XXX.—*On some Constituents of Rhubarb.*

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I. INVESTIGATION OF A DEPOSIT FOUND IN TINCTURE OF
RHUBARB.

It has been often observed that when freshly prepared tincture of rhubarb is left to itself for some time, it becomes turbid, and deposits a dark-coloured precipitate, which cannot be redissolved, either by heating the tincture or by diluting it with fresh alcohol. The attention of the Society was recently called to this circumstance by Mr. Whipple, who frequently has occasion to prepare the tincture of rhubarb on a large scale: Mr. Whipple, at the same time, gave an account of a few experiments he had made with the precipitate, and stated that his leisure did not permit of his investigating the subject further, but that he would furnish material to any member who might feel inclined to pursue the inquiry. As it appeared to be very probable that the deposit from the *tinctura rhei* contained some constituents of interest, we availed ourselves of Mr. Whipple's offer; and we take this opportunity to express to him our thanks for the liberal supply of material which he kindly placed at our disposal.

The deposit from rhubarb tincture is of a dark colour, and resinous nature; it resembles logwood extract coarsely powdered, and has in a slight degree the characteristic odour of rhubarb. When heated in a test-tube, it does not melt, but gives off yellow fumes, which condense to a yellow liquid, a black residue being left. Heated on platinum foil, it burns without melting, leaving a tolerably large quantity of ash, which consists principally of potash and lime. Boiled with water, it imparts a yellowish tint to it; but an almost inappreciable quantity of it is dissolved: alcohol, when boiled with the precipitate, assumes a dark yellow-brown tint, but the quantity dissolved is, nevertheless, very small. Similar results are obtained on treating the precipitate with ether, chloroform, and glacial acetic acid. Ammonia, and concentrated sulphuric acid dissolve the greater part, but not the whole of the

substance; the fixed alkalies, on the other hand, when aided by heat, completely dissolve it, with the exception of a slight residue, consisting of accidental impurities; the solution in ammonia, the alkalies, or sulphuric acid, is of a dark, dingy purple colour.

After having determined the leading properties of the deposit by the above-named experiments, its composition was investigated in the following manner:—A considerable quantity of the substance was pulverised as finely as possible and treated repeatedly with boiling spirit of wine (of 86 per cent.) until it no longer dissolved anything; the insoluble residue, which constituted by far the greater bulk of the deposit will be treated of hereafter. The dark yellow solution was filtered while hot, and concentrated by partially distilling off the alcohol; the concentrated solution, on cooling, deposited a flocculent matter of yellow colour. This deposit, after being several times dissolved in alcohol, and allowed to deposit therefrom, became crystalline, and exhibited all the properties of *chrysophane*.

In accordance with the method adopted by Schlossberger and Döpping,* in their analysis of rhubarb, the mother-liquor of the chrysophane was mixed with about an equal volume of ether, when a bulky brown precipitate was formed. This was allowed to stand for a while, and the clear supernatant liquor tested with a fresh portion of ether, in order to ascertain whether any more precipitate could be thrown down. After the precipitation was ascertained to be complete, the deposit was separated by filtration, and set aside. The filtrate was concentrated by distilling off the greater part of the ether, and was then allowed to evaporate spontaneously to dryness. The dry residue was again dissolved in alcohol, and the solution treated with ether, which again caused a precipitation; the filtered solution was then concentrated, and allowed to evaporate to dryness; and these operations were repeated as long as ether caused any precipitate in the alcoholic solution. Lastly, by evaporating the alcoholic solution to dryness, we obtained a small quantity of a substance which did not show any signs of crystallization; it had a brown resin-like appearance, and when powdered became yellow; it dissolved readily, with a turmeric tint, in alcohol, ether, and benzol, and gave a deep red solution with ammonia and the fixed alkalies, and exhibited the other characteristic properties of *Erythroretin*.

The brown deposit separated by ether from the solution of

* Ann. Ch. Pharm., l. 219.

erythroretin, after repeated solution in alcohol and precipitation with ether, resembles in all its properties the *Phæoretin* of Schlossberger and Döpping.

It will be recollected that we stated that the greater part of the deposit from the tincture of rhubarb, when treated with alcohol to remove chrysophane, erythroretin, and phæoretin, remained undissolved; by digesting this residue with a moderately strong solution of caustic potash, it dissolved completely, giving a dark brownish-red solution. To the alkaline solution hydrochloric acid was added; this caused the separation of a deep brown precipitate, which was first washed with water, then with alcohol, to remove a portion of phæoretin which it still contained. After drying, the precipitate formed an almost black resinous substance, nearly insoluble in alcohol, ether, chloroform, and benzol, but dissolving readily in the alkalis. When heated on a platinum foil, it takes fire without melting. These properties accord with those of the *Aporetin* of Schlossberger and Döpping.

These experiments tend to show that the deposit which forms in the tincture of rhubarb is composed chiefly of:

Chrysophane,
Erythroretin,
Phæoretin,
Aporetin,

the chief constituents being the last named. The chrysophane amounts to about 4 per cent., and hence the rhubarb-tincture deposit is a valuable material for its preparation.

II. PREPARATION OF CHRYSOPHANE.

The investigations of the deposit of the "Tinctura Rhei" afforded us an opportunity of studying the properties of chrysophane in connexion with the other constituents of the rhubarb root, and enabled us to devise a method for the preparation of chrysophane, which completely removes the difficulties hitherto experienced in the extraction of that substance from rhubarb. Having observed that chrysophane is only slightly soluble in alcohol, but that it dissolves readily in glacial acetic acid, amyl alcohol, oil of turpentine, coal naphtha, and especially in benzol, and in the lighter oils obtained from Burmese naphtha, to the exclusion of the greater part of the other constituents, it became apparent that the latter solvents might be used with great advantage in its preparation. A few preliminary experiments led to the selection of

benzol,* or the light oils of Burmese naphtha and of amyl-alcohol, as the best suited for the purpose. The deposit of the "Tinctura Rhei" parts readily with its chrysophane when treated in a finely powdered state with benzol (purified coal-tar naphtha may be substituted), in a Mohr's extraction apparatus. In order to prepare chrysophane from rhubarb itself, a preliminary operation is necessary; the crushed root must be previously macerated with cold water, which removes more than 50 per cent. of soluble matter; these not only unnecessarily increase the bulk of material to be operated on, but they also render the extraction of the chrysophane much more difficult. After maceration with water, the root is dried and treated with benzol in a Mohr's apparatus. By operating in the manner described, a very concentrated solution of chrysophane is obtained, and a comparatively small quantity of the solvent is employed.

The fact that chrysophane is but slightly soluble in alcohol, and much less so in the dilute alcohol employed in the preparation of the tincture of rhubarb, led to the conjecture that the greater part of the chrysophane remains in the residuary root. An experiment carried out with such residuary rhubarb as is thrown away in pharmaceutical laboratories, proved this conjecture to be well founded, as the residue furnished 2.6 per cent. of chrysophane. It is, indeed, better suited for treatment with benzol than the original root, in consequence of its not being necessary to macerate it previously with water.

The benzoic solution obtained from either of the above-named sources is concentrated by distilling off the greater part of the benzol; on cooling, the solution becomes nearly solid by depositing the crude chrysophane. The mother-liquor contains erythroretin, and a neutral fat, and it is advisable to sacrifice the small quantity of chrysophane retained in the mother-liquor, by at once pressing the crude chrysophane between blotting paper.

On redissolving the crude chrysophane in hot benzol, a reddish-yellow, and much less soluble body is left undissolved, and the

* Benzol, and the light hydrocarbons obtained from Burmese naphtha appear to be susceptible of a very general application in experimental research, as they are of great value in separating certain classes of bodies from others of a different nature. As examples of this application, we may state that benzoic acid can be readily separated from gum benzoin by means of benzol; guaiacic acid can also be separated by its means from gum guaiacum, the benzol dissolving the acids and leaving the gum unacted upon; on evaporation, the acids are obtained at once in remarkably fine crystals.

hot solution, on slightly cooling, deposits a still further quantity of it in the state of a light flocculent precipitate. The chrysophane is obtained by crystallization, after filtering off the flocculent matter, and concentration of the solution. In order to obtain the chrysophane quite pure, the operation must be repeated several times. The flocculent precipitate proved to be a new body, which appears to have escaped the notice of previous investigators of rhubarb.

In the final purification of chrysophane, both amyl-alcohol and glacial acetic acid offer advantages over benzol; for although it is possible to obtain that substance in beautiful crystals from a benzoic solution, yet the difficulties are less when either amyl alcohol or acetic acid is employed, in consequence of temperature affecting the solvent powers of these latter agents to a greater extent than those of benzol. Although alcohol is not adapted for the extraction of chrysophane, it may be nevertheless used in the final crystallization with advantage.

Pure chrysophane, when crystallized from benzol under favourable circumstances, forms six-sided plates (monoclinic prisms), which bear great resemblance to iodide of lead; the colour varies from a pale yellow to a deep orange, according to the size of the crystals. From alcohol, amyl-alcohol, and glacial acetic acid, it usually crystallises in moss-like aggregations of foliated crystals. It dissolves in 224 parts of boiling alcohol of 86 per cent, and in 1125 parts of alcohol at 30°C. (86°F.). When pure it melts, without decomposition, at 162°C. (323.°6F.), and solidifies on cooling to a crystalline mass.

Although chrysophane dissolves in alkalies, forming definite compounds, its acid properties are very feeble, for it not only does not drive off carbonic acid from its combinations, but even parts with ammonia, when the ammonia compound is evaporated.

It is well known that when chrysophane is dissolved in caustic potash of moderate strength, a beautiful purple compound is formed, the greater part of which remains in solution, but a portion of it gradually deposits as a flocculent precipitate. We have observed that if grape-sugar be added to the compound containing an excess of alkali, and the mixture kept for some hours in a well stoppered bottle, the purple colour gradually disappears, and the solution becomes of a brownish-yellow tint, this phenomenon being accompanied by the disappearance of the

flocculent precipitate. The solution, however, recovers its original purple colour when exposed in a shallow vessel to the air for a few minutes, and the flocculent precipitate is again formed.

Hydrate of potash, at its fusion-point, does not alter chrysophane at first; but if the temperature be raised or the action continued for some time, it first becomes blue, and is then decomposed, at the same time an odour resembling that of caprylic alcohol is emitted. Potassium-alcohol apparently does not destroy chrysophane; it gives rise to a purple compound and formation of alcohol.

Neither chlorine, bromine, nor nitric acid, destroys the yellow colour of chrysophane, but they undoubtedly alter its composition. Nitromuriatic acid, when boiled for some time with chrysophane, forms a liquid body which does not become crystalline on cooling; but it still retains the property of striking a red colour with caustic alkalis. A mixture of hydrochloric acid and chlorate of potash behaves in a somewhat similar manner. If chrysophane be dissolved in strong sulphuric acid, and peroxide of manganese be then added, the red colour disappears in consequence of the destruction of the chrysophane.

0·1426 gramme of chrysophane gave on combustion:—

0·3595 gramme of carbonic acid = 68·76 per cent. carbon.

0·0545 gramme of water = 4·25 „ hydrogen.

If these numbers be compared with those obtained by Rochleder and Held, who analyzed the substance obtained from the lichen *Par-melia parietina*, and by Schlossberger and Döpping, who analyzed the chrysophane of rhubarb, there will be found a perfect accordance in the results, as will be seen from the following table:—

	Rochleder & Held.		Schlossberger &	De La Rue
	I.	II.	Döpping.	& Müller.
Carbon	68·45	68·65	68·69	68·76
Hydrogen	4·56	4·59	4·24	4·25
Oxygen	26·99	26·76	27·07	27·09

Before concluding these observations respecting chrysophane, we are desirous of calling attention to the remarkable resemblance existing between the properties of that body and pipitzahoënic acid prepared from a Mexican root called *raiz del pipitzahuac*, and described by Weld;* but the analysis differs too much to admit of the two bodies being considered identical.

* Ann. Ch. Pharm. xcv. 138.

Weldo obtained the following numbers :—

				I.	II.
Carbon	..	..	..	72·58	73·24
Hydrogen	..	..	..	8·06	8·27

From the foregoing numbers Weld derives the formula $C_{30}H_{20}O_6$
 Rochleder and Heldt's formula for chrysophane is $C_{20}H_8O_6$

making a difference in the composition of the bodies of $C_{10}H_{12}$

We cannot refrain from pointing out the possibility of these two bodies being homologues, and differing by $5(C_2H_2)$; this would make the formula of pipitzahoëinic acid to be $C_{30}H_{18}O_6$, which requires 73·17 carbon and 7·31 hydrogen.

III. EMODIN.

In the description of the preparation of chrysophane, it was mentioned that on treating the crude chrysophane with benzol, there is left undissolved a yellowish red residue, and that a further quantity taken up by the hot benzol is deposited as the benzoic solution of the chrysophane becomes somewhat cooled. Although the insolubility of this body in benzol led to its detection, the complete separation of it from chrysophane is attended with many difficulties on account of the latter substance modifying to a considerable extent the properties of the new body.

The best mode of separating the new body from chrysophane is to dissolve the precipitate entirely in hot benzol, and to allow the benzoic solution to cool slowly; the deposit which forms is then separated by filtration, and dissolved by heat in glacial acetic acid, from which it is obtained, in a state of considerable purity and in beautiful crystals as the solution cools. This treatment with acetic acid appears to be essential on account of its removing some foreign matter, the presence of which interferes with the crystallization.

After purification in the foregoing manner, the new body may be dissolved in boiling alcohol, from which it separates on cooling in splendid prismatic crystals, sometimes two inches long, associated in concentric aggregations.

This substance, for which for the present we propose the name

of *Emodin*, is of a bright deep orange colour; in thick crystals it assumes almost a red tint. The crystals are monoclinic prisms, extremely brittle, and resembling isatin in appearance.

Emodin does not melt at a temperature below 250°C. (482°F.), while chrysophane melts at 162°C. ($323\cdot6\text{F.}$); during the fusion, a small portion volatilizes undecomposed, giving a yellow vapour which first condenses to a yellow liquid, and subsequently solidifies to a crystalline mass.

In its chemical properties, emodin closely resembles chrysophane, the different behaviour to some solvents being the principal distinction between them. Emodin is much more soluble than chrysophane in alcohol, glacial acetic acid, and amylic alcohol. In benzol, however, emodin is much less soluble than chrysophane; hence the value of the solvent in the separation of the two bodies.

Caustic alkalis dissolve emodin with the same phenomena as occur in the solution of chrysophane, and ammonia behaves to it as it does to the latter substance, giving a purple liquid, and flying off completely on evaporation of the solution.

On combustion, emodin gave the following numbers:—

I. 0.165 gramme substance gave :

0.4035 „ Carbonic acid = 66.69 Carbon

0.0605 „ Water = 4.07 Hydrogen.

II. 0.1688 gramme substance gave :

0.4120 „ Carbonic acid = 66.57 Carbon.

0.0603 „ Water = 4.13 Hydrogen.

The purely empirical formula $\text{C}_{40}\text{H}_{15}\text{O}_{13}$ agrees well with the foregoing analysis, as will be seen from the following table:—

	Theory.		Experiment.		Mean.
	I.	II.	I.	II.	
C_{40} —	240	—	66.85	66.69	66.63
H_{15} —	15	—	4.18	4.07	4.10
O_{13} —	104	—	28.97	..	29.27
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	359	100.00			100.00

Up to the present time, we have not been able to determine any rational formula for emodin.

IV. ACTION OF NITRIC ACID ON APORETIN.

When crude aporetin (that which we used for these experiments, contained phæoretin,) is brought in contact with concentrated nitric acid, a red-brown solution is formed which generates heat, and, evolving nitrous fumes, undergoes further decomposition; if, after the evolution of nitrous fumes has somewhat ceased, the action be assisted by heat, taking care that an excess of nitric acid is present, it will be observed, after boiling the mixture for several hours, that a yellow substance deposits, and that a further quantity may be obtained on the addition of water to the solution after it has become cold. This yellow body is a nitro-compound of acid properties, and is the principal product of the action of nitric acid on aporetin.

The mother-liquor is of a dark yellow colour, and gives, on evaporation, (which is facilitated by adding, from time to time, small quantities of alcohol in order to carry off the nitric acid,) a considerable quantity of oxalic acid coloured yellow with extraneous matter.

The liquor from which the oxalic acid has been separated, gives with alkalis, brownish red tints, in consequence of the formation of salts with an acid still to be examined.

No picric or styphnic acid could be detected among the products of the action of nitric acid on aporetin.

If the yellow nitro-compound is washed on a filter with water, the latter acquires, after some time, an amaranth-red colour; if the washing be continued with considerable quantities of water, it still continues to acquire a deep red colour without diminishing materially the bulk of the nitro-compound.

Boiling water and boiling alcohol dissolve the nitro-compound, and acquire a red colour, but the nitro-compound separates, on the cooling of these solutions, as a yellow powder. Alkaline solutions, when dilute, produce, with the nitro-compound, red solutions, but, when concentrated, a flocculent brown compound deposit, and the solutions become also brown in consequence of their decomposition.

Concentrated ammonia, at ordinary temperatures, forms a beautiful violet compound, part of which precipitates; when dry, it has a bronze lustre. The ammonia compound is soluble in water with a violet colour; acids do not precipitate the original yellow nitro-compound from this solution (as is the case when a very dilute

solution of ammonia is taken), but a violet compound which is soluble in an excess of acid with a red colour.

With a cold concentrated solution of carbonate of potash, the nitro-compound forms a reddish brown crystalline powder which dries with a metallic lustre; it is not very soluble in cold water, but dissolves much more readily in hot water with a purple colour. A hot solution of carbonate of potash acts like a solution of caustic alkali, producing instantaneously, with decomposition, a flocculent brown body.

The solution of the nitro-compound in ammonia changes its colour upon the addition of sulphuret of ammonium to purple and then soon to a dark indigo blue. If an acid be now added to this blue solution, a dark purple precipitate is the result; the precipitate settles readily, and when washed with cold water and dried, resembles indigo. Water dissolves this blue body very sparingly, with a purple colour; the alkalies dissolve it, giving a splendid blue solution. The blue compound is also formed when the solution of the nitro-compound in alcohol, to which has been added a small quantity of hydrochloric acid, is brought in contact with metallic zinc.

The dry nitro-compound, if slowly heated on platinum foil, gives off yellow fumes, leaving a carbonaceous residue; if quickly heated, it deflagrates, but the combustion in this case is also incomplete.

The behaviour of the nitro-compound produced by the action of nitric acid on aporetin, tends to prove that it is identical with chrysammic acid, which is so well characterized by its potash salt, by its transformation into chrysamminamid, and especially by the formation of that beautiful blue compound hydro-chrysammid.

The formation of chrysammic acid from aporetin is of some interest, inasmuch as it has hitherto only been obtained from aloes; it is therefore our intention to completely establish the identity of this acid as prepared from aporetin with that resulting from the action of nitric acid on aloes, by analyzing our substances as soon as we have a sufficient amount of material at command.