Higher
Chemistry

HSN13400
Unit 3 Topic 4

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Topic 4 – Chemical Industry

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Note: these are brief notes and must be supplemented by other sources.

Importance of the Chemical Industry

- the Chemical Industry is one of the largest British industries.
- its products are indespensable to many aspects of modern life and many are used for the benefit of society
- it is the only manufacturing industry to export more than it imports and so earns a trade balance surplus from these exports for Britain
- also invisible trade balance surplus from selling licences to use British processes abroad
- the chemical industry involves the investment of large sums of money but employs relatively few people making it a capital intensive and not a labour intensive industry.

What products does it make?

The 5 main categories of product that the industry makes are:
- basic inorganics and fertilisers
- dyestuffs, paint and pigments
- petrochemicals and polymers
- pharmaceuticals
- specialities

Stages in the manufacture of a new product

The manufacture of a new product is a step-wise process from its discovery, probably on a very small scale, to its production, on a large scale. The steps are:

research and development	a new potentially useful chemical is prepared and patented. Some products are discovered by accident but others as a result of long and expensive research.
laboratory process	small scale to review the production route
pilot study	the product is now required in larger amounts and will be manufactured in a pilot study using the route identified by the research group but in kilogramme quantities. Product quality, health hazards, and production costs will be discussed.
scaling up	planning the scaling up from lab quantities to full scale production will have been going on from the pilot study stage.
production	plant design, planning considerations, commissioning and start up
review	this will occur at each stage. All processes are reviewed and modifications are made.

Raw Materials and Feedstocks

A feedstock is a chemical from which other chemicals are manufactured. Feedstocks are made from raw materials; the basic resources that the earth supplies to us. They are:

- fossil fuels – coal, oil and natural gas
- metallic ores – eg aluminium extracted from bauxite (Al_2O_3)
- minerals – chlorine from sodium chloride
- water and air – water in hydration of ethene to ethanol and nitrogen in the Haber Process, oxygen in the catalytic oxidation of ammonia
- organic materials – of plant and animal origin eg vegetable oils and starch

Crude oil is a raw material from which naphtha is obtained by fractional distillation. Naphtha is a feedstock that can be cracked to produce ethene.

Batch and Continuous Processes

In a batch process the chemicals are loaded into the reaction vessel. The reaction is monitored and at the end of the reaction the product is separated and the reaction vessel cleaned out ready for the next batch. In a continuous process the reactants are continuously loaded at one end of the reaction vessel and the products are removed at the other end. Each process has advantages and disadvantages.

Batch Process

pros

- suited to smaller scale production up to 100 tons per annum
- more versatile than continuous as they can be used for more than one reaction
- more suited for multi step reactions or when reaction time is long

cons

- possibility of contamination from one batch to the next
- filling and emptying takes time during which no product, and hence no money, is being made
- safety – relatively large amounts of reactants may not be controllable in the event of an exothermic reaction going wrong

Continuous Process

pros

- suited to large scale production >1000 tons per annum
- suitable for fast single step processes
- more easily automated using computer control
- smaller workforce operates round the clock, 365 days per year
- greatest safety risk is at start up but this may be only every few months or years
- tend to operate with relatively low volumes of reactants allowing easy removal of excess heat energy

cons

- very much higher capital cost before any production can occur
- not versatile, can make only one product
- not cost effective when run below full capacity

In general products that are made on a very large scale will use a continuous process
eg. sulphuric acid, ammonia, iron, ethene, poly(ethene)

Products made on a smaller scale or when a continuous process would be difficult to devise or operate will use a batch process
eg. pharmaceuticals, dyes, copper refining by electrolysis

Factors Influencing the Choice of Synthetic Route

- cost, availability of feedstocks
- the yield of the reaction
- can unreacted starting materials be recycled?
- can by-products be sold?
- difficulty and cost of waste disposal
- energy consumption
- emissions to the atmosphere

Economic Aspects

Operating Conditions

The conditions under which a chemical process operates are chosen to maximise economic efficiency. We have considered these in other topics but examples are:

- raising the temperature may increase the rate of a reaction but it will increase energy costs so may not be economic
- increasing the pressure may shift an equilibrium in favour of the product but will mean using stronger reaction vessels and more powerful compressors and may not be economic.

Costs in the Chemical Industry

Costs come under 3 main categories – capital, fixed and variable costs.

The amount of money paid by the chemical industry for raw materials, energy, labour, research and development, plant design and construction, waste disposal, warehousing, packaging, distribution, marketing and sales must all be covered by the selling price of the product. Sales must also produce a profit to invest in new research and to pay off loans.

Capital Costs

These are incurred when building the plant. The life of a plant is assumed to be only about 10 years after which it is written off. The cost of this depreciation is recovered under fixed costs.

Fixed Costs

These are costs that are the same whether 1 ton or 1000 tons of product are made. The effect of the fixed cost decreases as the amount of product increases. They include:

- depreciation of the plant
- labour
- land purchase

Variable Costs

These are directly related to output and include

- raw materials and energy
- packaging
- waste disposal and effluent treatment

Use of Energy

As we have just seen, energy is an important variable cost and steps are taken to keep it to a minimum. This involves

- choosing processes which use less energy
- using the heat from exothermic reactions elsewhere in the plant, for example to supply heat to an endothermic reaction
- using waste heat to generate electricity to use in the plant or sell for district heating

Location of the Chemical Industry

Many locations are for historical and practical reasons. They had to be near

- raw materials
- water supply
- good communications; near ports, roads and rail
- reliable energy supplies
- available skilled labour

Safety and the Environment

The chemical industry is well aware of its environmental responsibilities and is acting accordingly.

- power stations that burn fossil fuels must remove the sulphur dioxide from the flue gases before release to the atmosphere. The SO_2 is converted to H_2SO_4 which is sold.
- waste used to be dumped in quarries, rivers, the sea or stored in containers from which it could leak into streams. These methods are no longer acceptable and are increasingly becoming illegal. Waste must be treated and discharged only when it is not harmful to the environment – it must meet requirements of pH and metal ion content.
- water containing organic waste must not be discharged into rivers or canals if it will reduce significantly the oxygen content of the water, causing fish to die.
- between 1990 and 1996 discharge of potentially harmful chemicals into UK rivers was reduced by 91 %.
- plants have reduced accidents by 50% in the last decade.
- road and rail tankers that carry chemicals are constructed to withstand impact in accidents.
- plants have their own fire fighting teams on site.
- plants are designed with safety in mind.

Chemicals are hazardous so the accident rate will never be zero but the aim is to learn from mistakes and reduce the rate to a minimum.