THE LEYDEN PAPYRUS X

An English Translation with Brief Notes

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I. Introduction

The chemical arts and knowledge of the ancient world are known to us chiefly through the writings of Pliny, Dioscorides, Theophrastus, Vitruvius, and a few other writers, aided in a considerable degree by the examination and chemical analysis of the various relics and remains of the older civilizations. While these writings do furnish us with a very considerable degree of information concerning the beginnings of chemical knowledge they are, at the best, only indirect sources and are lacking in details. By a fortunate chance, however, there have come to light in recent years two original sources in the form of two remarkable Greek papyri known to students of the early history of chemistry as the Leyden Papyrus X and the Stockholm Papyrus. These invaluable documents are by far the most ancient that we possess dealing with chemical arts and operations as such. The earliest authentic alchemical manuscript is that of St. Marks at Venice which is believed to have been transcribed from earlier writings during the tenth or eleventh centuries. These two papyri have, however, upon the basis of unquestioned philological and paleographic evidence, been ascertained to have been written at about the end of the third century A.D. so that they are by far the earliest original historical evidence that we have in our possession concerning the nature and the extent of ancient chemical knowledge. They are, therefore, of the highest value for the history of chemistry and throw a whole flood of light upon the origins of the pseudo-science, alchemy, as the researches of Berthelot have so clearly demonstrated.[1]

These two documents formed part of a valuable collection of Greek papyri gathered at Thebes by Johann d'Anastasy, vice-consul for Sweden at Alexandria, Egypt, during the first decades of the nineteenth century. The major portion of this collection was sold in 1828 to the Netherlands Government and deposited in the Museum of Antiquities at Leyden. The examination of the various papyri in this collection occupied a period of nearly forty years, the first results being published by the Netherlands Government in 1843. None of the papyri first translated offered any results of chemical interest. It was known, though, through preliminary researches that some of the remaining documents were in the nature of technical treatises. It was not until 1885 that the remaining papyri together with their Latin translations were made public by the Netherlands Government in the form of a volume entitled: *Papyri Graeci musei*

[1] M. Berthelot, "Les Origines de L'Alchemie," Paris, 1885.

antiquarii publici Lugduni Batavi . . . . Edidit, interpretationem latinam, annotationem, indices et tabulas addidit C. Leemans, Musei antiquarii Lugduni Batavi Director. From the chemical point of view the most interesting of the papyri then translated into Latin was the one now known as the Leyden Papyrus X, which is under our special consideration at the present time.

A similar Egyptian papyrus has been quite recently brought to light in Sweden and published with extensive notes by Otto Lagercrantz. An investigation has revealed the fact that this papyrus also formed part of the collection of Johann d'Anastasy and that it was a special gift made to the Swedish Academy of Antiquities at Stockholm by this collector in 1832. There it remained unnoticed until a transfer of the document to the Victoria Museum at Upsala brought it to the attention of the above-mentioned philologist. A comparison with the Leyden Papyrus has established the fact that the two papyri are not only contemporaneous, but that they were also probably the work of the same writer. Together they form a most remarkable collection of chemical recipes and processes. The writer hopes to publish in the near future a complete English translation of the Stockholm Papyrus similar to the translation of the Leyden Papyrus here given. This latter papyrus will now be especially considered.

The Leyden Papyrus X is in a remarkable state of preservation. It is formed of ten large leaves, each about thirty centimeters long and having a width of around thirty-four centimeters. It contains sixteen pages of writing of from twenty-eight to forty-seven lines each, in Greek capital letters such as were in use during the third century A.D. It gives evidence of having been copied from still earlier documents and is full of grammatical errors and incorrect spellings.[2] It is written in the form of a recipe book and the recipes are often in an abbreviated, incomplete form such as workers, more or less familiar with the nature of the process, would use. The total number of recipes given is one hundred and eleven. Seventy-five of these deal with methods for purifying metals, making alloys, testing metals for purity, imitating precious metals, and coloring the surfaces of metals and alloys. There are fifteen recipes on methods for writing in letters of gold and silver. Eleven recipes deal with methods of making dyes and dyeing cloth in purple and other colors. The last eleven recipes are simply short extracts from the *Materia Medica* of Dioscorides Pedanius. They are chiefly descriptions of certain minerals. It is of interest to note that the extracts in the papyrus are very close to the present editions of this Greek writer compiled from quite different sources. No translation is given of these extracts since they are coutained

[2] C. Leemans, *Op. Cit.*, and M. Berthelot, "Introduction a L'Etude de la Chimie Des Anciens et du Moyen Age," Paris, 1889.

in published editions of the work of this author.[3] No English translation of the papyrus in its entirety has ever been published as far as the writer knows. A few recipes have been published previously by Stillman but these have been retranslated here in a more accurate manner.[4] The author has based his translation upon the work of Leemans, previously noted, and upon the French translation of Berthelot.[5] An endeavor has been made to give a close literal translation. Words in parentheses are lacking in the original, but are thought necessary to give the proper meaning in the various places where used. Words and phrases needing special interpretation are discussed in the form of brief notes following each recipe. A more detailed discussion of the general chemical significance and value of the recipes will be given following the text of the translation.

II. The Translation

1. *Purification and Hardening of Lead.*

Melt it, spread on the surface lamellose alum and copperas reduced to a fine powder and mixed, and it will be hardened.

The word alum or rather "alumen" was employed by the ancient writers as a general term to signify a variety of products. Generally, they were impure mixtures of sulfates of iron and aluminum. This must have been widely used for purifying metals as the following recipes show.

2. *Another (Purification) of Tin.*

Lead and white tin are also purified with pitch and bitumen. They are made pure by having alum, salt of Cappadocia and stone of Magnesia thrown on their surfaces.

The ancient practice of naming chemical products and minerals according to the place of their origin is well shown in this recipe. The "salt of Cappadocia" probably was common salt while "stone of Magnesia" had various meanings but generally referred to magnetic iron oxide or to hematite.

3. *Purification of Tin that is put into the Alloy of Asem.*

Take tin purified of any other substance, melt it, let it cool; after having well mixed and covered it with oil, melt it again; then having crushed together some oil, some bitumen, and some salt, rub it on the metal and melt a third time; after fusion, break apart the tin after having purified it by washing; for it will be like hard silver. Then if you wish to employ it in the manufacture of silver objects, of such a kind that they cannot be found out and which have the hardness of silver, blend 4 parts of silver and 3 parts of tin and the product will become as a silver object.

The word asem or "asemon" was employed for alloys intended to imitate gold or silver, most generally the latter.

4. *Purification of Tin.*

Liquid pitch and bitumen, a part of each; throw (them on the tin), melt, stir. Dry pitch, 20 drachmas; bitumen, 12 drachmas.

[3] Such as "Des Pedanios Dioskorides....in fünf Buchern." Translated by J. Berendes, Stuttgart, 1902.

[4] Stillman, "Story of Early Chemistry," Chapter II, D. Appleton & Co., New York, 1924.

[5] Contained in his "Introduction a L'Etude de la Chimie Des Anciens et du Moyen Age."

5. *Manufacture of Asem.*

Tin, 12 drachmas; mercury, 4 drachmas; earth of Chios, 2 drachmas. To the melted tin, add the crushed earth, then the mercury, stir with an iron, and put (the product) in use.

The "earth of Chios" mentioned here was a kind of clay.

6. *The Doubling of Asem.*

One takes: refined copper, 40 drachmas; asem, 8 drachmas; tin in buttons, 40 drachmas; one first melts the copper and after two heatings, the tin; then the asem. When all are softened, remelt several times and cool by means of the preceding composition. After having augmented the metal by these proceedings, clean it with talc. The tripling is effected by the same procedure, the weights being proportioned in conformity with what has been stated above.

The preceding composition referred to in this recipe apparently refers to No. 5.

7. *Inexhaustible Stock.*

It is prepared by the procedures described in the doubling of asem. If you wish to deduct 8 drachmas from the stock, separate them and remelt with 4 drachmas of this same asem; melt these three times and then repeat, then cool and place in reserve in the talc.

8. *Manufacture of Asem.*

Take soft tin in small pieces, purified four times; take 4 parts of it and 3 parts of pure white copper and 1 part of asem. Melt, and after the casting, clean several times and make with it whatever you wish to. It will be asem of the first quality, which will deceive even the artisans.

The term, "white copper," refers to a particular copper alloy. A single word "Aes" was applied by the Ancients to both pure copper and its alloys.

9. *Manufacture of Fusible Asem.*

Copper of Cyprus, 1 mina; tin in sticks, 1 mina; stone of Magnesia, 16 drachmas; mercury, 8 drachmas, stone of Paros, 20 drachmas. Having melted the copper, throw the tin on it, then the stone of Magnesia in powdered form, then the stone of Paros, and finally the mercury; stir with an iron rod and pour at the desired time.

The island of Cyprus was an important source of copper in ancient times and the metal from this source was considered then to be of superior quality. "Stone of Paros" is mentioned by Pliny as being a white, hard stone similar to the marble from this place.

10. *Doubling of Asem.*

Take refined copper of Cyprus, throw upon it equal parts, that is, 4 drachmas of salt of Ammon and 4 drachmas of alum; melt and add equal parts of asem.

11. *Manufacture of Asem.*

Purify lead carefully with pitch and bitumen, or tin as well; and mix cadmia and litharge in equal parts with the lead, and stir until the alloy is completed and solidifies. It can be used like natural asem.

The word "cadmia" was applied to condensed fumes and smoke gathered from the interior of copper and brass smelters and hence was often a complex mixture of metallic oxides. In a special sense it meant zinc oxide. "Natural asem" was the naturally occurring alloy of gold and silver known as electrum.

12. Manufacture of Asem.

Take some shreds of (metallic) leaves, dip in vinegar and white lamellose alum and let them soak during seven days, and then melt with a fourth part of copper, 8 drachmas of earth of Chios, 8 drachmas of asemian earth, 1 drachma of salt of Cappadocia (and) additional lamellous alum, 1 drachma; mix, melt, and cast the black (refuse) from the surface.

The nature of the metal first used is not stated. The chemical nature of the "asemian earth" is also unknown to us.

13. Manufacture of an Alloy.

Copper from Galacia, 8 drachmas; tin in sticks, 12 drachmas; stone of Magnesia, 6 drachmas; mercury, 10 drachmas; asem, 5 drachmas.

14. Manufacture of an Alloy for a Preparation.

Copper, 1 mina, melt and throw on it 1 mina of tin in buttons and use thus.

15. The Coloration of Gold.

To color gold to render it fit for usage. Misy, salt, and vinegar accruing from the purification of gold; mix it all and throw in the vessel (which contains it) the gold described in the preceding preparation; let it remain some time, (and then) having drawn (the gold) from the vessel, heat it upon the coals; then again throw it in the vessel which contains the above-mentioned preparation; do this several times until it becomes fit for use.

According to Pliny the "misy" of the Ancients was either iron or copper pyrites or oxidation products of these, that is, basic iron or copper sulfates or various mixtures of these salts. (See Pliny, "Natural History," Book XXXIV, chap. 31.)

16. Augmentation of Gold.

To augment gold, take cadmia of Thracia, make the mixture with cadmia in crusts, or that from Galacia.

This is apparently the beginning of a longer recipe. No. 17 seems to be the remainder of it. Berthelot has suggested that the title of No. 17 was a comment or gloss erroneously copied into the papyrus by a copyist.

17. Falsification of Gold.

Misy and Sinopian red, equal parts to one part of gold. After the gold has been thrown in the furnace and it has become of good color, throw upon it these two ingredients, and removing (the gold) let it cool and the gold is doubled.

The meaning of "sinopian red" is various. The description of Dioscorides (*Materia Medica V*, 3) would make it appear that it was an iron ochre, although it sometimes referred to red lead.

18. Manufacture of Asem.

Tin, a tenth of a mina; copper of Cyprus, a sixteenth of a mina; mineral of Magnesia, a thirty-second; mercury, two staters. Melt the copper, throw on it at first, the tin, then the stone of Magnesia; then having melted these materials, add to them an eighth (part) of good white asem of a suitable nature. Then, when the alloying has taken place and at the time of cooling, or of remelting together, add then the mercury last of all.

19. Another (Formula).

Copper of Cyprus, 4 staters; earth of Samos, 4 staters; lamellose alum, 4 staters; common salt, 2 staters; blackened asem, 2 staters, or if you desire to make it more beautiful,

4 staters. Having melted the copper, spread upon it the earth of Chios and the lamellose alum crushed together, stir in such a way as to mix them; and having melted this asem, pour. Having mixed that which has just been melted with some (wood of) juniper, burn it; before setting aside after having heated it, extinguish the product in lamellose alum and salt taken in equal parts, with some slimy water slightly thick; and if you wish to finish the work immerse again in the above-mentioned; heat so (the metal) becomes white. Take care to employ refined copper beforehand, having heated it at the beginning and submitted it to the action of the bellows, until this has rejected its scale and become pure; and then use it as has just been stated.

20. Another (Formula).

Take a Ptolemaic Stater; for they contain copper in their composition and immerse it; now, the composition of the liquid for the immersion is this: lamellose alum, common salt, in vinegar for immersing; (make it of) slimy thickness. After having immersed and at the moment when the melted metal has been cleaned with this composition, heat, then immerse, then take out, then heat.

20. (An additional part without a title).

Here is the composition of the liquid for immersing: lamellose alum, common salt, in the vinegar for immersing; (make of) slimy thickness; having immersed in this mixture, heat, then immerse, then take out, then heat; when you have immersed four times or more, by previously heating each time, the (metal) will become superior to blackened asem. The more numerous the treatments, heatings, and immersions are the more it will improve.

21. Treatment of Hard Asem.

How it is expedient to proceed to change black and hard asem into a white and soft (metal). Taking some leaves of the castor-oil plant infuse them a day in water; then soak (it) in the water before melting and melt twice and sprinkle with aphronitron. And throw alum on the casting; put into use. It possesses quality for it is beautiful.

The word "aphronitron" was applied to a variety of saline efflorescences especially from dry or arid regions. Most probably it was a natural alkali which was essentially sodium carbonate.

22. Another (Formula).

A remedy for all tarnished asem. Taking straw, barley, and wild rue, infuse in vinegar, pour on it some salt and coals; throw it all in the furnace, blow for a long while and let cool.

23. Whitening of Copper.

For whitening copper, in order to mix it with equal parts of asem, so that no one can recognize it. Taking some Cyprian copper, melt it, throwing on it 1 mina of decomposed sandarach, 2 drachmas of sandarach of the color of iron, and 5 drachmas of lamellose alum and melt (again). In the second melting, there is thrown on 4 drachmas, or less, of wax of Pontus: it is heated and then poured.

Sandarach was the term used to denote the native arsenic sulfide that is today known as realgar by the mineralogists. "Decomposed sandarach" possibly referred to that subjected to a roasting process and would in reality be the oxide.

24. Hardening of Tin.

For hardening tin, spread separately (on its surface) lamellose alum and copperas; if, moreover, you have purified the tin as is necessary and have employed the materials

previously named, in such a way that they did not escape by flowing away during the heating, you will have Egyptian asem for the manufacture of objects (of jewelry).

25. Gold Polish.

For treating gold, otherwise called, purifying gold and rendering it brilliant: Misy, 4 parts; alum, 4 parts; salt, 4 parts. Pulverize with water. And having coated the gold (with it), place it in an earthenware vessel deposited in a furnace and luted with clay, (and heat) until the above-named substances have become molten, then withdraw it and scour carefully.

26. Purification of Silver.

How silver is purified and made brilliant. Take a part of silver and an equal weight of lead; place in a furnace, and keep up the melting until the lead has just been consumed; repeat the operation several times until it becomes brilliant.

27. Coloring in Silver.

For silvering objects of copper: tin in sticks, 2 drachmas; mercury, 2 drachmas; earth of Chios, 2 drachmas. Melt the tin, throw on the crushed earth, then the mercury, and stir with an iron and fashion into globules.

28. Manufacture of Copper Similar to Gold.

Crush some cumin; pour on it some water, dilute, and let it remain in contact during three days. On the fourth day shake, and if you wish to use it as a coating mix chrysocolla with it; and the gold will appear.

The word chrysocolla referred to salts of copper and to a gold alloy used for soldering gold. In the above recipe, which is evidently a varnish, the latter was probably used in a pulverized form.

29. Manufacture of Fusible Asem.

Copper of Cyprus, 1 part; tin, 1 part; stone of Magnesia, 1 part; raw stone of Paros powdered finely. One melts the copper first, then the tin, and then the stone of Magnesia; then next, one throws the pulverized stone of Paros upon this; the stirring is done with an iron and the operation is performed in a crucible.

30. Manufacture of Asem.

Tin, a measure; copper of Galacia, a half measure. Melt at first the copper, then the tin, stir with an iron, and throw on it dry pitch, until it is saturated; immediately pour, remelt, employing lamellose alum in the same manner as the pitch, and then pour (again). If you wish to melt the tin first, then the copper in filings after, follow the same proportions in the same manner.

31. Preparation of Chrysocolla.

Solder for gold is prepared thus: copper of Cyprus, 4 parts; asem, 2 parts; gold, 1 part. The copper is first melted, then the asem and finally the gold.

32. To Recognize the Purity of Tin.

After having melted, place some papyrus below it and pour; if the papyrus burns, the tin contains some lead.

33. Manufacture of Solder for Working Gold.

How one goes about making the solder for works of gold: Gold, 2 parts; Copper, 1 part; melt (and) divide up. When you desire a brilliant color melt with a little silver.

34. A Procedure for Writing in Letters of Gold.

To write in letters of gold, take some mercury, pour it in a suitable vessel, and add to it some gold in leaves; when the gold appears dissolved in the mercury, agitate sharply; add a little gum, 1 grain for example, and, (after) letting stand, write in the letters of gold.

35. Another (Recipe).

Golden-colored litharge, 1 part; alum, 2 parts.

36. Manufacture of Asem that is Black like Obsidian.

Asem, 2 parts, lead, 4 parts. Place in an earthen vessel, throw on it a triple weight of unburnt sulfur, and having placed it in the furnace, melt. And having withdrawn it from the furnace, beat, and make what you wish. If you wish to make figured objects in beaten or cast metal, then polish and cut. It will not rust.

37. Manufacture of Asem.

Good tin, 1 part; add to it, dry pitch, one quarter of the weight of the tin; having stirred, let the pitch froth until it has been completely ejected; then, having let the tin solidify, remelt it and add 13 drachmas of tin (and) 1 drachma of mercury, (then) stir up; let cool and work just like asem.

38. For Giving to Objects of Copper the Appearance of Gold.

And neither touch nor rubbing against the touchstone will detect them, but they can serve especially for (the manufacture of) a ring of fine appearance. Here is the preparation for this. Gold and lead are ground to a fine powder like flour, 2 parts of lead for 1 of gold, then having mixed, they are incorporated with gum, and one coats the ring with this mixture; then it is heated. One repeats this several times until the object has taken the color. It is difficult to detect (the fraud), because rubbing gives the mark of a gold object, and the heat consumes the lead but not the gold.

39. Writing in Letters of Gold.

Letters of gold: saffron (and) bile of a river tortoise.

40. Manufacture of Asem.

Take white tin, finely divided, (and) purify it four times; then take 4 parts of it, and a fourth part of pure white copper and 1 part of asem (and) melt: when the mixture has been melted sprinkle it with the greatest possible quantity of salt, and make what you wish with it, either by hammering or by any way you please. The metal will be equal to true asem, so much so as to deceive even the artisans.

41. Another (procedure).

Silver, 2 parts; purified tin, 3 parts; copper (?) drachmas; melt, then remove and clean; put in use for works of silver of the best kind.

42. Coating of Copper.

If you desire that the copper shall have the appearance of silver; after having purified the copper with care, place it in mercury and white lead; mercury alone suffices for coating it.

43. Testing of Gold.

If you wish to test the purity of gold, remelt it and heat it: if it is pure it will keep its color after heating and remain like a piece of money. If it becomes white, it contains silver; if it becames rougher and harder some copper and tin; if it blackens and softens, lead.

44. *Testing of Silver.*

Heat the silver or melt it, as with gold; and if it remains white (and) brilliant, it is pure and not false; if it appears black, it contains some lead; if it appears hard and yellow, it contains some copper.

45. *Writing in Letters of Gold.*

To write in letters of gold. Write what you desire with goldsmith's solder and vinegar.

46. *Cleaning of Copper Objects.*

Having boiled some beets, carefully clean the objects of copper and silver with the juice. The beets are boiled in water.

47. *Copper Equal to Gold.*

Copper equal to gold in color, as follows: grind some cumin in water; let it set carefully during three days; on the fourth, having wet (it) abundantly, coat the copper (with it) and write whatever you wish. For the coating and the writing have the same appearance.

48. *Cleaning of Silver Objects.*

Clean with sheep's wool, after having dipped in sharp brine; then clean with sweet water and put into use.

49. *Gilding of Silver.*

For gilding a vase of silver or copper without leaves (of gold), dissolve some yellow natron and some salt in water, rub it with this and it will be (gilded).

The chemical nature of "yellow natron" is not known with certainty. From certain passages in Pliny and other writers it would appear that this was a sodium sulfide made by fusing sulfur and native sodium carbonate together. In this case the metal would not be gilded but would at least be colored by the above recipe.

50. *Writing in Letters of Gold.*

Grind arsenic with gum, then with some well water; in the third place, write.

The word arsenic in this recipe refers to the native yellow arsenic sulfide.

51. *Gilding of Silver.*

Grind misy with sandarach and cinnabar and rub the object with it.

53. *Writing in Letters of Gold.*

After having dried the gold leaves, grind with gum and write.

54. *Preparation of Liquid Gold.*

Place some leaves of gold in a mortar, grind them with some mercury and it is done.

55. *Coloration in Gold.*

How one should prepare gilded silver. Mix some cinnabar with alum, pour some white vinegar upon this, and having brought it all to the consistency of wax, press out several times and let it stand over night.

56. *Preparation of Gold.*

Asem, 1 stater, or Copper of Cyprus, 3; 4 staters of gold; melt together.

57. *Another Preparation.*

To gild silver in a durable fashion. Take some mercury and some leaves of gold, and make up into the consistency of wax; taking the vessel of silver, clean it with alum, and taking a little of the waxy material, lay it on with the polisher and let the material fasten itself on. Do this five times. Hold the vessel with a genuine linen cloth in order not to soil it. Then taking some embers, prepare some ashes (and with them) smooth (it) with the polisher and use as a gold vessel. It can be submitted to the test for regular gold.

58. *Writing in Letters of Gold.*

Golden-colored arsenic, 20 drachmas; pulverized glass, 4 staters; of white of egg, 2 staters, white gum, 20 staters, saffron....after having written, let dry and polish with a tooth.

59. *Manufacture of Asem.*

Asem is also prepared with copper; (silver) 2 mina; tin in grains, 1 mina; melting first the copper, throw on it the tin and some talc called chalk, a half to one mina; proceed until you see the silver and the chalk melt; after which the remainder will have been dissipated and only the silver will remain, then let it cool, and use it as asem preferable to the genuine.....

The chemical nature of the mineral or flux called talc or chalk in this recipe is unknown. Certainly it does not correspond to the substances of that name that we are acquainted with.

60. *Another (Preparation).*

Everlasting asem is prepared thus: 1 stater of good asem; add to it 2 staters of refined copper, melt two or three times.

61. *Whitening of Tin.*

To whiten tin. Having heated (it) with alum and natron, melt.

62. *Writing in Letters of Asem.*

Dilute some copperas and some sulfur with vinegar; write with the thickened material.

63. *Writing in Letters of Gold.*

Flower of cnecos, white gum, white of egg mixed in a shell, and incorporate with bile of tortoise, by estimation as one does for colors; put into use. The very bitter bile of a calf also serves for the color.

The plant mentioned here was evidently one containing yellow coloring matter although its exact species is not known.

64. *Testing of Asem.*

To recognize if asem is false. Place it in brine (and) heat; if it is false, it will blacken.

65. *Cleaning of Tin.*

Place some gypsum on a rag and scour.

66. *Cleaning of Silver.*

Employ moist alum.

67. *Coloring of Asem.*

Cinnabar, 1 part, lamellous alum, 1 part, Cimolian earth, 1 part; moisten with sea water and put into use.

68. Softening of Copper.

Heat it; place it in bird dung and after cooling, take out.

69. Coloring of Gold.

Roasted misy, 3 parts; lamellose alum, (and) celandine, about 1 part; grind to the consistency of honey with the urine of a small child and color the object; heat and immerse in cold water.

70. Writing in Letters of Gold.

Take a quarter portion of tested gold, melt in a goldsmith's crucible; when it has become molten add a carat of lead; after it has become alloyed, set it aside, cool and take a mortar of jasper, throw in it the melted material; add 1 carat of natron and carefully mix the powder with some strong vinegar, in the same manner as for an eye-salve medicine, for three days; then when the mixture is completed, incorporate 1 carat of lamellose alum, write and polish with a tooth.

71. Writing in Letters of Gold.

Soft leaves of Gold; pulverize with mercury in a mortar; and employ them in writing, after the manner of black ink.

72. Another (Preparation).

Incombustible sulfur...., Lamellose alum...., gum...., sprinkle the gum with water.

73. Another (Preparation).

Unburnt sulfur...., lamellose alum, a drachma; add a medium quantity of dry rust; pulverize the rust, the sulfur, and the alum finely; mix properly, grind with care and employ it for writing in the same way as black ink by diluting it with some wine free from sea water. Write upon papyrus or parchment.

74. Another (Preparation).

To write in letters of gold, without gold. Celandine, 1 part; pure resin, 1 part; golden-colored arsenic, of the fragile kind, 1 part; pure gum; bile of tortoise, 1 part; the liquid part of eggs, 5 parts; take 20 staters by weight of all these materials dried; then throw in 4 staters of saffron of Cilicia. Can be used not only on papyrus or parchment, but also upon highly-polished marble, or as well when you wish to make a beautiful design upon some other object and give it the appearance of gold.

75. Gilding.

Gilding gives the same effect. Lamellose arsenic, copperas, golden sandarach, mercury, gum tragacanth, pith of arum, equal parts; dilute the whole with the bile of a goat. It is applied upon copper objects, upon silver objects, upon figures (in metal) and upon small shields. The copper should not have a rough surface.

The terms "lamellose arsenic" and "golden sandarach" in the above recipe undoubtedly referred to varieties of the native sulfides of arsenic that we term as realgar and orpiment. Pliny and Dioscorides both describe these minerals in their writings.

76. Another (Procedure).

Misy from the mines, 3 staters; alum from the mines, 3 staters; celandine, 1 stater; pour on these the urine of a small child; grind together until the mixture becomes viscous and immerse (the object in it).

77. Another (Procedure).

Take some cumin, crush it (and) let it infuse three days in water, on the fourth take out; coat the objects of copper with it, or whatever you wish. It is necessary to keep the vessel closed during the three days.

78. Writing in Letters of Gold.

Grind some gold leaves with gum, dry and use like black ink.

79. Writing in Letters of Silver.

To write in letters of silver. Litharge, 4 staters; dilute with the dung of a pigeon and some vinegar; write with a stylus passed through the fire.

80. Coloring of Asem.

Cinnabar, Cimolian earth (and) liquid alum, equal parts; mix with sea water, heat and dampen several times.

81. Coloration in Silver.

Such that it can only be removed by fire. Chrysocolla, ceruse, earth of Chios and mercury ground together; add some honey and having first treated the vessel with natron, coat (the vessel) with it.

Ceruse or *cerussa* was the ancient term for white lead, which was well-known and widely employed as a cosmetic by the Greeks and Romans.

82. Hardening of Tin.

Melt it, add to it a homogeneous mixture of lamellose alum and copperas; pulverize and sprinkle (over the metal) and it will be hard.

83. Manufacture of Asem.

Good tin, 1 mina; dry pitch, 13 staters; bitumen, 8 staters; melt in a vessel of baked earth luted around (the top); after having cooled, mix 10 staters of copper in round grains and 3 staters of asem first and (then) 12 staters of broken stone of Magnesia. Melt, and make what you wish.

84. Manufacture of Egyptian Asem.

Recipe of Phimenas (or Pammenes). Take some soft copper of Cyprus, purify it with some vinegar, some salt and some alum; after having purified it, melt 10 staters of the copper throwing on it 3 staters of well-purified ceruse, 2 staters of golden-colored litharge, after which it will become white. Then add to it 2 staters of very soft asem without blemish and the product will be obtained. Take care in melting that it does not liquate. This is not the work of an ignorant person, but of an experienced man, and the union of the two metals will be good.

85. Another (Procedure).

An exact preparation of asem, preferable to that of asem properly so-called. Take: orichalcum, 1 drachma for example; place in a crucible until it melts; throw upon it 4 drachmas of salt of Ammon or Cappadocian salt; remelt, add to it lamellose alum, (in an amount equal to) the weight of an Egyptian bean; remelt, add to it 1 drachma of decomposed sandarach, not the golden sandarach but that which whitens; then transfer to another crucible previously coated with earth of Chios; after fusion add a fourth part of asem and put into use.

Orichalcum or aurichalcum as it was sometimes spelled was an alloy consisting mainly of copper and zinc, in other words what we term today as brass. The term

"decomposed sandarach" in the above would seem to indicate that the native arsenic sulfides were sometimes roasted and the resulting product, which would be essentially arsenious oxide was then used in making alloys.

86. Another (Proceeding).

Take: tin, 12 drachmas; mercury, 4 drachmas; earth of Chios, 2 drachmas; melt the tin, throw upon it the earth in powder, (and) then the mercury; stir with a bar of iron; fashion into globules.

87. Doubling of Gold.

For augmenting the weight of gold. Melt (it) with a fourth part of cadmia, and it will become heavier and harder.

88. Another (Proceeding).

Gold can be altered and increased by means of misy and earth of Sinopus. One first casts it in the furnace with equal parts (of them). When it has become clear in the crucible, one adds each as it is desired, and the gold is doubled.

89. Another (Preparation).

The invention of sulfur water. A handful of lime and another of sulfur in fine powder; place them in a vessel containing strong vinegar or the urine of a small child. Heat it from below, until the supernatant liquid appears like blood. Decant this latter properly in order to separate it from the deposit, and use.

90. How Asem is Diluted.

Having reduced the asem into leaves and having covered it with mercury and applied (it) strongly upon the leaf, one sprinkles pyrites upon the leaf thus prepared, and places it upon the coals, in order to dry it up to the point when the color of the leaf appears changed; for the mercury evaporates and the leaf softens. Then one incorporates in the crucible 1 part of gold, (and) 2 parts of silver. Having blended them, throw upon the floating scum some golden-colored arsenic, some pyrites, some salt of Ammon, some chalcitis, (and) some blue; and having ground with sulfur water, heat, then spread mercury upon the surface.

In the above recipe appears for the first time in written form, evidence of symbolism in chemical arts, both gold and silver being designated by special characters. The word *chalcitis* was used in ancient times to designate copper minerals, especially, according to Pliny's descriptions, copper pyrites. The unknown blue substance hinted at in the above was also most probably a copper salt or mineral.

91. The Fixation of Alkanet.

Urine of sheep, or arbute-berry, or henbane in the same manner.

92. Falsification of Alkanet.

Alkanet is diluted with pine-cones, the inside part of peaches, purpura, beet juice, dregs of wine, the urine of a camel and the interior of citrons.

93. Fixation of Alkanet.

Navelwort and alum mixed in equal parts, crush finely (and) throw the alkanet in it.

94. Styptic Agents.

Melantheria, calcined copperas, alum, chalcitis, cinnabar, lime, bark of pomegranate, pod of a thorny tree, urine with aloes. These things serve in dyeing.

Melantheria was a word applied to the products of the weathering of copper ores at the surface of mine shafts. Usually these ores were sulfides and the product then must have been chiefly basic iron and copper sulfate.

95. *The Preparation of Purple.*

Break into small pieces stone of Phrygia; put it to boiling, and having immersed the wool, leave it until it cools. Then throwing in the vessel a mina of seaweed, put it to boiling and throw in it (again) a mina of seaweed. Let it boil and throw the wool into it, and letting cool, wash in sea water... [the stone of Phrygia is roasted before being broken]... until the purple coloration appears.

The "stone of Phrygia" was evidently some kind of a mordant and may have been, as Berthelot suggested, a type of alunite. The seaweed mentioned above was probably the so-called dyers moss or archil.

96. *Dyeing with Purple (Two Methods).*

Grind lime with water and let it stand over night. Having decanted, deposit the wool in the liquid for a day; take it out (and) dry it; having sprinkled the alkanet with some vinegar, put it to boiling and throw the wool in it and it will come out dyed in purple.... alkanet boiled with water and natron produces the purple color.

Then dry the wool, and dye it as follows: Boil the seaweed with water and when it has been exhausted, throw in the water an imperceptible quantity of copperas, in order to develop the purple, and then plunge the wool in it, and it will be dyed. If there is too much copperas, it becomes darker.

97. *Another (Procedure).*

Grind some walnuts with some alkanet of good quality. This done, place them in some strong vinegar; grind again; add some pomegranate bark to this; lay aside three days; and after this, plunge the wool in it and it will be dyed cold..... It is said that there is a certain acanthus which furnishes the purple color; moistened with some natron of Berenice in place of nuts, it produces the same effect.

98. *Another (Procedure).*

Clean the wool with fullers plant, and hold at your disposal some lamellose alum. (Then) grinding the interior part of gall-nut, throw it in a pot with the alum, then put in the wool and let it remain several hours. Take it out and let it dry. Follow this procedure first: Having ground the lees (from wine) and having placed them in a vessel, pour in sea water, agitate and set aside. Then, decant the clear water into another vessel and hold it at your disposal. Taking the alkanet and placing it in a vessel, mix with the water from the lees until it thickens conveniently and becomes as though sandy. Then place the product in a vessel, diluting it by estimation with the preceding water which comes from the alkanet. Then, when it has become as though slimy, place it in a small kettle, add to it the remainder of the alkanet water, and leave until lukewarm. Then plunge the wool in it, lay aside several hours, and you will find the purple fast.

99. *Another (Process).*

Taking alkanet, (and) some leontice, strip off the bark, take it and grind it as fine as stibnite in a mortar. Add to it some hydromel diluted with water, grind again, place the ground product in a vessel and boil. When you observe (the liquid) to be lukewarm, plunge the wool in it (and) let it remain. The wool ought to be cleaned with fullers plant and thickened. Then take it, plunge it in lime water; let it soak; take it out; wash thoroughly with some sea salt (and) dry. Plunge it again in the alkanet and let it remain.

100. Another (Procedure).

Take the juice of the upper part of the alkanet and a solid gall-nut roasted in the oven. Having ground it with the addition of a little copperas, mix with the juice, boil, and make the purple dye.

101. A Substitute for Greenish-Blue Color.

In place of greenish-blue color, take scoria of iron, crush it with care until reduced to the appearance of smegma, and boil it with some vinegar until it becomes stiff. Immerse the wool, previously cleaned with heavy fullers herb, and you will find it dyed in purple. Dye in this way with the colors that you have.

Iron oxide or scales from the forging of iron was called scoria of iron, while the term smegma was applied to copper oxide made by blowing across the surface of molten copper with bellows.

102. Arsenic.
103. Sandarach.
104. Misy.
105. Cadmia.
106. Chrysocolla.
107. Rubric of Sinopia.
108. Alum.
109. Natron.
110. Cinnabar.
111. Mercury.

As mentioned in the introduction, the last recipes in the papyrus are sections extracted from the well-known "Materia Medica" of Dioscorides. They are chiefly descriptive of certain minerals and metallurgical products used in antiquity. The title only of each recipe is given here since their contents have been widely published in the many editions of this writer's works.

III. Commentary

By reason of the antiquity and character of the papyrus there is much in it of great interest to historians and philologists, but no attempt will be made here to comment upon this phase of the subject. Its significance and meaning from the chemical standpoint will be chiefly stressed in as concise a way as possible; emphasis being placed upon its general nature rather than upon a detailed examination of each of its recipes and preparations.

Perhaps one of the most striking points to be noticed about the collection is the numerous repetitions in the nature of the recipes, many of them only varying slightly in the proportions of the same ingredients. This doubtless indicates that it was collected from various sources and from pre-existing documents now lost to us. Furthermore, this fact pushes still farther back the time when the chemical arts and operations described in the papyrus must have been known to mankind. To be remarked also is the fragmentary character of many of the recipes, and the essential omissions in many of them giving the impression that they

were rather in the nature of reminders for skilled workers rather than detailed descriptions for purposes of general information. This fact emphasizes the likelihood that this papyrus was a kind of a laboratory note-book of the operations of the chemical arts of the times.

The recipes dealing with metals and alloys are certainly the most numerous. These may be conveniently grouped as follows: The making of alloys, coloring the surfaces of metals, cleaning and purifying metals, and testing metals for purity.

The first of these, the manufacture of alloys, is the subject of the majority of the recipes. And, in nearly all cases the alloy being made is the same one namely, "asem." The word itself referred either to silver, alloys of silver and gold, or in fact to any alloy used in jewelry resembling these. As a matter of fact, the whole viewpoint of the ancients regarding substances was so entirely different from ours that we sometimes forget that they generally failed to distinguish metals, chemically, from each other very clearly and went wholly upon appearances. For example, if two alloys had the same appearance although differing in composition they considered them identical. This is checked further in other cases, notably among the Romans, who applied the same name "aes" to all kinds of copper alloys regardless of composition. In the papyrus most of the recipes are simply straightforward working directions, although in one or two cases there is direct evidence of an intention to deceive. Thus in No. 8 we read, "this will be asem of the first quality, which will deceive even the artisans," showing that there was some recognition of chemical differences aside from qualitative appearances. Perhaps the workers of the recipes knew this, but it is certain that this knowledge was not general, as the philosophy of the ancients so well informs us. It is these practical recipes and working directions for making alloys from various metals that later became fused with various mystical and philosophical doctrines and so grew into alchemy. Hence, the papyrus is of the highest historical importance chemically in showing the real starting point of the alchemical ideas of the transmutation of metals.

As to the practical composition of the alloys themselves, they are seen to vary from simple two-metal combinations to those containing four or five metals. The metals used were gold, silver, tin, copper, lead, mercury, arsenic, antimony, and zinc, the latter ones being used in the form of their compounds and not being distinguished in the metallic state. A curious fact to be noted in the making of these alloys is that in nearly all cases where compounds are employed there is no mention of a reducing agent being employed. Perhaps the furnaces used were operated under reducing conditions or it was understood by the workers that charcoal or wood was to be placed with the metals being fused. The limited range in the type of alloys whose manufacture is described indicates that the owner

or owners of the papyrus were chiefly interested in making ornamental jewelry and not in practical metals such as bronze and steel. At any rate the recipes for alloys in this papyrus are the earliest detailed quantitative directions for alloy manufacture that we have knowledge of. Other ancient writers such as Pliny and Dioscorides who touch upon technical subjects are singularly lacking in details, indicating their lack of direct knowledge, but the papyrus here considered is certainly a direct laboratory document and hence its importance for the history of chemistry.

Next in importance to the making of the alloys themselves come the recipes that deal with refining, cleaning, coloring, and otherwise treating metals. The second recipe in the papyrus is an example of the purification of metals by adding reducing agents to the molten metals, pitch and oils being used for this purpose. Another method of purification that was evidently in use in ancient times was the addition of various chemical salts to fused metals and alloys to serve as fluxes and solvents for the impurities. Alum, iron sulfate, crude soda ash, and common salt were most commonly employed for this purpose. Several recipes are given for cleaning and polishing the surface of cold metals. The softening and hardening of metals was also quite well-known then as several of the recipes show, and this is borne out by the fact that the hardening of steel by tempering was a familar operation in Roman times. A curious sidelight on the impurity of the crude metals then employed is shown by the fact that recipes for hardening lead are in reality only those for removing excessive impurities, an indication that the crude metal was mixed with quantities of oxides.

The coloring of metals superficially was evidently widely practised. Mercury was applied to alloys and base metals to give a silvery appearance as well as being incorporated in the alloys themselves. A curious method of gilding with gold is given in Recipe No. 38 in which a mixture of powdered gold and lead are fastened upon an object with the subsequent burning off of the base metal. The use of gold amalgam in gilding silver is also fully explained in No. 57. Besides using metals for coloring metallic surfaces they also employed various colored varnishes and dyes as several of the recipes of the papyrus indicate. Recipe No. 89 is especially interesting from the chemical point of view as being evidently a preparation of a solution of sulfides of calcium, the original lime-sulfur mixture. This is the only actual preparation of a chemical salt listed in the collection. Probably this was used to color the surfaces of metals also.

The crude methods of testing gold and silver for purity employed in those times are well described in Recipes No. 43 and 44. The discoloration of the metals by the formation of metallic oxides was depended upon to indicate fraud. No doubt this was sufficiently accurate to indicate

gross adulterations, but it certainly would not satisfy us in these days. The fact that metals had different melting points was well-recognized and used, as Recipe No. 32 on testing tin shows. Pliny also describes this method in Book XXXIV of the Natural History. This method would indeed distinguish between tin and lead, but eutectic mixtures must certainly have deceived some of the workers of those days. This crude method of determining temperatures is truly indicative of the elementary state of chemical arts at the opening of the Christian Era.

Writing and making inscriptions in metallic letters or in characters colored so as to resemble gold and silver must also have been an important operation for the workers of that period if the number of the recipes in the papyrus bearing upon the subject are to be taken as a true indication. Gold amalgam is used for the purpose in several recipes. A point worthy of note about these is that no mention is made of heating the finished writing to drive off the excess mercury. No doubt this was understood by the workers or transmitted by word of mouth. This fact well indicates the fragmentary and incomplete character of the procedures described. Litharge, sulfur, and various organic pigments and colors were also incorporated with gum water and other mediums to yield colored writing.

The last recipes in the papyrus deal with methods of dyeing cloths. Various vegetable substances were applied to this purpose. There is direct and indisputable evidence that the necessity and practice of mordanting cloth previous to dyeing it was well-understood. The fact that the recipes are usually those for dyeing in purple shows that this papyrus was probably used in connection with royal or priestly workshops since the nobility were the only ones then generally permitted to wear purple. These recipes also expose the common fallacy that the ancient peoples only obtained their purple from the shellfish murex. They evidently used other dyes to a larger extent. The fact that the dyeing of cloths is so little touched upon in the Leyden Papyrus X and was of such importance in ancient chemical arts leads us to believe that the papyrus gives us only a partial view of the state of ancient chemical art. The Stockholm Papyrus is really volume II of the set for in it very little space is given over to metallic arts while much space is devoted to dyeing cloths, imitating precious stones, and other operations not even mentioned in the Leyden Papyrus. As stated before the writer hopes to publish the contents of the second one in a similar translation in the near future. The recent finds of numerous papyri in Egypt may also bring to light those of technical importance and enrich our knowledge of the early period of chemical history, although there is a certain degree of improbability about this since it is a known historical fact that books on alchemical processes and technical arts were systematically destroyed in Egypt during the first centuries of the Christian Era.