Sources of Ideas in Industrial Chemical Research*

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Received November 8, 1961

Books are wonderful things, and one of the most wonderful of all books is the Unabridged Dictionary. It has become a habit with me, whenever someone gives me a title for a talk, to consult the dictionary to make sure that even the simplest words in the title are clearly defined in my mind. Following this technique for this talk, I went to the dictionary to look up the meaning of the word "Sources," and found the answer to my problem; for under the definition of this word there was a quote which seemed to me to summarize in a very few words the "Sources of Ideas in Industrial Chemical Research." The quote is by Locke—"This *source* of ideas every man has wholly in himself." In other words, the source of ideas is *people*, or the brains of people, especially those people who are concerned about something. I think it is important in these times to emphasize that the source of ideas *is* people and not mechanical sorting machines or other types of data processing equipment. So the problem we are discussing is what are the methods by which we activate people to obtain ideas of interest in the field of industrial chemistry? Very few ideas are obtained while sitting in an "ivory tower," out of contact with the works and the writings of others.

The first requirement to develop ideas that are of interest to industrial chemistry is to know what *has* been done by others. To me this means that one must establish a strong knowledge of the science of his own specialization. It is not a good idea, however, to be too highly specialized; it is better to have a general knowledge of several allied or related fields so that you have more than one point of view of the problem. Polanyi in his book on "Personal Knowledge" gave a very clear statement of what constitutes a problem, and I quote: "I mention it now only to make it clear that nothing is a problem or discovery in itself. It can be a problem only if it puzzles and worries somebody, and a discovery only if it relieves somebody from the burden of a problem." Hence you can see that on this definition, with which I concur, problems are related to puzzling and worrying or thinking about something or somebody. You must think about it so long that you can only be relieved of this burden and worry by discovering the solution. This is the frame of mind one needs to obtain an idea as to a problem, or how to solve the problem.

Assuming one has acquired, through formal study and continued study after graduation, a good basic knowledge in a science, the best source of industrial chemical ideas is simply to look around you and observe the things you see, use and do every day. Look at these things in a critical way and try to analyze *why* some of the preferred materials have the properties they contain. Let's take two specific examples where, by looking around and applying known chemistry, one could have arrived at the solution to the problem. I do not say that the method I cite is the method by which the solution was arrived at, nor do I say that it was as simple. But now that I know the problem has been solved, I can see how one might have arrived at the ideas on how to solve the problem.

Let's take the natural material silk and say that this is a very interesting material and has some unique properties. You would like to duplicate it. A quick examination of the literature would show that it has been known for many years that silk consists, to a large extent, of the simplest amino acid, glycine, and that it is very highly insoluble and decomposes under heat. A further search of the literature would show that a polyglycine had been prepared but that it was refractory and horn-like, and could not be dissolved or melted without decomposition. To many people this would mean that the problem was unsolvable and they would not worry or burden themselves further with the concept. However, one with a little more inquisitiveness might wonder how does the material get from the silkworm in a pseudo solution state through the spinneret into the fine fibers we know of as silk. One might decide that this would be an interesting problem and if he could solve it he would then have the solution to the problem of how to make synthetic silk. Whether this solution would produce a useful industrial product is up to you to decide. The other way you might look at it would be to say that silk is a fine material but it melts too high and you can't process it. You might conceive the way to reduce this melting point would be to put more carbon into the system because the higher the percentage of carbon in an amide, the lower the melting point. Therefore, you will explore the possibilities of higher carbon content amino acid polymer. If you follow this logic there are two ways that the carbon could be introduced into the system: (1) by using branch-chain alpha amino acids, and (2) by inserting more methylene groups between the amino and carboxylic acid group. If you really were far-sighted enough, you could arrive at the conclusion that an amino acid of about 6 methylene groups would be preferred because of the ease of ring formation or other side reactions at the low chain length.

I don't know whether this was the exact reasoning that went through Carothers' head, but now that I know he solved the problem by changes in structures of this type, the solution is obvious and any of us can follow back through the literature the type of reasoning we have just gone through to show what should have been done.

Another example will tend to illustrate the same thing. Let us look at soap, one of the oldest products known to man. Practically every person has observed that soap produces an insoluble calcium and magnesium salt and produces the famous "ring" around the tub. I don't believe there is a person who has not been called to task for not cleaning the tub and removing the "ring." I would also venture to say that most of us have wished

* Presented before the Division of Chemical Literature, American Chemical Society Meeting, Chicago, Illinois, September 4, 1961.

at one time for some solution to this problem. Now that we all know the solution to the problem, it is relatively easy to see that any chemist should have thought in terms of what other groups can be used besides the carboxyl group to produce a water-soluble long-chain hydrocarbon derivative. These ideas followed the normal expected developments of sulfation of the alcohol to form the sulfate esters, the sulfonic acids, and the polyethylene oxides as a solubilizing group. All of which have got around the difficult problem of the insoluble calcium soap. These developments presented new problems, however, some of which have not yet been solved. One of the most difficult problems was that the synthetic materials did not foam to the same extent as soap, which made it difficult to get them accepted by the housewife. Many of us feel that foam is not important, but from an industrial point of view, for common household uses people still relate cleaning power to foaming. Therefore, this property had to be built into these compositions. Maybe the next generation will not be as critical of this factor as their parents have been.

From these two problems, and many others like them, one can recapitulate and reassemble the general observation and follow it back to a perfectly normal chemical operation. But the trick is to start off on a new path and follow it back to some conclusion where you think it can be solved. There is one other trick that most people overlook in this connection, and that is that an industrial research problem must be one that is solvable with the skills and the tools at hand. If the problem is too simple then it is no problem at all because it offers no challenge or worry, and hence you will have no relief when it is solved. If the problem is too difficult, you may spend your entire life on it and have nothing to show for it. The selection of the problems for industrial chemical research is, therefore, a very delicate balance and you must be certain that you as an individual and your company select problems which will test your skills to the maximum. It must be something which puzzles and worries you but has a reasonable chance, in your opinion, of solution so that you can be relieved of the burden. After looking around at things in general, pick some object which seems to be in the realm of the solvable and then start searching through the literature to find out how much is known about this particular subject; try to analyze why the objective was not reached, and then consider ways and means of overcoming the difficulties which have been experienced by others. I think it is important, however, that one does not try to learn everthing in the literature before starting to work on an idea. I have never seen an idea which was so novel that I could not literally talk myself out of it or be talked out of it by an extensive quote from the works of others. It is generally stated that "a little knowledge is dangerous." This is true, but from an idea point of view, too much knowledge is even worse. Again we must have a balance between too little, so that we are foolish, or too much, so that we are overly cautious. Some of the problems you may consider too big or too difficult for you; other ideas may be well within your capacity but not of sufficient originality to justify the amount of effort it would take to solve the problem. In other words, the price is too high for the merchandise.

In searching through the literature for ideas of this type, I have always found it good practice to read the article on each side of the reference article under study. I think factually I have obtained more information from these articles than I have from the ones I was actually looking up. Some people like to call this "serendipity," but to me it is an observed fact that a large part of the scientific literature of a given period is closely related and therefore I am simply reading three articles instead of one. I could probably accomplish the same objective if I had adopted the policy of reading the 10th or 20th article from the one under study. I have generally found that the people with ideas read widely, not only in their own field, but in allied or disconnected fields. It is for this reason that I have always encouraged men who are attending scientific meetings, such as the A.C.S. Meeting, to listen to papers in fields other than their area of specialization. I urge my organic chemists to listen to papers on physical, biological, and inorganic chemistry. They are important because in the Organic Section the organic chemist is more or less listening to himself talk. It is like a minister giving a talk at a revival meeting where everybody is already "saved." He would be much better going out among the unconverted if the purpose of his sermon was to convert people. I know that physical chemists appreciate this point of view because they have never been able to convert all of us organic chemists to their faith.

Many of us, when we complete our academic training, have not been made aware of a great source of technical information, namely, the U. S. Patent. This is a very fertile field to study because it represents the accomplishments of the people who have had a burden or worry and have discovered a solution which fits the legal definition of an invention. If you just read these documents for what is in them, you will know the prior art but they will not help you in developing a source of ideas. I suggest that you try this method of reading the patents: Read the introduction, one example, and the claims; then start the mental process as outlined in my silk and soap cases and see if you can't work your way back to some logical technical reason by which you could have arrived at the satisfactory solution to the problem. If you do this you will often find that you might have an idea that is a simpler solution to the problem than the previous inventor had. Turn the problem around and see if you can't take the inventor's problem and idea, and extrapolate them into new areas. To get ideas one must have some way to practice, and this is the best way I know.

The third source of ideas is to ask questions of those who are working with you. This is often the fastest way but if you are not careful it can be the most dangerous, because the answers are often short and curt. But don't let us old-timers give you the brush-off. Make sure we understand your question and that the answer we give you is the answer to your question. This is an excellent way to practice the development of ideas. At first you may find that the ideas are old, but as a start who cares as long as your logic was sound. After a little practice you will find your ideas will increase in novelty.

Technology, with which industrial research is mainly concerned, differs from other thought processes in that once you have an idea on how to solve a problem, you must do something about it. Therefore, the technology with which we are concerned also involves action. It takes a lot of faith in your ideas and yourself to proceed to test your idea and finally commercialize a truly new product. As natural scientists it is our job to observe and study. As technologists it is our job to connive out of this information something which will do the job better, cheaper and easier than it has ever been done before.

I think we can sum up the situation by repeating Locke's quotation—"This source of ideas every man has wholly in himself."

WHAT AUTHORS AND EDITORS CAN DO TO PROVOKE THE CREATIVE REACTION*

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Received Nov. 8, 1961

Our first clue is obvious in the definition of the word "create." For if *you* will invest enough thought in your subject to achieve and communicate "a new form, office, or character," the reader who remains unstimulated is mired pretty deeply in his rut.

How much are you willing to do to get through to your audience?

In a lecture a few years ago to the Washington Junior Academy of Sciences, Dr. Hubert N. Alyea of Princeton went at a clip that reminded one of an L-P record played at 78 r.p.m. In one unforgettable sequence, Prof. Alyea seized two pressurized CO_2 fire extinguishers and rushed down the aisle through the audience, spraying carbon dioxide snow on both sides and shouting above the uproar his observations about phase change, the gas laws, and the relation between heat and temperature.

The ACS had a meeting in Buffalo in 1952—about the time the new "miracle" synthetic textile fibers were just beginning to earn major acceptance into the clothing field. The morning after a major symposium on the subject was presented at the meeting sessions, the front page of one of the Buffalo papers carried a picture of a fully-clothed, upper-middle-aged man standing in a hotel bathtub under a running shower. The man was the late Dr. Gustav Egloff, vice president of the Universal Oil Products Company. A lot of non-chemists in Buffalo (and probably quite a few chemists as well) got a pretty vivid impression of the water- and wrinkle-resistance of the new textiles. Also, many of them never again forgot that the petroleum industry had made its own significant contribution in developing petrochemical building blocks to an important new industry. That, incidentally, also probably will be the only time in history a bathtub picture of a middle-aged gentleman will ever make the front page of a newspaper.

In both these instances, a creative communicator presented a well-known item in an unusual context. In both instances, a lively interest and appreciation was awakened beyond any shadow of a doubt. And interest and knowledgeable appreciation are mighty good initiators for the creative process.

The effect of context is almost always important. And effectiveness can be achieved with either the shock-power of unexpected deeper pertinence, or of pertinent—and thus permissible—impertinence. One of my happier personal experiences was the way I finally discovered how to describe to the non-technical visitors the Tennessee Valley Authority's fertilizer phosphate research and production activities at Muscle Shoals, Alabama. This was in my first job after I graduated from engineering school, and pride of profession impelled me to seek some explanation that would do at least some justice to the significant process factors. Success came with recognition that the chemistry of all the processes could be explained in a single reference framework, the fluorine in the fluoroapatite constituent of the phosphate rock we were using. That fluorine, present in the calcium fluoride 'free loader" attached to an otherwise healthy and normal tricalcium phosphate molecule, had to be dislodged before the phosphate could be "digested" by the hungry roots of plants. That single explanation sufficed to convey some appreciation of the common purpose of fusion heat, electric-furnace treatment, or acids and alkalies in various fertilizer process investigations then under way in T.V.A.'s laboratories and pilot plants. And, I must add, it triggered a line of speculative technical thinking on my part that was rooted in more perceptive awareness of a key requirement than I had ever felt earlier.

These examples are taken from instances where the spoken word rather than the printed page was the vehicle of communication. Yet I believe they are valid in the context of my assignment. The interplay of established fact and unexpected association, which presents a new vantage point and challenges the observer to seek additional ones from the terrain he commands, can be accomplished equally on paper—as this discourse hopefully attempts to demonstrate.

In the realm of the printed document, consider thoughtfully the mode of presentation most likely to engage the greatest set of associations in the mind of the reader. The consequences can contribute much to the stimulant quality of your text. The alternative possibilities inherent in an alumina-from-clay process are illustrative. If your principal audience is the chemist, give him the equations (Fig. 1). His selectively tuned antennae will instantly begin to sense the nuances of main and byproduct reaction tendencies, thermodynamic threshholds, the implications of impurities in economically available reactants, and a host of similar hazards, possibilities, and half-glimpsed opportunities. The process