Indian Journal of History of Science, 27(2), 1992

'VAṄGASTAMBHANAŚODHANAṂ' : A CHAPTER ON METALLURGY OF TIN IN SANSKRIT ALCHEMICAL TEXT 'RASOPANIṢAD'*

VIJAYA DESHPANDE
Bhandarkar Oriental Research Institute
Pune-411 004

(Received 30 May 1991; after revision 30 September 1991)

'Rasopaniṣad[1]' is a Sanskrit alchemical text written in the medieval period. All of its eighteen chapters essentially deal with attempted transmutation of metals. The thirteenth chapter entitled *'Vaṅgastambhanaśodhanam'* describes purification of tin and syntheses of alchemical golds and silvers using tin. When we try to relate these processes to modern ideas of tin metallurgy, some interesting results are encountered. They demonstrate that each process was carefully designed, with deliberate inclusion or exclusion of certain ingredients and was carried out under specific experimental conditions to achieve the desired results. Thus, it points to considerable knowledge of metallurgy of the medieval Indian alchemist.

INTRODUCTION

'Rasopaniṣad' is one of the largest Sanskrit texts written on alchemy in the medieval period. For lack of concrete evidence, such as name of the author or mention of other *Rasāyana* text of a known date, etc., the date of *Rasopaniṣad* is not exactly known. Judging from the extent of alchemical knowledge contained in the text, it could not have been written earlier than the eleventh century AD. Further, it contains no medicinal chemistry and hence was probably written before the iatro-chemical period of Indian chemistry began, i.e. around the fourteenth century, the time of *Rasaratnasamuccaya*. Again, due to the absence of certain words, such as *Jasada* for zinc or *Dāhajala* for sulphuric acid, it appears to be an earlier production than *Dhātukriyā* or *Arkaprakāśa,* which are sixteenth century works. Hence, we may surmise that *Rasopaniṣad* was possibly written sometime between the eleventh and the thirteenth century AD. Internal evidence also brings it near the period of *Rasārṇava,* a twelfth century AD work.

'Rasopaniṣad' consists of eighteen chapters, all of which are devoted to gold and silver making processes. We see that usually such texts give primary information on the subject in the opening chapters.Description of apparatus, chemicals, processes and fires is given along with classification of plants and substances with their synonyms. Unlike such texts, *'Rasopaniṣad'* does not go into these details. After reviewing a few basic concepts and purification methods, the author goes on to describe intricate metallurgical operations, which suggests advanced state of chemical and alchemical knowledge of the period. It appears that the author had a vast knowledge of the plant kingdom as well.

* This work was done under a project sanctioned by the History of Science Division of the Indian National Science Academy.

The classification of chapters is based on the principal ingredient discussed in them and are named accordingly. For example, the one entitled *'Sulbārakālikācchedaḥ'* describes methods for removing tarnishes from copper and brass. The purified metal is later used in gold and silver making, to obtain superior products. In most of the cases they are alloys closely resembling the noble metal in colour. Yet another chapter entitled *'Nāgasaṁkramaṇaḥ'* describes similar methods using *Nāga* or lead as the starting material.

In this article we discuss the chapter entitled *'Vaṅgastambhanaśodhanaṃ'*, i.e. immobilization (of mercury) and purification of tin. The methods of purification of tin are described here. Also given are methods for synthesizing alchemical gold and silver from tin. They are called *'Vaṅgahāṭaka'* and *'Vaṅgatāra'* respectively. In this paper, we relate these processes to modern ideas of tin metallurgy. It should be noted though that our idea is not to write a comprehensive paper on tin metallurgy. It is part of a study of *Rasopaniṣad* conducted to understand and assess the alchemical and chemical development of the period. Though low melting point of tin was known even in the pre-Christian era and the two varieties of tin and other details regarding their properties had been given in *Rasārṇava* and *Rasaratnasamuccaya*, a separate chapter was not reserved for it as in *Rasopaniṣad.* Moreover, this chapter depicts the alchemist's knowledge of tin metallurgy, more clearly than the above-mentioned texts.

ANTIQUITY OF TIN

Tin has a long history in India. Bronze articles found at Indus Valley civilization sites contain 4.51 to 13.21% tin, suggesting intentional addition of tin in the alloys to make them harder. 'Kauṭilīya *Arthaśāstraṃ'* written around the fourth century BC describes ores of tin. *'Caraka-Saṃhitā'* written in the first-second century AD mentions tin among the then known six metals, viz. gold, silver, lead, copper, iron and tin.

Various names for tin, then in use, are given in verse in *Rasakāmadhenu*[2]. The author probably quotes *'Rasacintāmani'*, a text of the tantrik period (700 AD-1300 AD). The names are as follows[3]:

'Vaṅgaṃ, Raṅkaṃ, Ābhīraṃ, Trapu, Trapuka, Piccaṭa, Nāgā-jīvanaka, cakra, Mṛdvaṅgaṃ, Gurupatrakaṃ, Kastīraṃ[4], *Tamaraṃ, Svarṇabhavaṃ, Nāgabhavaṃ, Śvetarūpaṃ, Parāsaṃ, Trāyuṣaṃ, Mukha-bhūṣaṇaṃ, Kharaṭi, Ṣaṭlavaṇaṃ, Śvetakṛṣṇaṃ, Saṭham* and *Rajaḥ'*[4].

Out of the above list, *Ābhīraṃ* and *Kastīraṃ* indicate the lustrous appearance of tin (*kās* — to shine and *Ābha* — light), *Svetarūpaṃ, Parāsaṃ* (meaning superior) indicates its white colour, whereas *svarṇabhavaṃ* or *śaṭhaṃ* (meaning a cheat) and *raṅkaṃ* refer to its use in alchemy. *Piccaṭa* refers to its malleability; *Mṛdvaṅgaṃ* to its softness and *Mukhabhūṣaṇaṃ* to the application in jewellery and *Kharaṭi* to the noise made in breaking and handling it.

It is interesting to note that *'Rasopaniṣad'* refers to tin as *Vaṅgaṃ* only. *Kuṭila* (meaning fraudulant) was another name mentioned in *Rasārṇava,* the most frequently quoted among Sanskrit *Rasāyana* texts. It is not found in *'Rasopaniṣad'* though.

METALLURGY OF TIN IN 'RASOPANISAD'

If we study the history of metallurgy in the west, we find that, till Agricola's time, i.e. 15th-16th century AD, metallurgy of tin was not developed in Europe. The reason was the necessity of maintaining a strong reducing atmosphere, a mild cold blast and a comparatively low temperature demanded by the low melting point of tin[5].

On the contrary, every *Rasāyana* text of medieval period gives purification of tin and also various gold (i.e. alloy) making processes using tin as the starting material. This fact points to the early development of tin metallurgy in India.

Let us study the methods of purification of tin given in some prominent *Rasāyana* texts. *Rasārṇava*, written about 11th century AD, gives the following method[6,7]:

'By throwing powdered bones of a buffalo in the molten metal and by sprinkling its urine over it, tin is purified in fire. (Similarly) lead by means of bones and urine of an elephant'.

The author of *'Rasopaniṣad'* stresses the importance of purification of tin in the following verse[8]:

'Tin is the strongest among all the metals. Its purification is a very auspicious process, since it can accomplish immobilization of mercury'.

Purification of tin is achieved in the following way[9]:

'Take alkaline extracts of plants *Kuṭaja* and *Arka;* and *Viḍa*[10]. Sprinkle the juice of plants *Nirguṇḍī* and *Brahmī,* and also that of plants *Gandha* and *Gokśuraka* in the juice of *Brahmī* and *Anantā* plants. Powder all kinds of bones and also *viṣa* amd *bīja* in equal proportions. After mixing several times, add them to the oil of sesamum. By this method, in becomes pure and resembles a conch shell, milk and the moon, in colour and lustre'.

The modern method of extraction of tin from tinstone, i.e. SnO_2, involves reduction with carbon and purification by dissolving the metal in acid and subsequent electrolytic deposition.

In the verses from *Rasārṇava* and *Rasopaniṣad* we find that powdered bones are used for purification of tin. Bones contain phosphoric acid and so does urine. Phosphoric acid is known to react with metallic oxide, thus removing the impurity of tin oxide from the metal. Purification of tin by sprinkling urine could also be explained on the basis of a reaction between weakly basic urea, which is present in urine and amphoteric tin oxide, thus removing the impurity.

Moreover, alkaline extracts of various plants along with a number of *viṣas* are added to obtain a medium with the right pH value. This is a necessary precaution. Since SnO_2 (tin oxide) is amphoteric in nature, it dissolves in both acidic and basic solutions. Only the solutions should not be too strong, or else tin would also undergo reaction. In all probability, this is the reason for adding both acidic substances, i.e. *viṣas* and basic substances, i.e. *kṣāras* to the reaction mixture. The purpose of adding oil of sesamum is the same as that of adding lubricant, such as lard or oil in the modern methods. Since oil of sesamum is added after the reaction with bones, its purpose was not to reduce tin oxide but to render the metal soft and also prevent further oxidation of pure metal due to atmospheric oxygen, by providing a cover of the oil layer. Incidentally, plant products were also used as reducing agents in Sanskrit *Rasāyana* texts. We have as yet no idea why different plant products were used in metallurgical reduction though.

GOLD AND SILVER MAKING WITH TIN

The purest white crystalline form of tin resembles silver and tin amalgam is silver coloured.These facts are exploited in these methods. We find that tin is used in place of silver while combining with other metals like gold or copper in order to produce alloys of the desired colour.

After narrating purification of tin, the author of '*Rasopaniṣad*' describes a method for making *Vaṅga hāṭaka* and *Vaṅgatāra*[11], i.e. gold and silver coloured alloys of tin.

'Take one part each of powdered, killed mica, tin and borax'.

'Also add one part each of skull, ghee, bones of a crab and ginger. Also add *gorocana* and exudation of the fruit of lime and mix in the juice of plant *Kākamāci*'.

'Place it in a closed crucible with the flesh of a big rat and liquify it. We obtain the alloy of tin and mica. Mix it with superior mercury'.

'Add one eighth part of mercury to it till the six characteristic properties of mercury are destroyed. Take the previously collected first distillation portion of the liquor made from plant *Kuravaka* and add the above alloy to it'.

'Mix tin, mica and mercury in a hot crucible and add the juice of plants *Viṣālu,* and *Viṣamustā* over it'.

'With that very substance cover the paste and smear the outer surface of the crucible. Then cover it with a cloth and tie it with a thread'.

'After placing, smear it with *Tuttha*[12], which is obtained from the earth, and heat it in a closed crucible in the fire made by burning cowdung cakes, till it becomes hot'.

'When it cools down, take it out and rub in a stone vessel. When it becomes *Jīrṇodara(?)*, mix it with a part of itself'.

'Continue mixing till it attains the six characteristic properties. In this way after mixing with tin and mica, *Vaṅgahāṭaka*, which has a low melting point, is obtained'.

'After performing the *sāraṇā*[13] operation with equal amounts of silver and copper, perform *Vedhana*[14] operation. Take equal amount of gold as that of tin and mica, and add to it ghee made of milk of a *kapilā* (brown) cow'.

'When purified with *kurpatuttha(?)*, the best variety of *vaṅgahāṭaka* is obtained'.

The process essentially involves making an alloy of tin with mica, called *vaṅgābhra*, in the first place. Borax and powdered bones are used along with a number of plant juices. Once the tin-mica alloy is ready in a molten state, mercury is added to it. Apparently, mercury loses its volatility in this mixture and therefore this method is called *Stambhana* or inmobilisation of mercury. Borax acts as a flux.

When a mixture of tin and mica is strongly heated in a crucible along with borax, bones, acidic extracts of lime fruit and other plants, a metallic bead could possibly be obtained which will contain tin along with other metals. It is a conjecture though. No reference to tin-mica alloy is found in modern literature.

The union of tin, mica and mercury when heated in a closed crucible, which is smeared with *Tuttha*, yields *Vaṅgahāṭaka*. This product when melted with equal weight of either copper or silver is said to make (alchemical) gold.

In the first case, we obtain an alloy of tin, mercury and copper and in the second case it consists of tin, mercury and silver. Apparently, both are golden in colour. It is well known that an alloy of silver and copper with 30-50% silver is golden coloured. So, in the first case we may say that silver is replaced by tin to produce a similar alloy. In the second case, the golden colour is due to the formation of silver amalgam, which is golden.

Further, when an alloy of mica and tin is mixed with gold in equal quantities and again heated in a similar crucible, as described above, it is said to yield a superior kind of *Vaṅgahātaka* or golden alloy of tin.

In the case of alloys of noble metals, other elements are melted first, along with the deoxidizers, cast and rolled; and then remelted with the noble metal to produce the final alloy. This ensures homogeneous alloys, and also avoids unnecessary loss of the noble metal. We find that this is the practice followed in the above process, where gold is added at a later stage.

The last verse of this chapter of '*Rasopaniṣad*' describes a method for making *Vaṅṅgatāra*[15] which is a pure, white crystalline form of tin resembling silver.

'Carry out mixing by stirring one part of the above *Viḍa* in hundred parts of tin. It makes *Vaṅgatāra* without any doubt, which resembles the moon in colour and lustre'.

In yet another method[16], silver is added to pure tin in the proportion 1:20 of silver to tin. This product is very white and is said to be free from nine faults. Then a large quantity of pure tin is added to get a silvery alloy.

'Throw one part of the above *(viḍa)* in hundred parts of pure tin and stir. Then add tin to it in which one twentieth part of silver is added'.

'It becomes free from nine faults, purified by fire and very white in colour. It can nourish a thousand people and it can be duly applied in thorough manifestation of *Dharma* and *Artha*'.

Tin exists in two allotropic crystalline modifications, viz. α-tin which is grey coloured with density 5.75 and β-tin which is white with density 7.3. The conversion occurs at 13.2°C.

$$\text{Thus,} \quad \alpha\text{ - tin} \xrightleftharpoons{13.2^\circ C} \beta\text{ - tin}$$

Now to maintain the white silver-like appearance of tin, i.e., to inhibit the transformation from β-tin to α-tin, certain common impurities of tin are effective[17]. The presence of bismuth ensures that no change occurs. Gold and silver are somewhat less effective, but they also inhibit this transformation. Apart from improving the colour and texture of the product, this could be another reason for adding silver to pure tin in the above method of synthesis of *Vaṅgatāra.*

It is possible that these two forms are described[18] as *kṣūrakaṃ* (for β-tin) and *miśrakaṃ* (for α-tin) in the following verses of *Rasaratnasamuccya,* which was written in the iatro-chemical period (1300 AD-1550 AD).

'*Vaṅgaṃ* (tin) is of two kinds, *kṣūrakam* and *miśrakam.* The former is endowed with superior qualities and the latter cannot be recommended for medicinal use'.

'*Kṣūrakam* is white... This is an anthelmintic and a destroyer of urinary disorder'.

Synthesis of a Green Alloy

Verses 20 and 21 describe the synthesis of a green alloy in the following way[19]:

'The alloy of tin and mica with equal amount of gold is placed in a closed crucible along with *Vimala* and roasted'.

'When it is accomplished in a '*kūrpatuttha*', it resembles an emerald in colour and lustre'.

The possible elements in the final alloy are tin, gold, zinc and copper (the last two obtained from '*tuttha*').

We find several references to a green alloy containing gold and silver as major constituents in modern literature.

In '*Metal's handbook*', we find[20]:

"The addition of silver to gold apparently reduces the reflectivity in the extreme red, with the result that a 75% Au and 25% Ag (18 carat) alloy has quite a good green colour.... The 58.35% Au and 41.65% Ag (14 carat) alloy has an unattractive greenish white colour, and also is too soft to be useful, but if 6 to 12% of this silver is replaced by copper, a fair green colour results, which is somewhat improved by the replacement of a certain amount of silver by zinc".

Also Forbes[21] writes in *Metallurgy in Antiquity*:

"The alloy of gold and silver presents a range of colours varying according to the increasing silver content from reddish yellow through pale yellow to white. For instance, the modern alloy of silver and gold called electrum (specific gravity 12.5-15.5; 22-55% gold) varies from pale yellow to white. By adding copper to a silver-gold alloy containing 10% silver, we get the modern alloy known as green gold".

Also, Needham[22] mentions a 'green gold' in his *Science and Civilization in China*, which has the following percentage composition: 75% Au, 12% Ag, 9% Cu and 4% Cd.

We find a similar 'green gold' in *Rasopaniṣad* which is described as *Marakatasaprabham*, i.e. 'resembling an emerald'. An alloy of gold, silver and copper in a particular proportion of approximately 60% Au, 30% Ag, and 10% Cu is fairly green coloured. If silver is replaced by pure tin, again a green product could be expected, since pure tin largely resembles silver. This green colour improves when half of copper is replaced by zinc. If we assume that *Pārthiva Tuttha* contains both zinc and copper compounds, then the emerald colour produced by the above method can be explained, so that the composition could be 60% Au, 30% Sn, 5% Cu and 5% Zn. There is no evidence of such an alloy in Indian archeo-metallurgy.

It is interesting to note that compounds of arsenic, namely, *Haritāla,* i.e. orpiment, and *manaḥśilā,* i.e. realgar, which are usually employed in gold making processes, are absent in this chapter on tin. It is possible that the property of tin, namely even 0.1% of arsenic in it renders it very hard, was known to the alchemists[23].

CONCLUSION

A detailed study of the thirteenth chapter of '*Rasopaniṣad*' entitled "*Vaṅgastambhanaśodhanaṃ*" discloses the alchemist's knowledge of tin metallurgy.

It is observed that the following facts were known to the alchemists, at the time of the writing of '*Rasopaniṣad*':

1. Tin exists in two (crystalline) modifications, one is α-tin which is grey coloured and the other, β-tin, which is white, as known now.

2. Tin reacts with strong acids and bases.

3. Tin has a low melting point.

4. Tin oxide, SnO_2, the cause of rusting of tin, could be removed in the presence of bones and urine to obtain pure tin, by converting the oxide into soluble tin compounds.

5. Borax can act as a flux to remove the dross.

6. Pure crystalline tin resembles silver and when a little silver is added to it, the colour improves (possibly due to the inhibition of β-tin to α-tin transformation).

7. Extracts of plants *Kuṭaja, Arka, Nirguṇḍī* and *Brahmī* are alkaline.

8. A mixture of *Kṣāras* (alkalies) and *Viṣas* (acids) could give a near neutral solution in which only SnO_2 dissolves and not tin.

9. Oil of sesamum could be used as a lubricant.

10. Tin combines with copper and gold to produce a golden alloy.

11. A green alloy could be obtained by mixing tin and gold in a '*kurpatuttha*' where *tuttha* (copper sulphate or zinc carbonate) is smeared on the inner surface of the crucible.

12. While synthesizing the alloys of noble metals, the noble metal is added during the second melting to get homogeneous alloys and to reduce the unnecessary loss of the noble metal.

13. Arsenic compounds are to be avoided in tin metallurgy.

The aforesaid facts suggest that the medieval alchemist knew a great deal about metallurgy of tin. This knowledge was acquired as a result of his experiments in gold and silver making. When modern ideas of chemistry were not known, the coloured alloys or amalgams were considered to be real gold and silver. Although the alchemist was aware that they lacked some essential qualities, he attributed these lacunae to the impure ingredients or imperfect methods, necessitating strenuous experimentation to obtain better products. Metals were purified with care, their surface blemishes or colorations removed, and a right mixture of plant juices was chosen to obtain the desired medium for chemical reactions. Oxidising and reducing agents were discovered and employed. After hundreds of trials, finally the alchemist landed upon the right method, which he noted down.

A reader of these texts is usually puzzled by the long and complicated processes described in them. They involved addition of innumerable substances, including animal and plant products. Due to the difficulty incurred in the identification of these substances and plants and also their specific functions, they are considered as 'trial and error' methods. A close study of these processes indicates that this was not the case. On the contrary, they are fruits of great research and experimentation.

ACKNOWLEDGEMENT

Thanks are due to the referee, whose valuable suggestions led to an improved version of this paper.

REFERENCES AND NOTES

1. Sambaśivasastri, K. (ed), *Rasopaniṣad,* printed by the Superintendent, Govt. Printing Press, Trivandrum, 1928, Trivandrum Sanskrit Series No. XCII.
2. Jadavji Trikumji Acharya (ed) '*Rasakāmadhenu*' Subodhini Printing Press, Bombay, 1925.
3. वङ्ग गम् रङ्कमामीरं त्रपुस्त्रपुक पिच्चटे।
नागजीवनकं चक्रं मृदवङ्गं गुरूपत्रकम्॥ 457॥
कस्तीरं तमरं स्वर्णभवं नागमवं तथा।
श्वेतरूपं परासं च त्रायुषं मुखभूषणम्॥ 458॥
खरटी स्यात्सलवर्णं श्वेतकृष्णं 'शठं रजः।

– *Rasakāmadhenu,* p. 171
4. The name '*kastīra*' was known to the Chaldeans and Arabs from which Greek Cassiteros probably originated.
5. Hoover, H.C. & Hoover, L.H. (tr.), *De Re Metallica of Georgius Agricola,* Dover Publications, New York, 1950.
6. Ray, P.C. & Haris Chandra Kaviratna (ed), '*Rasārṇavam*' Bibliotheca Indica, Series No. 174, Asiatic Society, Calcutta, 1910.
7. महिष्यास्थिचूर्णेन वापात्तन्मूत्रसेचनात्।
वङ्गशुध्दं भवेदग्नौ नागो नागास्थिमूत्रतः॥ 112॥

– *Rasārṇavam,* the seventh chapter

8. सर्वेशामेव लोहानां बलवान् वङ्ग उच्यते।
तस्य संशोधनं दिव्यं स्तम्भनं च रसस्य तु॥ 6॥

9. कुटजार्कविटक्षारे निर्गुण्डीब्रह्मवृक्षयोः।
गन्धगोक्षुरके ब्रह्म्यानन्तायां निषेचयेत्॥ 8॥
सञ्चूर्ण्य सर्वाण्यस्थीनि विषबीजसमानि च।
प्रतिवाप्य बहून् वारान् तिलतैले निषेचयेत्॥ 9॥
एवं शुध्दं भवेद वङ्गं शङ्ख क्षीरेन्दुसन्निभम्॥ 19-1॥

— *Rasopaniṣad,* the thirteenth chapter

Kuṭaja — Holarrhena antidysenterica
Arka — Calotropis gigantea
Nirguṇḍī — Vitex negundo
Brahmī — Herpestres monnieria
Gandha — Artemisia maritima
Gokṣuraka — Tribulus terestris
Ananta — Hemidesmus indicus

10. *Viḍa — Viṭa — lavaṇa* or black salt with a small portion of embelic myrobalan. The produce of muriate of soda, with small quantities of muriate of lime, sulphur and oxide of iron.

11. मृताभ्रचूर्णं वङ्गं च समं टङ्कणभागिकम् ॥ 10 ॥
शिरः कपालपाज्यास्थिकुलीरार्द्रस्य भागिकम् ।
कापित्थनिम्बनिर्यासकाकमाचीरसप्लुतम् ॥ 11 ॥
महास्नुमांससहितमन्धमूषीकृतं द्रुतम् ।
वङ्ग गाभ्रं नाम वैकृन्तं रसराजेन चारयेत् ॥ 12 ॥
अष्टांशेन रसस्योक्तं यावत् षड्गुणजीर्णताम् ।
पूर्वं कुम्भकाद्यायां सुरायां बहु पातिते ॥ 13 ॥
तप्तमूषासहे चैवं वङ्गाभ्ररसचारणम् ।
विषालु विषमुस्तायां रसं निक्षिप्य चोपरि ॥ 14 ॥
तेनैवाच्छाद्य तत्कल्कं बाहयतः सम्पलेपयेत् ।
ततो वस्त्रेण संवेष्टय बन्धितं सूतरज्जुना ॥ 15 ॥
स्थापितं पार्थिवे तुत्थे लिप्त्वा चाप्यन्यमूषितम् ।
दहेत् तं गोमयेनाग्नौ यदा तन्मूषवापितम् ॥ 16 ॥
शीतीभूतं तदुदधृत्य निघर्षयेच्छैलभाजने ।
जीर्णोदरं तदा दृष्ट्वा तद्भागेनैव चारयेत् ॥ 17 ॥
एवमेव प्रजीर्येत् यावत् षड्गुणतां व्रजेत् ।
एवं वङ्गाभ्रसज्जीर्णं वङ्गहाटक सुद्रुतम् ॥ 18 ॥
सारितं तत्समांशेन वेधयेत् तारताम्रयोः ।
वङ्गाभ्रकसमं हेम कपिलाधृतवापितम् ॥ 19 ॥
कूर्पतुल्यविशुध्दं तु वङ्ग गहाटकमुत्तमम् ॥ 20-1 ॥ — *Rasopaniṣad,* the thirteenth chapter

12. *Pārthiva Tuttha — Tuttha* extracted from the earth. *Tuttha* was the name for sulphate of copper and iron in earlier *Rasāyana* texts.In later texts like *Rasendrasārasaṃgraha,* we find that this word is applied to zinc carbonate, i.e. calamine as well. Since all of them (or mixtures) could be extracted from the earth, from their respective ores, *Pārthiva tuttha* could mean $CuSO_4$, $ZnCO_3$, or $FeSO_4$ or the mixture of two or three of them.

समवीजजीर्णे सूतैक्यकरणमं सारणा / रसकामधेनु ।

13. *Sāraṇā* — The process *Sāraṇā* involves mixing of mercury with an equal amount of *bīja,* i.e. pure gold or silver. Various oils are also added in this process. They are called *Sāraṇātaila.*
14. *Vedhana* — The process of adding mercury along with certain plant juices to molten base metals whereby the so-called 'transmutation' is achieved, is called a *'Vedhana'* process.

15. वङ्गमावर्त्य शतकं निर्वहेद विड्मेकतः ।
कुर्याच्छशिनिभाकारं वङ्ग गतारं न संशयः ॥ 29 ॥

– *Rasopaniṣad,* the thirteenth chapter

16. वङ्गमावर्त्य संशुध्दं वपेद भागे शतांशके ।
तस्मिन् निषचयेद वङ्ग गं विषांशे तारयोजितम् ॥ 25 ॥
नवदोषविनिर्मुक्तं तापशुध्दं सुपाण्डरम् ।
सहस्रपोषकं सम्यग् धर्मार्थ सम्प्रदर्शितम् ॥ 26 ॥

17. Taylor, Lyman (ed), *Metal's handbook*, American Society for Metals, Metal's Park, Novelty, Ohio, 1948, repr. 1960, p. 1067

18. खुरकं मिश्रकं चेति द्विविधं वङ्गमुच्यते।
खुरं तत्र गुणैः श्रेष्ठं मिश्रकं न हितं मतं ॥ 153 ॥
धवलं मृदुलं स्निग्धं दंतद्रावं सगौरवम्।
निःशब्दं खुरवङ्गं स्यान्मिश्रकं श्यामशुभ्रकम् ॥ 154 ॥
वङ्गं तिक्तोष्णकं रुद्रमौषदवातप्रकोपनम्।
मेहश्लेष्मामयघ्नं च मेदोघ्नं कृमिनाशनम् ॥ 155 ॥

– *Rasaratnasamuccaya* – the fifth chapter

19. वङ्गामहेमसहितं विमलं चान्धमूषितम् ॥ 20-2 ॥
निर्वाहितं कूर्पतूल्ये भवेन्मरतकप्रभम् ॥ 21-1 ॥

20. Taylor, (1948), p. 1117.
21. Forbes, R.J., *Metallurgy in antiquity*, E.J. Brill, Leiden, Netherlands, 1950, p. 153
22. Needham, J., *Science and Civilization in China*, Vol. V, Pt. II, Cambridge University Press, 1974, p. 194.
23. Taylor (1948), p. 1166.