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ON ARSENIC AS A POISON; ITS TESTS AND ANTIDOTE.

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Arsenic is a substance so commonly used for criminal purposes, and so little under the control of any chemical substance as an antidote, that it is very desirable to establish some certain mode of *detecting* and *showing* it so clearly that medical practitioners may be able to swear, *most positively*, as to its existence or not.

The late trial of Madame Lafarge, in France, although the chemical and physiological parts of it were conducted by some of the first men of the age, terminated in such a manner as to convince most English chemists that the proof of arsenic having existed in the body of Lafarge, was not established in so distinct a manner as would have carried conviction in this country; and, as I took great interest in it whilst it lasted, I was led to attend to the subject.

In order to show the existence of arsenic in a court of justice in England, we should be enabled to prove the following facts so satisfactorily, that a jury may not only see, but *perfectly understand* them.

1st. The *metal* should be produced either from the contents of the stomach, intestines, or urine, if the patient should survive; or, if dead, from those and some part of the body.

2nd. We should be able to prove that the animal substances experimented upon were the excretions, and parts of the patient's body only; *unmixed with any other matter*.

3rd. We must also prove that the tests we use to show the existence of arsenic *have not a particle of arsenic in themselves*; and this requires great caution, because a skilful advocate might make a guilty prisoner appear innocent, owing to this omission.

4th. As *antimony, bismuth, tin, zinc, lead, tellurium, cadmium, selenium, and potassium*, sublime in a somewhat similar manner to *arsenic*, and *may be mistaken for it*; it is quite necessary for an inexperienced eye to guard against such a mistake.

It is therefore my intention, in as simple and clear a manner as I possibly can, to endeavour to show that arsenic can be tested from the most minute particle, so clearly that an unscientific person cannot mistake it; and, also, that this can be done easily, without using any chemical substance known to contain arsenic.

The most common and efficacious manner of proceeding, when the contents of the stomach, or a decoction of the stomach, liver, &c., in distilled water, is to be operated upon, is that recommended by Dr. Christison. The first point is to get rid of the animal matter. After boiling for half an hour in distilled water, the solution

should be filtered. This is a tedious process. When you have obtained a clear solution, animal matter may often be deposited by adding strong acetic acid, which coagulates the casein. Neutralize this acid with potass or ammonia, and then try the sulphuretted hydrogen test. If this does not act, all you have to do is, slowly to evaporate the solution to dryness in a porcelain dish, redissolve it in distilled water, and when cold, filter. This process, several times repeated, eventually gets rid of the whole of the animal matter.

I had an opportunity of proving this a few years since, in the case of a cow belonging to a nobleman in the neighbourhood, which had been evidently poisoned. Mr. Peach, our eminent veterinary surgeon, was called in, who not being willing to give an opinion as to what was the poison, his lordship begged of me to try to ascertain it. At that time the stomach and its contents had been buried a day or two, and I had to pick out any part that appeared inflamed to operate upon. The animal matter in this case was very large, but by attending to the above rules, I obtained a sufficient quantity of arsenic to have convinced, as I then thought, the most sceptical of its presence. I showed the crust I procured to Mr. West, of Leeds, who said there was no substance but arsenic capable of showing that appearance.

When a clear solution is obtained, with but a small portion of animal matter in it, the *ammoniacal nitrate of silver* gives a *lively lemon-yellow precipitate—the arsenite of silver*. The *ammoniacal sulphate of copper* gives an *apple or grass-green precipitate—the arsenite of copper*. And the transmission of *sulphuretted hydrogen gas* through this solution, previously neutralized, and then slightly acidulated with acetic acid, throws down an abundant *sulphur-yellow precipitate—the sulphuret of arsenic*.

It is the best plan to boil the last precipitate in the solution a few minutes, which drives off the excess of sulphuretted hydrogen gas, and allows the whole of the sulphuret of arsenic to deposit. This is to be collected on a filter; dried on a watch glass; introduced into the bottom of a bulb tube, and covered with black flux, or what is perhaps better, freshly ignited charcoal. The tube is then to be heated by a spirit lamp, first at the part just above where the flux is, and then gradually below, so as to sublime the metallic arsenic all round the tube; which forms a *brilliant polished metallic appearance*, that cannot be easily mistaken when once seen: and which I once heard given in evidence as the only proof of arsenic in one of our courts of justice:—the fallacy of which opinion I think I shall be able to prove.

The metallic arsenic should afterwards be oxidized by the heat of the spirit lamp and the oxygen of the air, and driven up the tube, so as to allow it to form *octohedral crystals of arsenious acid, with triangular facettes*.

In estimating the process which I have now

described, an English jury would wish to know, before they condemned a fellow creature to death, *if there is no other mode of detecting and proving arsenic; and if no other substance gives the same crystals as arsenious acid?*

This gap was, in a degree, filled up, by Marsh's hydrogen test; where hydrogen gas is generated from zinc, sulphuric acid and water, and the suspected substance in solution added to it; if arsenic be present, hydrogen has such an affinity for it, that it will combine with the whole of it very quickly. The arseniетted hydrogen being ignited, the *metallic arsenic* is deposited on porcelain or glass, which can be seen in *rhomboidal crystals* with a powerful microscope.

The only objection to this test is, that you are obliged to use *zinc*, which is *known often to contain arsenic*: and, although it shows the most minute portion of arsenic that can possibly be exhibited, yet, *how can you swear that, after the first layer of zinc is oxidized, there may not be some arsenic in the next?* for we know that arsenic runs in veins of the zinc ore.

The next test I would describe is that beautiful one of Professor Reinsch, modified by Christison, which is well suited for detecting arsenic in animal and vegetable substances. Mix the suspected matter with distilled water: add at least two drachms of pure hydrochloric acid to every eight ounces of fluid. Put a few bits of very thin and bright copper plate into it, boil for half an hour, and the arsenic will be gradually deposited on the copper plates. We have here for analysis, animal matter in solution with arsenious acid by heat, hydrochloric acid, water and copper. As far as I can ascertain at present, the following is the result. The water and arsenious acid are both decomposed: the oxygen of the water unites with the copper, forming oxide of copper: the hydrogen of the water unites with the metallic arsenic, forming arseniетted hydrogen, which is decomposed by the oxide of copper—the metallic arsenic of the arseniетted hydrogen forming a coat on the oxide of copper; while the free hydrogen goes to combine with another portion of the oxygen of the arsenious acid, and forms water: thus accounting for the gradual coating of the copper with arsenic. The hydrochloric acid unites with the ammonia of the animal matter as it is decomposed by the heat, forming hydrochlorate of ammonia; and, if in excess, remains free in the solution. These arseniетted copper plates are to be taken out, cut into small chips, introduced into a bulbéd tube, and exposed to a low red heat over a spirit lamp, and the *arsenious acid* is sublimed in *octohedral crystals with triangular facettes*. These may be rendered more distinct if you turn out the copper chips, close the tube with the finger, and chase the oxide up and down with the lamp. By dissolving this oxide in distilled water, you may go through the whole of the former tests.

A very easy mode of ascertaining the *exact weight of arsenic* in any given quantity of fluid, would be to previously weigh the dry glass tube before introducing the arseniетted copper chips, and to weigh it again after the arsenious acid is sublimed; the copper being removed, the increase in weight would give the quantity of arsenic.

A most ingenious, scientific and elegant mode of detecting arsenic has lately been introduced by Robert Ellis, Esq., of University College, London; to whose polite attention I am indebted for his apparatus, made entirely of glass, in which I have now the pleasure of exhibiting his plan. He has discovered that the oxides of copper have such affinity for arsenic, that by merely passing arseniетted hydrogen over them, a double decomposition takes place; caloric is given out; the oxygen of the copper uniting with part of the hydrogen, forms water, which is seen in the process; the arsenic of the arseniетted hydrogen uniting with the copper, forms arseniuret of copper:

the remaining hydrogen being set free. This arseniuret of copper may be easily sublimed in a glass tube; when the whole of the *arsenious acid* will be deposited in *thick brilliant clusters of octohedral crystals* on the tube.

The objection urged against Marsh's apparatus, will, of course, equally apply to this, in being obliged to use zinc for the generation of hydrogen.

There is another test which I think deserves more attention than it has yet met with—viz., the *decomposition of distilled water by galvanism, to which the suspected solution is added, with pure sulphuric acid*, collecting the hydrogen from the negative pole or zincode of Smee's battery, igniting it, and examining the stain left in a glass tube open at both ends. If there is the smallest particle of arsenic, the hydrogen will combine with it, and you then have a stain of *metallic arsenic with rhomboidal crystals*; which you may oxidize, collect, and dissolve in water; go through the fluid tests, reduce the sulphuret in a tube, and sublimite it into arsenious acid again. This is the most delicate test known, and is perfectly free from the charge of using any substance in which arsenic can exist; on which account I think it the most valuable of them all, and the one to which I would this evening particularly direct the attention of the Society.

I have likewise combined this mode of producing arseniетted hydrogen with Ellis's plan of testing it by the oxides of copper, and have succeeded in obtaining decided crystals of arsenious acid by it; thus doing away with the necessity of using zinc.

The most likely substance to be mistaken for arsenic by any of these tests is *antimony*, because *antimony sublimes into the same kind of crystals as arsenic does*. But by attending to the following rules the two substances may, I think, be easily distinguished.

Metallic arsenic sublimes at a heat of 356° without liquifying into rhomboidal crystals; arsenious acid sublimes at 380°, into octohedral crystals; metallic antimony sublimes not under 810°; and on cooling, acquires a highly lamellated texture, and yields octohedral crystals like arsenic. After you have obtained a deposit of the suspected metal in a glass tube, if you heat the tube gradually by a spirit lamp; *should the metal be arsenic*, it sublimes on the *cool part of the tube into octohedral crystals*; which can be dissolved in water, and tested by the three fluid tests. If it is *antimony*, it first produces *dense white fumes*, and an *amorphous white powder is deposited*; and the heat being kept up, the tube is lined with a *white crust, which is insoluble in water*.

By this method, both arsenic and antimony may be tested at the same time. *Arsenic* will be sublimed in oxide at the *cool part of the tube*: antimony remaining at the *hot part*.

In the reduction test with sulphuretted hydrogen gas, it should be carefully remembered that the *sulphurets of antimony, tin, selenium, cadmium, and tellurium*, have nearly the same yellow colour, and are deposited in the same manner as the *sulphuret of arsenic*; and when reduced to their metallic state with black flux, they not only give an appearance so much like arsenic, that it requires a very practised eye to distinguish each—if even that be possible, but tellurium and cadmium also exhale a garlic odour, like arsenic.

L. Thompson, Esq., has shown that *antimoniu-retted hydrogen* when ignited, not only gives a stain very similar to arseniетted hydrogen, but also that the smell of both are very similar, and suggests the following mode of distinguishing them:—Dissolve the crust left on the glass by a drop of nitric acid: evaporate it to dryness, and a white powder will be left in either case: add now, a little weak solution of nitrate of silver, and expose it to the fumes of ammonia from a glass stopper. Antimony will give a white precipitate, and arsenic a yellow flocculent one. In answer to the above objection, Marsh proposed the following

ingenious plan :—Moisten the porcelain or glass with a drop of water, and hold it an inch above the flame of the jet of burning hydrogen: the arsenic, if any, will be oxidized at the time the hydrogen is undergoing combustion, and is dissolved in the water as arsenious acid; which can be proved by adding a drop of a solution of nitrate of silver to it, which gives a lively lemon-coloured precipitate, while the colour of antimony will not be changed. But I have so repeatedly found phosphuretted hydrogen give the same results, that I cannot think this test can be depended upon.

The question then comes—*how can a witness swear most positively that a substance is arsenic, and nothing else? And how can he convince an unscientific jury of that fact?* I think, only in the following manner :—

1st. *By producing the metal and showing its crystals.*
 2nd. *Reducing it to the oxide, and showing its crystals.*
 3rd. *From these crystals going through all the fluid tests.*

4th. *Reducing the sulphuret again to its metallic state, then to the oxide, and again going through the fluid tests.*

5th. And if this be shown clearly, with all the before mentioned tests, it will be impossible for any advocate to mislead a jury.

There is no substance but antimony that will form crystals like arsenic, which can be mistaken for arsenic by any other test.

It is not at all necessary here, to describe the symptoms attending poisoning by arsenic; but I would remark that there may be a great deal of injury done by improper interference with the stomach pump, in consequence of the softening of the sub-mucous cellular tissue from acute inflammation. As far as I have been able to collect from the best writers on this subject, the following is the most successful mode of managing these cases. If called in immediately after arsenic has been swallowed, use the stomach pump at once: inject large quantities of milk; or, if not at hand, mucilage or groat gruel, and withdraw it again repeatedly. Or if the stomach pump is not ready, and vomiting does not exist in consequence of the effect of the arsenic, it should be promoted (in a case where there will be no legal inquiry instituted) by giving a large dose of sulphate of zinc immediately, shortly followed by copious doses of the moist hydrated per-oxide of iron, in water or milk, until you can procure it. But when the life of a fellow-creature will depend upon the evidence given as to the chemical proof of arsenic having been exhibited, it was suggested by Dr. Favell, the President, that either sulphate of copper or mustard should be used as an emetic, instead of zinc, to prevent the possibility of an advocate having it in his power to say that zinc had been used in any form. Although pure crystallized sulphate of zinc could not possibly contain arsenic, I think this is a very proper precaution.

The only antidotes which have been discovered for arsenic are the moist hydrated per-oxide of iron, and the moist hydrated per-sulphuret of iron. A few years ago I tried the effect of the hydrated per-oxide of iron on six dogs of the same age. I gave each of them ten grains of oxide of arsenic in various forms. The first was killed with it in four hours. In the second, I allowed half an hour to elapse before I gave the iron: he died. To the third I gave the iron with the arsenic: he never had a symptom of poisoning. The fourth I killed with the iron, as it was not well prepared. The 5th took the iron a quarter of an hour after the arsenic: he was very ill several days, but perfectly recovered. The 6th took it half an hour after the arsenic, and died the following day. I examined the stomachs of all the dogs that died, and found them exhibit the highly injected diffuse red appearance so well described by Drs. Hope, Carswell, and Roupell, in their plates.

I have lately given dogs and rabbits large doses of arsenious acid in solution and powder; and immediately afterwards large doses of the moist hydrated per-

oxide of iron, and then killed them within a short time. The stomachs have shown patches of inflammation, but no arsenious acid could be detected by Reinsch's method, the copper plates having merely a scaly deposit of iron upon them; nor could arsenious acid be detected in any other way. This is a strong presumption that the whole of the arsenic was reduced to its metallic state. So that, from the results of my own experiments, and the accounts I have read of the successful use of the hydrated per-oxide of iron as an antidote to arsenic in the human subject by many practitioners, I am induced to place great reliance on this substance.

In the 1st vol. of the London Medical Gazette, for 1841-2, page 116, is a communication from the celebrated Dr. Beck, containing an account of no less than twenty-nine successful cases of recovery from poisoning by arsenic, by the prompt use of the moist hydrated per-oxide of iron in the human species. And I could point out more, which I have observed related in the journals.

The last edition of the Edinburgh Pharmacopœia gives a very good formula for preparing this antidote, under the name of "Ferrugo." It can be kept good, and fit for use, in stoppered bottles, covered with water. I respectfully beg to suggest to my medical brethren, that they provide themselves with a proper supply of it, so as to be ready in a moment. A table-spoonful should be given in plenty of water, every five minutes, to an adult; and a dessert-spoonful to a child, until relief from the urgent symptoms is obtained. *It is perfectly inert if kept dry.* Dr. Golding Bird has mentioned that the hydrated per-oxide of iron may be extemporaneously prepared, by adding one ounce of liquor potassæ, to half an ounce of tincture of sesquichloride of iron. This may be almost always obtained in a short time from any druggist.

I have never tried the moist hydrated per-sulphuret of iron, but have no doubt it may act as an antidote, by reducing the oxide of arsenic to a sulphuret, which is much less poisonous. The hydrated per-oxide, I should think, acts by the free hydrogen combining with the oxygen of the arsenic, forming water, and leaving metallic arsenic, which is insoluble and inert, behind.

The carbonate of iron is mentioned as another antidote, but I should prefer the others.

The stomach pump should never be used after the arsenic has had time to act on the mucous membrane, as it is very liable to penetrate through all the coats of the stomach.

Arsenietted hydrogen gas is the most destructive mode of introducing arsenic into the system. Several deaths have been recorded from it; and I would mention, with the most sincere regret, the state into which it has brought a most intelligent and valued pupil of mine. He is the inventor of the present mode of gilding and silvering by galvanism. Zinc is most extensively used in the works which he has superintended, and he has so long breathed an atmosphere of arsenietted hydrogen gas there, and in his private experiments, that it brought on a peculiar kind of epilepsy, much like what is described by Dr. Christison, which has latterly been gradually increasing; and his intellect, which was once one of the brightest, is now reduced nearly to fatuity.

There are a few more observations closely connected with this subject, which I should have taken the liberty of making, but I fear this paper will be considered too long already. It now only remains for me to thank you for so patiently listening to this very imperfect digest of so important a subject; and if the errors I have either committed or omitted, should lead my professional brethren to attend more minutely to the subject, and point them out, I shall with great pleasure receive their reproof and instruction.

The whole of the experiments described in this paper, with the pathological appearances of the stomachs, were satisfactorily exhibited to the Society.