



Figure 1.3 Process design starts with the reactor. The reactor design dictates the separation and recycle problem. (From Smith R. and Linnhoff B. 1998, *Trans IChemE CAERD*, **66**:195 by permission of the Institution of Chemical Engineers).

Now, there is not only much less *FEED* in the reactor effluent but also more *PRODUCT* and *BYPRODUCT*. However, the increase in *BYPRODUCT* is larger than the increase in *PRODUCT*. Thus, although the reactor has the same three components in its effluent as the reactor in Figure 1.3a, there is less *FEED*, more *PRODUCT* and significantly more *BYPRODUCT*. This change in reactor design generates a different task for the separation system, and it is possible that a separation system different from that shown in Figures 1.3 and 1.4 is now appropriate. Figure 1.5 shows a possible alternative. This also uses two distillation columns, but the separations are carried out in a different order.

Figure 1.5 shows a flowsheet without any heat integration for the different reactor and separation system. As before, this is probably too inefficient in the use of energy, and heat integration schemes can be explored. Figure 1.6⁵ shows two of the many possible flowsheets.

Different complete flowsheets can be evaluated by simulation and costing. On this basis, the flowsheet in Figure 1.4b might be more promising than the flowsheets in Figures 1.4a, 1.6a and b. However, the best flowsheet cannot be identified without first optimizing the operating conditions for each. The flowsheet in Figure 1.6b might have greater scope for improvement than that in Figure 1.4b, and so on.

Thus, the complexity of chemical process synthesis is twofold. First, can all possible structures be identified? It might be considered that all the structural options can be found by inspection, at least all of the significant ones. The fact that even long-established processes are still being improved bears evidence to just how difficult this is. Second, can each structure be optimized for a valid comparison? When optimizing the structure, there may be many ways in which each individual task can be performed and many ways in which the individual tasks can be interconnected. This means that the operating conditions for a multitude of structural options must be simulated and optimized. At first sight, this appears to be an overwhelmingly complex problem.

It is helpful when developing a methodology if there is a clearer picture of the nature of the problem. If the process requires a reactor, this is where the design starts. This is likely to be the only place in the process where raw materials are converted into products. The chosen reactor design produces a mixture of unreacted feed materials, products and byproducts that need separating. Unreacted feed material is recycled. The reactor design dictates the separation and recycle problem. Thus, design of the separation and recycle system follows the reactor design. The reactor and separation and recycle system designs together define the process for heating and cooling duties.

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This document contains my own solutions to the problems proposed at the end of each chapter of the book "Process Modelling, Simulation and Control for Chemical Engineers" Second Edition, by William L. Luyben.

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