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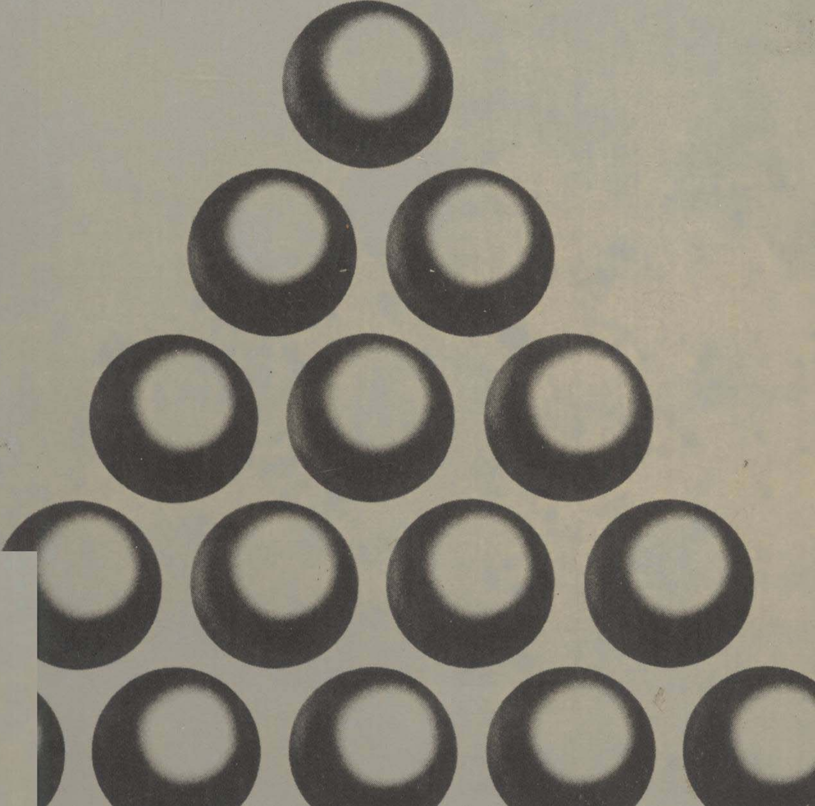
the chemist in industry 3

management and economics

M. H. Freemantle

editor

E. S. Stern



E. S. STERN (Editor)

The chemist in industry (3): management and economics

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Polytechnic of the South Bank

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Editor's foreword

THE original purpose of this small 'series within a series' was to provide some understanding of the role of the chemist in industry and of some of the problems he faces as chemist. We hoped to do this by illustrating the approach to chemical-industry problems, thus implicitly establishing the atmosphere of industrial chemistry and also a feeling for it. We hope the texts on the fine chemicals (OCS 12) and on the biological chemicals industry (OCS 16) have helped in this way. A discussion of the petrochemicals industry planned on similar lines has been delayed because we hope to take into account some of the recent major changes in the petroleum industry.

The reception of the books so far has been both kind and encouraging. Yet we sense that those who have not worked in industry would find it easier to understand and accept the different way of thinking and activity if they were presented with an explicit introduction alongside the actual industrial illustrations originally envisaged. Hence the present text. It is meant to answer questions like: What is industry? How does it differ from academic institutions? How does it operate? What is the individual's role? Who takes decisions and on what basis? Since we address ourselves to chemists, some emphasis is given to the chemical industries, chemical companies, and chemical problems. It is clear, however, that the problems discussed are universal. Moreover, since there is a wide area of ignorance, a lot of questions can be formulated—but in limited space only some important ones can be answered. The author, Dr. Freemantle, has experience of some years both in the chemical industry and in the realm of higher education, where he is exposed to just such questions. His selection of topics and their discussion therefore reflect the worries of undergraduates who see a possible career in industry. Just because in the university environment chemists learn nothing of industrial economics, nor of modern 'man-management', they are bound to wonder how they as individuals, with their own objectives, might fit into industry. We hope this book will give them some of the answers they seek.

E. S. Stern

Preface

ON entering industry graduates in chemistry and related disciplines frequently find that they are faced with problems and situations of which they have little experience or knowledge. To tackle these problems the graduate will often need to acquire knowledge and skills in disciplines such as management and economics, and he will find it necessary to integrate the knowledge and skills from the various disciplines. This book aims to help chemistry students and chemists in industry by introducing some basic principles of management and economics which have wide application in the chemical industry.

The chapter entitled 'A systems approach' offers an approach for solving problems and taking decisions. This approach is related to the role of the manager and illustrated by reference to the production and marketing functions in the chapter on organization. Throughout, the importance of clarifying objectives is stressed. The objectives of the individual may often clash with organizational objectives, however; the fourth chapter therefore surveys some theories of the human-relations school of management. If objectives are to be achieved analysis of performance and control of operations is necessary; Chapter 5 examines some techniques for cost analysis and control, with particular reference to production in the chemical industry. Whereas Chapters 3, 4, and 5 are concerned with the current activities of an organization, Chapters 6 and 7 look to the future. The importance of technological innovation with respect to the future operations of a business is stressed in the Chapter on R&D. Finally some techniques for evaluating projects are described in Chapter 7.

I must acknowledge my indebtedness to those who have helped and encouraged me to make the publication of this book possible: to my colleagues and many students at the Polytechnic of the South Bank; to the editors, and particularly to Dr. Edward Stern who has given me much of his time and invaluable advice and assistance whilst writing this book; to Mary, Helen, and Charlotte, to other members of my family, and particularly to my brother David, who has been my mentor on several topics in this book.

I wish to thank the following publishers for permission to use material from their publications: John Wiley and Sons, *Introduction to technological economics* by D. S. Davies and C. McCarthy; Edward Arnold, *Principles of management* by H. L. Sisk, and *Petrochemicals today* by Joy P. Stern and Edward S. Stern; The Society of Chemical Industry for permission to print a figure from *Chemistry and Industry*.

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M.H.F.

Contents

1. Introduction

Chemistry courses and the chemist in industry

ANY course in higher education has disciplinary, educational, and vocational aims. Chemistry courses, usually mainly concerned with disciplinary aims, typically consist of a diet of organic, inorganic, and physical chemistry, and their variants, with supplementary courses in physics and mathematics. Little or no attention is paid to topics of potential use to the large number (approximately 45 per cent) of graduate chemists who are likely to take industrial or similar employment and to whom some knowledge of management and business methods would have been helpful. Approximately 65 per cent of all chemistry graduates in chemical industry are in positions where a mixed formal training in business and chemistry would have been beneficial (Parker 1973); about 15 per cent are in production and a further 15 per cent in management. Thus to serve the vocational needs of chemistry students there is a strong case for including in chemistry courses topics usually grouped under the headings of 'business studies' or 'industrial administration'. This is now well recognized. Most polytechnics and many universities, particularly the technological universities, present business studies or industrial administration as part of chemistry and related courses.

However, trying to serve the vocational aims of chemistry students raises another problem. For example, lectures in economics are often given by lecturers who have no formal qualifications and little interest in the chemical industry. Similarly, lectures in chemistry are given by lecturers who have no formal qualifications and little interest in economics. Indeed, it would be virtually impossible to find lecturers who had the appropriate mix of formal qualifications for teaching economics to chemistry students because of the traditional emphasis on the disciplinary aims of courses in higher education. There are many people with a degree in chemistry and many with a degree in economics; but how many with a degree in chemistry-with-economics? Some polytechnics and universities are moving towards interdisplinary studies, helped by the recent trend towards modular courses. Meanwhile chemistry students interested in business subjects such as economics often find much of what is taught irrelevant and integration of the business and science or technological content of their courses difficult. The result, a very fragmented knowledge and understanding of independents disciplines, is far from ideal.

Although the chemist embarking on a career in industry feels the need for some knowledge of administrative and business methods, the industrial employer may not agree or may accept that purely vocational knowledge is useful especially in the short term. Industry is multifarious—no two companies are alike—no course can cover them all. Moreover, employers usually engage chemists not for their immediate academic knowledge but because they trust that, in time, the chemist will apply skill to a range of tasks. Initially, the chemist's success may, indeed, be largely based on academic knowledge; but later, inherent ability, flexibility, and personality become overwhelmingly important. Years of development both of the company and of the chemist produce situations that cannot even be guessed at the time of recruitment and may make initial academic teaching irrelevant.

This book is meant to help chemistry students. It would be mistaken, therefore, to attempt an exhaustive treatment of industrial practices for the graduate chemist. Instead, some aspects of economic and managerial practice in industry are highlighted here. Industry exists to produce goods wanted by the community at large and by individuals. Industrial activity ranges from extraction of primary commodities (ores, fuel, timber), through provision of necessities (food, clothes, shelter), to the manufacture of highly sophisticated articles. Throughout, industry searches deliberately for the best reward for the effort deployed (and in this differs characteristically from the academic pursuit and search for knowledge). Achievement of the best results requires organizational skills. The existence of an evolving organization confers a particular atmosphere on a company. It is hoped to convey this industrial atmosphere so that the inexperienced reader may decide whether he is attracted to industry; and if he is, to prepare him to some extent for what he will find.

Scope of and framework for this book

In traditional science courses in higher education there is strong emphasis on the analysis of the subject matter and presentation of the subject in digestible amounts. A typical example of the analysis of a course in chemistry is shown in Fig. 1.1. The first step is the breakdown into organic, inorganic, and physical chemistry. Yet the student cannot swallow any branch of chemistry all at once, so the subject matter is broken down into items such as 'the Arrhenius equation' and 'the third law'. Once this stage is reached the subject matter is collected in the form of a syllabus; the solution to the problem 'how can we present chemistry to students?' is the breakdown into isolated topics. The answer to the question 'what chemistry is being taught?' is in the collection of topics, the re-synthezised syllabus.

In industry and elsewhere, it is necessary to combine an analytical and a synthetic approach to work situations, problems, and decision. A model illustrating the processes involved is shown in Fig. 1.2. Most

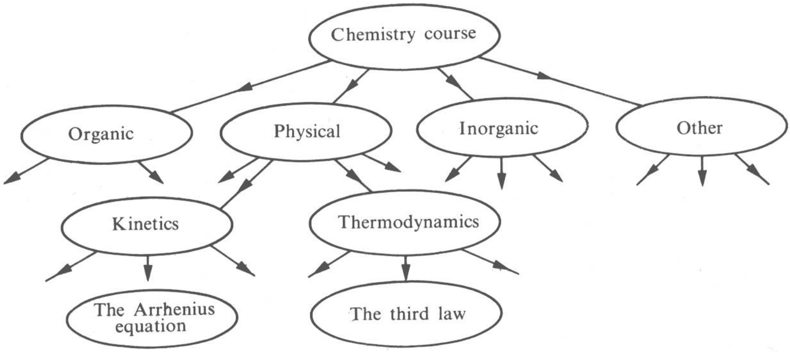

FIG. 1.1. A typical analysis of a chemistry course.

of the digestible portions or components of chemistry courses are not used in the solution of a specific problem; some may never be used by the chemist. Instead, he will need to acquire disciplines and other chemistry components of which he has little or no previous experience. Indeed, in an age of growing technological, economic, and social complexity it would be impossible to cover all these components and disciplines in one course. The recognition of these analytic and synthetic processes may be more important than the components or content of courses. Traditionally, undergraduate courses have not primarily been concerned with the careers students intended to pursue, and rightly so. For example, the plant manager in the chemical industry is often a graduate chemist. As we shall see later, his job has several components, including technology, human relations, management principles and

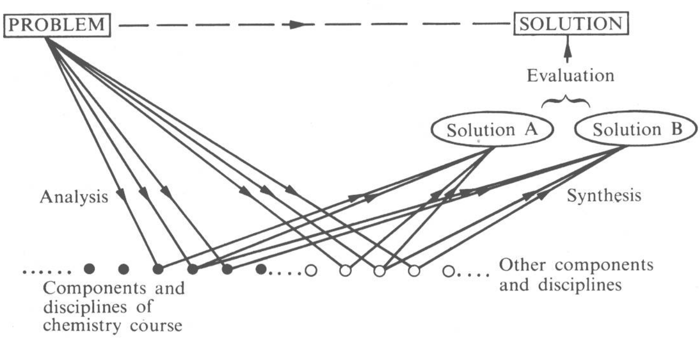

FIG. 1.2. The analysis of a problem and synthesis of a solution.

practice, accountancy, and economics. The particular technology will vary from plant to plant and product to product, and the accounting system from company to company. To provide a course in higher education to cover the plant manager's vocational needs would be pointless; such a specific mix of disciplines is best acquired 'on the job'. The potential plant manager, however, must have the tools to acquire the skills he needs. He should be able to analyse his job, to know where to look for the appropriate knowledge and to apply it in order to do his job. This analytic-synthetic approach to work situations, problems, and decisions is one of the important common features of professional careers.

This book emphasizes the analytic-synthetic processes essential to the work of the qualified chemist in industry. For example, Chapter 2 will be devoted mainly to a systems approach embodying the analytic-synthetic processes. Each analysis presented is neither unique nor definitive, but illustrative. Clearly, there may be as many solutions as there are plant managers to the problem, 'what are the major components of a plant-managers job?'.

The main concern of this book is communication. Perhaps the most important thing a chemist learns in his course is to communicate chemistry, despite the scant direct regard paid to this in many courses. A chemist may not know how to obtain dichloro(di-t-butylacetylene) (*p*-toluidine) platinum, but he should know how to find out—whom to ask or alternatively how to search the literature and retrieve from it what he needs. Furthermore, the qualified chemist should be able to report both verbally and in writing on his findings. In industry most problems are not quite so straightfoward as 'how can dichloro(di-t-butylacetylene) (*p*-toluidine) platinum be obtained?'. For example, an analysis of the problem 'how can the throughput of process X be improved?' may lead to some standard cost calculations, and thus communication with an accountant; the analysis may also indicate that plant modifications are required, in which case communication with engineers would be necessary. Communication is therefore an essential factor in the analytic-synthetic approach. Since management is concerned with solving problems and decision-making, communication is necessarily a key management process.

Management

In the last few decades management has emerged as a discipline in its own right. As is appropriate with disciplines there are a number of schools. The *management process school* which is a development of '*scientific management*' is one such school. The management process school views management as a combination of several processes. The four basic processes are planning, organizing, directing or leading, and controlling; the fifth process sometimes included is staffing. The sixth process, communication, correlates all of these processes. The *human-relations school* is primarily concerned with getting things done by motivating individuals and groups. We shall look at the scientific management and the human-relations schools in Chapter 4. If any label were to be attached to the approach presented in this book it might be 'eclectic'.

Economics

At the national level economics is concerned with the quantitative relations between consumption, investment, national income, employment, taxes, imports, and exports. However, as far as the individual is concerned, the definition of Davies and McCarthy (1967) may be useful: 'Economics . . . can most usefully be defined as the attempt to provide a quantitative basis for decision-taking in social affairs'. Economics, like management, is a common, essential thread running through the work of the chemist in industry. In addition, the specialized topic of chemical process economics is of particular concern to the chemist and the chemical engineer in plant design and in the economic operation of existing plants; this has been developed by Happel (1958).

The principle economic aim of any company is the efficient use of available resources in order to maximize benefit over the agreed time span. If performance and efficiency are to be measured, the objectives have to be quantified and the resources defined. The basic scarce resource in the Western world is capital; but other resources, for example, labour, or raw materials, may be scarce, or in special cases floor-area (on a limited manufacturing site) or water (in a desert environment). Market penetration may be vitally important (either as total sales volume or as a share of the total market). Objectives will be formulated for all the important factors. In the chemical industry objectives are normally expressed in terms of rewarding the capital invested—as percentage return either on the total capital or on shareholders' funds. The objective of a major company is usually to achieve a reward sufficient to ensure the company's well-being in the longer term, rather than to maximize reward in the immediate short term (for example, by stopping all development work, which may put the company out of business in 3-5 years).

Measurement and control of present operations are essential if company objectives are to be achieved. Chapter 5 is therefore devoted to cost analysis and control, especially with regard to chemical production. No company can stand still; its process technology and products will be overtaken by competitors and unless new investments are made and proved successful, the company will die. Innovation and especially technological research and development in the chemical industry is therefore essential to the survival of a company. Some aspects of research and development are discussed in Chapter 6. Evaluation of future opportunities is an important part of a company's activities (even though only a small team may be engaged on this task). Different projects compete for available cash and the determination of those best suited to the company involves specialized economic assessments; techniques for these are discussed in Chapter 7.

This book is intended to be read rather than studied as a text. By the end of the book the reader should have some idea of how to approach any job, situation, problem, or decision systematically and should have acquired also some of the language of management and economics relevant to the work of the chemist in industry.

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2. A systems approach

This chapter explains that a systematic approach is possible to situations that require action. Action has to be preceded by thought, preferably in an orderly way, if the best results are to be achieved. This approach is illustrated by reference to the management function.

Introduction

IN our studies, our work, and in most aspects of our life we are concerned with solving problems and involved in making decisions. To solve a problem we have to make a decision; for example, what test to use in a chemical analysis or what indicator to use in a titration. Most of the time we do not explicitly consider processes that cause us to solve the problems and make decisions, nor is it necessary that we should. Nevertheless, by adopting a disciplined and systematic approach to solving problems and making decisions, we can be more effective and efficient in what we do. It is up to us as individuals to decide where this approach might be useful and where not.

Our systems approach may be considered to have three primary components:

objectives,
decisions,
problems.

All these components are interrelated and they could be discussed in any order. With our simple, non-mathematical treatment we shall take them in the above order and then indicate their importance in planning, organizing, and control. Moreover, these are all aspects of the management function and therefore a discussion of this follows naturally.

Objectives

In the previous chapter we saw that the principal economic aim of any company is the achievement of the company's objectives with the available resources.

An aim requires a starting point and an end point. Before a company can define its aims and objectives it is necessary to have a clear knowledge of its strengths, weaknesses, and assets. The company's objectives are the end points to which its activities are directed. Although objectives may be either implicit or explicit, it is a basic tenet that when a number of people, that is a team, is collaborating, objectives must be explicit, otherwise the collaboration will lose effectiveness. The definition of explicit objectives is also fundamental to many individual activities including the following:

decision-making,
problem-solving,
planning,
organizing,
controlling.

If we wish to improve the effectiveness and efficiency of our activities or performance, it is necessary to clarify and agree our objectives. Having done this we are in a position to consider how to attain them. This involves making decisions.

Decisions

A simple scheme for decision-making consisting of four steps appears in Table 2.1. We have already seen that objectives should be clear. This should be the first step in a decision-making process. When the objectives

TABLE 2.1

A simple four-step scheme for decision-making

1. Establishing objectives.
2. Identifying possibilities.
3. Discovering consequences.
4. Making a choice.

have been agreed, possible methods of achieving them must be identified. Before we can choose between the various possibilities, we need information about the possible outcomes or consequences of each. Only then can we choose a method for achieving our objective. Making this choice is only one of the steps in the decision-making process. Decision-making is itself a key process in solving problems (Fig. 2.1).

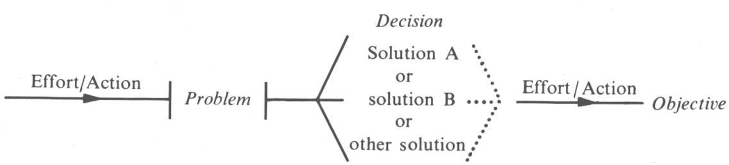

FIG. 2.1. The decision stage in problem-solving.

Problems

Problem-solving is a process that culminates in making a decision. The basic steps in the problem-solving process illustrated in Fig. 1.2 are summarized in Table 2.2.

TABLE 2.2

A three-step scheme for problem-solving

1. Analysis of problem.
2. Synthesis of solutions.
3. Evaluation of solutions.

The first step is the analysis of the problem into its component elements, factors, and assumptions, both explicit and implicit. We next attempt to structure these factors into a form that yields a solution. Many problems yield more than one solution, in which case we may have to evaluate the solutions and possibly make a choice. In science we often consider there may be only one solution to each problem. In real life usually only one solution can be attempted—no 'best' solution established by a series of experiments is possible. Yet many differing solutions exist to managerial and economic problems; this is part of the fascination of business or 'real life' activities, and an important difference between scientific and other problems.

In a simple scientific problem, for example:

Calculate the pressure at which 1 mol of gaseous ammonia occupies 1 dm^3 at 273 K,

there are several elements:

1. The gas is ammonia. We could either
   (a) assume ideal behaviour, or
   (b) assume gaseous ammonia behaves according to van der Waals, equation, or some other equation of state, under these conditions.
2. Amount of ammonia, $n = 1$ mol.
3. Volume, $V = 1\ dm^3$.
4. Temperature, $T = 273$ K.
5. Pressure is required.

Having analysed the problem we may consider the relationships between the elements and synthesize solutions. The alternatives are:

1. We assume ideal-gas behaviour; the ideal-gas equation

$$PV = nRT$$

   is then used, where R is the gas constant.

2. We use the van der Waals equation

$$\left(P + \frac{n^2a}{V}\right) \times (V - nb) = nRT.$$

In this case we have to find values for the constants a and b; then the pressure P can be calculated.

The problem, tackled in the above way, yields two solutions:

(a) $P = 24{\cdot}58 \times 10^5\,\mathrm{N\,m^{-2}}$
(b) $P = 21{\cdot}51 \times 10^5\,\mathrm{N\,m^{-2}}$,

or we could possibly find other solutions by using other equations of state. We can see that we are now left with another problem, that is:

'How do we evaluate these solutions?'

The above example not only outlines the problem solving process but also shows that even apparently simple problems can be complex.

O'Shaughnessy (1972) considers that each complex or unstructured problem is made up of five categories of problem each of which requires a decision. The five categories are listed in Table 2.3.

TABLE 2.3

The five problem categories

1. Description.
2. Explanation.
3. Prediction.
4. Evaluation.
5. Prescription.

For example, in reporting a laboratory experiment we may be faced with the problem of deciding how to describe the composition of a liquid solution. In this example there are several possibilities, for example:

molarity,
normality,
molality,
mole fraction,
weight/weight per cent,
weight/volume per cent,
volume/volume per cent.

In this case we have a descriptive problem requiring a descriptive decision. To guide us in making the relevant decision we need an objective. We need criteria or scales of relative worth against which we can value the various solutions. If the objective of the above experiment is the determination of molecular weight from depression of freezing-point observations we might decide to describe the composition of the solution in terms of molality. In the ammonia-gas problem we cannot evaluate the various solutions until we know the objective of the calculation in more detail.

A decision between possible proposed courses of action is called, in the above classification, a *prescriptive decision*. This is the most important category of decision.

Having discussed objectives, decisions, and problems we are now in a position to tie all three elements together by considering systems.

Systems

There are many definitions of a system. For example, scientists and engineers often refer to a system as that part of the universe under investigation. The system is thus defined by a boundary or surface. For our purposes a system is defined by a problem or group of problems. In this way the problem is central to our approach.

An example will help to illustrate this. The human body is a very complex system. However, if we consider solely the problem of slimming, a much simpler system is defined. The system need only include the factors associated with the problem. In our example the factors are: (1) the energy value, q of the food we consume; (2) the energy, w we expend through work, exercise, and other activities; (3) our weight change ΔW. We thus have three variables in our system, two of which are independent (q and w) and one which is dependent (ΔW). The system can be represented by a mathematical model,

$$\Delta W = q - w. \tag{2.1}$$

When the structure of a system A can be understood by relating it to a system B, then system B is said to be a model of A. If the relations between the elements of system A are identical to the relations between the elements of system B the two systems are said to be *isomorphs* of each other. In our example, eqn (2.1) and the slimming system are isomorphic.

Before the system can be defined, however, the problem must be clearly defined. In the slimming problem, has the problem been clearly defined? We have not considered the economic element. The problem could be redefined as: 'How to slim without incurring additional food costs?' If the normal food costs are C_n and the food costs whilst slimming are C_s then we could rewrite the mathematical model as