Science
Level 1/2

Cambridge NATIONALS

Unit R071 – How scientific ideas have an impact on our lives

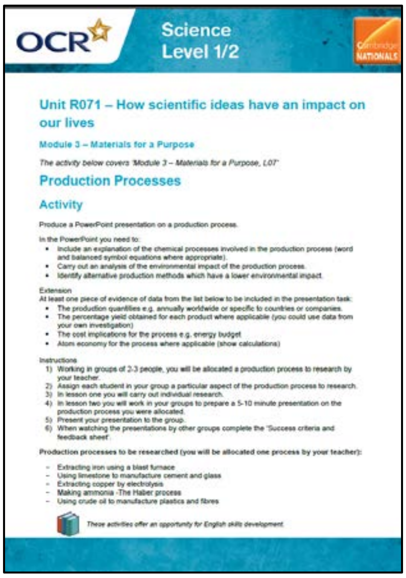
Module 3 – Materials for a Purpose

Production Processes

Instructions and answers for the teachers

These instructions should accompany the learner tasks - OCR resource ‘Benefits and risks of using nuclear radiation’, which supports Cambridge Nationals in Science Level 1/2 Unit R071 – How scientific ideas have an impact on our lives.

The learner tasks cover ‘Module 3 – Materials for a Purpose, LO7’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Unit R071 – How scientific ideas have an impact on our lives

Module 3 – Materials for a Purpose

The activity below covers ‘Module 3 – Materials for a Purpose, LO7’

Production Processes

Activity

Produce a PowerPoint presentation on a production process.

In the PowerPoint you need to:
- Include an explanation of the chemical processes involved in the production process (word and balanced symbol equations where appropriate).
- Carry out an analysis of the environmental impact of the production process.
- Identify alternative production methods which have a lower environmental impact.

Extension
At least one piece of evidence of data from the list below to be included in the presentation task:
- The production quantities e.g. annually worldwide or specific to countries or companies.
- The percentage yield obtained for each product where applicable (you could use data from your own investigation)
- The cost implications for the process e.g. energy budget
- Atom economy for the process where applicable (show calculations)

Instructions
1) Working in groups of 2-3 people, you will be allocated a production process to research by your teacher.
2) Assign each student in your group a particular aspect of the production process to research.
3) In lesson one you will carry out individual research.
4) In lesson two you will work in your groups to prepare a 5-10 minute presentation on the production process you were allocated.
5) Present your presentation to the group.
6) When watching the presentations by other groups complete the ‘Success criteria and feedback sheet’.

Production processes to be researched (you will be allocated one process by your teacher):

- Extracting iron using a blast furnace
- Using limestone to manufacture cement and glass
- Extracting copper by electrolysis
- Making ammonia -The Haber process
- Using crude oil to manufacture plastics and fibres

These activities offer an opportunity for English skills development.

Associated Files:
Production Processes

Expected Duration: approx 3 hours
Individual research approx 45 minutes
Presentation preparation approx 60 minutes
Presentation delivery and feedback approx 60 minutes

Five potential production processes are given on the following pages. The answers (except for atom economy calculations) below are not exhaustive; learners may include alternative or additional answers.

The ‘Success criteria and feedback sheet’ for the presentation can be found at the end of these answers.

A) Extracting iron using a blast furnace

Process
You would expect learners to identify:
- The raw materials needed to extract iron ie, iron ore, limestone, and coke
- Reactions in the blast furnace
- Word and balanced symbol equations for each stage of the reactions in the blast furnace.

Environmental impact
Learners may identify environmental problems associated with mining and transporting the raw materials such as:
- Loss of landscape due to mining, processing and transporting the iron ore, coke and limestone
- Noise and air pollution, for example carbon dioxide which contributes to the greenhouse effect, sulphur dioxide from the sulphur content of the ores which contributes to acid rain
- Disposal of the slag
- Transport of the finished iron.

Alternative method(s)
A possible alternative method to the blast furnace learners may suggest is called Hismelt. Hismelt is short for 'high intensity smelting'. Hismelt is a direct smelting process where iron is produced with no slag waste product. The process allows iron ore with significant impurities to be used, and cheaper non coking coal instead of coke.

Extension: Atom Economy for reduction of iron-oxide to iron

Balanced equation: Fe_2O_3 + 3CO (g) →2Fe (l) + $3CO_2$ (g)

Atom economy = mass of useful product /total mass of products x 100

(A_r values Fe = 56, C = 12, O = 16) So M_r Fe = 2x 56 = 112 M_r CO_2 = 3X 44 =132

Atom Economy = [112/ (112+ 132)] x 100 = [112 / 244] x 100 = 45.90%

B) Using limestone to manufacture cement and glass

a) Using limestone to make cement

Process
You would expect learners to identify:
- The raw materials ie, limestone, sand, shale, clay, and iron ore
- The role of the thermal decomposition of limestone in the process of cement making
- The conditions required for the production of cement
- Word and balanced symbol equations for the thermal decomposition of limestone ie $CaCO_3$(s) →CaO(s) + CO_2 (g)

b) Using limestone to make glass

Process
You would expect learners to identify:
- The raw materials ie, sand, limestone and sodium carbonate soda
- The roles of limestone and sodium carbonate
- The conditions required to make glass ie the raw materials are heated to 1500^0C.

Environmental impact
The main environmental impact associated with limestone is quarrying, therefore the main issues that may be identified by learners are:
- Noise and heavy traffic
- Quarrying processes eg, blasting rocks apart with explosives makes lots of noise and dust
- Destruction of the habitats of animals and birds.

In addition, energy is needed to produce cement and this is likely to come from the burning fossil of fuels which causes pollution.

Alternative method(s)
Learners may identify that kilns could be heated with alternative fuels. They may also come across a new type of cement called Eco-cement. Eco-cement is an environmentally sustainable blended cement which incorporates reactive magnesia and produces wastes that are more environmentally sustainable. This new cement aims to reduce the amount of CO_2 emitted by 80% and to reduce the amount of energy consumed by the manufacturing process by 50%.

Extension: Atom Economy for thermal decomposition of Limestone
In the Kiln the reaction is: $CaCO_3$(s) → CaO(s) + CO_2 (g)

(A_r values: Ca = 40, C = 12, O = 16)

So M_r values are $CaCO_3$ = 100; CaO = 56 and CO_2 = 44

Atom economy = mass of useful product /total mass of products x 100

Atom economy = [56/(56 + 44)] x 100 = 56%

C) Extracting copper by electrolysis

Process
Learners may include a discussion about the production of smelting to produce impure copper. You would expect learners to identify:
- That electrolysis is used to purify copper
- Electricity is passed through solutions containing copper compounds eg, copper sulphate
- The anode is made is made from impure copper and the cathode is made from thin pure copper
- The movement of ions to produce copper at the cathode ie
  (Cathode) $Cu^{2+} + 2e^- \rightarrow Cu$, (Anode): $Cu \rightarrow Cu^{2+} + 2e^-$
- The production of sludge at the anode and the change in mass at the cathode and anode.

Environmental impact
Learners may discuss how the electricity used in electrolysis involves burning fossil fuels in power stations, which in turn release greenhouse gases contributing to global warming and acid rain.

Alternative method(s)
Possible alternatives learners may identify:

- Bioleaching - Using bacteria to separate copper from copper sulphide. The bacteria get energy from the bond between copper and sulphur, separating out the copper from its ore in the process. The leachate (the solution produced by the process) contains copper, which can be extracted by filtering. This process has a low set-up cost, does not need huge pen cast mines that scar the landscape, uses a lot less energy and does not produce sulphur dioxide gas. It can also be used on ores that would pollute the air when smelted, eg copper ores containing toxic arsenic. However, it does not recover precious metals, sometimes acid has to be added to the ore which costs money, sometimes the bacteria themselves produce too much acid –which has to be neutralised and it can take years to extract only 50% of the copper from the ores.
- Phytomining - This involves growing plants in soil that contains copper. The plants can't use or get rid of the copper so it gradually builds up in the leaves. The plants can then be harvested, dried and burned in a furnace. The copper is then collected from the ash left in the furnace.
- Displacement reactions - Copper can be extracted from solutions of copper salts using scrap iron. Iron is more reactive than copper so it can displace copper from copper salts eg:

  Chemical word equation: copper sulphate + iron → iron sulphate + copper

  Symbol equation: $Fe\ (s) + CuSO_4\ (aq) \rightarrow FeSO_4\ (aq) + Cu(s)$

Extension: Atom Economy for displacement reaction for extracting copper from copper sulphate

Symbol equation: $Fe\ (s) + CuSO_4\ (aq) \rightarrow FeSO_4\ (aq) + Cu(s)$

Atom Economy = mass of useful product /total mass of products x 100

(A_r values Fe = 56, S = 32, O=16, Cu=63.5) So M_r $FeSO_4$ = 56+ 32 + 4X16 =152, M_r Cu= 63.5

Atom Economy = [163.5/(63.5 +152)] = [56/208] x 100 = 26.9%

Atom Economy for reduction of malachite (copper carbonate) to copper

Equation 1: $\mathbf{2CuCO_3} \longrightarrow 2CuO + 2CO_2$

Equation 2: $2CuO + C \longrightarrow \mathbf{2Cu} + CO_2$

(A_r values Cu = 63.5, C = 12, O = 16) So M_r CO_2 = 44, CuO = 79.5)

For equation 1, Atom Economy is [(79.5 x2) / (2x79.5 + 2 x 44)] x 100 = [159/247] x 100 = 64.3%

For equation 2, Atom Economy is [(2x 63.5)/(2x63.5 + 44)] x 100 = [127/171] x100 = 74.3%

D) Making Ammonia - The Haber process

Process
You would expect learners to identify:

- The raw materials ie, hydrogen and nitrogen.
- The conditions ie, a high temperature (about 450°C) , a high pressure (about 200 atmospheres) and an iron catalyst
- The main stages in the Haber Process
- Word and balanced symbol equations eg $N_2 (g) + 3H_2 (g) \rightleftharpoons 2NH_3 (g)$

Environmental impact
Learners may identify:

- Hydrogen comes from fossil fuels which contribute to the greenhouse effect and global warming
- Ammonia is used to make fertilisers which can cause eutrophication and water pollution.

Alternative method(s)
An alternative process uses renewable local feedstock in the process to make ammonia. This process is low cost production compared with the more expensive method of making ammonia from natural gas (Haber process). The fact that everything is kept locally eg, local distribution and consumption helps to reduce costs such as for transportation.

Percentage yield of the Haber process
Using a pressure of around 200 atms and a temperature of about 500^0C the yield of ammonia using the Haber process is between 10-20%.

Atom Economy for Haber process
Since only one product is made, the atom economy is 100%

E) Using crude oil to manufacture plastics and fibres

Process
Learners may identify:

- The process of cracking
- The process of addition polymerisation
- Condensation reactions
- How ethene is the starting material for plastics

Environmental impact
Learners may identify the following impacts on the environment:

- Oil spills can happen as the oil is being transported by tanker
- Burning fossil fuels releases CO_2 and SO_2 which contributes to global warming and acid rain
- Most polymers are not biodegradable.

Alternative method(s)

Learners may identify the following alternatives:

- Recycling and reusing plastics that already exist. Recycling is a more cost-effective and environmentally friendly method to meet the demands for plastics.

- Non-petroleum based plastics. For example, corn is used to make bio-plastic drinking cups; and soy is used as insulating foam for seat cushions and buildings.
- Degradable plastics-The following methods have been developed by scientists to make plastics more biodegradable:
  - Chemists have designed polymer chains containing certain groups of atoms that absorb light energy. These types of plastics have bonds within their structure that can be weakened and broken by sunlight or contain a chemical additive which absorbs light and then attacks the polymers and breaks some of the bonds. The light energy absorbed splits the chain at those groups and breaks the plastics into smaller pieces which rot away more quickly.
  - New plastics have been made by bacteria. The bacteria produce granules of a plastic that is totally biodegradable and completely breaks down in nature in about 9 months. This type of plastic is 15 times more expensive than normal plastics.
  - Plastics that are soluble in water. By changing the reacting mixture, it is possible to get plastics to dissolve in water at different temperatures.

Extension: Atom Economy for manufacturing plastics and fibres

- Addition polymerisation used to make plastics has 100% atom economy as only one product is made.
- Condensation polymerisation used to make fibres involves the elimination of water molecules hence does not have 100% atom economy.

Success criteria and feedback sheet for presentation

Peer-assessment Skills

- During the presentations complete the table below (tick if achieved in PowerPoint or cross if not)

Success Criteria	Group1	Group 2	Group 3	Group 4	Group 5	Group 6
Use of word equation and chemical equation to explain chemical process						
Environmental impact discussed						
Alternative production methods discussed						
Evidence of data handling eg percentage yield, atom economy calculation etc						

Success Criteria	Group1	Group 2	Group 3	Group 4	Group 5	Group 6
Each member of group actively involved in presentation						
Group members show understanding during presentation-not just reading text out loud						
Information written in own words-not just cut and paste						
Bibliography within text seen						
Any other comments						