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SOME PROBLEMS OF THE INDUSTRIAL CHEMIST[1]

THIS address or talk is the outcome of a conversation with Professor Dennis a couple of months ago. After a rather prolonged discussion of many phases of industrial chemistry of mutual interest to both of us, he very kindly suggested that you as students and workers in chemistry might be glad to hear some of these same problems discussed in the same way. I am particularly happy to undertake this task because for six years I was a part of the university here and looked at chemical problems from what I may collectively call the university point of view, while for the last nearly four years I have been engaged in looking at these problems mainly from their commercial side. Due to a combination of circumstances, it was necessary for me to assume responsibility in manufacturing chemicals along lines I had never anticipated, and to come into intimate contact with every phase of the history of these chemicals, including their sale. A further combination of circumstances has put me into intimate touch with many industries not primarily chemical, but, being users of chemicals, they have troubles and call for assistance.

When you leave the university you will, as I have, of course, many times be forced to assume the responsibility of making decisions and giving some kind of a sensible judgment based on inaccurate knowledge

[1] Address given before the Cornell Section of the American Chemical Society, February 27, 1908.

or insufficient data. Many times you will fervently wish that you had become more thoroughly familiar with the characteristics of this or that chemical, or with standard practise in machine design, factory construction, the iron and steel industry, boiler construction, engines and a thousand and one things that could not possibly all be crowded into a college course of reasonable length. I have had under my direction or in my employ or associated with me quite a large number of engineers, chemical engineers, engineering chemists, industrial chemists, industrial engineers, draftsmen, chemical experts, manufacturing chemists and just plain chemists, besides one or two of those chemists who would have graduated in June only their eyes gave out about the first of February. These men have been graduates of European universities, including Berlin, Luxembourg and Upsala; American universities, including Cornell, Harvard, Princeton, Syracuse, Lafayette, Vermont and Massachusetts Institute of Technology and the Rensselaer Polytechnic; others of the men, among them some of the most efficient in chemical manufacture, have had no university training whatever, but have entered chemical works as boys and obtained their training there.

I have endeavored to note the merits and deficiencies of all these men as well as my own shortcomings, or lack of preparation, and want to give you to-night, first, a few of the lines along which I think you would do well to work in your chemical preparation, and, second, sketch a few of the industries which show a good future for the chemist and a few of the problems that confront him there.

The selection of the subjects to be considered will be a purely arbitrary one. It will not at all be based on their comparative importance or extent, but will be determined solely by whether I happen to have first-hand knowledge regarding them.

This decision and restriction require no little firmness of mind. It shuts me out of nearly the whole field of modern chemical research and discovery. It would be such a delight to expatiate on radium and its emanations and allies, or the possible degradation of copper into lithium, or the fulfillment of our long hope of fixing atmospheric nitrogen, or the marvelous developments in electric furnace work and manufacture of alloys, or the changes taking place in the iron and steel industry, the explosives industry and the cement industry, or any other branch of chemical industry which has been undergoing revolutionary changes, regarding which I may have a smattering of information. But it is amazing how small and how prosaic one's information is, when it is restricted to those matters of which he has definite first-hand information.

Taking up now the deficiencies in knowledge or training which the young graduate chemist shows when he meets his first employer, the most striking one to my mind is his ignorance of the comparative *commercial* importance of chemicals; the comparative extent of their manufacture and sale. When you study chemistry as a science solely this question of commercial importance does not and should not arise. Indium should receive as much attention as aluminum or lead. The mere fact that one is bought and sold while the other isn't has no bearing whatever on their relation to the science of chemistry. And further, I do not want to be understood as indicating that chemistry should be taught in any other way than as a science. The business of the student during his four years here is to learn the fundamental principles underlying the various branches of chemistry, acquire a certain familiarity with its representative elements and compounds, and study it as an art in so far as the various analytical and other methods used are applicable through *all* or most branches of chemical industry. To my mind it is no part of the duty of a university to turn out trained soap makers, acid makers, paint makers, etc., but it is her duty to turn out men whose knowledge of chemicals and the principles of chemistry is broad enough so that they can enter any of these industries and make themselves valuable.

The moment a man enters *any* branch of chemical industry then aluminum and lead and iron, we will say, become much more important than indium. This is a situation that will face *every* chemist; it follows that his training in the science and art should be supplemented by some knowledge of commercial chemistry before he leaves the university. Such materials as sulphuric, nitric, hydrochloric and hydrofluoric acid; ammonia, soda ash, sal soda, glaubers salt, epsom salt, copperas, blue vitriol, caustic soda, caustic potash, and the like, concern such a great variety of industries that the chemist is sure to come in contact with most of them in a commercial way. His employers and associates, often not themselves chemists, will have a certain fund of information regarding such materials; any lack of it on the part of the chemist at once produces the impression that he is only a "theoretical" chemist, which is the polite expression used in the trade to damn a man as absolutely useless.

The young chemist should know, for instance, the percentages and gravities at which ordinary acids and alkalies are sold, and his disgust for the Beaumé and Fahrenheit scales should not prevent his being familiar enough with both so that any figures given in either will convey distinct impressions to his mind. He should know in what packages and quantities these common chemicals are shipped and the basis on which settlement is made.

For instance, he should know that sulphuric acid is shipped in three different kinds of packages, tank cars, drums and carboys; that it is shipped in three different strengths of approximately 65, 78, 93 per cent. strength, besides some shipped as 98 per cent. and as fuming acid or 100 per cent. acid containing free sulphur trioxide. These strengths are known in commerce as 50°, 60° and 66°, 98 per cent. and fuming. In the same way he should know the character of package, commercial appearance and strength of nitric acid, mixed acid, hydrochloric acid, hydrofluoric acid, aqua ammonia, carbonate of soda and caustic soda. He should know the distinction between nitric acid and aqua fortis, the basis on which soda ash and caustic soda are sold, respectively, one being on the 48 per cent. strength and the other on the 60 per cent. of Na_2O. He should know that bisulphate of soda is sold by the carload, while bisulphate of potash is more likely to be sold by the pound. Glaubers, epsom, copperas, blue vitriol, magnesium oxide, magnesium chloride, zinc chloride, chlorides of tin, calcium chloride, barium peroxide, all of these substances should be familiar to him, and in each case he should know the kind of package and strength, and the approximate cost of the commercial product. In this connection, I think it would be wise in any museum of industrial chemistry to have two sections to which the attention of students is especially called. One section devoted to chemicals which can be produced according to good processes in large quantities, but which are still hunting for profitable uses, and another section devoted to waste products and by-products of all descriptions which it is desirable to convert into marketable goods. The student should also be thoroughly familiar with the physical appearance and properties of these common products as they exist in commerce, so that he may recognize it at a glance if a mistake in the kind or quality of material has been made, before this mistake has cost his firm a considerable sum of money. Such mistakes will occur so long as purely human agencies handle chemicals. One of the most ludicrous ones that has recently come to my attention was a case where a consignment of soft soap was delivered on an order for thick silicate of soda.

Of course, it may be urged that the chemist can acquire all this information after he has left the university, and this is readily granted. But the acquiring of the knowledge outside is usually tedious and difficult and only accomplished after the chemist has been repeatedly subjected to mistakes and embarrassment due to his ignorance. Then, too, many of us believe that chemistry is a profession, and if so it is as essential for the chemist to be familiar with the present situation and relative importance of the materials with which he has to deal, as it is for the physician or lawyer in his profession.

If the functions of the chemist, the engineer, the business man and the manager could be sharply divided in chemical manufacture so that the chemist would not be asked any questions excepting those which fall entirely within the field of pure chemistry, the demands on his training and information, of course, would be much smaller and the reward of his labors would be correspondingly decreased.

The next place where the young chemist is usually most ignorant and most in need of assistance to my mind is in his knowledge or lack of knowledge of materials of construction and their comparative ability to resist the action of common chemicals. In his university work beakers and flasks and test-tubes and porcelain and platinum dishes, and rubber and glass tubing have always been available and have usually been adequate in size and quality for all his purposes. As soon as he enters chemical industry other materials must be sought more durable than glass and less costly than platinum. What accurate information does he possess regarding the comparative merits of cast iron, wrought iron and steel, for example, in resisting the action of caustic soda solutions, of sulphuric, hydrochloric or nitric acids, chlorine, sulphur dioxide or sodium carbonate solutions. Where are copper and brass and lead necessary or permissible. Where can he use Portland cement or Pecora cement, or silicate of soda or fire clay or ordinary mortar in making tight joints or linings.

To illustrate take the metal copper. It is most valuable in making stills and condensers for wood alcohol, acetone, acetic acid, turpentine, etc., and its alloy brass is extensively used in valves. Yet its use often leads to serious difficulties.

For example, I have seen iron drums to be used for shipping aqua ammonia in which the inside seams had been brazed, and bottling machines for use in bottling ammonia solutions containing brass parts exposed to the liquor. In both cases the final products, of course, were beautifully colored but unsuitable for the market. Similarly I have seen both copper and brass work placed in position where they would be continuously exposed to acetylene containing its ordinary impurities, ammonia, phosphine, etc.

In all these cases there were chemists in charge. They probably knew in a general way something about the action of ammonia and acetylene on copper and copper alloys, but their information was not indexed in their brains under the head of materials of construction.

Take again the case of sulphuric acid,

which is probably manufactured in larger quantities and goes into more industries than any other chemical. As we noted above, it is sold in about five strengths of 65, 78, 93, 98 per cent. strength, respectively, and fuming acid in addition. All these grades of acid must be made, concentrated and shipped, and the first and most important question to be decided is the kind of material to use at each separate stage of the process.

You are all no doubt perfectly familiar with the general features of the process of manufacturing sulphuric acid by the chamber and the contact methods, using either brimstone or pyrites. At the risk of wearying you, I am going to take some time to sketch through these processes, keeping in mind continuously the extreme importance of a knowledge of the action of chemicals on materials used in the construction of apparatus. When sulphur or pyrites is used as the raw material a large amount of cast iron enters into the construction of the burners and very often they are made entirely of cast iron, this in spite of the fact that one of the first freshman experiments proves that when sulphur is burned in the presence of iron, the products unite to form a sulphide of iron. When brimstone is burned in cast-iron burners this same action takes place to a certain extent, but the coating of sulphide of iron formed protects the rest of the iron from injury.

When sulphur is burned in the form either of brimstone or of pyrites the greater part, of course, forms SO_2, but about 6 per cent. burns to SO_3. Either of these two gases may be moved continuously and without danger in cast-iron pipes regardless, within reasonable limits, of how hot they become. On the other hand, a certain amount of moisture, depending on the day and the location of the plant, passes in with the air used for combustion (unless especial precautions have been taken to dry it all) and appears in the SO_2 gases. If these gases are allowed to cool the moisture combines with SO_3 in the gas to form dilute H_2SO_4, which destroys cast iron very rapidly. At the point where the gases are cooled in the contact process, or enter the glover tower in the chamber process, the iron must be abandoned, and all the cast-iron pipes must be arranged to drain forward and not backward. This same feature comes up in making nitric, muriatic acetic and hydrofluoric acids, all of which attack iron rapidly, and still all are made in iron retorts or furnaces. The necessary precaution, of course, is that no part of the retort or furnace should be allowed to cool enough to permit any condensation to form liquid products. If the retort is not properly insulated at any place a hole eats through with amazing rapidity.

Returning to the sulphur dioxide gases, then, we must change from cast iron to lead as soon as the temperature goes low enough to permit condensation. This material is not attacked by weak sulphuric acid. We, of course, could not use lead all the way back to the furnaces, as the excessive heat would melt it. In the chamber system the gases must now continue in lead throughout. In the contact system the sulphuric acid is filtered out after cooling and the gases continue their course in cast iron and steel to the very end without danger.

In concentrating H_2SO_4 still more interesting details arise regarding the materials that may be used. Many have been suggested, and among others glass and porcelain have been used with more or less success. But a factory is no place for glass and porcelain apparatus if any other materials can be found. The four materials now in fairly common use are lead, cast iron, volvic lava and platinum. Lead may be used so long as the acid does not exceed 80 per cent. in strength and so long as direct heat is not applied. Platinum is satisfactory while the acid is between 80 per cent. and 94 per cent. strength, but the installation is very expensive and the loss of platinum is very large if an attempt is made to concentrate above 94 per cent. Cast iron is very satisfactory between 88 per cent. and 98 per cent. Below 80 percent. its life is too short to be considered. Cast iron is always attacked in any case, but it is usually cheaper to use cast-iron pans for six months or so and then replace them than it is to make more expensive installations. Fortunately only a small proportion of the iron dissolved by the acid from the pans remains in solution in the acid; nearly all of it is in the form of a sulphate of iron almost insoluble in either water or sulphuric acid, so it readily settles out, leaving a clear acid.

Where it is desired to produce 98 per cent. acid by concentration, a common custom is to evaporate in lead pans by waste heat to 78 per cent., then in platinum stills by direct heat to 93 per cent., then in cast-iron stills to 98 per cent. What evaporates from the lead pans is mainly water and is disregarded. The evaporation from the platinum stills forms a 35 per cent. acid, which can, of course, be condensed in lead. That from the cast-iron stills is over 90 per cent. and must be condensed in platinum. If the acid to be evaporated contains much sediment, as is liable to be the case when it is made from pyrites, or if the platinum stills are allowed to become dry and burn, they may be nearly ruined in a single night by a careless workman. The only material to use in mending the leaks which frequently occur in the platinum stills is gold. This seems rather startling when we consider that the acid itself is sold in quantity for less than a cent a pound, while the brimstone from which it is made costs more than a cent a pound.

Another common and satisfactory arrangement where it is only desired to concentrate up to 93 per cent. strength, is to evaporate in lead pans by waste heat up to 80 per cent. and feed this 80 per cent. acid directly into a large cast-iron still of such capacity that the whole body of acid in it always averages over 90 per cent. This prolongs the life of the iron often to two or three years, instead of its usual life of three to six months.

The distillate from such an iron still can, of course, be condensed in lead, but the upper part of the still itself would soon be eaten out by the weak distillate unless it were lined with acid brick or repressed red brick set in Portland cement neat, or mixed with silica or fine asbestos. Portland cement will stand the action of hot weak sulphuric acid for a very considerable time. A still of this type, if properly cared for, usually meets its end from cracking rather than from eating through. This is due to the caking of the peculiar sulphate of iron, which I mentioned above, on the bottom of the still to such an extent that the heat cracks the iron. When such an accident occurs there is, of course, a delay in operation, which is always expensive, aside from the cost of the new still and possibly a loss of several tons of acid.

Concentration in apparatus made of volvic or volcanic lava rock by driving hot furnace gases directly over and through the sulphuric acid is very satisfactory. The cost of installation is large, but not so large as that of platinum. The lava rock used comes from a mountain near Clermont-Ferrand in central France and so far no satisfactory substitute for it has been found in this country, although a number have been tried, among them some of the hard red sandstones of New York. In the volvic lava concentrating apparatus the stones are liable to crack from heat if stilling is pushed too hard, and, of course, the lead and porcelain parts of the apparatus give out repeatedly.

In making sulphuric acid by the chamber process, the chambers of course are entirely made of lead; but as nitric acid and nitrogen oxides are mixed with the sulphur dioxide gases the strength of sulphuric acid in the chambers can never be allowed to fall below 45°; otherwise it will dissolve nitric acid in sufficient quantity to attack the lead very rapidly. If, on the other hand, the strength in any chamber is allowed to go above 55° nitrogen oxides are dissolved which also attack lead. Between 45° and 55° strength, however, almost no nitric acid or nitrogen oxides are dissolved and the chambers are safe. The action of nitric acid on lead chambers is very insidious and its affects are difficult to detect until a hole finally comes through the lead, probably simultaneous with the descent of several tons of acid.

I might go on to discuss acid eggs, pumps, sprays, piping, tower filling and tanks of a sulphuric-acid plant. In every one of these a careful consideration of the strength and temperature of acid is necessary before we can determine what materials are best or are even to be considered in its construction. I might go on to other industries and discuss why, for instance, in C.P. acids we are reduced to the use of glass, porcelain or platinum, while for C.P. ammonia iron is perfectly permissible, and for pure acetic to be used for vinegar none of these will do (except possibly glass), but we must use silver. Go through every branch of chemical industry, undertake to transport any chemical reaction from a laboratory to a works, and the very first problem that confronts you is what material to use in making your apparatus. The thing I want to impress on you is that you can not make a chemical, you can not make a thing in a chemical works without something to make it in, and the choice of that something is exceedingly important and worthy of serious consideration.

The next line upon which I would recommend the young chemist to be better equipped than chemists usually are, is in his knowledge of power accessories and transmission machinery. I do not mean that he should have any extensive knowledge along these lines, but he should certainly know the principles of a steam engine, how to start and stop it and when it is running properly. He should know the principles of boiler construction and boiler setting and how to care for a boiler; what amounts of fuel can be burned on a given grate surface, what evaporation may be expected from this fuel, and what power it will furnish, and what temperature and analysis of flue gases may be considered economical operation. He should know about steam pumps, their valve arrangement and how to compute their capacity under various pressures. He should know centrifugal pumps and under what circumstances they may be used; blowers plus pressure blowers and exhausts, mechanical stirring apparatus, shafting and pulleys and how to place them. By all this I do not mean that he should be an expert in factory design, or even a millwright or pipe fitter, or engineer or stoker, although he would certainly be much better equipped if he did have all these accomplishments. Yet all these things I have mentioned are the very tools of his trade, they are his beakers, and bunsen burners, and suction pumps, and stirring rods and steam-baths. If the young chemist gets on at all in manufacturing or using chemicals he must use all these appliances, and men working under his direction must manipulate them all, so it seems to me the part of wisdom for him to assimilate all the information along these lines that comes his way.

At the same time the chemist should know his limitations. He is not an engineer and does not pretend to be; he simply reaches out for that small portion of the field of engineering where machinery comes in contact with his chemicals. In this limited field he may acquire and pretend to special information, but beyond it he would do well not to go. Let him rather call his brother engineer into consultation when he gets beyond his depth, so that the brother engineer may in return more readily call the chemist in consultation, to the mutual advantage of both.

The next place where I think the average chemist's stock of information could be profitably enlarged is in his knowledge of what industries use the common chemicals and how they use them. You will notice throughout that I use the term common chemicals. I realize perfectly that if a young man undertook to inform himself fully and broadly regarding all chemicals, along the various lines I have indicated from the beginning of this address, he would die of old age before graduation. Throughout all I have said I refer only or mainly to the three or four dozen chemicals which are largely used and widely distributed. Chemicals are manufactured for one purpose and only one—to make money. Chemicals are used for one purpose and only one—to make more money, and the sooner a chemist learns how and why this and that chemical is used the more valuable he becomes to himself or his employer.

Two mottoes that might well adorn the walls of any chemical works, judging from the view-point of the owners, are: First, "This is not a charitable institution"; second, "If you can't make good get out."

A student in an institution like your university here is furnished with every opportunity and every facility for either practise or investigation work, and no expense is considered too great if it leads to a discovery of some new fact, new law or new relationship of chemicals. The student at the same time is surrounded by a group of thoroughly trained investigators ready and willing to give him information or direct him where to obtain it.

When the chemist is in actual practise, however, he is usually discouraged in spending either time or money in any work which does not show very strong probability of bringing fairly immediate returns. He is in a position of one who is expected to give information, not to receive it, and the answer to the questions asked him is not always found in the back of the book.

Going back to the details of uses of common chemicals, the chemist will be required to have more or less familiarity with a great number of industries such as rubber, glass, leather, tanning, silk, cotton, ice-making, cement, etc., in order to know what kind of chemicals these industries use and what grades of chemicals they require.

To résumé the chief points to which I think young chemists do not pay sufficient attention and do seem to me of extreme necessity in their work are, first, a knowledge of the commercial importance of chemicals and the availability of these chemicals. Second, a knowledge of the action of common chemicals on materials ordinarily used in the construction of apparatus. Third, a knowledge of power accessories and transmission machinery. Fourth, a knowledge of the industries in which common chemicals are used and how they are used; and last, a knowledge of the impurities existing in the common chemicals as they appear on the market.

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