disease little if any benefit is derived from treatment. In other words, those cases in which the disease has become established upon an organic foundation require to be lodged preferably in an institution for epileptics, where they may be prescribed (1) regular and congenial employment, (2) a judicious alternation of work and play, and (3) a suitably arranged and simple mode of life, with avoidance of excitement and abstinence from alcoholic liquors.

ON FERRO-SILICON, WITH SPECIAL REFERENCE TO THE POISONOUS GASES LIABLE TO BE EVOLVED THEREFROM.¹

By H. WILSON HAKE, PH.D., F.I.C., F.C.S.,

LECTURER ON TOXICOLOGY AT THE WESTMINSTER HOSPITAL MEDICAL SCHOOL AND AT THE LONDON SCHOOL OF MEDICINE FOR WOMEN.

Dr. Arthur Newsholme, in some prefatory remarks in a recently published supplement to the Thirty-eighth Annual Report of the Local Government Board dealing with ferro-silicon,² briefly sums up the circumstances which led to a special investigation of this material in the following words:—

The possibility of danger to life from the transport of ferro-silicon had already received attention in this country through a "Notice to Ship-owners, Shipmasters, and Shippers" issued by the Board of Trade in September, 1907, but the magnitude of the risks involved in the treatment of this material and the need for more stringent regulations was strikingly demonstrated by the death of five Russian immigrants on board the s.s. *Ashton* in December, 1908, during this ship's voyage from Antwerp to Grimsby. Inquiries made on behalf of the Local Government Board into this occurrence brought to light a number of previous accidents in connexion with the transport of ferro-silicon, and after conference with the Home Office and the Board of Trade the full investigation of this subject was placed in the hands of Dr. Copeman.

For the purposes of this investigation Dr. S. M. Copeman visited in the first instance Sheffield, and later Rotherham, Hull, Grimsby, Liverpool, Manchester, and Wednesfield, and was assisted in his inquiries in Sheffield by Mr. R. S. Bennett, one of H.M. inspectors of factories. Dr. Copeman also visited various factories where ferro-silicon is made in the south-eastern district of France, whence the greater quantity of this material is exported to England. Ferro-silicon is also manufactured in some parts of Austria, Switzerland, and Italy, and in Norway and Sweden. Dr. Copeman inspected the various processes of manufacture, and collected a large number of samples of this material from the manufacturers and users, and I esteem myself fortunate in having been recommended by him to examine these samples chemically and "to assist in defining the nature and extent of the danger from ferro-silicon."

The report which Dr. Copeman recently presented on the whole matter covers 115 pages, and includes a report by Mr. Bennett on the physical structure and properties of ferro-silicon and my own investigations. This report is already becoming scarce owing to the great demand for it on the part of those specially interested, and I thought that a very brief *résumé* of the main facts set forth, and more particularly as regards the poisonous gases liable to be evolved from ferro-silicon, would also have a special interest for this society, as the subject is comparatively new from a toxicological point of view, and is essentially medico-legal in its aspects.

Nature and Uses of Ferro-silicon.

Few people are aware of the nature and uses of ferro-silicon, which has only been manufactured on a large scale during the last ten years and of which some 4000 tons are annually imported into England from France. Without entering into unnecessary details, I may say that ferro-silicon is a physico-chemical alloy of iron and silicon which is employed in the manufacture of steel. Silicon has a high calorific value and acts as a metallurgical fuel; hence, by causing molten steel to remain fluid for a long time it enables thin and intricate castings to be made, and by its reducing action it prevents the formation of blowholes in castings. The addition of silicon to steel imparts to it, among other valuable physical properties, a high tensile strength when

present to the extent of rather less than 1 per cent., together with small proportions of carbon and manganese. Hence, silicon steels are used in motor-car construction. The proportion of silicon in ferro-silicon varies from 10 per cent. to 96 per cent. When the proportion of silicon is under 25 per cent. the alloy is known as low-grade, while when it is above 25 per cent. the alloy is called high-grade ferro-silicon. The low-grade variety can be made in blast furnaces, but the higher grades require the very high temperatures only obtainable by the electric furnace. Hence, while low-grade ferro-silicon is made in England, high-grade ferro-silicon is at present almost exclusively manufactured on the continent. Although the high-grade variety is more costly, certain technical advantages derived from its employment have caused it to largely displace the low-grade ferro-silicon.

Fatal and other Accidents due to Transport and Storage.

It has, however, been discovered, and the facts have only gradually come to light in connexion with what seems to me an appalling sacrifice of human life, that high-grade ferro-silicon is liable to evolve gases of a deadly poisonous nature when brought into contact with water, or even when exposed to the action of moist air. In the first portion of his report Dr. Copeman describes in detail the various accidents, fatal and otherwise, which are known to have occurred up to the present time in connexion with the storage and transport of ferro-silicon. A very brief reference to these will be of interest.

December, 1903.—The earliest record is that of an explosion of some iron drums containing ferro-silicon which had been brought to Liverpool by the s.s. *Veria*. A porter was seriously injured by the explosion. The late Dr. Dupré, F.R.S., and Captain Lloyd, R.A., investigated the matter and attributed the explosion to the presence of phosphoretted hydrogen. Mr. Watson Gray came to a similar conclusion and also found that acetylene and arseniuretted hydrogen were evolved by the material.

January, 1905.—On the s.s. *Vaderland* during a voyage from Antwerp to New York 50 of the steerage passengers lodged over a hold in which a cargo of ferro-silicon was stored were made seriously ill by the fumes given off by this substance and 11 died on board. The deaths were certified as due to "pneumonia"; a first official inquiry attributed them to unknown causes; later, a fuller inquiry revealed the true cause.

October, 1905.—Dr. J. F. Robertson of Althorpe was called to the Keadby Canal to see two children, aged 3 and 4 years, lying ill in a canal boat. One of the children was dead before he arrived, the other was in a state of collapse and died soon afterwards. The father and mother suffered from abdominal pain, sickness, and diarrhoea. A peculiar and pronounced smell was noticeable in the cabin. No poison was found in the food or viscera in the post-mortem examination, only some congestion of the lungs was observed. Five tons of ferro-silicon were on board. Death was attributed to the fumes from this material. The coroner communicated the facts to the Board of Trade.

March, 1906.—Two children died on board a Rhine boat (*Caroline*) of Mannheim. There was a cargo of 750 cwt. of high-grade ferro-silicon on board which was stored immediately under the cabin. Dr. Lehnkering of Duisberg investigated the matter and proved the evolution of phosphoretted hydrogen from the cargo. The parents of the children suffered from headache and giddiness, but kept as much as possible on deck. Dr. Lehnkering refers to other similar instances of poisoning and one death on Rhine boats.

February, 1907.—The *Olaf-Wyk* arrived at Antwerp on the evening of Feb. 12th, having left Gothenburg on the 9th with six passengers; four of the passengers died during the voyage; the captain, the stewardess, and some of the crew were also taken ill, but recovered. Fifteen tons of ferro-silicon were on board in the hold of the vessel immediately under the passenger cabins. Professor Cronquist of Stockholm and Messrs. Bruylants and Druyts of Antwerp investigated the matter and proved evolution of phosphoretted and arseniuretted hydrogen. The latter calculated from their experiments that the cargo was capable of evolving 2500 litres of phosphoretted hydrogen containing 5 per cent. of arseniuretted hydrogen. (0.025 per cent. PH_3 in air is a fatal proportion.)

May, 1908.—On the s.s. *Vleaborg* during a voyage from Stockholm to St. Petersburg nearly all the crew and second-class passengers were taken ill; two deaths occurred.

¹ A paper read before the Medico-Legal Society on June 21st, 1910.

² On the Nature, Uses, and Manufacture of Ferro-silicon, with Special Reference to Possible Danger arising from its Transport and Storage (Cd. 4958), 1909.

Forty-five tons of ferro-silicon were stored in the holds of the ship.

October, 1908.—The "captain" and his mate on board the canal boat *Harry* were taken ill and died from the effects of poisoning by fumes from 91 barrels of ferro-silicon during a voyage from Goole to Sheffield. The "captain's" wife, Mrs. B., was taken ill, but recovered. The ferro-silicon was described as "scrap iron." Ptomaine poisoning was suspected at first. Legal proceedings were taken by Mrs. B., who was awarded damages.

Other canal-boat cases.—On further inquiry at Sheffield several similar cases on canal boats were brought to light. In one instance two boys aged 14 and 16 years, and in another two children were found unconscious in their cabins; in the latter case a dog was found dead in the same cabin.

December, 1908.—Finally, the death of five Russian immigrants occurred on the s.s. *Ashton* during a 24 hours' voyage from Antwerp to Grimsby. This was widely reported in the press and will probably be fresh in the minds of members of this society. Dr. W. B. Simpson investigated the cause of death. Cholera and ptomaine poisoning were suspected, but the deaths were finally traced to the evolution of gases from a cargo of ferro-silicon by Professor W. R. Smith.

Illness among workmen.—Reference is also made to illness among workmen in steel works due to fumes from ferro-silicon.

As already noted, it was this last unfortunate incident on the s.s. *Ashton* which determined the investigation of the whole matter by the Local Government Board.

It will have been seen that in connexion with most of the inquiries relating to these numerous fatalities there was, in the first instance, considerable mystery as to the cause of death, and although several eminent scientific workers were engaged in some of the investigations it only gradually became clear that this product of technical industry, which was held in such high esteem by its manufacturers and users, was also, under certain circumstances, a dangerous and deadly instrument of destruction.

Notwithstanding these tragic events the material continued to be manufactured and used, a condition which necessarily obtains when a large outlay of capital is involved, but some echo of a growing uneasiness began to be reflected on the part of shippers who refused to take consignments of ferro-silicon, and among foreign manufacturers, who met to discuss the precautions necessary to be taken in view of the fatalities which had occurred. Matters had reached this stage when Dr. Copeman commenced his inquiry, which may well be described as a delicate and difficult one, inasmuch as the interests of the steel trade were at stake as well as those of the manufacturers, and there was a tendency among shippers to condemn the material wholesale. More minute inquiries have shown that this dangerous tendency to evolve poisonous gases was more especially referable to certain grades of ferro-silicon, notably to those averaging a content of between 40 per cent. and 60 per cent. silicon, and that some of these grades especially showed the curious physical property of spontaneous disintegration; the lumps of which they consisted were found to be liable to crumble during transport and in some instances to actually fall to powder, thus presenting a larger surface to the action of a moist atmosphere and hence becoming liable to evolve greater quantities of injurious gases.

Chemical Investigation of Ferro-silicon.

A careful examination of a large number of samples has fortunately demonstrated that this tendency to disintegration is confined more especially to the middle grades, while in the lower and higher grades it is absent, and the serious situation which had arisen seems now in a fair way to a successful solution. I propose to show you briefly some of the steps by which this desirable conclusion was reached.

In describing my own experiments I should like to say that without the mass of information and intimate acquaintance of the various conditions involved, which Dr. Copeman placed at my disposal, I could not, even in the six months over which my work extended, have arrived with equal certainty at the conclusions which I am glad to think "assisted in defining the nature and extent of the danger from ferro-silicon." (I had over 70 samples of this material submitted to me, representing all grades and most leading manufacturers.)

I will first point out the origin of the impurities which

cause the evolution of these poisonous gases from certain grades of ferro-silicon. For this purpose I must refer briefly to the method of manufacture of the higher grades.

Manufacture.—A mixture of steel turnings obtained from gun foundries, together with quartz and coal from neighbouring mines, is put into an electric furnace of a capacity of about 1500 kilogrammes and heated to a temperature roughly computed at from 1800° to 2000° C. The quantities of quartz (which contains about 96 per cent. of silica or silicon dioxide, SiO_2) and anthracite coal (containing about 90 per cent. of carbon and 10 per cent. of ash) are always used in the proportion of one molecule of silica to two atoms of carbon, so that complete reduction of the former to silicon (Si) shall occur, according to the chemical equation:— $\text{SiO}_2 + 2\text{C} = \text{Si} + 2\text{CO}$. The proportion of iron taken varies, and depends on the grade of ferro-silicon required—that is, on the desired percentage of silicon in the alloy ultimately produced.

Impurities.—Certain impurities originally present in the coal, iron, and quartz used, or formed from them during the process of manufacture, are always present, and some of these, although amounting to a very small percentage of the finished product, are the ultimate cause of the serious mishaps which have arisen from the extended use of ferro-silicon.

Calcium phosphate [$\text{Ca}_3(\text{PO}_4)_2$], one of the impurities present in coal and in quartz, which in itself is a perfectly harmless salt, insoluble in water and widely diffused in nature, is responsible for the production of a dangerous compound by reduction in the electric furnace, in the presence of carbon, to *calcium phosphide* (Ca_3P_2). This calcium phosphide remains in the ferro-silicon, and in contact with water or moist air is decomposed with evolution of *phosphoretted hydrogen* (PH_3), the intensely poisonous character of which has been referred to above. I examined three samples of quartz and three samples of coal or coke used by various manufacturers and found calcium phosphate in considerable quantity in all of them.

Arsenic, again, an element closely allied to phosphorus in its properties, is another impurity liable to be present in various combinations in coal and in iron, and this element also finds its way into the ferro-silicon apparently as *calcium arsenide*. Calcium arsenide is also decomposed by water or moist air, evolving *arseniuretted hydrogen* (AsH_3), a gas scarcely, if at all, less poisonous than phosphoretted hydrogen.

Acetylene (C_2H_2) was formerly found as an impurity evolved by ferro-silicon, but this was probably due to the fact that furnaces used for the manufacture of calcium carbide were also used for making ferro-silicon. This is no longer the case. Acetylene is not generally considered poisonous unless present in large proportions in air, its alleged poisonous properties being in all probability due to a small amount of phosphoretted hydrogen which it is likely to contain.

Siliciuretted hydrogen (SiH_4) has also been somewhat loosely suggested as an impurity liable to be evolved by ferro-silicon, but this gas is decomposed in contact with moist air into silica and hydrogen.

From my own experiments, as well as from a consideration of the chemical facts above referred to and of the mode of manufacture, it became finally evident that the poisonous emanations evolved from ferro-silicon by the action of water consist mainly of phosphoretted hydrogen—sometimes alone, but for the most part accompanied by varying proportions of arseniuretted hydrogen. These two gases are deadly poisons, and among the symptoms common to both, produced by their inhalation, are severe abdominal pains, nausea, vomiting, great weakness and prostration, gradual loss of consciousness, and death frequently within 24 hours. Phosphoretted hydrogen has been proved by recent experiments³ to be fatal to animals when present in air in the small proportion of 0.025 per cent., and, so far as experience goes, arseniuretted hydrogen is scarcely less toxic.

Qualitative proof of phosphoretted hydrogen.—The first step in the examination of the samples was to prove by a qualitative test the presence or absence of phosphoretted hydrogen. I devised for this purpose a simple and rapid test based on Scherer's test for phosphorus in cases of poisoning by that element. Phosphoretted hydrogen, as is well known, blackens filter-paper which has been moistened with a solution of silver nitrate, but will not affect a test

³ Jokote: Archiv für Hygiene, Band xlix., pp. 275-306, 1904.

paper moistened with a solution of lead acetate. Inasmuch as sulphuretted hydrogen blackens both of these test papers this gas must be absent when the test is applied. In only one sample out of the many which I tested did I find sulphuretted hydrogen evolved by the action of water alone on ferro-silicon. I took a conical Erlenmeyer flask of about 75 cubic centimetres capacity and fitted it with a cork, into which was inserted a short piece of glass rod, the free end of which was drawn out so as to form a double hook. On these hooks were hung the two test papers above referred to. About 1 gramme of the freshly powdered sample was placed in the bottom of the flask, half a cubic centimetre of water was added so as to moisten the powder, and the cork with its suspended test papers quickly replaced in the neck of the flask. Without entering into details the following table summarises the results of this preliminary test with 64 samples:—

Percentage of silicon in samples.	Effect produced on test-paper, moistened with silver nitrate solution, by gases evolved from 1 gramme of powdered ferro-silicon samples by the action of water at ordinary temperatures.		
	Number of samples producing—		
	(a) Faint or no colouration.	(b) Brown, orange, or gradual black.	(c) Immediate intense black.
10 to 35	16	None.	None.
42 „ 52	1	4	28
60 „ 75	None.	2	7
80 „ 96	None.	2	4

Quantitative Determination of Poisonous Gases Evolved from Ferro-Silicon.

It is obvious from a consideration of the chemical work already published that the object of the various investigators has been in each case to show that, under the particular circumstances of a given fatality, sufficient amounts of phosphoretted (and arseniuretted) hydrogen were yielded by the action of moist air on the ferro-silicon cargoes to produce an atmosphere containing a toxic proportion of these gases. To prove this point they took samples of the ferro-silicon, and having broken them up into small fragments they placed them in a tube, flask, or other convenient vessel, so that moist air could be passed over the lumps and be subsequently examined by qualitative or quantitative tests. Great ingenuity and skill have been displayed in such experiments, but the processes employed were for the most part capable of affording approximative results only and tended rather to underestimate than otherwise the phosphorus and arsenic present in gaseous combination. The problem I had before me in examining a large number of samples of ferro-silicon from very various sources was, however, of an entirely different character, for it was obvious, in the first place, that it was essential not only to prove the presence or absence of phosphoretted and arseniuretted hydrogen, but to make the experiments in such a manner as to compare all the samples without prejudice to any particular manufacturer. In order to cope with this problem successfully it was clearly necessary to determine the total poisonous impurities in each of the typical samples examined. On this basis only was it possible to make a complete and entirely fair comparison. It further became necessary to devise some of the methods by which both the phosphoretted hydrogen and arseniuretted hydrogen could be accurately and separately determined, as especially in the case of the first-named gas no generally recognised methods have been suggested. I think, however, I have successfully overcome this difficulty. Estimation of phosphoretted hydrogen.—After several attempts to oxidise the phosphoretted hydrogen by passage of the gas evolved from the samples into (1) nitric acid, (2) permanganic acid, (3) bromine water, &c., none of which methods proved satisfactory for various reasons, I finally made the following three series of experiments on a number of typical samples, approaching the estimation from three entirely different standpoints, with what, I think, may be considered a practically perfect agreement of results. The following is a description of the methods employed:— In all cases immediately before making the estimations the sample was powdered and three quantities of 10 or 20

grammes were weighed at once and placed in three flasks of 100 cubic centimetres capacity, with 20 cubic centimetres of water, and the flasks corked. Identical samples were thus secured, and the following three estimations carried out without delay. (a) Estimation of silver precipitated from a decinormal solution of silver nitrate by the gas evolved from a known weight of the powdered sample by the action of water. [3 Ag = PH₃].—One of the flasks containing the sample mixed with water, as above described, was next fitted with a cork through which a piece of thermometer tubing, bent twice at right angles, was passed, a pipette being attached to the free end of this delivery tube. The flask with cork and fitted tubes attached was then fixed over a sandbath, and the end of the pipette arranged to dip to the bottom of a conical vessel containing 10 cubic centimetres of decinormal silver nitrate solution. The sandbath was then heated and the temperature gradually raised till the water in the flask boiled. As the gas evolved bubbled through the silver nitrate solution, a black precipitate of silver phosphide was immediately produced. The heating was continued usually for about 10 to 15 minutes until no more gas was evolved, which was proved by disconnecting the pipette from the delivery tube and testing the issuing steam with a moist silver nitrate paper, when usually no discolouration occurred or the faintest brown tinge was produced. The pipette was then rinsed into the conical vessel and the silver solution filtered from the black precipitate, which was washed until the washings were free from silver. To the filtrate were then added 10 cubic centimetres of strong nitric acid and 5 cubic centimetres of saturated iron solution, and it was then titrated with decinormal ammonium thiocyanate according to the well-known method of Volhard. The residual un-reduced silver was thus estimated. By this process, which has the special advantage not only of extreme accuracy but also of great rapidity, the weight of silver reduced by the gas evolved from a known weight of the sample is found. From the relation 3Ag=PH₃ the number of cubic centimetres of phosphoretted hydrogen corresponding to the weight of silver precipitated can be calculated. Absolutely identical results are obtained on repeating the estimations, provided that the material for experiment is taken from the same powdered example. (b) Estimation of gold precipitated from a solution of gold chloride by the gas evolved from a known weight of the powdered sample by the action of water. [Au = PH₃].—Exactly the same apparatus was used as above described and the experiment carried out in the same manner, except that the gas evolved was led into 25 cubic centimetres of a 0.5 per cent. solution of gold chloride and the metallic gold so precipitated was collected on a filter and weighed. (c) Oxidation, and estimation as magnesium pyrophosphate, of phosphorus precipitated as silver phosphide in a solution of silver nitrate by the gas evolved from a known weight of the powdered sample by the action of water. [Mg₂P₂O₇ = 2PH₃].—This experiment was carried out exactly as described under (a), but instead of filtering the silver solution, this solution, together with the suspended precipitate, was transferred to a dish, oxidised with nitric acid, the silver removed by means of sulphuretted hydrogen, and the phosphoric acid present estimated as magnesium pyrophosphate. The results of all three experiments in this series were then compared, and were found, on the whole, to agree closely, although one or two of the silver estimations showed a rather higher result than was given by the gold and pyrophosphate methods. The following examples illustrate this agreement:—

Number of sample.	Volume of phosphoretted hydrogen evolved from 10 grammes of powdered sample, calculated from:—		
	(a) Weight of silver.	(b) Weight of gold.	(c) Weight of pyrophosphate.
LI.	2.52 c.c.	2.36 c.c.	2.50 c.c.
LII.	3.03 „	2.93 „	3.00 „
XXXIV.	3.60 „	3.61 „	3.50 „
XXXV.	1.26 „	1.01 „	1.08 „
„	1.63 „	1.41 „	1.50 „
LIX.	4.74 „	4.39 „	4.42 „

(d) *Estimation of alkalinity (lime) of samples after being acted upon by water.*—It has already been pointed out that by the reduction of calcium phosphate [$\text{Ca}_3(\text{PO}_4)_2$] present in coal and quartz, calcium phosphide (Ca_3P_2) is liable to be formed during the manufacture of ferro-silicon.

I tested the samples of ferro-silicon after they had been acted upon by water and found that when any gas had been evolved the contents of the flask were invariably alkaline to litmus and that the water used contained free lime. I therefore made determinations of the alkalinity after the action of water in a large number of samples.

I had hoped that these lime estimations would add a fourth method to those already described for the estimation of phosphoretted hydrogen. But assuming the lime to have been originally present in the sample as calcium phosphide (Ca_3P_2), the quantities found corresponded, in the majority of instances, to only one-third or one-half of the volume of phosphoretted hydrogen found by the previous three methods, except in the case of samples containing from 60 to 96 per cent. silicon, where for the most part the agreement was fairly close, while in two instances an excess of lime was found. The discrepancies noted, therefore, require explanation, and the following occurs to me as probable—viz., that the greater amounts of phosphoretted hydrogen found by the first three methods of determination (which agree *inter se*) are partly accounted for by the presence of calcium phosphide and partly by the fact that some free phosphoretted hydrogen is occluded in the samples.

The assumption of occlusion in certain grades is strengthened by the sudden evolution of gas which occurs on breaking lumps of ferro-silicon containing about 50 per cent. of silicon. This sudden evolution of offensive gas which is so characteristic can scarcely be accounted for by the decomposition of calcium phosphide only, which, although it occurs rapidly in a moist atmosphere, is not instantaneous.

Arsenic.—That arseniuretted hydrogen is present in some samples has already been demonstrated by previous investigators. Apparently, however, no attempt has been made to test directly for arsenic in the gas evolved by the action of water on ferro-silicon, to effect which I devised the following experiment:—

Carbon dioxide evolved from pure marble and pure hydrochloric acid in a Kipp's apparatus was passed first through a Drechsel wash-bottle, containing a solution of sodium bicarbonate, to arrest any traces of hydrochloric acid, and next into a flask containing the powdered ferro-silicon and water. This flask was fitted with an indiarubber stopper perforated by two tubes, one for the inlet of the carbon dioxide, the other for the outlet of the same gas, together with any other gases evolved. The mixed gases were then passed through another Drechsel wash-bottle containing a little water, and finally through a calcium chloride tube before passing through a narrow tube of Jena glass with its end drawn out, such as is used for the deposition of arsenic from a Marsh-Berzelius apparatus. The Jena glass tube was heated by a small Bunsen flame.

The carbon dioxide gas was first tested for arsenic by passing it for a considerable time through the apparatus before putting the flask containing the sample into connexion. The flask containing 10 or 20 grammes of the powdered ferro-silicon together with 20 cubic centimetres of water was then connected up and gently heated and the carbon dioxide slowly passed through. In the majority of cases, with certain exceptions, a black deposit was obtained, which in all instances was proved to be arsenic by the production of well-defined microscopic crystals (tetrahedra and octohedra) of arsenious oxide in the usual way.

I had hoped to estimate the arsenic by this method, by weighing the Jena tube before and after the experiment, and did in fact make a few such weighings. Obviously, however, some phosphorus was also deposited, the amount of which, though exceedingly small, proved sufficient to entirely vitiate the quantitative estimation of the arsenic. Sometimes the phosphorus was just visible as an orange deposit near the flame, while sometimes, though present, was not to be seen. I therefore resorted to another method of estimating the arsenic after the removal of the phosphoretted hydrogen which is described later.

These preliminary experiments, however, served a useful purpose, and it is for this reason that they are mentioned—viz., they proved the simultaneous presence of phosphoretted

and arseniuretted hydrogen in the gases obtained direct by the action of water on ferro-silicon samples.

The phosphorus deposited with the arsenic in these experiments was proved to be such by conversion into phosphoric acid with nitric acid and application of the molybdate test. Some experiments were made with calcium phosphide and water alone under the same experimental conditions, the results of which showed that about 20 per cent. of the phosphorus present in the phosphoretted hydrogen evolved was thus deposited, the remaining 80 per cent. being volatilised.

Estimation of arsenic in the samples.—The gases evolved from 10 or 20 grammes of a powdered sample of ferro-silicon by the action of water were passed into decinormal silver nitrate solution and the reduced silver solution filtered. Any traces of arsenic present would be contained in the filtrate in the form of arsenious acid (Hoffmann's reaction). The filtrate was then poured into a Marsh-Berzelius apparatus in which hydrogen was being evolved. In nearly all cases, with some exceptions, arsenic was deposited as a mirror in the Jena glass tube and its weight obtained.

All the usual extreme precautions were taken in these estimations. The Marsh-Berzelius apparatus was entirely constructed of glass; the zinc and hydrochloric acid used for the evolution of hydrogen were specially tested for purity, &c., in the manner well known to toxicologists.

From the amount of arsenic obtained from a known weight of the sample the corresponding volume of arseniuretted hydrogen was calculated from the relation $\text{As} = \text{AsH}_3$.

The greatest amount of arsenic obtained from 10 grammes of any sample was 1.6 milligrammes. In some cases, however, the reaction was negative and in others varied from an unweighable trace to 1.2 milligrammes. The volumes corresponding to these weights are 0.0 to 0.47 cubic centimetre, or, expressed as percentage volume of total poisonous gas evolved, from 0.0 to 13.0 per cent., the average being about 7.5 per cent.

I have omitted reference to many other experiments which I made in the course of my investigations, such as determinations of relative hardness and specific gravity, observations as to presence or absence of disintegration after the lapse of some months' storage, and of the effect of exposure of samples to moist and dry air respectively, all of which are described at length in the Local Government Board Report. I should also have liked to refer to Mr. Bennett's interesting report on the physical structure and properties of ferro-silicon, but time will not permit me to discuss these points.

I will therefore conclude by a reference to the general summary of my results in which I have expressed approximately the total volume of poisonous gases evolved from some samples of ferro-silicon in cubic feet per ton. The following abbreviated table will suffice to indicate the general results arrived at on this point:—

Percentage of silicon in samples.	Number of samples examined.	Number of samples evolving PH_3 and AsH_3 in contact with water.	Range of volume of poisonous gases evolved (cubic feet per ton).
10-29	3	1	0.26
30-35	1	1	0.13
42-49	9	9	2.1 to 16.4
50-52	8	8	2.4 to 15.8
60-62	1	1	1.0
70-96	6	6	2.1 to 5.7
—	28	26	—

These figures are given with a view to emphasise the potential danger of certain grades of ferro-silicon in connexion with its transport, storage, and use in large bulk; and when it is remembered that phosphoretted hydrogen acts fatally when present in so small a quantity as $2\frac{1}{2}$ volumes of the gas in 10,000 volumes of air, and that arseniuretted hydrogen is scarcely less dangerous, it will be seen that the atmosphere of a cabin on board ship might, under certain conditions, very rapidly assume a toxic character if ferro-silicon forms a part of the cargo, as has indeed been sadly demonstrated by the fatalities already recorded.

After consultation with Dr. Copeman, and as a general conclusion based on the examination of 64 samples of all grades, I have classified these grades in three groups as follows:—

Class I., 10 to 30 per cent. silicon, containing practically no poisonous impurities and not liable to spontaneous disintegration.

Class II., 70 to 96 per cent. silicon, not entirely free from poisonous impurities but also not liable to disintegrate spontaneously.

Class III., 35 to 60 per cent. silicon, containing, in most instances, a considerable proportion of poisonous impurities and in addition being more or less liable to spontaneous disintegration.

Finally, I am pleased to be able to state that the summary of conclusions and suggested regulations as to precautionary measures in connexion with the transport and storage of ferro-silicon put forward by Dr. Copeman on pp. 113–115 of his report have been officially adopted without any modification by the Board of Trade.

ON THE NOTIFICATION OF CONSUMPTION.

BY THE RIGHT HON. R. FARQUHARSON, M.D. EDIN.

IN January of this year what the admirable John Burns calls “our great Notification of Tuberculosis Order” was issued, and is now, I presume, rigorously enforced. Medical opinion seems to be strongly in its favour, and the general public, with the indolent and lamblike docility which is so much easier than independent thought, peacefully follow suit. Shall I be considered very ignorant and retrograde if I interpose my possibly insignificant Partington mop between these surging, popular waves and their victims, and give some reasons for my belief that this legislation is hasty, unnecessary, and likely to cause so much oppression, that many may consider the remedy to be even worse than the disease.

Now, on what do I base this conviction? First and foremost on the admitted fact that consumption, instead of being on the increase, is rapidly diminishing, and although it is sadly true that “the world loses 70,000 people through the scourge of tuberculosis every year, in the past 40 years it has been reduced some 50 per cent. The death-rate was 247 per 100,000 in 1860–70; it was but 115 per 100,000 in 1906, or 52 per cent. decrease in forty years.” There can be no doubt about the absolute authority of these figures, for they were quoted by the President of the Local Government Board in the practical and eloquent address delivered by him when he opened the Whitechapel Tuberculosis Exhibition in June, 1909.

And do they not give us cause for serious reflection? If the incidence and spread of consumption are really on the downward grade, what is the excuse for all this excitement and worry about it? The British nation, as we all know, are subject to periodical scares, which blaze up on slight provocation and happily cool down with equal rapidity, and it ought to be the duty and the privilege of the medical profession to check the supply of fuel to the flames. Many ignorant people honestly believe that mere contact with a consumptive is dangerous; that the air they breathe is impregnated with infection, and that if he ventures to spit, they must flee in terror to some safer place. Foreign health resorts are boycotted because a few poor victims may be seen to drag their feeble limbs up and down the parade, or to seek the sheltered security of a bath-chair. The phthisical member of a family is looked upon with suspicion; a fit of coughing at a public dinner table fills the other guests with dismay, and if the official regulations for compulsory notification are rigidly enforced, the working man, branded as a leper and proclaimed to the world as a focus of infection, must necessarily join the already swollen ranks of the unemployed and with his family belongings become a burden to the State.

Now comes the next and even more important point—and that is a grave doubt in my mind as to the really dangerous infection of consumption. In my student days we were taught to look upon the Italians as little better than lunatics because they brought forward plausible evidence in favour of the direct personal communication of tubercle, in which they enthusiastically believed, and professional scepticism on this

point was not only removed but exchanged for ardent advocacy the other way by Villemin's experiments. Scientific scepticism is a valuable thing, more especially when it is allied to Scotch caution, so I think I need make no apology for hesitating to accept the brilliant Frenchman's conclusions as absolutely satisfying. An animal known to be exceptionally susceptible to consumption is removed from its familiar surroundings. It is closely caged in a box under depressing and insanitary conditions; a lump of tubercle (probably what Professor Sims Woodhead calls “a maximum dose of infection far in excess of what was necessary to produce infection under ordinary circumstances”) is violently thrust into its tissues, and before it has had complete time to recover from the shock and general disturbance it is killed and evidences of infection are not unnaturally found. I for one decline to accept the full analogy between this artificially created chain of events and what takes place in the human body, and to show that I do not stand alone in doubting the necessarily fertile effects of the grain when planted on ordinary soil I will appeal to the high authority of speakers at the recent conference in Edinburgh—many of whom agreed that caution towards animal experimentation was necessary.

The first witness I call in favour of my contention is no less a person than the late President of the Royal College of Physicians of London. My friend Dr. D. W. Samways of Mentone, in a remarkably able and suggestive letter in the *British Medical Journal*, quotes Sir Douglas Powell as saying:—

My own personal experience and observation convince me that, apart from artificial conditions, such as those brought about by experiment and in the ordinary circumstances of life, phthisis is not an infectious malady.

Laennec's experience was the same, and Dr. Samways adds his own opinion:—

It took centuries for the profession to discover phthisis was infectious, and it is doubtful had we depended upon clinical observation and experience alone whether it would not have taken centuries more. Is a phthisical patient who has been taught to expectorate into a suitable receiver a danger to anyone? If not, why should he be treated as an outcast?¹

The opinion of the world-renowned authority, Koch, stated in his paper translated for the Sydenham Society by Mr. Stanley Boyd:—

Many practical men have no doubt kept in mind the possibility of infection, but with the medical profession generally phthisis is regarded as the result of constitutional peculiarities rather than of direct contagion.

Dr. Sinclair Coghill spoke of consumption as “conditionally infectious—i.e., certain conditions must be present before the invading element, the bacillus, can initiate the infective process”; and, again, Sir Hugh Beevor concluded as a result of a close examination of the problem that “the term infectious is too loose a term to apply to both measles and tuberculosis.” He suggests that “sub-infectious” is the most appropriate term.

Whitelegge and Newman in their text-book speak of phthisis as “a true infective disease, but a sub-infectious one.”² Dr. Hermann Biggs has laid special stress on the importance of differentiating between tuberculosis and the acute infectious diseases, and Dr. H. T. Bulstrode, with the judicial impartiality which distinguishes his admirable report, thus sums up the case:—

Tuberculosis may, perhaps, be best viewed as occupying a distinct and separate position from the exanthemata, and as regards its duration, and low degree of infectivity, meriting a class by itself. (The italics are mine.)

But if consumption were really so infectious in its nature as popular, no less than some medical, opinion seems to believe, we should naturally find that those whose occupations bring them perpetually into contact with the sick would fall victims to the disease. But here again the evidence points the other way. Dr. Samuel West, one of our leading authorities, says:—

If phthisis were a contagious malady we should expect to find the clearest proof of it among those who are placed relative with the sick, e.g., among married couples, among nurses and doctors, and among inmates of the same house or institution.

And Ransome also says:—

That if the simple contagion theory were true, hospitals for consumption should have been, at any rate in the past, centres and hotbeds of

¹ Misconceptions concerning the Riviera, *Brit. Med. Jour.*

² Report of Medical Officer of Local Government Board, 1905, p. 77.