, lead, tin, zinc; a few alloys (such as brass, bronze and combinations of five metals) were also included;
- poisons (*viṣa* or *garala*) and plants; among the latter, over 200 are named in the texts (their identification is not always certain); plants were required, in particular, to treat or 'digest' metals and minerals.

In the quest for the elixir of life, mercurial preparations were supposed to bestow long life and youthful vigour; mercury was sometimes called *amṛtadhātu* or 'immortal metal'. In practice, some Ayurvedic and Siddha medicines were derived from various metals and minerals, but only after those had undergone complex purificatory processes so as to remove their toxic effects (or 'kill' them, as the texts say) and make them fit for internal use. For instance, although mercury compounds are regarded as poisonous, cinnabar (mercuric sulphide, HgS) went through eighteen complex processes (*saṃskāras*), including rubbing with various medicinally efficacious plant juices and extracts, incorporation of sulphur, mica, alkaline substances, etc. The resulting mercury compound was then declared fit for consumption and believed to lead to the body's rejuvenation. Similar processes existed in Tamil alchemy and the Siddha system of medicine, which developed, in addition, special techniques in connection with naturally occurring salts, especially three of them (*muppu*), consisting of rock salts and various carbonates.

Native cinnabar or mercuric sulphide (courtesy: Wikipedia).

Transmuting base metals, such as lead, tin or copper, into gold was another pursuit of alchemy, and involved five operations: smearing, throwing, pouring, fumigating and impact. Here again, mercury, sometimes called *svarṇakāraka* or 'maker of gold', often played a major role. The processes described in the texts are quite elaborate, extending to many days; their precise details cannot often be followed, however, as there are uncertainties about some plants, minerals, or their treatments. But transmutation was not regarded as a purely mechanical process: honesty, self-control, sincerity of purpose,



Why were moral qualities given as much importance as technical knowledge of alchemy?

devotion to God, obedience to the guru and faith in *rasavidyā* were regarded as essential for the *rasavādin* to achieve success. Actual practices were kept secret, as the goal would fail to be reached if they were divulged to the uninitiated.

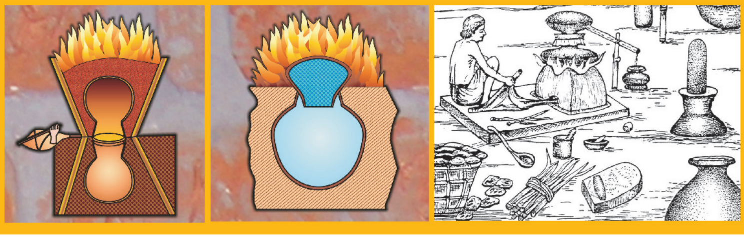
Claims of actual production of gold out of base metals extend to recent times, such as a 1941 demonstration recorded on a marble slab at New Delhi's Lakshminarayan temple; naturally, such claims must be viewed with the greatest scepticism. More likely, the colour of the metal was so altered that it appeared golden; indeed, some texts refer to gold-looking alloys of silver, copper and mercury. In the alchemical tradition, the transmutation of metals may also be taken as a metaphor for the body's own transmutation through the elixir of life, which was the ultimate objective of Indian alchemists. In any case, the quest for this elixir or the transmutation of base metals did lead to actual and valuable chemical techniques, in the medical field in particular, and eventually contributed to the Ayurvedic and Siddha pharmacopoeias.

Laboratory and Apparatus

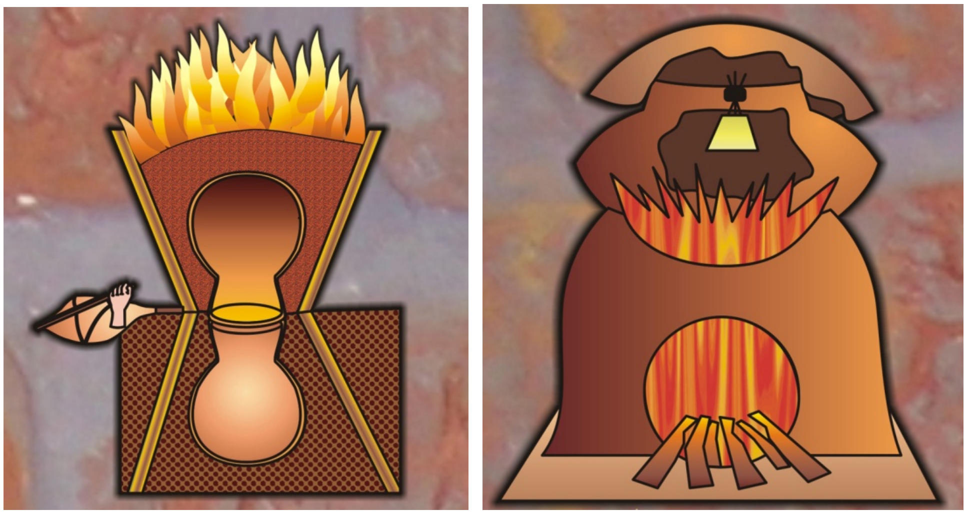
The texts carefully spell out the layout of the laboratory, with four doors, an esoteric symbol (*rasaliṅga*) in the east, furnaces in the southeast, instruments in the northwest, etc. Besides mortars (of stone or iron) and pestles, bellows (to heat the furnaces), sieves, pans, tongs, scissors and earthen or glass vessels, the apparatus included specialized instruments ingeniously developed for heating, steaming, distilling, triturating or extracting substances. Let us mention just a few of them:

An artist's view of an alchemical laboratory or *rasaśālā* (courtesy: INSA).

- the *mūsa yantra* or crucible, usually made of white clay or of the earth of an anthill mixed with rice husk, iron dust, chalk, etc.; such crucibles would have various shapes and sizes, depending on their application;

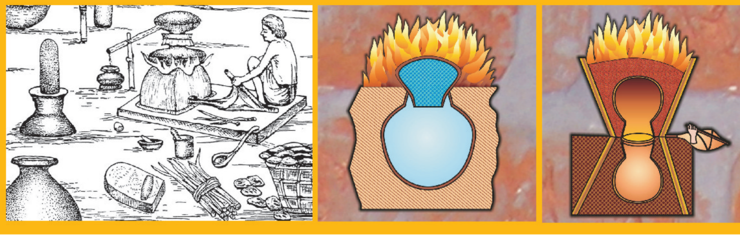


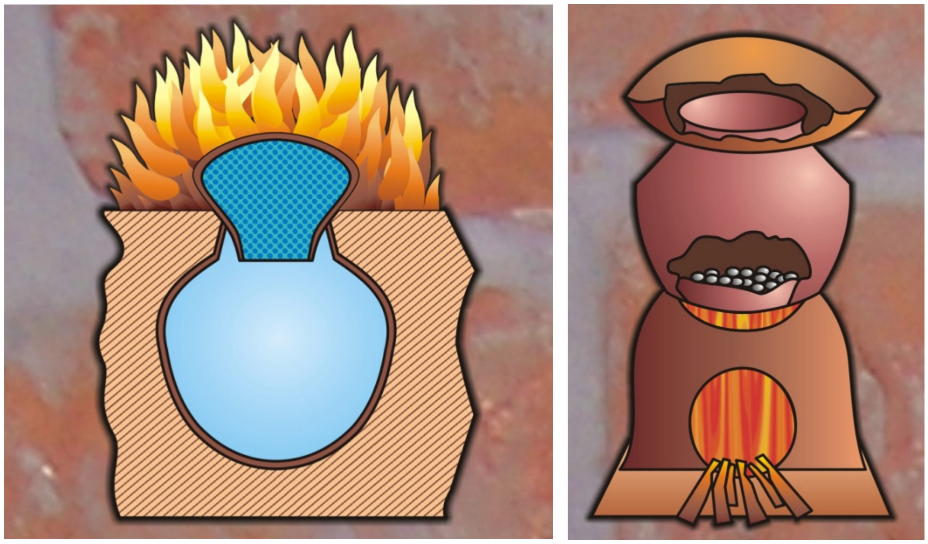
- the *koṣṭhi yantra,* for the extraction of 'essences' of metals, consisting of two rimmed vessels, with fire urged from above and a side blower; besides the metals, the vessels would be filled with charcoal;
- the *svedanī yantra*, a big earthen vessel used for steaming;
- the *dolā yantra,* in which a pot is half-filled with a liquid and a suspended substance absorbs the liquid's vapours;



A representation of the *koṣṭhi yantra (left)* and the *dolā yantra (right)*
(Courtesy: National Science Centre, New Delhi)

- the *pātana yantra,* for sublimation or distillation; it could be upward, downward or sideways; the second was the *ādhana yantra,* in which a paste of mercury was coated at the bottom of the upper vessel, allowing vapours to descend into the lower vessel and combine with substances kept there;
- the *dhūpa yantra*, used for fumigation of gold leaves or silver foils with fumes of sulphur or other substances.





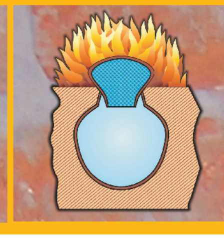
A representation of the *ādhana yantra (left)* and the *dhūpa yantra (right)*
(Courtesy: National Science Centre, New Delhi)

Altogether, India's chemical traditions were rich and varied, and fused elaborate techniques with a spiritual component. Although they may not have directly contributed to the birth of modern chemistry, they did result in considerable practical applications, especially in fields like metallurgy, gemmology and medicine.

***

Comprehension

1. What distinguishes an organic pigment from a mineral one?
2. How was the atom described in early Indian philosophical systems?
3. What distinguishes semiprecious from precious stones?
4. Write a few lines on two principal applications of chemical practices in India.
5. Why did mercury come to be called *amṛtadhātu*?

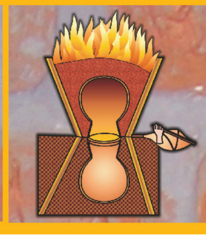


Match the following

Arthaśāstra	bleached semiprecious beads
Harappan technologies	Female
dhātus	natural salts
sulphur	distillation
Siddha medicine	governance
pātana yantra	seven metals

Project ideas

- Explore the various technologies practised by Harappans and how they helped in the evolution of the Indus civilization.
- List out the various pigments used in Ajanta's paintings and the ways in which they were used. Make a PowerPoint presentation.
- Compare the *yantras* or instruments of the Indian alchemist's laboratory with instruments currently used in chemical laboratories. Can any parallels be drawn, either in the instruments or in the processes they were designed for?
- Among the *mahārasas* and *uparasas*, how many chemicals can you identify? What are their main properties? Prepare a table for at least eight of those sixteen chemicals, with five columns: 1. common name (for instance, 'orpiment'); 2. Sanskrit name when available (*tālaka*); 3. technical name (arsenic trisulphide); 4. formula (As_2S_3); 5. properties (a naturally occurring toxic mineral; used as a yellow pigment).

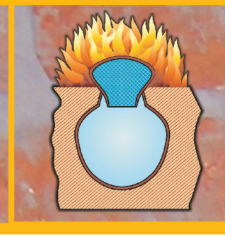


Extension activities

- Under the guidance of an experienced potter, collect clay, shape it into a pot and fire it in a kiln. Each student should make at least five pots of different sizes and shapes.
- Varāhamihira's *Bṛhat Samhitā* has a set of recipes to make perfumes by mixing in different proportions the following sixteen fundamental substances: *ghana*, *vālaka, śaibya, karpūra, uśira, nāgapuṣpa, vyāghranakha, spṛkkā, agaru, madanaka, nakha, tagara, dhānya, karcūra, coraka, candana*. (A translation provided in one of the editions read: *Cyperus rotundus, Aporosa lindieyana,* benzoin, camphor *Vetiveria zizaniodes*, *Mesua ferrea*, cuttlefish bone, *Bryonopsis laciniosa, Aquilaria agallocha, Randia dumetorum*, shell perfume, *Valeriana wallichii*, coriander, *Hedychium spicatum*, *Scirpus articulatus*, sandal.) Are you familiar with some of them? Can you identify a few more on the Internet? Where can they be got today? Why do you think they were selected as basic ingredients for perfumes?

Further Reading

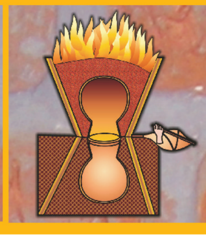
1. A.K. Bag, ed., *History of Technology in India,* Vol. 1: *From Antiquity to c. 1200 AD*, Indian National Science Academy, New Delhi, 1997
2. D.M. Bose, S.N. Sen & B.V. Subbarayappa, eds, *A Concise History of Science in India*, Universities Press, Hyderabad, 2nd edn, 2009
3. K.V. Mital, ed., *History of Technology in India,* Vol. 3: *From 1801 to 1947 AD*, Indian National Science Academy, New Delhi, 2001
4. Acharya Praphulla Chandra Ray, *A History of Hindu Chemistry*, 1902, republ., Shaibya Prakashan Bibhag, centenary edition, Kolkata, 2002
5. P. Ray, *History of Chemistry in Ancient and Medieval India,* Indian Chemical Society, Calcutta, 1956
6. B.N. Seal, *Hindu Chemistry,* 1911, republ. Bharatiya Kala Prakashan, New Delhi, 2008
7. B.V. Subbarayappa, ed., *Chemistry and Chemical Techniques in India*, Project of History of Indian Science, Philosophy and Culture, & Centre for Studies in Civilizations, New Delhi, vol. IV, part 1, 1999



Internet Resources (all URLs accessed in May 2012)

- A summary of the history of Indian chemistry:
  www.infinityfoundation.com/mandala/t_es/t_es_agraw_chemistry.htm.
- Extracts from a book on alchemical traditions in Siddha medicine:
  http://thehealingproject.net.au/wp-content/uploads/2009/10/David-WHITE.-The-Alchemical-Body.-Siddha-Traditions-in-Med%E2%80%A6.pdf
- A brief account of Acharya Prafulla Chandra Ray's life:
  www.vigyanprasar.gov.in/scientists/pcray/PCRay.htm
- Online version of Acharya Prafulla Chandra Ray's *History of Hindu Chemistry*, vol. 1:
  http://archive.org/download/historyofhinduch01rayprich/historyofhinduch01rayprich.pdf
- Brief overviews of the world history of chemistry:
  www.experiment-resources.com/alchemy.html
  www.chm.bris.ac.uk/webprojects2002/crabb/history.html
- Brief overviews of the world history of alchemy:
  www.chemistrydaily.com/chemistry/Alchemy
  www.alchemylab.com/history_of_alchemy.htm
- An online course and resources on the world history of alchemy:
  www.kean.edu/~bregal/HIST4236.htm
- A brief history of chemistry in ancient and medieval ages:
  https://www.mtholyoke.edu/courses/smoss/TEI_projects/chem250_sp06/MamtaDass/chart.html
- A history of chemistry in the West:
  www.waldorfresearchinstitute.org/pdf/RCChemistryRidenour.pdf
- Resources on (mostly modern) chemistry:
  www.chemheritage.org/discover/online-resources/chemistry-in-history/index.aspx





Primary Texts on Chemistry in India: A Selection

Note: Indian texts of chemistry / alchemy deal primarily with the extraction, processing and purification of metals, especially for medicinal purposes. A few such excerpts are presented in the selection of primary texts for the module on **Metallurgy in India**. Here, with the exception of the king of metals — mercury — passages of a different nature have been selected so as to give a feel of the range of the discipline.

Vātsyāyana (4th to 6th century CE), *Kāmasūtra* (tr. Richard Burton)

Note: Chapter 3 of the *Kāmasūtra*, entitled 'On the Arts and Sciences to be Studied', contains a list of 64 arts which men and women alike were expected to study. Many of those arts have to do with music and other arts, poetry, language, decorative arts, and various mind games such as brain-teasers, riddles, secret codes, etc. The following concern technical knowledge and show the importance attached in that era to chemistry, gemmology and metallurgy.

> … 34. Carpentry, or the work of a carpenter. 35. Architecture, or the art of building. **36. Knowledge about gold and silver coins, and jewels and gems. 37. Chemistry and mineralogy. 38. Colour jewels, gems and beads. 39. Knowledge of mines and quarries.** 40. Gardening, knowledge of treating the diseases of trees and plants, of nourishing them, and determining their ages. …

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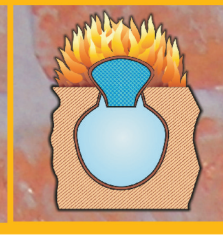


Nāgārjuna (7th or 8th century CE), *Rasendramaṅgalam* (tr. H.S. Sharma)

Note: This text deals with the eighteen processes which mercury had to undergo before it was considered to have reached a form suitable for internal consumption. (Note that the processes are only named, not fully explained.) Medicine was clearly one of the chief applications of chemistry.

> For the treatment [of diseases], mercury and mercurials along with minerals and metals etc. are useful, therefore in the first chapter the process of incineration, in second the process of melting into various minerals, in third the holding of quicksilver [= mercury], in fourth the process of making pills, in fifth the treatment of all diseases caused through vitiated *vāta* and humours of the body, in sixth the attractive and odorous preparations of microfine powders, in seventh detoxication and [enema] eye treatment, and in eighth chapter various classifications are described. (1.3–5)
>
> The quicksilver is subjected to 1) fomentation, 2) tormentation, 3) calcination, 4) elevation, 5) distillation, 6) stimulation, 7) limitation, 8) confination, 9) transmission, 10) abortion, 11) dissolution (inner melting and outer melting), 12) oxidation, 13) morsel-size determination, 14) dyeing function, 15) transmigration, 16) interruption, 17) metallic-penetration, 18) administration on human body. If one does not know all these processes of mercury he is harmful for everyone. Therefore, after obtaining the proper knowledge of all these mercurial processes and having assistance of such experts along with all requisite apparatus, start the *rasakarma* [practice of chemistry]. (1.22–24)

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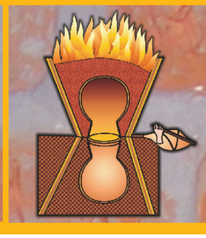

Al-Bīrūnī's India (11th century) (tr. Edward Sachau)

Note: Al-Bīrūnī was a Persian scholar and scientist travelled to India as part of Mahmūd of Ghazni's entourage and authored in 1030 a comprehensive study of Indian customs and sciences, especially astronomy. Here he records what he has heard of Indian alchemy (and continues with a strong condemnation of the whole discipline). There are a few inaccuracies in his account (*rasa* refers to mercury, not gold; *tālaka* is orpiment, not talc), but it is still useful as independent evidence that alchemy was well established in India by this time.

> The [Indian] adepts in this art try to keep it concealed, and shrink back from intercourse with those who do not belong to them. Therefore I have not been able to learn from the Hindus which methods they follow in this science, and what element they principally use, whether a mineral or an animal or a vegetable one. I only heard them speaking of the process of *sublimation*; of *calcination*, of *analysis*, and of the *waxing of talc*, which they call in their language *tālaka* [orpiment or arsenic trisulphide], and so I guess that they incline towards the mineralogical method of alchemy.
>
> They have a science similar to alchemy which is quite peculiar to them. They call it *Rasāyana*, a word composed with *rasa*, i.e. gold. It means an art which is restricted to certain operations, drugs, and compound medicines, most of which are taken from plants. Its principles restore the health of those who were ill beyond hope, and give back youth to fading old age, so that people become again what they were in the age near puberty; white hair becomes black again, the keenness of the senses is restored as well as the capacity for juvenile agility ... (Chapter 17)

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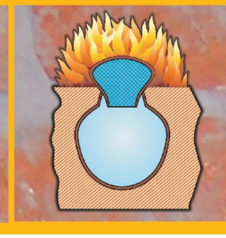
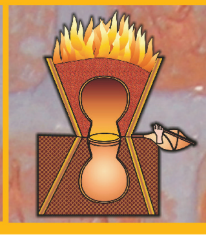


Rasārṇavakalpa (author unknown, about 11th century) (tr. Mira Roy & B.V. Subbarayappa)

Note: This text deals with mercury processing, both its supposed transmutation into gold and its preparation for medicinal use. Some of the plants mentioned here have not been securely identified. Although it is not easy to understand the precise processes involved, they were clearly very elaborate, and brought into play a number of plant extracts, among other natural chemicals.

> Mercury is to be considered as endowed with the properties of all metals. It pleases the Lord of Uma [i.e., Shiva, identified in alchemy with mercury]. What is the utility of narrating much, as what is it [on the earth] that cannot be acquired with mercury?
>
> Mercury [*liṅga*] being rubbed in a silver vessel, is to be placed therein. This mercury, with the application of medicinal plants and being roasted in *puṭa* [an appliance], becomes the bestower of happiness.
>
> Mercury being treated well is endowed with the qualities of metals [*dhāturūpīrasa*]. It is considered an auspicious [substance]. He, who is blessed with this mercury, becomes invincible, even by gods.
>
> All undertakings relating to different preparations are considered as best when performed in a well-situated place having beautiful environment on an auspicious and excellent day. The preparations are to be carried out after properly pondering secretly over the [alchemical] operations.
>
> Half *tolā* [a unit of weight] of the aforesaid preparation of mercury and one *tulā* [a larger unit of weight] of yellow orpiment [arsenic trisulphide] after mixing thoroughly in mortar with pestle, [the mass] is to be mixed with





the juice of *bhṛṅga* [a plant, *Eclipta alba*]. After drying, it is to be roasted in moderate heat.

The roasted mass is to be [then] left undisturbed for three days, and is again to be ground to a fine powder. This [powdered mass] is to be then dried without exposure to the sun, and is to be heated thrice with the aid of the juice of *apāmārga* [a plant, *Achyranthes aspera*].

The roasted product is to be then finely ground and dried in shade. It is to be roasted nine times with [the juice of] *payovallī*, dried perfectly, and powdered well.

The juices of *puṣpī* [a plant, *Pandanus odoratissimus*], *śvetā* and *girikarṇikā* [together], hundred *ṭaṅkas* by weight, are to be dried in shade.

The juices of *śambhu*, *arkavallī*, *vellakāra* and *suśīrakī* [together] are to be mixed separately with the juice of *nāgavallī*, and then with hundred *ṭaṅkas* of the [above-mentioned] juice.

The mixture is to be roasted in *puṭa* eleven times. Orpiment [probably the above-mentioned preparation of orpiment] should be added to it. The fine paste prepared from the mixture of the two is to be pounded with orpiment.

This product is to be roasted again six times in *puṭa* with the aid of juice of the [above-mentioned] plants. Then it is to be covered carefully with the expressed juices of completely matured *kumārī* [probably *Aloe indica*] and of *bahulā* [a name of several plants] on being admixed with the juice of *mūlaka* [*Raphanus sativus*].

O Physician [alchemist]! transform mercury which has been kept in secret into gold [with the aid of the above-prepared substance].

Cinnabar [mercuric sulphide], on being pressed thoroughly, is to be rubbed with the application of [the juice of] *kanyā* [*Aloe indica*] eleven times. It is to be then filtered through fine cloth, and [the filtered product] is to be mixed with pure orpiment. Mercury which is [thus] produced [from the processing of cinnabar] loses its fluidity [when mixed with orpiment].

This mercury is to be mixed with the juices of leaves of *haṁsagamanī* [perhaps *Herpestis monniera*], *gajadhvajī* [perhaps *Heliotropium indicum*], *lajjakā* [*Hibiscus vitifolius*], *arkanamitā* [*Gynandropsis pentaphylla*] and *anāmikā*, and of all the parts of *arka* [*Calotropis gigantea*] for a fortnight. It is to be then treated with [the juice of] *vallaki* for twenty-eight days.

The mass is to be dried in shade, pressed and dipped in the juice exuded from lac. After preparing solid mercurial drug [*rasāyana*], the juices of plants, like *arka* [*Calotropis gigantea*], *pippala* [or *aśvattha,* the peepal tree, *Ficus religiosa*] and *jaṭadhara* [perhaps *Nardostachys jatamamsi*], are to be mixed with this.

This mercurial drug is to be rubbed in the liquid content [i.e. juices of three aforementioned plants], which is the repository of *guṇas* [properties befitting the preparation]. This is to be made into small balls. The performance is to be carried out in an auspicious house. When treated seven times in liquid content, the substance [i.e. the mercurial drug] loses its fluidity and attains the capacity of penetrating into the metals. May this product be auspicious for us! (53–68)

Mercury and sulphur are turned into nectar and poison according to purposes of their uses. When they are taken according to rule they act as nectar but when they are used without observing any rule, they act like poison. (336–337)

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Vāgbhaṭa (13th century), *Rasaratnasamuccaya* (tr. adapted from Damodar Joshi)

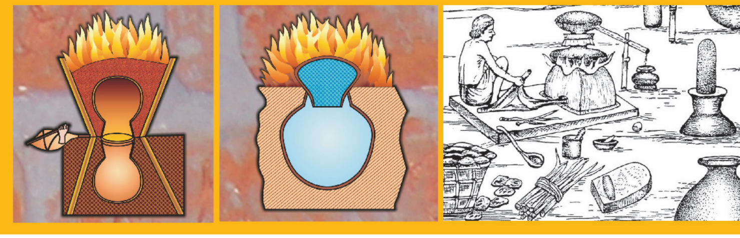
Note: This text explains many processes for the purification and use of mercury and other metals. The selected passages deal with the qualifications of a teacher and a student, and the specifications of the laboratory and its instruments.

Qualities of a teacher of *rasaśāstra*

Rasavidyā Guru [a teacher of alchemy] should possess the following qualities: all the knowledge, expertise in various processes and a thorough knowledge of all the literature on *rasa*. He shall have achieved success in many sacred texts, shall always have courage, a highly distinguished personality and an unswerving mind; he shall be very affectionate of Lord Siva and a thorough devotee of Goddess Pārvatī, and have firm belief in all the gods and oblations. He shall also have a specialized knowledge of all sacred traditions and texts and shall be very competent in performing alchemical operations. (6.3-4)

Qualities of a disciple

Only a disciple possessing the following qualities is expected to achieve success in alchemical operations. He shall be highly devoted to the teachers, possess good moral conduct, shall always be truthful, persevering, energetic, sincere and duty-conscious, obedient, free from arrogance and malice, dedicated to the respective traditions, efficient, peace-loving and shall regularly practise the sacred texts or prayers. (6.6)



Disqualifications of a disciple

For persons who are disbelievers, who possess corrupt manner and conduct, are selfish or greedy, desirous of acquiring knowledge from persons other than gurus by trickery, deception, mischievous methods and insolence, even a little success in gems, hymns or medicines is impossible. And if through ignorance such persons indulge in the practice of *rasakarma* [alchemical practices] they are likely to waste their wealth and will not get happiness either in this world or in the other world. (6.8–9)

Hence, it is only when the teacher is pleased with the devotion of the disciple that the latter should start learning *rasavidyā* for his own success, as the knowledge received with folded hands and bowed head can alone prove successful and produce best results. (6.10)

Location and building of the *rasaśālā* [laboratory]

The *rasaśālā* should be built in a place which is free from all fears and disturbances; is rich in all kinds of medicinal herbs; is very charming; is endowed with a well; and is located in the very auspicious northern, northeastern or eastern direction or region of the earth. Its building should be well protected with high boundary walls and it should be well equipped with all necessary instruments. (7.1-2)

Working arrangement of *rasaśālā* according to direction

The working of *rasaśālā* is said to have been divided in the following eight divisions. In the eastern region [*purva digbhaga*] of the *rasaśālā* should be installed a statue of Lord Bhairava [an aspect of Shiva]. In the southeastern quarter [*āgneya koṇa*] the pharmaceutical operations involving the use of fire should be performed. In the southern part [*yāmya bhāga*] the works involving the use of stone made implements should be done. In southwestern quarter [*naiṛtya koṇa*] the operations involving the use of sharp instruments [*śastras*] such as cutting, slicing, etc. should be conducted. The western part [*vāruṇa bhāga*] should be used for washing, cleaning, etc. where the use of water is required. In the northwestern quarter [*vāyavya koṇa*] the drying of the drugs or preparations should be done. The works related to transformation of lower metals into higher metals [*vedhakarmas*] should be done in the northern region [*uttara digbhāga*] of the *śālā* and the prepared medicines or products should be stored in the northeastern quarter [*Īśakoṇa*] of the pharmacy. (7.3-4).

Materials and equipments

It is further mentioned in this context that the *rasaśālā* should have a collection of all the materials required for performing alchemical operations. The following is the list. [There follows a long and detailed list of all the instruments, tools and natural ingredients that a properly equipped laboratory should have.] (7.6)

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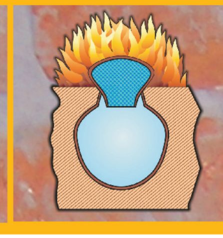
Yaśodhara Bhaṭṭa (13th century), *Rasaprakāśa Sudhākara* (tr. adapted from Damodar Joshi)

Note: This text gives a detailed description of some of the standard apparatus used in the laboratory, and examples of processes they are used for. A few more preparations from the same text have been excerpted.



Pātana saṃskāra [process of distillation]

Pātana [distillation / sublimation] is an important *karma* [practice] which I will mention here in detail. *Pātana* is of three types, namely, *urdhvapātana* [upward distillation], *adhaḥpātana* [downward distillation] and *tiryakpātana* [lateral distillation]. It destroys *rasa doṣas* [mercurial impurities].

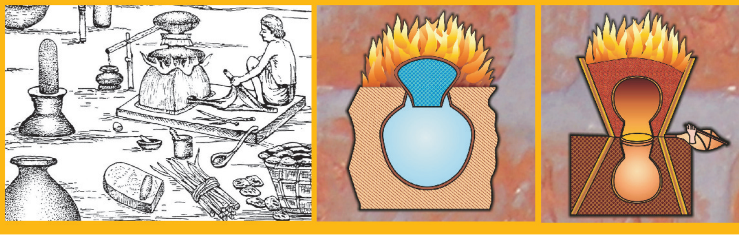
Urdhvapātana yantra: apparatus for upward sublimation

Here the definition of *urdhvapātana yantra* is given. Take an earthen pot of wide mouth having six *aṅgulas* height, seven *aṅgulas* mouth dimension and thirteen *aṅgulas* circumference. Take another wide mouth earthen pot of same size.

Prepare a paste of mercury with two *kṣāras* [alkalis, *sarjikṣāra* and *yavakṣāra*], *hiṅgu* [*asa foetida*, sometimes cinnabar], five *lavaṇas* [salts, *saindhava*, *sāmudra*, *viḍya*, *sauvarcala* and *romaka*] and the drugs of *amla varga* [plants with acid leaves or fruits] separately. This *kalka* should be pasted inside the lower vessel. Place the upper vessel upside down on the mouth of lower vessel to make like a *saṃpuṭa*. Seal the joint of this assemble with a paste made of ash and salt. Place this apparatus on the *culhī* [furnace] and apply *dhānyāgni* [mild heat]. Make a *jalādhāna* [water tank] on the upper surface of the upper vessel to fill the water and to keep it cool. The heat should be given for four *yāmas* [twelve hours]. On self cooling collect the sublimated mercury from the upper vessel after opening the apparatus. It is called *urdhvapātana* and is used for the sublimation of mercury.

Adhaḥpātana yantra: apparatus for downward sublimation

The same apparatus prepared with wide-mouth vessels if kept in opposite manner [i.e. keeping mercury containing pot up and empty pot down in a pit



containing mud]. Apply heat on its upper portion for three *yāmas* [nine hours]. And thus, mercury is sublimated downward and condenses in the lower cool vessel. Experts of *rasaśāstra* call it as *adhaḥpātana yantra* [apparatus for downward sublimation of mercury].

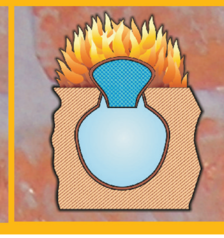
Tiryakpātanam: apparatus for lateral sublimation

First prepare a paste of mercury with the drugs mentioned earlier. Apply this paste of mercury in a *tiryakghaṭa* [pot placed transversely]. Fix another small pot in its mouth. Make a hole in the middle of the upper pot and insert an iron rod in this hole keeping the other end of the rod in a pot containing water. Seal the joints properly with the paste mentioned above. Apply strong heat to the pot containing mercury paste for three *yāmas* [nine hours]. Thus, mercury moves in a transverse direction, is distilled and gets condensed in the vessel containing cool water. The arrangement should also be made to cool the iron rod to achieve proper condensation of mercury vapours. At present we may use modern distillation apparatus attached to the traditional apparatus [for proper condensation of mercury vapours] for this purpose.

The simple method for the preparation of all the three *pātana yantras* is said by me here as per the description of Rasa texts (1.49–62).

Sāraṇa saṃskāra: blending a seed with mercury

Now I am describing the method of *sāraṇa saṃskāra* which is an essential means of *vedha* [transformation] and *vṛddhi* [improvement] in the colour [of lower metals into that of higher metals] and which grants *mahāsiddhi* [great success] in all the *karmas* [practices]. Mercury processed with *jāraṇa saṃskāra* [calcination] should be kept in the *mūṣā* [crucible], with *sāraṇa taila* [oil of *sāraṇa,* see next section], *kalka* [paste or ball] and *bīja* [a seed used in



transmutation] mixed with *kalka* in *pidhānikā mūṣā* [a crucible used as a lid for another]. Close the mouth of the *rasa mūṣā* [the crucible containing mercury] with *pidhanikā mūṣā* and *pidhanika mūṣā* with a paste made of *bhasma* [calcined metal] and *lavaṇa* [salt]. Put three-fourth part of *mūṣā yugma* [the two crucibles joined together] in a pit prepared on the ground. Place strongly burning charcoals over the *mūṣā* and apply strong heat by blowing, in this way *bīja jāraṇa* [calcination] is done properly. ... And so *jārita* mercury develops wonderful properties. The mercury first treated with *jāraṅa* and then with *sāraṇa saṃskāra* becomes capable of giving all types of *siddhis* [success] both in *lohavedha* [transmutation of metals] and *dehavedha* [transformation of the body]. Without mercury being treated with *jāraṇa* and *sāraṇa,* how can one do the *bandhana* [alloying] of *pārada* [mercury]?

I witnessed this *sāraṇa karma* of mercury being done by my teacher; I have also performed it with my own hands and not merely heard about it. (1.119-124)

Sāraṇa taila: oil of *sāraṇa*

Sāraṇa taila may be prepared with the fats collected from *matsya* [fish], *kacchapa* [tortoise], *maṇḍūka* [frogs], *jalukā* [leaches], *meṣa* [sheep] and *śūkara* [pigs].

Bhūnāga viṭ [faecal mater of earthworms], *kṣaudra* [a type of honey], *purīṣa* of *salabhādi* [faecal matter of a grasshopper] and *karṇa mala* of *mahīṣa* [buffalo’s earwax], mix all these together in 1/16th part of mercury and prepare a paste which should be filtered in an oil; that oil is known as *sāraṇa taila.* (1.125–126)

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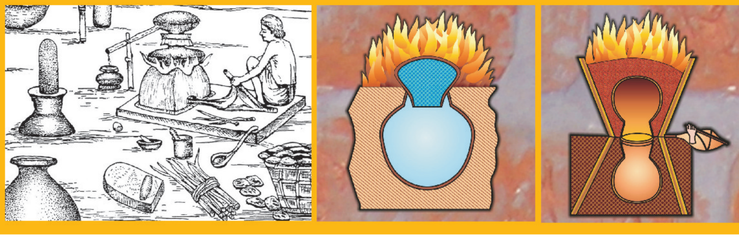
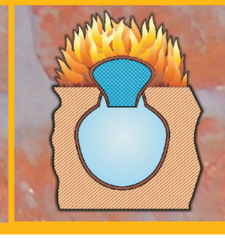
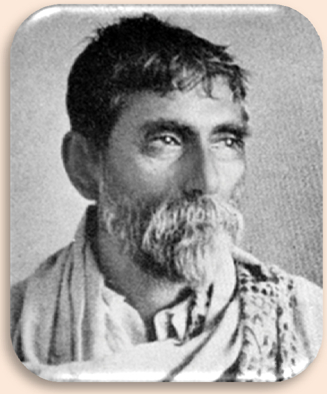


Comprehension / Activities

1. In the excerpts from Yaśodhara Bhaṭṭa, can you correlate some of the instruments with those described in the survey text on **Chemistry in India**?
2. In the excerpts from *Rasārṇavakalpa* and *Rasaprakāśa Sudhākara*, how many plants can you identify, either through their Sanskrit or botanical names?
3. Compare the qualities expected from a teacher and a student of alchemy with those expected from a teacher and a student in any discipline today.
4. What other knowledge tradition does the location of the laboratories' various activities with regard to the cardinal directions remind you of? (You will find a clue in the module on **Indian architecture**.)

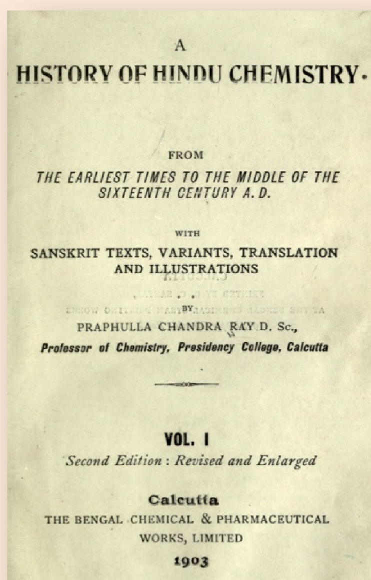



Praffula Chandra Ray (1861–1944) is well known as a pioneer of modern chemistry in India. What is less well known is that he went on to become the first historian of Indian chemistry.

A brilliant student, he secured against severe odds a scholarship from the Edinburgh University. On his return to India, he taught chemistry at the Presidency College, where he created India's first chemistry research laboratory and gathered around him a group of enthusiastic students who all became eminent chemists. Acharya Praffula Chandra Ray, as he became known, himself published numerous research papers, some of which contained important discoveries. In 1916, he joined the new University College of Science of the Calcutta University, and lived there in a room that had just the barest essentials, giving away most of his earnings to needy students and various charities.

He founded the Indian Chemical Society, but in accordance with his vision of self-sufficiency for India, also created many industries, beginning with Bengal Chemical & Pharmaceutical Works. He took part in the nationalist movement, declaring once: 'There are occasions that demanded that I should leave the test-tube to attend to the call of the country. Science can wait, Swaraj cannot.'



A
HISTORY OF HINDU CHEMISTRY.

FROM
THE EARLIEST TIMES TO THE MIDDLE OF THE SIXTEENTH CENTURY A. D.

WITH
SANSKRIT TEXTS, VARIANTS, TRANSLATION AND ILLUSTRATIONS

BY
PRAPHULLA CHANDRA RAY D. Sc.,
Professor of Chemistry, Presidency College, Calcutta

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1903

Finding that western histories of chemistry had no information on India, Acharya P.C. Ray spent years researching long-forgotten manuscripts. His *History of Hindu Chemistry*, first published in 1901, revealed considerable knowledge of acids, alkalis, metals and alloys, and their medical uses, and included many original texts for the first time. In his preface, Acharya Ray acknowledged his debt to the French chemist and science historian Berthelot, who had encouraged him in this task, and who reviewed the book at length. It was praised in England as 'a work of which both the scientific and linguistic attainments are equally remarkable, and of which, if on any book, we may pronounce that it is definitive.'

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