Unit 5: Chemicals for a purpose

In this unit students find out about:

- organic and inorganic compounds
- the chemistry of oil products
- manufacturing processes
- the preparation and analysis of a chemical product.

Students' portfolio evidence should consist of a portfolio related to information on organisations that use science to analyse processes.

The activities

These give students experience of and an opportunity to demonstrate their ability to:

- describe two examples of inorganic and two examples of organic chemical products, discussing their uses, properties and chemical structure, including more detail about one example of a product made from oil to show how its structure and chemistry relate directly to its use
- discuss two industrial processes that produce two different chemical products - at least one process will involve the use of a catalyst, whose action they will explain - evaluating each process by discussing its advantages and disadvantages, and by clearly explaining the importance of the products it produces
- a sample and account of the preparation of a product that has been synthesised, purified and analysed for purity in the laboratory.

The grid below summarises the activities. They provide more opportunities than students will probably have the time for and so suitable ones will need to be selected.

Note: The activity summaries refer to those aspects that link directly to the specifications. All are set in context and so have some other parts to them.

The activities have been devised to develop knowledge, understanding and skills in a logical and progressive way. It is suggested that they are used in the given order.

A Preparative chemists

Students learn about:

- skills and knowledge needed by preparative chemists
- properties of molecular compounds
  - bonding in molecules
  - shapes of molecules
  - functional groups
  - reactions of molecules
- practical skills and techniques used by preparative chemists
  - measuring melting and boiling points
  - microscale preparation of hexanedioic acid
  - small scale preparation of a solid (benzoic acid)
  - small scale preparation of a liquid (2-methylbut-2-ene).

B The chemical industry

Students learn about:

- the chemical industry and the difference between bulk chemicals and fine (or speciality) chemicals
- sustainability and the chemical industry, and investigate one industrial process in detail

- primary inorganic industries (chloralkali, nitrogen, sulfur and phosphorus) and the manufacture of bulk inorganics
- fine inorganics.

C The petrochemical industry

Students learn about:

- molecular formula, structural formula, displayed formula, skeletal formula by looking at
  - alkanes
  - alkenes
  - arenes
- bond strengths
- branched, unbranched and cyclic hydrocarbons
- the use of
  - mass spectroscopy
  - infrared spectroscopy
  - nuclear magnetic resonance spectroscopy

  to determine the structure of organic molecules
- processing oil.

D Petrochemical products

Students learn about:

- addition polymers formed from alkenes, and the importance of catalysts in the reactions
- organic solvents made in bulk by the petrochemical industry
- condensation polymers, including preparing nylon in the laboratory
- the nature of chemicals used as soaps and detergents, including making and testing soaps and detergent in the laboratory.

E Functional groups

Students learn about:

- recognising functional groups in compounds
  - alkene
  - alcohol
  - carboxylic acid
  - ester
  - aldehyde
  - ketone
  - amide
  - amine
- naming organic compounds.

F Making new compounds

Students learn about:

- the use of computational chemistry, combinatorial chemistry, small scale preparation and pilot scale preparation in making new compounds
- making esters, including
  - using parallel synthesis and small scale synthesis to make samples of esters
  - suggesting a scheme to automate the process
  - using spectra to follow the reaction

- making azo dyes, including
  - using microscale and small scale preparations
  - suggesting a scheme to automate the process
- how one of the following techniques is used in a research laboratory to identify or work out the structure of a chemical compound
  - mass spectrometry
  - infra-red spectroscopy
  - nuclear magnetic resonance spectroscopy.

G Making inorganic compounds

Students learn about:

- inorganic compounds found in mineral supplements
- how to make samples of metal sulfate from copper(II) oxide, magnesium carbonate, zinc oxide and sulfuric acid
- the pigments malachite, green verditer and blue verditer
- how to make these pigments in the laboratory and determine their purity.

OCR
AS GCE APPLIED SCIENCE
UNIT 5: CHEMICALS FOR A PURPOSE

B

THE CHEMICAL INDUSTRY

Specification links

This report relates to the following parts of Unit 5: Chemicals for a purpose

Content

- Organics and inorganics (the range of chemicals produced by the chemical industry)
- Inorganic compounds used and made in industry
- Research and study some large-scale chemical processes

Assessment

Students need to include

- a discussion of two industrial processes that produce two different chemical product

science

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THE REPORT

THE CHEMICAL INDUSTRY

Earth is amazing. Its natural resources have sustained the evolution of life since the first living organisms emerged. Nowadays these resources are used to make medicines, plastics, agrochemicals, fibres, detergents, dyes, fragrances, fuels, explosives, fertilisers, metals, glasses and many other products. This is the business of the chemical industry. The industry constantly seeks ways to protect our environment and to preserve these valuable, but finite, resources.

Contents

The science at work

From raw materials …

Raw materials come from:

- the ground (the lithosphere);
- the oceans, lakes and rivers (the hydrosphere);
- the air we breathe (the atmosphere).

Raw materials are converted into bulk chemicals, both inorganic and organic.

These commodity chemicals are made in large quantities - several thousand tonnes each year. They are used as starting materials in a wide variety of processes. Fine (or speciality) chemicals are made on a smaller scale, often for specialised uses.

Most of the chemical products we use are formulations. These are made by mixing pure chemicals according to a formulation. Look, for example, at a box of washing powder, a tube of toothpaste or a bottle of shampoo - the ingredients are listed but not their quantities or the way they are put together. The exact formulation may be a trade secret.

Sustainability

Supplies of raw materials and energy resources such as fossil fuels are limited. Modern chemical processes are designed to make efficient use of raw materials and energy.

Further, designers do everything possible to reduce waste from a process. This is sustainability in the chemical industry. Catalysts have a vital role in sustainability. They can allow reactions to be carried out under conditions which require less energy, and reduce the formation of by-products.

Making a process sustainable can also reduce costs.

Your brief

You will find out about:

- the range of compounds produced by the industry;
- some manufacturing processes used in the chemical industry;
- the concepts of sustainability and green chemistry.

Work in a pair on this task. You might find it helpful to share your ideas with another pair.

The report

The chemical industry

1 Obtain a copy of *Datasheet: The chemical industry*. Fill in the boxes with examples. The chart is based on one produced by the Department for Trade and Industry. The distinction between **Consumers** and **Industry and agriculture** is that products are sold:

- either directly to us ('Consumers');
- or to other manufacturing, processing and service industries ('Industry and agriculture').

Use a range of resources including the internet, your library, newspapers and the TV news. Keep a list of the range of sources you have used. These might be a useful starting point:

- Department for Trade and Industry
  http://www.dti.gov.uk/comp/benchmark/pdf_file/chemical.pdf
- Chemical Industry Association http://www.cia.org.uk/newsite/
- ICI http://www.ici.com/ICIPLC/home/index.jsp
- Johnson Matthey http://www.matthey.com/
- BASF http://www.corporate.basf.com/en/?id=V00-7urak7vY-bcp49z
- European Chemical Industry Council http://www.cefic.be/ (take a look at: Chemistry in Your Everyday Life: Chemistry Sectors)
- For data try http://www.cefic.org/factsandfigures/level02/profile_index.html (of particular interest might be profile of the chemical industry and sectional breakdown of the EU chemical industry sales).

You may find it hard to decide in which box to put some chemicals. This is because the terms in the flow chart are not precisely defined and categories may overlap. Different parts of the chemical industry use them differently. You may also come across other terms.

2 Find out how fine or speciality chemicals are defined in terms of the quantities produced. They have a known chemical identity and are bought and sold on the basis of their purity.

3 Chemists describe chemicals as inorganic and organic. For the chemicals you put on *Datasheet: The chemical industry* indicate whether they are inorganic or organic.

Sustainability and the chemical industry

1 Think about the term **sustainability** and agree a description with your partner.

2 Now work with another pair to research definitions of sustainability. Make a note of the sources of information you found. Organise the data into two lists:

- statements about sustainability that appear in most of the sources;
- statements about sustainability that appear in only one or two sources.

Review your own description of sustainability and modify it if you think you need to.

3 Choose one of the chemicals you found out about when filling in *Datasheet: The chemical industry*. With your partner, produce a five minute presentation to the rest of the class about how it is manufactured. Include information about:

- starting materials - materials needed for the process and their source;
- products and their use - main products and, if any, side products and their usefulness;
- scale of production - bulk commodity or fine;
- type of production (use and explain the terms 'batch' or 'continuous' in the manufacture of chemicals);
- conditions - temperature, pressure and catalyst (use and explain the terms homogeneous catalysts and heterogeneous catalysts);
- sustainability - raw materials, energy efficiency, waste production and any effect on the environment;
- location of manufacturing plant(s);
- safety considerations taken into account during manufacture or transport of reactants/products;
- profitability of the process, including an idea of future demand for the product.

Listen to all the presentations, filling in key details of each process on *Datasheet: Manufacturing inorganic chemicals*. You will keep a record of organic manufacturing processes when you complete the activity *The petrochemical industry*.

Primary inorganic industries

You will find out about the manufacture of organic compounds in the activity *The petrochemical industry*. But here, you will look at the inorganic chemical industry.

1 Work with another pair and allocate one of the following primary inorganic chemical industries to each member of your group:

chloralkali • nitrogen • sulfur • phosphorus

For each industry find out about:

- the raw materials used, where they come from and how they are obtained;
- the uses of the primary products from these industries, including the types of companies that use the primary products to make fine/speciality chemicals;
- the processes used (give as much information as possible about energy costs, waste products, availability of raw materials and sustainability).

2 Chose one of the primary inorganic chemical industries and produce a brief newspaper article, aimed at non-science specialists, that provides an overview of the industry.

Describe the advantages and disadvantages of one of the key processes used in your chosen industry. Include information about sustainability, raw materials, energy use and any other items you consider important.

3 Optional. Share your newspaper reports among the group. Pick one of them and write a letter to the editor of the newspaper. This might be:

- a personal response to issues raised;
- a summary of new things you learned;
- an extension of ideas you read that show the importance of the compound/industry to modern society.

Fine inorganics

There are hundreds of thousands of companies around the world specialising in producing just one or two fine (or speciality) inorganic chemicals in various quantities and degrees of purity. They often supply a niche market.

Working with the others in your group, list 10 fine inorganic chemical and, for each, say who manufactures it and what it's used for. Examples can be found using search engines, e.g. Http://www.excite.co.uk/directory/Business/Chemicals/Basic_Chemicals/Inorganic

If you want to find out about elements and their compounds try: Http://www.webelements.com/

Your findings

Keep this activity sheet together with your answers to the questions in your portfolio. Make sure you:

- include the completed *Datasheet: The chemical industry;*
- add examples to the *Datasheet: Manufacturing chemicals;*
- include your newspaper article on an industrial process.

Useful resources

- *The UK Chemical Industry*. Obtainable from the Chemical Industries Association (CIA), Kings Buildings, Smith Square, London SW1P 3IJ and CIA's website: http://www.cia.org.uk/newsite/
- *Chemical Industry Data*. A brief guide to the chemical industry, London, Royal Society of Chemistry, 1997.
- *Alchemy?* A CD ROM produced by the Royal Society of Chemistry, containing video clips of many important industrial processes.
- Sustainability and green chemistry. Lots of information available, for example:

  http://www.uyseg.org/sustain%2Ded/pages/Process/ProcessFrameset.htm

  http://www.uyseg.org/sustain%2Ded/index.htm

  http://corporate.basf.com/en/sustainability/?id=jFns281nKbcp2p7

  http://www.bp.com/genericsection.do?categoryId=4445&contentId=7005392

  http://www.uyseg.org/greener_industry/images/menus/content_03.htm, and follow links for details of specific chemical manufacture.
- Try internet searches using the names of well-known chemical manufacturers such a Johnson Matthey, BASF, BP Chemicals, Shell Chemicals, Unilever, ICI.

  Here are some sites you might try:

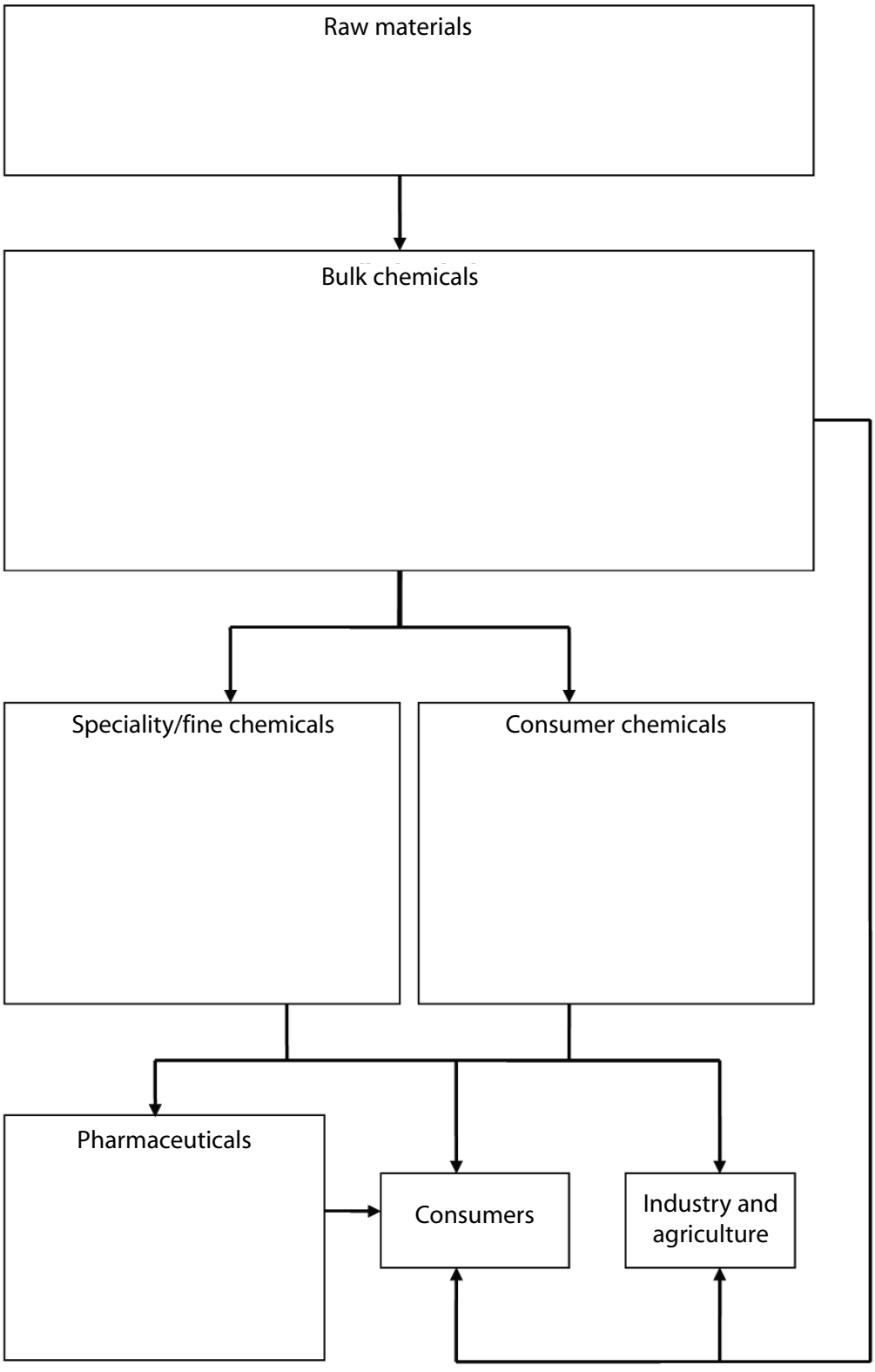
  http://www.eurochlor.org/europeanchlorineindustry

  http://www.dti.gov.uk/sectors_chemicals.html

  http://www.lyondell.com/index.asp

  http://www.cefic.org/factsandfigures/level02/profile_index.html

Datasheet: The chemical industry



Datasheet: Manufacturing inorganic chemicals

Process: Haber process for ammonia

Starting materials	Products and their use	Conditions (including catalyst)	Sustainability e.g. raw materials, energy efficiency, waste

Process: Contact process for sulfuric acid

Starting materials	Products and their use	Conditions (including catalyst)	Sustainability e.g. raw materials, energy efficiency, waste

Process:			
Starting materials	Products and their use	Conditions (including catalyst)	Sustainability e.g. raw materials, energy efficiency, waste

Process:			
Starting materials	Products and their use	Conditions (including catalyst)	Sustainability e.g. raw materials, energy efficiency, waste

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Outline

The purpose of this activity is to introduce students to the chemical industry. It's suggested that each student works with a partner.

The chemical industry

Students undertake research to find out about the chemical industry. They are given a blank copy of the diagram and asked to fill in examples. They might be given some 'starters' which they sort into the boxes and then add examples of their own, e.g. crude oil, water, sulfuric acid, ethene, pain relievers, shampoos, cosmetics, food additives, paints. Here is what might be found in each box:

Raw materials

- crude oil, coal and natural gas
- minerals and ores
- water
- air

Speciality chemicals

- adhesives
- fine organics
- food additives
- electronic materials

Consumer chemicals

- cosmetics
- personal care products
- paints and varnishes
- photographic

Bulk chemicals

- From the primary chemical industries:
  - Chloralkali industry: chlorine, sodium hydroxide, sodium carbonate
  - Sulfur industry: sulfuric acid
  - Nitrogen industry: nitric acid, ammonia
  - Phosphorus industry: phosphoric(V) acids, phosphates
  - Petrochemical industry: e.g. ethene, propene, methylbenzene (toluene)
- Bulk industrial chemicals

These are manufactured from products of the primary chemical industries. Examples include: ethylene oxide, ethanoic acid, solvents, polymers, fibres, fertilisers.

This activity is followed naturally by *The petrochemical industry*.

If available, the BBC Panorama video on the accident at Bhopal might be shown. A substantial amount of information about the chemical industry can be learned from this and social, ethical and moral issues will be raised. This could lead to a lively discussion.

Sustainability and the chemical industry

Students think about the term sustainability and then test out their ideas by researching in books and the internet. Using a range of sources, students should check for consistency of ideas and be evaluative about what they find. It's important to encourage them to separate opinions from fact.

Each pair should give a 5 minute presentation to the class on the manufacture of one chemical. The class can add examples to their copy of *Datasheet: The chemical industry*.

Primary inorganic industries

This compliments the activity *The petrochemical industry*. Each student finds out about one of the primary inorganic chemical industries: chloralkali, nitrogen, sulfur, phosphorus. Their findings might be presented as a newspaper article, though other ideas might be considered.

Fine inorganics

This is intended to be a quick exercise, designed to get them to look beyond bulk chemical industries.

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