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Chemistry in Engineering

CHEMISTRY

in Engineering

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Preface

This book is written for students or graduate engineers whose major interest is in fields other than chemistry or chemical engineering. The subject matter is based on lectures given to second-year students in engineering physics, and in civil, electrical and mechanical engineering. The topics dealt with are those of most interest to students in these courses.

The reader will find the approach less formal (and less formidable) than that used for a treatise on "pure" chemistry. The text supports the conviction of many engineering faculties that the modern graduate should understand something of the chemical as well as the physical nature and properties of the materials he uses. In all fields of engineering, many "mistakes" in the use of materials can be traced to a lack of knowledge of the simple chemistry involved.

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1 An Introduction

The student in civil, mechanical, or electrical engineering confronted with another course in chemistry may ask why the engineering faculty insists on a second course in chemistry. Isn't it enough to have passed a first year course in the subject? Why not forget about chemistry and get on with engineering?

Very good answers to these questions were given over twenty years ago.[1] It was pointed out that many of the new products of the chemical industries found application in all the fields of engineering. Their use was often dependent on their *chemical behavior* more than on their physical properties. Physical properties may be altered markedly by slight changes in chemical composition.

With each successive year, the role of chemistry and chemical products in every branch of engineering has been greatly enlarged. Mr. C. L. McCuen, Vice-President of General Motors, head of the engineering division, stated: "Every advance in automotive engineering either produces a new chemical demand, or awaits upon chemical developments for its introduction."[2] In this industry some 256 chemical products are used. Mr. O. H. York of The Curtis-Wright Corporation Research Laboratories believes that "For real

1 *Journal of Chemical Education* **12** (1935), 422.

2 Published address, "Chemical Problems of the Automobile."

progress in aircraft, the chemist and engineer are inseparable."[1] The aeronautical engineer must know something of the chemical properties of the new materials provided by the chemist.

Even the highway engineer has to work more and more with chemical materials. He uses his knowledge of colloid chemistry to help create conditions for soil stabilization. He has a choice of materials for de-icing. Different types of paint are used on highways. In 1955 about four million gallons were used on state highways alone.[2] This included not only ordinary outside paints, but also special items such as pavement markers, luminous paints, silicones for the bridges on the New York Thruway and the new Toronto Cross-town Thruway, special paints for masonry, and thousands of tons of fine glass beads. Plastic pipe, tapes and reflectors, rubber, asphalt, pesticides, herbicides, and deionizing resins are some of the materials furnished by the chemical industry for the modern highway.

The selection of the proper metal, alloy, or combination of metals, the best oil for a certain job, the correct plastic or textile for a particular set of conditions, or the best type of synthetic rubber for a given purpose is made by considering the *chemical properties* even more than the physical properties of these related materials.

The engineering graduate who knows the differences in chemical properties of alternative materials and who understands the general chemical principles on which their behavior depends will be a better engineer than one who does not.

Time and again, engineers and contractors could have saved themselves great embarrassment, lawsuits, or their jobs had they known some principles of chemistry in engineering. Here are a few examples observed by the author.

The town engineer of an east coast town, who was a graduate in civil engineering, had the additional task one summer of supervising the construction of a new town hall. He knew that copper was resistant to corrosion, and he accordingly specified copper eaves troughs and down drains supported by iron brackets. In a very few years the rather expensive troughs were hanging loose. He apparently had not heard of the first principles of electrochemical corrosion! At that time, most of the industries and many of the homes of the town burned soft coal with a fairly high sulfur content. The damp salty sea air and a plentiful rainfall were also instrumental in creating the necessary conditions for an ideal electrolytic corrosion cell.

Some years ago, an electrical engineer employed by a company in the communications field was awaiting my return from the lecture room. He wished to know how he could neutralize calcium chloride. As you may remember, pure calcium chloride in aqueous solution becomes acidic because of hydrolysis. He was concerned, however, with an *alkaline* brine, which

1 *Chemical and Engineering News* **22,** No. 2 (1944), 86.
2 F. Burggraf, *Industrial and Engineering Chemistry*, **48,** No. 9 (1956), 26A.

indicated that he was using a technical grade containing some slaked lime. Asked what use he made of the material, he replied, "I used it as an antifreeze, but in spite of the fact that I neutralized it to some extent by adding sodium bichromate, when the mechanics removed the engine head, they found terrific corrosion."

I invited him into the laboratory where we connected a square of iron gauze, representing the engine block, to one side of a milliammeter and a square of copper foil, representing the radiator, to the other. When these were placed in a big beaker of calcium chloride brine, a large deflection was obtained, and after a few minutes the brine became distinctly rust-colored. This type of cell was used in the cooling system of the company's trucks. Of course the engineer was wrong in attributing the corrosive action to the alkaline nature of the solution. The success of chromate as a corrosion inhibitor depends on its concentration.

When explanations were over, the visitor departed with the remark, "I sure wish I'd paid more attention to chemistry when I was at college. But being in electrical engineering, we only had the one course."

The electric clock in our kitchen was made by a well-known manufacturer, who employs competent electrical engineers on his staff. However, someone in the firm should be given some instruction in applied chemistry. The white face of this reliable timepiece became darker and darker, until finally the enamel had to be removed and a correct type of enamel applied. The man in charge of the company's finishing department had not heard of the chemical reasons for *never* using a white lead paint or enamel in a kitchen.

Even scientific equipment companies sometimes make such "boners." One company manufactured a constant temperature bath with a chromium plated cylindrical cased stirrer cooled by a coil of tubing made of tin.

Professor M. G. Fontana tells of several examples of how expensive ignorance of chemical principles can be in the realm of building construction.[1] In one case, a new manufacturing plant was built of structural steel with an aluminum roof and sides bolted to the steel. The manufacturing process involved the evaporation of water. In the cold weather, the moisture condensed on the cold aluminum and dripped into the finished product! Another contractor was given the job of insulating the roof and walls. Apparently, he did not know sufficient chemistry either, for he used an alkaline binder to hold the insulation.

The result of the improper use of good materials by the two contractors is described by Professor Fontana: "After a short time the insulation became soaked and gobs of it dropped off the roof [presumably into the manufacturer's product!]. Needless to say the manufacturer was even more unhappy. Corrosion also occurred. Thousands of holes appeared in the roofing, most of them in lines adjacent to the steel perlins . . . . Defects in

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1 *Industrial and Engineering Chemistry*, **48** (Nov. 1956), 53A.

the sprayed coating also resulted in small anodes [corrosion sites] . . . . Practically everyone involved hired lawyers and consultants."

You will be expected to explain this "holey mess" and suggest remedies after you have studied the section on corrosion.

There are many other instances where mistakes in engineering design of structures and equipment occurred because of neglect of the chemistry of corrosion. Some of these will be discussed in the later chapters. Your instructor can doubtless supply additional examples from his own experience or knowledge.

This text, written to discuss practical applications of some of the principles and facts of chemistry to civil, mechanical, and electrical engineering, presents the simpler chemical aspects of old and new materials used by the engineer. Its scope may be estimated from the Table of Contents or the review questions.

Here are a few questions taken from different chapters. If you can answer 25 per cent of them correctly, you have more chemical knowledge than the average student who has passed first year chemistry, and you should do well in the course. If you cannot answer 25 per cent of these, then the text will broaden your knowledge of engineering by increasing your understanding of the materials you will use in your future work.

1. A city changed its fuel service from coal gas to natural gas. What burner adjustments were made necessary by the change? Why?
2. Indicate the type of chemical additive used in lubricating oil (a) as a pour-point depressant, (b) a detergent, (c) viscosity-index improver, (d) for heavy loads.
3. What is the difference between "reformed" gasoline and "alkylate"?
4. How would you determine the *p*H and total acidity of a dark-colored, turbid mine water?
5. How can the formation of silica scale be prevented in high-pressure steam boilers?
6. Name five tests required for sewage effluents or trade wastes.
7. What are the differences in chemical components in paints for (a) stucco, (b) ships' bottoms, (c) diesel-exhaust pipes?
8. Indicate the role of interfacial tensions in the spreading of a liquid over a surface.
9. Name five different types of synthetic rubber and indicate which you would use for (a) resistance to chlorinated solvents, (b) gas retention, (c) resistance to high temperatures.
10. Give the chemical formula for (a) an organic inhibitor, (b) a synthetic lubricant, (c) phenol, (d) a ketone.

11. Name the following compounds, indicating an engineering use for each:

    (a) $CH_3{\cdot}C(CH_3)_2{\cdot}CH_2{\cdot}CH(CH_3){\cdot}CH_3$

    (b) $CH_2{\cdot}CH_2$ (each CH_2 bonded to an OH)
    $OH\quad OH$

    (c) CH_2ONO_2
    |
    $CHONO_2$
    |
    CH_2ONO_2

12. What synthetic resin or plastic would you choose for (a) high-frequency insulation, (b) a weatherproof adhesive, (c) an *ab*hesive?