



INDIAN KNOWLEDGE SYSTEMS DIVISION

Ministry of Education, Govt of India.

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PROJECT COMPLETION REPORT

PROJECT TITLE

Exploring mineral acids in Rasayana Shastra texts from ancient and medieval India

SUBMITTED BY

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(Date of Submission)

FUNDED BY

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Govt of India**

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Project Duration: From August 2022 to July 2024

PROJECT COMPLETION REPORT

One soft copy of the Project Completion Report should be submitted on email. The Report should consist of Part A - Summary Report and Part B - Comprehensive Report. The report should be on the Standard Format provided.

1. Project Title: Exploring mineral acids in Rasayana Shastra texts from ancient and medieval India

2.

3. Duration of Project: From August 2022 To July 2024

4. Focus Area: Ancient Rasayana Shastra

5. Principal Investigator

Name: Dr. Venkatnarayan Ramanathan

Organisation/Institution: Department of Chemistry, IIT (BHU), Varanasi

6. Co-Principal Investigators NA

Name:

Organisation/Institution:

7. Collaborating Organisations: NA

Organisation	Team Members	Activities/Tasks assigned

Part A - Summary Report

1. Project Objectives

Objective as per the approved Project	Fully Achieved/Partially Achieved (indicate shortfall)	Reason for Partial Achievement
To recreate the process described in ancient Indian texts, prior to 14th CE where in situ production of mineral acids is anticipated.	Fully Achieved	

2. Deliverables

Deliverables as per the approved Project	Fully/Partially/Not Achieved	Reason for Partial/ Non-Achievement
Literature Review on mineral acids in ancient Indian texts	Fully Achieved	
Compilation of relevant textual excerpts	Fully Achieved	
Experimental setup for recreating ancient processes	Fully Achieved	
Conducting experiments on the interaction of substances with urine	Fully Achieved	
pH measurements and data analysis	Fully Achieved	
Drafting of research papers for publication	Fully Achieved	
Preparation of conference presentations	Fully Achieved	
Development of a project report	Fully Achieved	

3. Specific Benefits/Outcome

(Please give details)

- Rewriting the History of Chemistry:** This research challenges the prevailing narrative that limits early Indian chemistry to organic acids. It provides compelling evidence that ancient Indian scholars possessed sophisticated knowledge of mineral acids and their applications, significantly impacting our understanding of the history of chemistry.
- Enhanced Understanding of Ancient Indian Science:** The project sheds light on the advanced scientific and technological capabilities of ancient Indian civilizations. It demonstrates a deeper understanding of their knowledge of chemistry, metallurgy, and medicine.
- New Insights into Alchemical Practices:** The research provides valuable insights into the techniques, procedures, and philosophical underpinnings of ancient Indian alchemy, contributing to a richer understanding of this fascinating and complex field.
- Potential for Innovation:** The study may inspire new research directions and innovative applications based on the principles and practices discovered in ancient Indian texts.
- Cultural Significance:** By showcasing the significant contributions of ancient India to the field of chemistry, this research enhances national pride and cultural identity.
- Educational Value:** The findings can be integrated into educational curricula to provide a more comprehensive and nuanced understanding of the history of science and technology.

- Patent, if any: **NA**
- Product/Process developed/ technology transferred: **NA**

- List of Publications arising from the Project
(Indicate Impact Factors of the Journals; attach Copies of the Papers)

Refer to Annex 1

- i. Sharma, V., & Ramanathan, V. (2024). *Mineral acids in Ancient Indian texts: A historical perspective and contemporary validation*. Indian Journal of History of Science. IF=0.1

Linkages developed: NA

4. Manpower trained: 1

- No. of Students based on the project:1
- No. of Master's Thesis/Reports based on the project: 0
- Position and Number of Other Technical Staff Trained: 0

5. Methodology (Minimum 250 Words):

• Salient Research Achievements

This project aims to investigate the presence and knowledge of mineral acids in ancient Indian texts prior to the 8th CE and recreate the process of in situ production described there. Historians of science and chemists have opined that prior to the iatrochemistry period (*Rasaśāstra*), ancient Indian chemists had limited knowledge of acids and were only familiar with organic acids derived from plants and animals. It is believed that the mineral acid was introduced to the Indians by the Persians after the alleged discovery of mineral acid (royal water) by Jābir ibn Hayyān after the 9th CE. A literature review was conducted of ancient texts prior to the 12th CE, in which passages and verses that may contain references to mineral acids were identified. The pH levels of the solutions described in the texts were measured to detect mineral acids. Based on the results of the literature survey, Indian scholars exhibited significant knowledge of mineral acids, especially pertaining to *Lohasiddhi*, the transformation of base metals into noble ones, and *Dehasiddhi*, the attainment of rejuvenation and well-being. The experimental results that confirmed mineral acids during replication processes establish the relevance and accuracy of ancient knowledge about mineral acids and reinforce their validity. By bridging the gap between historical practices and modern scientific understanding, this study is a significant contribution to the field of Indian knowledge systems.

• New Observations (minimum 200 words):

Experimental Corroborations

1. Presence of In Situ Mineral Acid Production in Ancient Texts:

- Analysis of classical Indian texts such as the *Arthaśāstra* and *Suśruta Saṃhitā* suggests descriptions of processes that implicitly rely on the presence of mineral acids.

- Experiments with traditional substances like Puṣpakāśīsa and Tuttha, detailed in these texts, confirmed the acidifying effect in biological mediums such as cow and goat urine, indicating knowledge of acid-producing reactions.
- Advanced Material and Reaction Knowledge:** Mineral like Tuttha, Kāśīsa, Haritāla, and Manahṣilā exhibited specific chemical properties that were effectively utilized in alchemical and medicinal practices. These substances' ability to dissociate and produce hydrogen ions (H⁺) supports the notion of a sophisticated understanding of chemical reactivity.
- The findings indicate the use of substances that mimic mineral acid behavior, thus predating external influences or discoveries from the 9th century CE.

2. Broader Implications for Alchemical Knowledge:

- The experimental outcomes underscore the advanced chemical understanding embedded in ancient Indian alchemy. The processes for creating strong solvents and acids highlight a continuum of practical and theoretical knowledge that predates comparable discoveries in the West.

The research illustrates the sophistication of Indian alchemical and metallurgical traditions. It provides evidence for the preparation of mineral acids and their applications in medical, metallurgical, and alchemical contexts. The comparative study of historical texts and experimental validation highlights the contributions of Indian knowledge systems to the global history of chemistry.

• Innovations (Give bulleted list):

1. Finding of Earliest Indian Reference to Acidic Reactions

- Identified and validated the earliest known textual evidence of mineral acid-like reactions in *Arthashastra* (4th century BCE), redefining the timeline of chemical knowledge in India.

2. Establishment of Indian Precedence in Acid Chemistry

- Demonstrated that mineral acid preparation techniques mentioned in Indian texts predate similar processes in Western and Chinese traditions, contributing to global alchemical history.

3. Development of Analytical Protocols for Historical Chemistry

- Innovated experimental protocols for verifying ancient recipes involving acid-like compounds, combining traditional materials with modern analytical tools.

4. Linguistic-Chemical Correlation

- Pioneered a linguistic and chemical analysis to decode terminologies like *Vida* and *Viṣodaka*, linking their descriptions in ancient texts to specific chemical properties and formulations.

5. Integration of Transcultural Knowledge

- Introduced a framework for analyzing the transfer of chemical and metallurgical knowledge between India, China, and the West, focusing on shared and unique advancements.

6. Reconstruction of Alchemical Techniques

- Successfully reconstructed mineral acid preparation using descriptions from *Rasārṇava* and *Rasahṛdayatantra*, offering new insights into ancient metallurgical and medicinal practices.

6. Indication of scope for future work (Maximum 300 Words):

1. Deeper Historical Exploration:

- **Textual Analysis:** Conduct more in-depth analysis of other ancient Indian texts, including medical treatises, philosophical texts, and archaeological records, to uncover further evidence of mineral acid knowledge and utilization.
- **Cross-cultural Comparisons:** Investigate potential connections and influences between Indian alchemical practices and those of other ancient civilizations, such as those in China, Greece, and the Islamic world.

2. Experimental Investigations:

- **Systematic Study of Alchemical Processes:** Conduct more systematic and controlled experiments to replicate and analyze various alchemical processes described in ancient texts, focusing on the role of mineral acids in these processes.
- **Characterization of Ancient Materials:** Utilize advanced analytical techniques (e.g., Raman spectroscopy, X-ray diffraction) to characterize the nature and composition of materials used in ancient alchemical practices, including mineral acids and their reaction products.

3. Development of Modern Applications:

- **Biomedical Applications:** Explore the potential of ancient alchemical formulations and principles for developing novel biomedical applications, such as drug delivery systems, antimicrobial agents, and wound healing therapies.
- **Materials Science Applications:** Investigate the potential of ancient alchemical techniques for developing new materials with unique properties, such as advanced ceramics, catalysts, and corrosion-resistant materials.

4. Public Outreach and Education:

- **Develop educational resources:** Create interactive exhibits, documentaries, and educational materials that communicate the findings of this research to the public, fostering a greater appreciation for the history of science and technology in India.
- **Organize workshops and seminars:** Conduct workshops and seminars for students, researchers, and the general public to disseminate the findings of this research and encourage further exploration of this fascinating field.

7. Procurement/Usage of Equipment:

Table (A):

Expense Head: Non-recurring (Equipment)				
Sr. No	Bill No.	Name of the Employ/vendor	Expenditure	Total Amount in Rs. for each Expense Head
1	Chemistry/IIT(BHU)/2022-2023/SA/IKS/367/17 dated 25.2.23	Global scientific traders	398400/-	398400/-
			Total	3,98,400/-

Part B – Comprehensive Report

(The Comprehensive Report should be precise in detail and self-contained)

1. Project Title: Exploring mineral acids in Rasayana Shastra texts from ancient and medieval India

2. Literature Review

It has been mentioned by several historians of science that the knowledge of the ancient Indian chemists was only restricted to organic acids derived from various products of plant and animal origin and that they lacked the knowledge about the mineral acids. It has been stated by the historians of science in the last 100 years that ancient Indians digested even precious stones using only vegetable acids like sour gruel (impure vinegar) and juice of certain plants and fruits like those belonging to the citron family, pomegranate etc. Interestingly there are copious references where we get a hint of mineral acids being used but scholars have been circumspect in crediting our past chemists for having used the mineral acids. This is what Prof. P. C. Ray has to say about the use of mineral acids in ancient India (1): “We have, however, no evidence that the acid thus derived was ever used as a solvent. At the same time, it might be pointed out that Rasarnava and similar other works lay stress upon *vida*, in which aqua regia may be said to be potentially present, and which is fully described as capable of hilling all the metals. The preparation of mineral acids is incidentally described in several exclusively medical works, composed probably 16th and the 17th centuries.” Another scholar, Prof. P. Ray repeats on similar line and has the following to say (2): “The mineral acids were however unknown to Indians until a later period in the alchemical age. The distillation of alum, referred to in Rasarnava and of green vitriol in Rasaratnasamuchchaya obviously give rise to some sulphuric acid. Only in some medical works of 16th and 17th centuries, the preparation of mineral acids has been described in some details.” Further ahead there are other scholars like Prof. A. K. Biswas has stated the following about the use of mineral acids in India (3): “There were certain interaction: the medieval Rasasastra texts referred to syphilis, the venereal disease carried by the Portuguese navigators, mercurial remedies (mentioned by Paracelsus as well), cobcini, opium (*ahiphe*) and other remedial drugs, the profound use of strong mineral acids, the discovery and first use of which are still shrouded in mystery.” He has left a benefit of doubt regarding the use of mineral acids by ancient Indians by stating that its antiquity is shrouded in mystery. Vladimir Karpenko and co-workers have the following to say about the use of mineral acids by Indians in their research on the history of nitric acid (4): “Killing of gold could be comprehended as its dissolution. Depending on the quantity of the combined substances and their processing, the Indian recipe could indeed have led to aqua regia, even though it would likely have contained other compounds as well.” In the same article they further quote Bose and Subbarayappa and restate the shaky antiquity of mineral acids. Bose and Subbarayappa has documented the following in their edited volume concerning the scientific history of India (5):

“A number of acids were also known. The organic acids of citrons, tamarind, pomegranate and of a few other plant products were in use. The earlier text on medicine do not speak of any mineral acid. In this connection it may be noted that some of the compositions including nitre and alum used by the Indian alchemists for the purification of metals might have constituted the ingredients necessary to give rise to mineral acids in the process, although there is no explicit reference to mineral acids. The Indian experimentalists did not seem to have any knowledge of the mineral acids in contradistinction to the acids of plant products of which they were quite aware.” Hence we see that several scholars who have given a vivid account of the ancient’s contribution to chemistry, have been either circumspect or completely deny the knowledge of mineral acids by the ancient chemists. In this proposal I would like to recreate the conditions

mentioned in Arthasastra, a text which predates the alchemical texts by at least a millennium and explore whether the mineral acid is getting formed or not

3. Methodology adopted for Development of the Product/Process in the Research

Project *(State briefly in 800 words)*

The methodology for this project was designed to systematically explore the potential formation of mineral acids as described in ancient Indian texts, focusing on key chemical reactions involving traditional substances.

Sample Preparation and Identification

1. Procurement of Substances:

- Traditional Ayurvedic and alchemical materials, including **Puṣpakāsīsa** (green vitriol, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$), **Tuttha** (blue vitriol, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$), **Haritāla** (orpiment, As_2S_3), and **Manahśilā** (realgar, As_2S_2), were sourced from reputable suppliers (Kremer Pigments and Sigma-Aldrich).
- Goat and cow urine, required for the experiments, was collected following traditional guidelines outlined in *Suśruta Saṃhitā*.

2. Verification of Substances:

- The identity and purity of the substances were confirmed using Raman Spectroscopy and X-ray Diffraction (XRD) to ensure reliable experimental results.

Experimental Design

1. Preparation of Test Solutions:

- Solutions were prepared by mixing varying amounts of substances like **Puṣpakāsīsa** with fresh cow or goat urine in different ratios (1:0.5, 1:1, 1:2, and 1:4).
- Specific combinations of the five traditional drugs were also tested using goat urine to assess their collective effect on pH reduction and mineral acid formation.

2. pH Monitoring:

- The initial pH of the urine samples was measured using a digital pH meter and validated with litmus paper.
- pH readings were recorded over a 16-hour period, with measurements taken hourly at room temperature ($24 \pm 2^\circ\text{C}$).

3. Controlled Conditions:

- Experiments were conducted in a closed environment to minimize external factors influencing the solutions' pH.
- Fresh urine was stored at 4°C and filtered prior to use to remove any contaminants.

Data Collection and Analysis

1. Tracking Acidification:

- The effect of varying concentrations of **Puṣpakāsīsa** and other drugs on the pH of urine was analyzed to determine the acidification pattern and its dependence on concentration.
- Trends in pH reduction over time were studied to evaluate the influence of the urine's buffering capacity.

2. Replication of Historical Descriptions:

- Historical experiments described in the *Arthaśāstra* and *Suśruta Saṃhitā* were recreated to verify the formation of mineral acids.
- Specific attention was given to reported reactions involving **Puṣpakāsīsa** and its interaction with animal-derived substrates like urine.

3. Observation of Acid Formation:

- The presence of mineral acid indicators, such as significant pH drops, was used as evidence to assess whether ancient recipes could have led to the in-situ production of mineral acids.

Validation and Comparison

1. Historical Contextualization:

- Observations were compared with descriptions from ancient texts to align findings with documented alchemical practices.
- Cross-references were made with historical interpretations by scholars like P. C. Ray and A. K. Biswas.

2. Modern Analytical Techniques:

- Complementary analyses using FTIR (Fourier-Transform Infrared Spectroscopy) and UV-Vis Spectroscopy were planned to further validate the presence of acidic compounds in the test solutions.

4. Description of the any Product/Process developed during the project

While the primary focus of the project was on historical research and experimental validation of ancient Indian alchemical practices, it's important to note that the development of a tangible "product" in the traditional sense might not have been the primary objective.

However, several valuable "products" can be identified:

- **A Comprehensive Dataset:** The project likely resulted in a comprehensive dataset, including:
 - i. **A curated collection of textual excerpts:** This collection can serve as a valuable resource for future scholars studying ancient Indian chemistry and alchemy.
 - ii. **Experimental data:** The data collected from the pH measurements and other experiments provides valuable insights into the chemical reactions involved in ancient alchemical processes.
- **A Refined Methodology:** The project may have refined the methodology for investigating and replicating ancient alchemical processes, which can be valuable for future research in this area.
- **A New Framework for Understanding Ancient Indian Chemistry:** The research findings contribute to a new framework for understanding the scope and sophistication of early Indian chemistry, challenging existing narratives and providing a more nuanced perspective.

5. Outputs & Outcomes:

a. Technology Development

- Technology developed at Lab scale/pilot scale/commercial scale: NA
- Technology demonstration in field setup - NA
- Technology Transfer to industry: NA
- Buyers/End users of product: NA
- Affordability: NA

b. Knowledge Creation

- Patent filings: NA
- Participation in conference/ training workshops attended: **2 & Refer to Annex 2**

c. Knowledge Dissemination

. Conference Presentations:

- **National Youth Conference on Indian Knowledge Systems (IIT Roorkee, August 25-27, 2023):** Presented the poster "Exploring the Antiquity of Mineral Acids in Indian Texts" and received the Best Poster Award.
- **Research and Innovation Day (IIT (BHU), September 05, 2024):** Presented the poster "Exploring Mineral Acids in Rasāyana Śāstra Texts from Ancient and Medieval India" and received a Certificate of Appreciation.

d . Publications

Type of Publications	Number of Publications	List of Publications	Authors & Co-Authors	Theme of the publication	References/links of the Publications (link not required for books)
Research Papers	1	Sharma, V., & Ramanathan, V. (2024). Mineral acids in Ancient Indian texts: A historical perspective and contemporary validation. Indian Journal of History of Science. IF=0.1	Sharma, V., & Ramanathan, V.	Sharma, V., & Ramanathan, V.	
Books					
Articles					
Poster presentations					
Journals published through IKS center / Project					
Magazines					

e. Describe how the project How the project resulted in integration of IKS and Contemporary knowledge

i. Bridging Ancient and Modern Science:

- The project employed modern scientific techniques (e.g., pH measurements, chemical analysis) to investigate and validate claims made in ancient Indian texts.
- This approach allowed for a critical examination of ancient knowledge through the lens of contemporary scientific understanding, fostering a dialogue between historical and modern perspectives.

ii. Reinterpreting Historical Evidence:

- By applying modern scientific methods to ancient texts, the project has reinterpreted historical evidence, challenging conventional narratives about the limitations of early Indian chemistry.
- It has demonstrated that ancient Indian scholars possessed a sophisticated understanding of chemical principles, including the use of mineral acids.

iii. Inspiring New Research Directions:

- The findings of this project have opened up new avenues for research, inspiring further exploration of ancient Indian scientific and technological advancements.
- This includes investigating the potential applications of ancient Indian knowledge in modern fields such as materials science, medicine, and environmental science.

iv. Promoting Cultural Understanding:

- By highlighting the significant contributions of ancient India to the field of chemistry, the project promotes a deeper understanding and appreciation of Indian culture and its rich intellectual heritage.
- It contributes to a more inclusive and nuanced understanding of the history of science and technology.

v. Educational Impact:

- The findings of this project can be integrated into educational curricula, providing students with a more comprehensive and nuanced understanding of the history of science and technology.
- This can help to foster a greater appreciation for the contributions of Indian knowledge systems to global scientific progress.

By integrating ancient Indian knowledge with contemporary scientific methodologies and perspectives, this project has not only shed light on the past but also opened up new avenues for future research and innovation.

f. Knowledge Repository

Structure and Organization:

- **Categorization:** The knowledge repository could be organized into several key categories:
 - **Historical Texts:**
 - Original texts (in Sanskrit/other languages)
 - English translations of relevant passages
 - Scholarly commentaries and interpretations
 - **Experimental Data:**
 - Raw data from pH measurements and other experiments
 - Data analysis and visualizations

- Experimental protocols and methodologies
- **Research Findings:**
 - Summary of key findings and conclusions
 - Scholarly articles and publications
 - Conference presentations and abstracts
- **Multimedia:**
 - Images and videos related to the project (e.g., experimental setups, historical artifacts)
 - Interactive visualizations and simulations
- **Metadata:** Each piece of information within the repository should be accompanied by detailed metadata, including:
 - i. Title
 - ii. Author(s)
 - iii. Date of creation/publication
 - iv. Source (e.g., journal, conference proceedings, personal notes)
 - v. Keywords
 - vi. Abstract/description
 - vii. File format
- **Search Functionality:** Implement a robust search engine with advanced filtering options (e.g., by keyword, author, date, file type) to enable users to easily find relevant information.

User Access and Utilization:

- **Public Accessibility:**
 - **Open Access Repository:** If appropriate, consider hosting the repository on an open-access platform (e.g., Zenodo, Figshare, institutional repository) to make the research findings freely available to the public.
 - **Project Website:** Create a dedicated project website to host the repository and provide access to key resources.
- **User Interface:** Design a user-friendly interface with clear navigation and intuitive search functionality.
- **Documentation:** Provide comprehensive documentation on how to access, navigate, and utilize the repository.
- **Community Engagement:** Promote the repository through various channels (e.g., social media, academic networks) to encourage wider use and engagement.

g. Capacity building

- Officers/faculty: 0
- Temporary manpower recruited/trained: 1

h. Results & Analysis with figures

Experimental evidence

Alchemy, the ancient practice of transmuting metals and preparing elixirs of life, was divided into two main pursuits: *Lohasiddhi* (transformation of lower metals to noble metals) and *Dehasiddhi*. *Rasāyana*, a branch of alchemy, involves a rejuvenation therapy that includes the internal use of elixirs believed to bestow long life (Savrikar and Ravishankar, 2011). The ancient Indian texts like *Arthaśāstra*, *Caraka* and *Suśruta Samhitā*, two ancient Indian medical texts, mention alum, saltpetre, borax, blue vitriol, green vitriol, sulphur, realgar, orpiment, and sal ammoniac. This suggests that there is reason to anticipate that further research may uncover evidence of the preparation of mineral acids and mixtures of mineral acids in India well before even the common era.

The earliest known reference to mineral acids in Indian literature is found in the *Arthaśāstra* (4th BC), “जातिहिङ्गुलकेन पुष्पकासीसेन वा गोमूत्रभावितेन दिग्धेनाग्रहस्तेन संस्पृष्टं सुवर्णं श्वेतीभवति”, which describes a process for testing gold using green vitriol ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$). When gold (*Suvarṇa*) is touched by the edge of a palm dipped in a solution of *Jātihiṅgulaka* (vermilion) or *Puṣpakāsīsa* (green vitriol) mixed with cow's urine, it turns white (Shamasastriy, 1956). In order to determine whether this process produces mineral acid, we replicated the test by adding green vitriol to the cow's urine in order to ascertain whether mineral acid is formed (Fig. 1). We purchased *Haritāla* (orpiment) and *Manahsilā* (realgar) from Kremer Pigments. Similarly, *Tuttha* (blue vitriol) and *Puṣpakāsīsa* (green vitriol) were purchased from Sigma-Aldrich. A certified Ayurvedic Vaidya generously gifted Gorochana (cattle gallstone) for research purpose. Before starting our experiments, we used Raman spectroscopy and XRD to confirm identity and purity of all the samples.

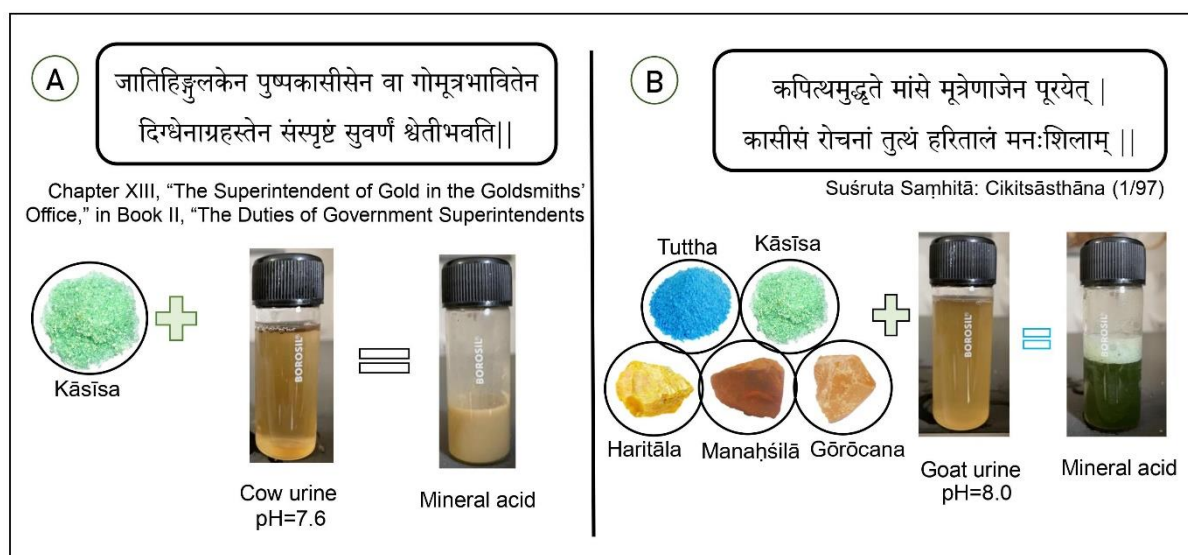


Fig. 1 Replication of an ancient Indian alchemy experiment from the (A) *Arthaśāstra* (B) *Suśruta Saṃhitā*.

We carried out an experiment to investigate how *Puṣpakāsīsa* ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$) influences the pH of fresh cow urine. The collection of cow urine was done as per the instructions given in *Suśruta Saṃhitā* (*Sūtrasthāna*, 36/16). After the young cow's food had been fully digested, we collected urine samples in sterile 50 ml containers. We then measured the pH immediately using a digital pH meter and litmus paper. We then transferred containers to the laboratory without any delay and stored them at 4°C. The urine samples were checked for the presence of debris, dung, or hair to ensure that we did not have any contaminants in our samples. This is done by filtering the urine through a cotton filter to eliminate any suspended materials. After that, four solutions were prepared, each with different ratios of *Puṣpakāsīsa* to urine (e.g., 1:0.5 for solution A, 1:1 for solution B, 1:2 for solution C, and 1:4 for solution D):

1. **Solution A:** 4 g of *Puṣpakāsīsa* in 2 ml of urine.
2. **Solution B:** 4 g of *Puṣpakāsīsa* in 4 ml of urine.
3. **Solution C:** 4 g of *Puṣpakāsīsa* in 8 ml of urine.
4. **Solution D:** 4 g of *Puṣpakāsīsa* in 16 ml of urine.

The initial pH of each solution (A, B, C, D) was measured at room temperature ($24 \pm 2^\circ\text{C}$). The pH was monitored over a 16-hour period, with measurements taken at each one-hour interval after the addition of *Puṣpakāśīsa*. After every hour, we checked the pH again at room temperature. We repeated this process in a closed environment to reduce the impact of external influences on the solutions.

The pH of young cow fresh urine was found to be 7.6. The initial pH increased with decreasing *Puṣpakāśīsa* concentration. Solution D (highest urine volume, lowest *Puṣpakāśīsa* concentration) had the highest initial pH (3.7), while solution A (lowest urine volume, highest *Puṣpakāśīsa* concentration) had the lowest initial pH (2.3). This suggests that *Puṣpakāśīsa* addition acidifies the urine, with a stronger effect at higher concentrations. There appears to be minimal change in pH within the first 2 hours for all solutions. After 5 hours, a slight decrease in pH was observed in all four solutions. This suggests a potential initial buffering capacity in the urine that diminishes over time, allowing the acidic effect of *Puṣpakāśīsa* to become more pronounced. The data suggests a possible concentration dependence on pH change. Solutions A and B (higher *Puṣpakāśīsa* concentration) exhibited a larger decrease in pH compared to solutions C and D (lower *Puṣpakāśīsa* concentration) after 5 hours (Fig. 2). *Puṣpakāśīsa* is water-soluble sulphate that can dissociate in solution, releasing hydrogen ions (H^+) that contribute to acidity. This supports the initial observation that higher *Puṣpakāśīsa* concentration leads to a stronger acidifying effect. Overall, the findings suggest that *Puṣpakāśīsa* addition acidifies fresh cow urine, with the effect being more pronounced at higher concentrations and potentially influenced by the urine's buffering capacity.

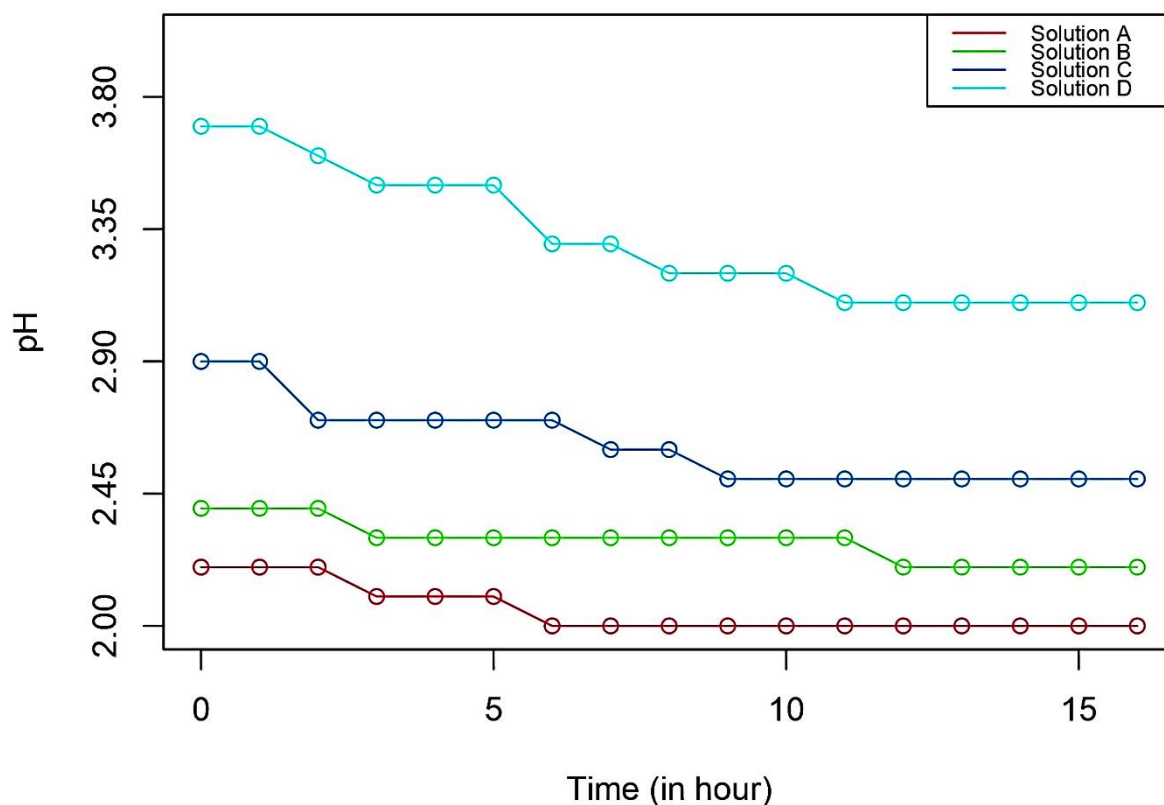


Fig. 2 Time-dependent changes in pH of fresh cow urine treated with *Puṣpakāśīsa*

Similarly, *Ācārya Suśruta* (6th BC) mentions the use of mineral acids in *Pāṇḍu Karma*, a practice aimed at restoring the natural skin colour of scars “कपित्थमुद्धृते मांसे मूत्रेणाजेन पूरयेत् । कासीसं रोचनां तुत्थं हरितालं मनःशिलाम्॥” (Shastri, 2003). This experiment investigated the effects of five traditional Ayurvedic drugs- *Tuttha* ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$), *Kāsīsa* ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$), *Haritāla* (As_2S_3), *Manahśilā* (As_2S_2), and *Gōrōcana*-on the pH of fresh goat urine. The process of collecting goat urine was the same as cow urine. The pH value of goat urine was initially 7.9. An equal quantity (2 gm each) of the five substances was combined to form a mixture. Four solutions (P, Q, R, and S) were prepared, where goat urine volumes were varied (5 ml, 10 ml, 20 ml, and 40 ml, respectively), keeping the same amount of the drug mixture (10 gm). The term drug-to-urine ratio of 1:0.5, 1:1, 1:2, and 1:4 for solutions P, Q, R, and S, respectively applies. After the filtration process, we measured the pH of the solutions. The pH of all four solutions was measured over a 16-hour period. The data reveals a clear trend of decreasing pH in all solutions over time. The initial pH values (2.8, 3.3, 4.1, and 4.3) increased with increasing urine volume (decreasing drug concentration). This indicates that the goat urine has a buffering capacity that initially counteracts the acidic nature of the drug mixture. All solutions exhibited a continuous decrease in pH throughout the 16 hours measured. This reveals that the progressive reaction between the drug components and the urine, as a result of which the overall pH is lowered, appears to be taking place. The rate of pH decrease seems to be dependent on the initial drug-to-urine ratio. Solutions with higher ratios (A: 1:0.5 and B: 1:1) showed a faster initial decrease compared to solutions with lower ratios (C: 1:2 and D: 1:4). This implies a concentration-driven reaction. Similarly, the pH values appear to stabilize between 13 and 16 hours in all solutions (Fig. 3). This might mean that the reaction is approaching an equilibrium state at this point, where the remaining buffering capacity controls further pH reduction. *Tuttha* and *Kāsīsa* are water-soluble sulphates that can dissociate in solution, releasing hydrogen ions (H^+) that contribute to acidity. *Haritāla* and *Manahśilā* are arsenic sulphides, and while less soluble than the sulphates, hydrolysis in water can still generate H^+ ions. *Gōrōcana*, the primary component of cattle gallstones, is expected to have minimal impact on the overall pH due to its basic nature. This experiment shows that the decrease in pH of fresh goat urine is a concentration-dependent, time-dependent reaction with the drug mixture. The pH decrease appears to be concentration-dependent.

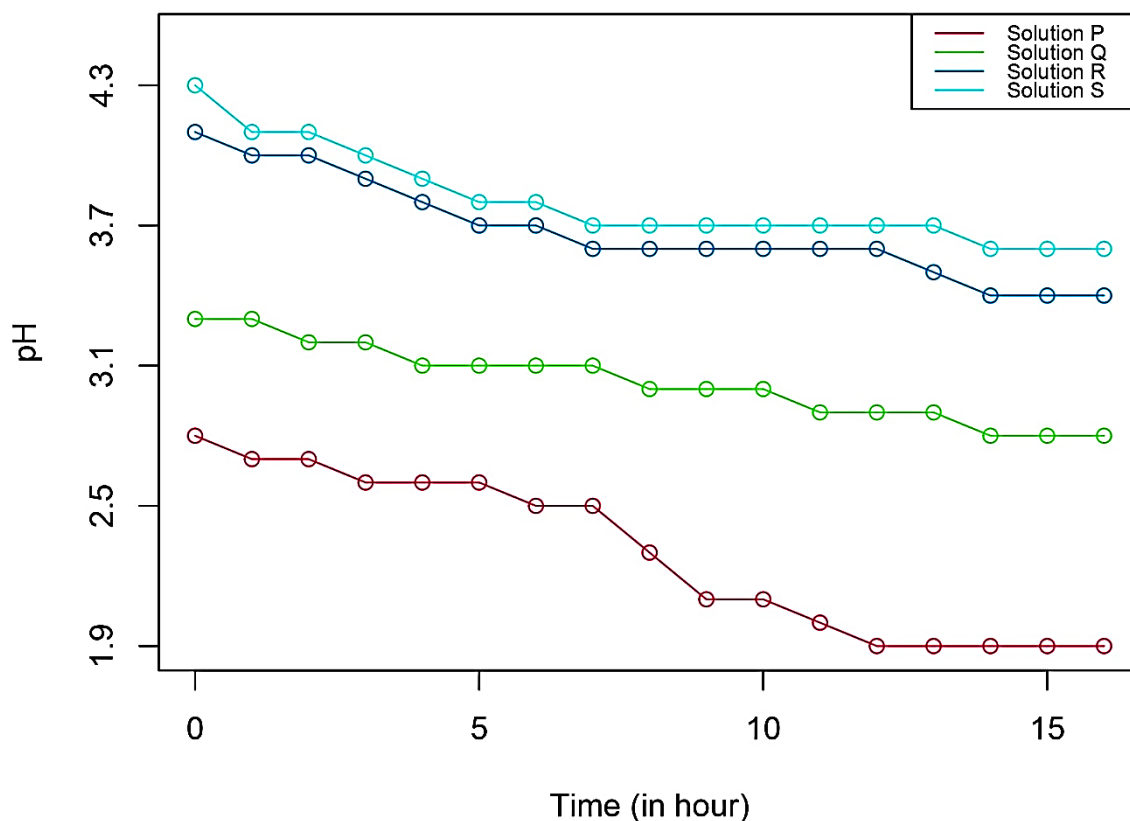


Fig. 3 Time-dependent changes in pH of fresh goat urine treated with varying concentrations of ayurvedic formulations.

i. Achievements/ highlights of the project

- **Challenging Existing Narratives:** The project successfully challenged the conventional view that limited early Indian chemistry to organic acids. It presented compelling evidence that ancient Indian scholars possessed a sophisticated understanding of mineral acids and their applications.
- **Reinterpreting Historical Evidence:** By combining historical research with experimental validation, the project reinterpreted historical evidence, providing a more nuanced and accurate understanding of early Indian chemical knowledge.
- **Bridging Ancient and Modern Science:** The project successfully integrated ancient Indian knowledge with contemporary scientific methodologies, fostering a dialogue between historical and modern perspectives.
- **Dissemination of Knowledge:** The project effectively disseminated its findings through various channels, including conference presentations, publications, and potential online resources, contributing to the broader understanding of Indian scientific heritage.
- **Recognition and Awards:** The project garnered recognition through awards such as "Best Poster Award" at the National Youth Conference on Indian Knowledge Systems and "Certificate of Appreciation" at the Research and Innovation Day. (**Refer to Annex 2**)

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k. Appendices

- NA

l. Project Outcomes Contribution to (Bullet points. No more than 250 words in each category)

Dṛṣṭi (Worldview):

- **Reframing Historical Narratives:** This project challenges the limited view of early Indian chemistry, fostering a more inclusive understanding of global scientific progress. It highlights the significant contributions of ancient India to the field of chemistry.
- **Appreciating Indigenous Knowledge Systems:** The project emphasizes the value of investigating and integrating traditional knowledge systems like Rasayana Shastra with contemporary science. This promotes a more holistic approach to scientific inquiry.
- **Rethinking the Past:** By demonstrating the advanced knowledge of mineral acids in ancient India, the project encourages us to re-evaluate our understanding of past civilizations and their scientific capabilities.

Jñāna (Knowledge):

- **Enhanced Understanding of Ancient Indian Chemistry:** The project sheds light on the sophisticated use of mineral acids in ancient Indian alchemical practices. This expands our knowledge of their chemical processes and technological advancements.
- **New Interpretations of Historical Texts:** The research provides new insights into the meaning and applications described in Rasayana Shastra texts. This enriches our understanding of ancient scientific literature.

- **Development of Methodologies for Studying Ancient Science:** The project establishes a valuable methodology for investigating and validating claims made in historical texts through experimental replication. This can be applied to further research in the field.

***Laukika-prayojana* (Practical Applications):**

- **Inspiration for New Research Directions:** The project's findings can inspire further research on the potential applications of ancient Indian knowledge in modern fields like materials science, medicine, and environmental science.
- **Preservation of Cultural Heritage:** By documenting and validating ancient scientific practices, the project contributes to the preservation of India's rich cultural heritage and intellectual traditions.
- **Promoting Public Engagement with Science:** The project's findings can be used to develop educational resources and outreach programs, fostering public interest and engagement with the history of science and technology.

ANNEXURE 1

Publications

Indian Journal of History of Science
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ARTICLE



Mineral acids in ancient Indian texts: a historical perspective and contemporary validation

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Abstract

This paper aims to investigate the presence and knowledge of mineral acids in ancient Indian texts prior to the eighth century CE and recreate the process of in situ production described there. Historians of science and chemists have opined that prior to the iatrochemistry period (*Rasaśāstra*), ancient Indian chemists had limited knowledge of acids and were only familiar with organic acids derived from plants and animals. It is believed that the mineral acid was introduced to the Indians by the Persians after the alleged discovery of mineral acid (royal water) by *Jābir ibn Hayyān* after the ninth century CE. A literature review was conducted of ancient texts before the twelfth century CE, in which passages and verses containing references to mineral acids were identified. The mineral acids were detected by measuring the pH levels of the solutions described in the texts. Based on the literature survey results, Indian scholars exhibited significant knowledge of mineral acids, especially pertaining to *Lohasiddhi*, the transformation of base metals into noble ones, and *Dehasiddhi*, the attainment of rejuvenation and well-being. The experimental results that confirmed mineral acids during replication processes establish the relevance and accuracy of ancient knowledge about mineral acids and reinforce their validity. By bridging the gap between historical practices and modern scientific understanding, this study is a significant contribution to the field of Indian knowledge systems.

Keywords Mineral acid · Alchemy · Jabir · Geber · *Rasārṇava* · *Puṣpakāśīsa*

1 Introduction

Historians of science and chemists alike have opined that prior to the period of iatrochemistry (*Rasaśāstra*), ancient Indian chemists had limited knowledge of acids and were only familiar with organic acids derived from plants and animals (Bose et al., 1975; Ray, 1948, 2000). These included sour gruel (a type of vinegar), citrus fruits, bladder dock, and various other plants (Biswas, 2010; Wujastyk, 2013). Notably, these organic acids proved effective in purifying, dissolving, and killing mercury (a process called '*Māraṇa*'—the calcination of mercury) and minerals (Biswas, 2010). It is widely believed that ancient Indian chemists were unaware of mineral acids or, at best, did not use them as a

separate solvent (Ray, 1903). It is now generally accepted that mineral acid was introduced to the Indians by the Persians after the alleged discovery of mineral acid (Royal Water) by *Jābir ibn Hayyān* after the ninth century CE (Holmyard, 1923). *Jābir ibn Hayyān* was also recognized by the Latinized name Geber (Karpenko & Norris, 2002).

After analyzing research conducted by Berthelot (1893, p. 343) and later, as well as Holmyard (1923) and Ruska (1929), Lockemann determined that the Latin Geber texts were not written in the eighth century but more likely at the end of the thirteenth century (Lockemann, 1950, p. 35; Walden, 1954). Additionally, the prominent chemist "Jabir", believed to have lived in the eighth century, is now considered a mythical figure, as the texts attributed to him are forgeries created by a later Arabic religious group (Walden, 1954). Paul Walden concludes that "Jabir", the chemist, is a mythical person, and the works credited to him are forgeries created by a later Arabic religious group based on several historical and textual analyses. Walden points to research from authors such as Berthelot, Holmyard, Ruska, and Krauss, which posits that the Latin texts attributed to Geber were not from the eighth century but from the end of the thirteenth century.

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According to Walden, the texts show a level of technical expertise and practical experience in metal foundries and chemical works that aligns much more with the practices of central European mines and smelting plants of the thirteenth century than eighth century Baghdad. Second, the nomenclature and concepts used in the texts like 'affinitas', 'vitriol', 'amalgam', and 'alcohol', unknown before the twelfth century, indicate a later origin. Third, the lack of references among the Geber texts to Arabic writers and sources is unusual, if indeed from a genuinely Arabic origin. The oldest manuscripts of Geber's works are found north of the Alps; it was thus probably produced closer to monastic activities in Europe than in the Middle East. Fourth, the texts do mention substances like mercury and *Tutia* (zinc oxide)¹ with weight designations that point to European mining and metallurgical practice (Walden, 1954). Fifth, the texts describe the processing of large quantities of the substances and the use of such equipment as sublimation vessels, which would point to operations at a manufacturing scale typical of European practices. Finally, textual descriptions include, for example, likening sublimed mercuric chloride to "pure white and glistening snow", thus assuming a colder climate, indicative of European rather than Arabic origin (Walden, 1954).

An intriguing matter of fact is that when the original references are gleaned, several instances come to the fore that suggest that mineral acids might have been used, without which the described process would not have taken place in Indian texts. This aspect of the mineral acids being used in situ has not been given thorough attention, and the same has been taken up in this work.

The objective of the study presented herein is to investigate the presence and knowledge of mineral acids in ancient Indian texts prior to the eighth century and recreate the process of in situ production described there. To achieve this, an extensive literature review was carried out of ancient texts prior to the eighth century, and passages/verses that may contain references to mineral acids were identified. Sections related to vitriol (green and blue), alum, sulphur, salt

(*Nausādara*, *Biḍa*, etc.), saltpetre (*Yavakṣāra*, *Sajjikṣāra*, etc.) were particularly focused. The processes described in such texts were replicated, and the pH of the reaction mixture was measured using both a digital waterproof pH meter (Eutech pH Testr 10) and pH indicator litmus paper (Merck). Standard procedures and controls were used to ensure the accuracy and reliability of the results.

2 Early knowledge of mineral acids

According to Needham, the first written account of making mineral acid (aqua fortis) in Western Europe is often said to be in the *De Inventionem Veritatis*, a treatise composed in the late 13th or early fourteenth century CE. However, Partington has shown that it is also found in the *Pro Conservanda Sanitate* by the French franciscan *vitalis du four*, c. + 1295 (Needham, 1954). P.C. Ray argues that mineral acids were not known to either Arab or European alchemists in the thirteenth century. He believes that a Latin author who assumed the name Geber wrote the famous *Summa Perfectionis Magisterii* in the latter half of the thirteenth century to gain public trust. Ray also states that the preparation of mineral acids in India was only mentioned in medical works of the sixteenth and seventeenth centuries, such as *Rasaratnapradīpa* (fifteenth century CE) and *Rasakaumudī* (sixteenth century) by *Mādhavakara* (Ray, 1903). However, he notes that the *Rasārṇava* (circa 900 CE, as per Ray) frequently mentions a process for killing gold, copper, etc., by embedding thin leaves of these metals in a mixture of alum, green vitriol, rock-salt, and nitre in a crucible. This mixture, technically termed *Vida*, contains aqua regia in potential (Ray, 1919).

The first written account of a mineral acid in Western Europe comes from the Pseudo or False Geber (13th CE). His works included the *Summa Perfectionis Magisterii*, *De Investigationem Perfectionis*, *Liber De Inventionem Veritatis*, and *Liber Fornacum*. According to Newman, the *Liber De Inventionem Veritatis* was written shortly after the *Summa Perfectionis* as a commentary on this book (Newman, 1991, p. 81).

The Pseudo-Geber text *liber De Inventionem Veritatis* contains a recipe for a mineral acid:

To begin with, I would like to discuss our solvent, aqua nostra dissolutiva, which I had previously mentioned in our *Summa* when discussing the dissolution of substances with strong liquids. To prepare this solvent, you will need one pound of vitriol ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$), half a pound of saltpetre (KNO_3), and a quarter of a pound of alum ($\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$). Use a red alembic to prepare this liquid as it has a high solvent action. You can use it as described in the preceding chapters. If you dissolve a quarter of a pound of sal ammoniac

¹ It is intriguing that words such *Tūtīyā*, *Tuttha*, *Yashad*, *Kharpara*, etc., have been used for zinc in many texts. Old Islamic writings such as *Āin-i Akbarī* and *Al-Biruni* credit Indian scholars with having developed advanced techniques of zinc extraction and identifying *Tūtīyā* as zinc oxide (Craddock, 2018; Ramanathan and Desiraju, 2024). *Ain-i Akbari* identifies *Tūtīyā* as the mineral mined at Zawar. The classical Sanskrit lexicon *Amarakośa* defines "*Tuttha*" as copper sulphate, which reflects its contemporary meaning. However, the commentator of *Arthaśāstra* interprets "*Tuttha*" as zinc ore (Ramanathan and Desiraju, 2024). However, ancient Indians had knowledge of both zinc oxide and blue vitriol. *Puṣpāñjana*, described in *Caraka Samhitā* and *Suśruta Samhitā* for treating eyes and wounds, refers to zinc oxide. Similarly, *Caraka Samhitā* (*Kuṣṭha Cikitsā Adhyāya* 7/108) also describes two specific types of *Tuttha* "*Mayūra Tuttha*" (blue vitriol) and "*Kharpariya Tuttha*" (zinc ore), for the preparation of *Tiktekṣvākvādi Taila* (Trikamji, 1948, p.455).



(NH_4Cl) in it, the solvent will become even stronger. This liquid is capable of dissolving gold, sulphur, and silver." (Darmstaedter, 1922, p.113; Stillman, 1960; Karpenko, 2009).

Needham, a leading scholar of Chinese science, observed several instances in Chinese literature that refer to Indian visitors and their scientific knowledge. Chinese alchemy texts describe a method for making mineral acid by distilling green vitriol, sulphur, alum, and saltpetre together. *Li Shih-Chen* wrote in 1580 CE that a "sulphur juice" or "liquor" (*Liu Huang I*) could be prepared by heating saltpetre with sulphur in a closed bamboo tube at the temperature of burning horse dung for a month (Needham, 1976).

Our analysis draws on historical texts that suggest the transmission of knowledge concerning longevity drugs between India and China during the early medieval period. The allusion to a substance that could dissolve wood, gold, and iron already appeared in the *Yu Yang Tsa Tsu* (Miscellany of forgotten lore) by *Duan Chengshi* in 863 CE (Needham, 1954). The following para from *Yu Yang Tsa Tsu* refers to Indians, and it shows that Indians had knowledge of elixirs of longevity, immortality, saltpetre, metallurgy, as well as mineral acids that existed in seventh century China:

Xuanzang was a Chinese scholar and Buddhist monk who lived in the seventh century during the Tang dynasty. In the years 627–643, *Xuanzang* travelled to India under the rule of Emperor *Harshvardhan* (590–647 CE) (Mishra, 2023; Sen, 2001). *Xuanzang* documented the remarkable expertise of the *Brahmans* in India, especially in longevity and medicine (Sen, 2001). Before esoteric Buddhism emerged in eighth-century Tang China with its own paths to immortality, many sought the *Brahmans* for their renowned longevity drugs. In the last years of his reign, Emperor *Taizong* of the Tang Dynasty became obsessed with finding ways to extend his life. Concerned about his health, the emperor sought spiritual and medicinal remedies, including life-prolonging drugs from India. This pursuit was inspired by influential figures such as *Xuanzang* and returning Tang envoys (Sen, 2001). The Chinese translated the word "*Brahmana*" as "*Ching Sying Che*" meaning "one who follows a path of purity," or they transliterated it as "*Po-Lo-Men*" (Deshpande, 1991).

Inspired by *Xuanzang*'s earlier travels in +646 CE, the Tang Dynasty emperor sent *Wang Xuance* as an ambassador to *Magadha* (West-central Bihar, India) in 648 CE. Upon arrival in *Magadha*, *Wang* realized that Emperor *Harshvardhan* had died. A usurper named *A-Lo-Na-Shun* (Supposedly *Arunāsva*) seized the throne. This new king attacked *Wang* and his entourage. *Wang* fled to the mountains, reaching out to the Kings of *Nepal* and *Tibet*, who were allies of China. With their support, he returned with an army and toppled the usurper. *Wang* captured the usurper and other Indian prisoners, bringing

them back to the Emperor *Taizong* at *Chang'an* (modern *Sian*). Among the captives was a scholar, *Na-Lo-Mi-So-Po* (*Nārāyanasvāmin*), who was known for his arts and magic and claimed an age of 200 years. Emperor *Taizong* was very interested and invited him to stay in *Chin Yen Men* (Palace) so that he could make medicines to prolong his life (Burgess, 1880, p. 21; Needham, 1954, pp. 211–212; Needham, 1976; Needham, 1980).

According to the account, *Nārāyanasvāmin* told the emperor that in the country of the *Brahmins*, there is a substance called *Pan-Chha-Cho Shui* (*Pan-Chha-Cho* water), which is produced from minerals in the mountain river (Needham, 1980). The river *Pan-Da-Fa* (Burgess, 1880, p. 21) flowed from a stone trough and was guarded by statues of stone men. This river contained seven types of water, some hot and some cold. The hot water rapidly dissolved plants, herbs, and metals; anyone who put their hand in it would find it cooked and dissolved instantly. This water was collected with a camel's skull and poured into a calabash (Burgess, 1880, p. 21; Needham, 1980). There is a tree called *Ta-Lai-La*, with leaves resembling those of *li* (a type of ebony), "*Nārāyanasvāmin* claimed. It grows on the rugged sides of a steep mountain, guarded by a serpent hidden in a cave. People shoot arrows with four-cornered points at the branches to obtain the leaves, but birds quickly carry them off. They must shoot more arrows to finally collect the leaves (Burgess, 1880, p. 21).

The emperor, stricken with a severe illness, ordered him to prepare his excellent remedy. *Thsui-Tun-Li*, the chief minister of war, was assigned to protect his emissaries. These emissaries travelled across the empire, collecting rare medicinal plants and minerals. Some even journeyed into the distant kingdoms of the *Brahmans* (*Po-Lo-Men*). However, his magical remedies proved ineffective. The emperor eventually allowed him to leave, but before he could depart, *Nārāyanasvāmin* passed away in *Chang'an*, the imperial capital of China (Burgess, 1880, p. 21; Needham, 1954, pp. 211–212; Needham, 1976; Needham, 1980, pp. 197–198).

Similarly, an account in the *Rasārnavakalpa* (text on alchemy, allegedly dated to circa eleventh century CE) under the category of *Viśodaka* (poisonous water), which specifically matches the description of *Pan-Chha-Cho Shui* exists. The poisonous water in the *Rasārnavakalpa* (verse 730–743) is characterized by its glossy appearance, with three kinds represented by red, yellow, and black colours, indicating varying degrees of potency. They are capable of destroying animals, birds, and humans, respectively. Coming into contact with these waters causes the hairs and teeth to crumble, and shadows are not reflected in the water. The substance is called *Viśodaka*, a potent element that bestows perfection in alchemical pursuits.



The process of collecting this water involves using *Palāsa* (*Butea monosperma*) leaves and keeping it in the hollow portion of a bitter gourd, pouring the juices of *Triphalā* (fruits of *Terminalia chebula* (*Haritaki*), *Terminalia bellerica* (*Bibhitaki*), and *Emblica officinalis* (*Āmalaki*)) into it, and retrieving it with proper muttering of mantras (mystic syllables) (Roy & Subbarayappa, 1976).

The process described in the text involves carefully covering the *Viṣodaka* with *Palāsa* (*Butea monosperma*) leaves and letting it rest in heaps of paddy for 3 weeks. After this period, it is removed from the paddy and prepared on an auspicious day. The grains of the *Śālī* (a variety of paddy) are pounded with *Viṣodaka* and mixed with *Pārada* (mercury) and *Ajākṣīra* (goat's milk) to make pills. These pills, weighing one *Śāna* each, are taken daily with milk, followed by drinking additional milk after digestion. A salt- and sour-free diet is recommended throughout. After 1 month of following this regimen, the individual using it becomes free from wrinkles and grey hair, attaining a youthful appearance akin to that of a 16-year-old and achieving *Dehasiddhi*, the transformation of a body free from disease and aging (Roy & Subbarayappa, 1976).

The name *Pan-da-fa* river is a direct transcription of the Persian word پنجاب “Panjab” (*Pañca-āp*), which means “five waters” or “five rivers” (Burgess, 1880, p. 21). In Sanskrit, this is known as “*Panchananda*”. By adding “*Udaka*”, which means water, we get “*Pañca-Viśa-Udaka*” or “*Pañca-Viśodaka*”. When transliterated, “*Pañca-Viśodaka*” becomes “*Pan-Chha-Cho-Shui*” (Deshpande, 1984). Similarly, Needham also speculates that *Pan-Chha-Cho-Shui* might be a transliteration of “Panjab Water”. A more likely origin could be “*Pañca-Viśa*” referring to a type of water that dissolves or destroys all five elements. This etymology of “*Pan-Chha-Cho-water*” closely aligns with “*Viśodaka*”, as mentioned in the *Rasārṇavakalpa* (Needham, 1980, pp. 197–198; Deshpande, 1984).

The above-mentioned account is significant because historical accounts from *Nārāyaṇasvāmin* (seventh century CE) describe *Pan-Chha-Cho-Shui* for longevity, a substance with properties similar to those in the *Rasārṇavakalpa* (eleventh century CE). This similarity suggests that the understanding of such chemical processes was established 4–5 centuries earlier to the alleged dating of *Rasārṇavakalpa* eleventh century. Cultural exchanges between India and China likely preserved and expanded these ancient alchemical practices. This historical context supports the idea that these processes were known, highlighting the enduring continuity of alchemical traditions across cultures and time.

Medieval Indian scholars coined the Sanskrit term “*Drāvaka*” to refer to mineral acids. In a twelfth century CE medical manuscript, *Vaṅgsena* mentions a formulation called *Śaṅkhadrāva* in *Udararogādhikāra* (verses 173–175)

of *Cikitsāsārasaṅgraha*, in which alum, rock salt, green vitriol, borax, sal ammoniac and saltpetre powder in equal quantities are put into a distillation apparatus to extract liquid acid. This acid was used to treat gastrointestinal disorders (Vidyasagara, 1893, p. 505).

स्वर्जिका च यवक्षारः कासीसं टङ्कणं तथा ।
सौराह्वं सैन्धवचैव लवणं स्फटिकानि च ॥ १७३ ॥
सर्वमेकत्र कर्तव्यं सूक्ष्मचूर्णन्तु कारयेत् ।
कूपमध्ये क्षिपेत्तन्तु द्रावयेद् द्रावयन्त्रके ॥ १७४ ॥
गुल्मं प्लीहान्तथानाहं सर्वोदरांस्तथैव च ।
अर्शासि ग्रहणीदोष भगन्दरव्रणानि च ॥ १७५ ॥
नाशयेन्नात्र सन्देहो नान्यथा शङ्करोऽब्रवीत् । इति शंखद्राव ।

svarjikā ca yavakṣāraḥ kāsīsam taṅkaṇam tathā ।
saurāhvam saindhavaccaiva lavaṇam sphatikāni ca
॥ 173 ॥
sarvamekatra kartavyam sūkṣmacūrṇantu kārayet ।
kūpamadhye kṣipettantu drāvayed drāvayantrake ॥
174 ॥
gulmaṁ plīhāntathānāhaṁ sarvodarāṁstathaiva ca ।
arśāsi grahaṇīdoṣa bhagandaravraṇāni ca । 175 ॥
nāśayennātra sandeho nānyathā śaṅkaro'bravīt । iti
śaṅkhadrāva ।

In *Rasārṇava* (9/2) and *Rasahrdayatantra* (7/2), the preparation of *Viḍa*, a type of mineral acid, is described. The ingredients for *Viḍa* include *Kāśīsa* (Green vitriol), *Saindhava Lavaṇa* (Rock salt), *Kāṅkṣi* (Potash alum), *Viṣa* (Three spices-dry ginger, long pepper, and black pepper), *Gandhaka* (Sulphur), *Sauvarcala Lavaṇa* (Black salt), *Sarjikākṣāra* (Saltpetre), and *Mālatīraja* (Borax). These ingredients are moistened with the *Śigrumūla Rasa* (juice of the root of *Moringa oleifera* Lam.), which could dissolve metals. In another verse (9/8), another type of strong *Viḍa* is described, which is prepared by digesting *Gandhaka*, *Haritāla* (Orpiment), *Cūlikā Lavana* (Ammonium chloride), *Taṅkaṇa* (Borax), *Bhū* (Potash alum), and *Khaga* (Green vitriol) with *Kṣāra* (Saltpetre) and *Mūtra* (Urine). This type of *Viḍa* resembles a volcano (Ray, 1985).

Comparing the preparation of mineral acid by *Rasārṇava* and *Rasahrdayatantra* with what is found in the so-called Pseudo-Geber's *Liber De Inventionem Veritatis* from the thirteenth century brings up salient similarities between the two methods. Both describe the preparation of the strongest dissolvent capable of dissolving all things, including metals such as gold, sulphur, and silver. As for the preparation of mineral acids, the similarities between these ancient texts and the Pseudo-Geber text point to common knowledge or influence regarding the preparation of mineral acids between cultures and time periods. It underscores the significance of alchemical practices and the pursuit of chemical knowledge throughout history.



3 Exploring the origins and influence of *Rasārṇava* in Indian alchemy

According to Needham, during the *Sui* Dynasty (581–618 CE), a number of Brahmin books were translated into Chinese, as evidenced by the *Sui Shu* bibliography (Needham, 1976, p. 160). One of these translations, the *Po-lo-men Yao Fang* (*Brahmin Pharmaceuticals*), may have contained some alchemical material bordering on medicine. However, all such texts were lost centuries ago, and we shall probably never have a sight of their contents (Needham, 1976, p. 160). The famous Buddhist monk *Xuanzang* (602–664 CE), who stayed in India from 629 CE onwards, greatly praised the knowledge of *Nāgārjuna* (c. 150–250 CE) in the science of medicine. He said that *Nāgārjuna* was able to nourish his life for many hundreds of years by taking a preparation (pill or cake) of his own making so that neither his mind nor his appearance decayed (Beal, 2014, p. 212). This story is similar to one found in the *Kathāsaritsāgara*, a text from the eleventh century (Durgaprasad and Parab, 1915).

The peak of *Rasaśāstra*, the Indian alchemical tradition, is generally considered to have occurred between the pre-Buddhist era and the twelfth century CE (Tripathi, 2012). Historians attribute the development of *Rasaśāstra* as a specialized branch to the renowned Buddhist sage *Nāgārjuna* (Father of *Rasaśāstra*) around the eighth century (Savrikar & Ravishankar, 2011). The *Rasārṇava* is a renowned treatise on *Rasaśāstra*, consisting of 18 chapters and over 2300 verses, and is considered a foundational treatise on alchemy and medicine. This treatise has been framed as a dialogue between Parvati and Parameshwara (Ray, 1985). Although the date and authorship of this text are not clearly known, it is believed to be from the twelfth century (Ray, 1948).

P. C. Ray prepared the first edition of the *Rasārṇava*, which was published in 1910 by the Asiatic Society of Bengal, Calcutta (Ray, 1985, p. 141). However, his views on the dating of the *Rasārṇava* appear to be changing constantly, as explained in the following lines. In the first volume of his work "History of Hindu Chemistry" (Ray, 1903), Ray suggested that the text was composed between 1000–1300 CE. However, in the second volume (Ray, 1909), he revised this estimate to the twelfth century. Furthermore, in an article that he published in 1919, he revised the date to around 900 CE (Ray, 1919). In the 16-year time frame of Ray's rendezvous with this text, it is evident that he revised the date continuously, the latest being 900 CE. It is worth noting that despite this modification in the dating of *Rasārṇava* to 900 CE by Ray, the contemporary adherence and belief of the *Rasaśāstra* community that *Rasārṇava* belongs to twelfth century CE is indeed intriguing. This reveals an element of uncertainty about the exact timeframe of the text's composition.

However, it is quite formidable to determine the exact date of composition of *Rasārṇava*. Influenced by P.C. Ray's analysis, several historians and *Rasaśāstra* scholars date *Rasārṇava* to the twelfth century (Biswas, 2001; Sharma, 1985). Evidence supporting the twelfth century date includes mention of *Rasārṇava* in *Nityanātha's Rasaratnākara* (thirteenth century) and *Mādhavācārya's Sarvadarśanasamgraha* (fourteenth century) [(Original verse accessed from Saligram, 2018; Sharma, 1964, p. 376]. Ray's argument is predicated on the assumption that the citation of the *Rasārṇava* as a canonical work in the *Sarvadarśanasamgraha* implies a temporal distance of at least one or two centuries between the two texts. However, D.G. White offers a compelling counterpoint. According to White, *Rasārṇava* was composed in the eleventh century. He suggests that while Buddhist alchemy, as described in the *Kālacakratānta* and its *Vimalaprabhā* commentary (early eleventh century), mainly centres on internal practices-channeling energies for enlightenment-there are passages in the *Vimalaprabhā* that hint at something more. These passages share striking similarities with the external alchemical processes found in the Hindu *Rasārṇava* text. Both texts, he notes, discuss the external conversion of metals and mercurial (White, 1996, p. 71).

On the other hand, Hindi translations, namely, *Rasārṇavam Nāma Rasatantram* claim that the *Rasārṇava* is an ancient text dating back to the BCE era (Tripathi, 2012). Therefore, western scholars believed that Indians were not particularly concerned with time due to their philosophical views, so they did not frequently date their texts (Karpenko, 2009).

Similarly, historians believe that Indian texts mention mercury treatment from 800 CE onwards (Ghosh, 1935). At the same time, the work of Pliny the Elder (first century) gives detailed descriptions of the properties of mercury and its use in various fields, including medicine (trachoma and venereal diseases) and alchemy (extraction of mercury from cinnabar) (Mariana Marchini et al., 2022; Norn et al., 2008). However, Ayurvedic texts before the eighth century CE also mention the internal use of compounds of mercury, chalcopyrite, black bitumen, and other substances to achieve physical immortality. The internal use of mercury is mentioned in the *Rasāyanavidhi Prakaraṇa* of the *Aṣṭāṅgasamgraha Uttara Sthāna* (49/214) and *Aṣṭāṅgaḥṛdaya Uttara Sthāna* (39/161): "*Śīlājatukṣa udraviḍaṅgasarpilohāmayā pāradatāpyabhakṣaḥ*" which are generally attributed to sixth century CE (Original verse accessed from the publication by Gupta, 1950, pp. 575–576).

A similar description is also quoted for the same purpose in the *Bṛhatsamhitā* (76/3) and *Rasārṇava* (18/14). It is possible that the text of the *Rasārṇava*



itself is ancient, or that the author of the text borrowed this description from an even earlier source. In the *Bṛhatsaṃhitā*, *Varāhamihira* (c. 550 CE) describes a slightly modified version of the same formulation (Jha, 2014).

There is also a debate regarding whether the ancient Indian text *Rasārṇava* or *Rasaratnākara* influenced the other. Additionally, Ray argued that *Nāgārjuna*'s *Rasaratnākara* is a typical Mahayana work, likely written in the 7th or eighth century CE. He believed that *Rasaratnākara* is one of the earliest works on iatrochemistry and that *Rasārṇava* borrowed heavily from it (Ray, 1909). However, in the first chapter of *Siddhanāgārjuna-Kakṣapuṭa*, *Nāgārjuna* (8th CE) lists *Rasārṇava* among the names of *Āgama/Tantra* texts, suggesting the antiquity of *Rasārṇava* before the eighth century CE (Khandelwal, 1996, p.2).

On the other hand, Dr. Bhudeb Mookerjee opposed it, asserting that *Rasaratnākara*, authored by *Nāgārjuna*, is undoubtedly a copy of *Rasārṇava*. Mookerjee argued that this is evident because Shambhu, the author of *Rasārṇava*, predates *Nāgārjuna* by at least 800 years. He highlighted the similarities between the two texts to support his view that P. C. Ray overlooked the authorship of *Rasārṇava*. According to Bhudeb Mookerjee, *Rasārṇava* dates back to 400 CE, much earlier than the 1200 CE date suggested by Ray (Mookerjee, 1938, p. 28).

In the *Rasaratnasamuccaya*, *Vāgbhaṭa* mentions the names of ancient authors (listed as 27 Acharya *Rassiddhis*). Shambhu's name comes before *Nāgārjuna* on this list (Original verse accessed from (Shankar, 2019)). Similarly, in *Nityānātha Siddha*'s *Rasaratnākara* (1/16), there is a verse that states: *Yaduktam śambhunāpūrvam rasakhaṇḍerasārṇave, rasasyavandanārthe ca dīpikāramaṅgale, vyādhitānām hitārthāya proktaṃ nāgārjunānena yat* "whatever has been stated by Shambhu in *Rasārṇava*, for the worship of mercury in the *Rasamaṅgala grantha* and has been said by *Nāgārjuna* for the well-being of patients" [Original verse accessed from (Shaligram, 2018, p. 4)].

According to Bhudeb Mookerjee, various authors have translated this line as "whatever has been revealed by Shiva in *Rasārṇava*". Here, "Shambhu" does not refer to the god Shiva, but rather to the human chemist Shambhu, who is mentioned in several books (Mookerjee, 1938, p. 28). This suggests that *Nityānātha* considered Shambhu to be an earlier authority than *Nāgārjuna*. While it is difficult to determine the exact date of composition of *Rasārṇava*, it is certain that it is an earlier text than *Rasaratnasamuccaya* (13th CE) and *Rasaratnakara* (8th CE). Bhudeb Mookerjee concluded that the evidence supports his perspective and refutes Ray's assumption.

Furthermore, Dominik Wujastyk clarifies that there was no *Rasaratnākara* by *Nāgārjuna*. Instead, *Nāgārjuna Siddha* authored *Rasendramaṅgala*, and *Nityānātha Siddha* wrote *Rasaratnākara*. Wujastyk explains that the latter contains a section derived from the *Siddhanāgārjuna-Kakṣapuṭa* by *Nāgārjuna*. The supposed *Rasaratnākara* by *Nāgārjuna* is a fictional work mistakenly identified by P.C. Ray, who was misled by a manuscript at the Raghunatha Temple Library in Jammu, Kashmir. This manuscript had mixed leaves from both *Rasaratnākara* and *Rasendramaṅgala*. Additionally, rumours that Jivarama Kalidasa Shastri published an edition of *Rasendramaṅgala* in the 1950s are incorrect. Wujastyk noted that he searched Gujarat and visited Shastri's son in Gondal, confirming that no such publication exists (Wujastyk, 1984). So, the question of which text influenced the other remains a mystery, with new information challenging old assumptions.

4 Experimental evidence

Alchemy, the ancient practice of transmuting metals and preparing elixirs of life, was divided into two main pursuits: *Lohasiddhi* (transformation of lower metals to noble metals) and *Dehasiddhi*. *Rasāyana*, a branch of alchemy, involves a rejuvenation therapy that includes the internal use of elixirs believed to bestow long life (Savrikar & Ravishankar, 2011). The ancient Indian texts like *Arthaśāstra*, *Caraka*, and *Suśruta Saṃhitā*, two ancient Indian medical texts, mention alum, saltpetre, borax, blue vitriol, green vitriol, sulphur, realgar, orpiment, and sal ammoniac. This suggests that there is reason to anticipate that further research may uncover evidence of the preparation of mineral acids and mixtures of mineral acids in India well before even the common era.

The earliest known reference to mineral acids in Indian literature is found in the *Arthaśāstra* (4th BCE), "जातिहिङ्गुलकेन पुष्पकासीसेन वा गोमूत्रभाविनेन दिग्धेनाग्रहस्तेन संस्मृष्टं सुवर्णं श्वेतीभवति (*jātihiṅgulukena puṣpakāsīsena vā gomūtrabhāvitena digdhenāgrahastena saṃsprṣṭaṃ suvarṇaṃ śvetībhavati*)", which describes a process for testing gold using green vitriol ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$). When gold (*Suvarṇa*) is touched by the edge of a palm dipped in a solution of *Jātihiṅgulaka* (vermillion) or *Puṣpakāsīsa* (green vitriol) mixed with cow's urine, it turns white (Shamasastri, 1956). In order to determine whether this process produces mineral acid, the test was replicated by adding green vitriol to the cow's urine (Fig. 1a). All materials were procured from a registered supplier (Shanti trading company) at the Ayurvedic Pharmacy, Banaras Hindu University, Varanasi. *Gōrōcana* was



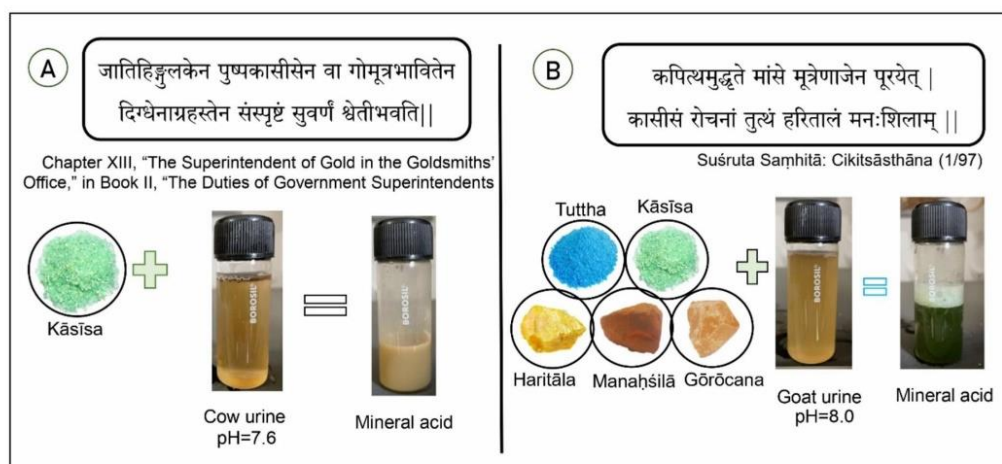


Fig. 1 Replication of an ancient Indian alchemy experiment from the a *Arthaśāstra*, b *Suśruta Saṃhitā*

generously gifted for research purposes by a certified Ayurvedic Vaidya (Reg No. 64435). Authentication of the raw materials was done based on the *Grahya Lakṣaṇa* (characteristic features) described in the *Rasatarāṅgiṇī*. The identity and purity of all the samples were confirmed using Raman spectroscopy (Research India; 785 nm, CCD detector with grating groove dispersion) and XRD (Rigaku SmartLab, Japan).

The effect of *Puṣpakāśīsa* ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$) on the pH of freshly collected cow-urine was further experimented. The collection of cow urine was done as per the instructions given in *Suśruta Saṃhitā* (*Sūtrasthāna*, 36/16). After the young cow's food had been fully digested, urine samples were collected in a sterile 50 ml containers. The pH was measured immediately using a digital pH meter and litmus paper. The samples were stored in a laboratory refrigerator. The urine samples were subjected to filtration through cotton gauze in order to preclude any suspended or undissolved solid impurities, for further pH measurements. Four solutions were prepared, each with different ratios of *Puṣpakāśīsa* to urine (e.g., 1:0.5 for solution A, 1:1 for solution B, 1:2 for solution C, and 1:4 for solution D):

1. *Solution A*: 4 g of *Puṣpakāśīsa* in 2 ml of urine.
2. *Solution B*: 4 g of *Puṣpakāśīsa* in 4 ml of urine.
3. *Solution C*: 4 g of *Puṣpakāśīsa* in 8 ml of urine.
4. *Solution D*: 4 g of *Puṣpakāśīsa* in 16 ml of urine.

The initial pH of each solution (A, B, C, D) was measured at room temperature ($28 \pm 2^\circ\text{C}$). The pH was

monitored over a 16-h period, with measurements taken at each 1-h interval after the addition of *Puṣpakāśīsa*.²

Time (h)	pH @ $\sim 27^\circ\text{C}$	pH @ $\sim 4^\circ\text{C}$
11:55	8.1	8.0
12:56	8.4	8.2
14:58	8.5	8.3
16:55	8.5	8.4
18:55	8.6	8.4
20:55	8.5	8.4
23:55	8.3	8.6
01:55	8.3	8.6
08:45	8.3	8.6

The pH of young cow fresh urine was found to be 7.6. The initial pH increased with decreasing *Puṣpakāśīsa* concentration. Solution D (highest urine volume, lowest *Puṣpakāśīsa* concentration) had the highest initial pH (3.7), while solution A (lowest urine volume, highest *Puṣpakāśīsa* concentration) had the lowest initial pH (2.3). This suggests that *Puṣpakāśīsa* addition acidifies the urine, with a stronger

² The experiment measured the effect of temperature with time on the pH of fresh cow urine in the table below. The urine was collected at 09:55 AM, and the initial pH was 7.9. The sample was divided into two containers, one stored inside a refrigerator at $\sim 4^\circ\text{C}$ (taken out only for pH measurement) and another kept at room temperature ($\sim 27^\circ\text{C}$). pH was measured for the samples at different intervals, where the pH was seen to increase mildly in both cases. The increase in pH is due to the enzymatic activity, which further reinforces the unequivocal formation of mineral acids reported in this work, as the pH would have been even lower in the absence of enzymes.

Effect of storage temperature on the pH variation of fresh cow urine over time:



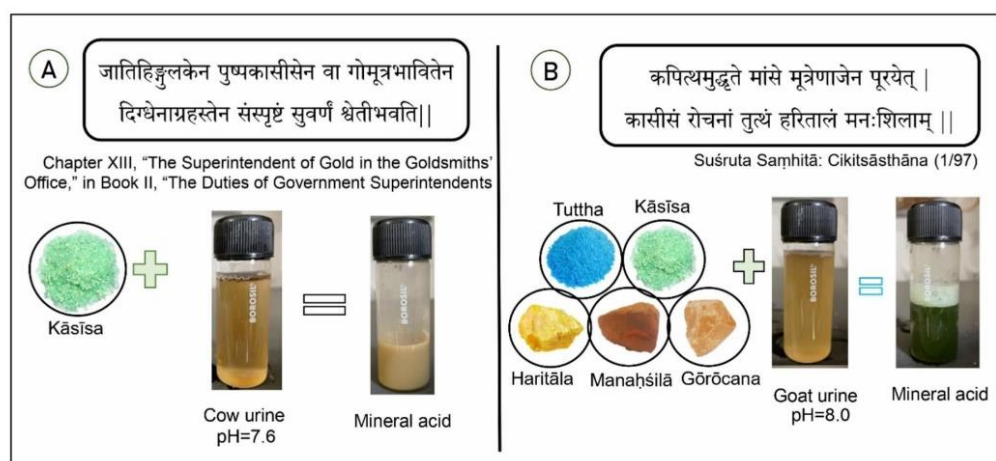


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Effect of storage temperature on the pH variation of fresh cow urine over time:

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and in situ production of mineral acids in different contexts. The experimental results, which confirmed mineral acids during the replication processes, establish the relevance and accuracy of ancient knowledge about mineral acids and reinforce their validity. Historical accounts presented in this work reveal the transmission of Indian knowledge of mineral acids to China. Furthermore, this work emphasizes the urgent need to address ongoing debates surrounding the authorship and dating of *Rasārṇava*.

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Author's contributions VR conceived the idea, arranged resources, analyzed data, designed the experiment, wrote the initial draft, and edited the draft. VS executed the work, generated data reviewed the literature, and wrote and revised the initial draft.

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Declarations

Conflict of interest None.

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ANNEXURE 2

A2. Awards and Recognitions

- I. Received the **Best Poster Award** for the poster "*Exploring the Antiquity of Mineral Acids in Indian Texts*" at the National Youth Conference on Indian Knowledge Systems held on August 25–27, 2023, at IIT Roorkee.



- II. Received the **Certificate of Appreciation** for the poster titled "*Exploring Mineral Acids in Rasāyana Śāstra Texts from Ancient and Medieval India*", presented on September 05, 2024, during the Research and Innovation Day at IIT (BHU).



Name of PI

Name of Co-PI

Head of the Institution

Signature of PI

Signature of Co-PI

Signature