Production of Materials

1. Fossil fuels provide both energy and raw materials such as ethylene, for the production of other substances.

1.1 Identify the industrial source of ethylene from the cracking of some of the fractions from the refining of petroleum.

1.1.1 Describe the composition of petroleum.

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1.1.2 When petroleum undergoes distillation, fractions are produced. Identify some of these.

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1.1.3

(a) Define fractional distillation.

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(b) Use a diagram to show the industrial process of fractional distillation of petroleum.

(c) Use a diagram to show the process of fractional distillation in the school laboratory.

1.1.4

(a) Identify the IUPAC name for ethylene.

(b) Construct the structural formula for ethylene.

(c) Outline the main source of ethylene.

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1.1.5 Ethene is produced by the cracking of petroleum fractions. Describe the process of cracking.

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1.2 Identify that ethylene, because of the high reactivity of its double bond, is readily transformed into many useful products.

1.2.1 Complete the following:

Ethylene (ethene) belongs to a homologous group of hydrocarbons called ..... .
All Alkenes have a ..... bond as their functional group. This is called a covalent bond because the carbon atoms ..... electrons. It is called a double bond because the ..... atoms share ..... pairs of ..... .

1.2.2

(a) Complete the following table to summarise the differences between the three series of hydrocarbons, alkanes, alkenes and alkynes.

Homologous series	General formula	Functional group
Alkane		
	C_nH_{2n}	
		–C≡C–

(b) Write molecular formulas for:

(i) ethane .....

(ii) ethene .....

(iii) ethyne .....

1.2.3 Ethane and ethene (ethylene) are both hydrocarbons, and they share a number of properties. They both have small, non-polar molecules, with weak dispersion forces between their molecules, they are both relatively insoluble in water, have low melting and boiling points and they both burn readily in air or oxygen. Despite these similarities, ethene is used much more extensively in industry than ethane. Account for this difference in use.

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1.2.4 Alkanes such as ethane undergo substitution reactions.

(a) What is meant by a substitution reaction?

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(b) Use an equation to show an example of a substitution reaction.

1.2.5 Alkenes such as ethene (ethylene) undergo addition reactions.

(a) What is meant by an addition reaction?

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(b) Use an equation with structural formulas to show the addition of hydrogen to ethane.

(c) Use an equation with structural formulas to show the addition of chlorine to ethene (ethylene).

1.3 Identify data, plan and perform a first-hand investigation to compare the reactivities of appropriate alkenes with the corresponding alkanes in bromine water.

1.3.1 Describe the test you would use to distinguish an alkane such as ethane from an alkene such as ethene (ethylene). (This should include test results and equations.)

1.3.2 During your course, you planned and performed a first-hand investigation to compare the reactivities of appropriate alkenes with the corresponding alkanes in bromine water.

(a) Identify the chemicals you used and justify their choice.

(b) Explain one safety precaution necessary when carrying out this experiment.

1.4 Identify that ethylene serves as a monomer from which polymers are made.

1.4.1

(a) Define monomer.

(b) Define polymer and identify three examples of polymers.

(c) Identify the term used to describe the process by which monomers are converted to a polymer.

1.4.2 Justify the classification of ethylene (ethene) as a monomer.

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1.4.3 Classify each of the following as either a monomer or a polymer.

(a) starch .....

(b) glucose .....

(c) ethylene (ethene) .....

(d) polyethylene .....

1.5 Identify polyethylene as an addition polymer and explain the meaning of this term.

1.5.1 Define what is meant by an addition polymer.

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1.5.2

(a) Identify the monomer used to manufacture the polymer called polyethylene.

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(b) Use an equation to show that polyethylene is an addition polymer.

(c) Draw the structural formula for a part of a polyethylene molecule showing three monomer units joined together.

1.6 Outline the steps in the production of polyethylene as an example of a commercially and industrially important polymer.

1.6.1 Justify the statement that polyethylene is a commercially important polymer.

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1.6.2 Outline the steps in the production of polyethylene.

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1.6.3

(a) Explain what is meant by a free radical.

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(b) Explain how the formation of an ethene free radical assists in the formation of a polymer.

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1.6.4

(a) Identify the type of catalyst used in the industrial production of polyethylene.

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(b) Describe the effect of this catalyst on the polymerisation process.

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1.6.5 Use a flow chart to show the industrial production of polyethylene from ethylene.

1.6.6 In industrial processes such as polymerisation, quality control is carried out. Identify three factors that would need to be continually monitored and explain why this process is important in the production of polyethylene.

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1.6.7 During the production of polyethylene it is important to monitor temperature of the reaction vessel. Explain.

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1.7 Analyse information from secondary sources such as computer simulations, molecular model kits or multimedia resources to model the polymerisation process.

1.7.1 Describe how you modelled the polymerisation process in class.

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1.8 Identify the following as commercially significant monomers:

- **vinyl chloride**
- **styrene**

by both their systematic and common names.

1.8.1 Complete the following table to summarise information about the monomers vinyl chloride and styrene.

Common name of monomer	Systematic name of monomer	Formula of monomer	Name of polymer
Vinyl chloride			
Styrene (Vinyl benzene)			

1.9 Describe the uses of the polymers made from the above monomers in terms of their properties.

1.9.1 Use the following table to summarise some uses of the polymers made from the monomers vinyl chloride and styrene.

Name of polymer	Structure of polymer	Uses
Polyvinyl chloride (PVC)		
Polystyrene		

1.9.2 Complete the following table to link the uses of the different forms of the polymers shown to properties that allow them to be used in these ways.

Name of polymer	Use	Property that determines this use
PVC	Flooring and carpet backing	
PVC	Sheets for roofs and skylights	
Polyethylene	Natural gas pipes Coating steel pipes	
Polyethylene	Plastic bags and Food containers	
Polyethylene	Sheathing for wire cables used for phone and TV	
Polystyrene	Disposable foam cups	
Polystyrene	Surfboards	

1.9.3 Assess the impact of the development of the production of polymers on society and on the environment.

2. Some scientists research the extraction of materials from biomass to reduce our dependence on fossil fuels.

2.1 Discuss the need for alternative sources of the compounds presently obtained from the petrochemical industry.

2.1.1 What is meant by the petrochemical industry?

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2.1.2 Identify 10 chemicals presently produced by the petrochemical industry.

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2.1.3 Discuss the need for alternative sources of compounds presently manufactured by the petrochemical industry.

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2.2 Use available evidence to gather and present data from secondary sources and analyse progress in the recent development and use of a named biopolymer. This analysis should name the specific enzyme(s) used or organism used to synthesise the material and an evaluation of the use or potential use of the polymer produced related to its properties.

2.2.1 Define the term biopolymer.

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2.2.2

(a) Identify a biopolymer which is produced commercially.

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(b) Describe the structure of this polymer.

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(c) Identify and give the formula of the monomer(s) used to manufacture this named biopolymer.

(d) Identify the source of the monomer(s).

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2.2.3 Answer the following questions about the biopolymer identified in Question 2.2.2.

(a) Name the specific enzyme(s) or organism(s) used to synthesise this biopolymer.

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(b) Analyse progress in the development of this biopolymer.

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(c) Identify uses of this biopolymer.

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(d) Identify properties of this biopolymer.

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(e) Choose one use of this biopolymer and relate this use to its properties.

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(f) Analyse progress in the uses of this biopolymer.

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2.3 Explain what is meant by a condensation polymer.

2.3.1 Explain what is meant by a condensation polymer and identify three examples.

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2.4 Describe the reaction involved when a condensation polymer is formed.

2.4.1 Use an equation to show the formation of a condensation polymer.

2.4.2 Describe the reaction involved when a condensation polymer is formed.

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2.4.3 Compare condensation and addition reactions.

Condensation reactions	Addition reactions
Both involve ..... joining to form a long chain molecule.	
No double bonds necessary	
	No small molecule produced

3. Other resources, such as ethanol, are readily available from renewable resources such as plants.

3.1 Describe the dehydration of ethanol to ethylene and identify the need for a catalyst in this process and the catalyst used.

3.1.1

(a) Write the structural formula of ethanol.

(b) Justify the classification of ethanol as an alkanol.

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3.1.2

(a) What is meant by a dehydration reaction?

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(b) Constuct an equation to illustrate the dehydration of ethanol to ethylene.

(c) Describe the dehydration of ethanol.

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3.1.3 Outline a reason for the use of a catalyst in the dehydration of ethanol.

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3.2 Describe the addition of water to ethylene resulting in the production of ethanol and identify the need for a catalyst in this process and the catalyst used.

3.2.1 Write a molecular equation to show the addition of water to ethylene to produce ethanol.

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3.2.2 Describe the addition of water to ethylene to produce ethanol.

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3.3 Process information from secondary sources such as molecular model kits, digital technologies or computer simulations to model:

- **the dehydration of ethanol**
- **the addition of water to ethylene.**

3.3.1 Use structural formulas to model the following reactions:

(a) dehydration of ethanol

(b) addition of water to ethylene

3.3.2 Describe how you modelled one of the following reactions:

- the dehydration of ethanol
- the addition of water to ethylene.

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3.4 Process information from secondary sources to summarise the processes involved in the industrial production of ethanol from sugar cane.

3.4.1 Outline the processes involved in the industrial production of ethanol from sugar cane.

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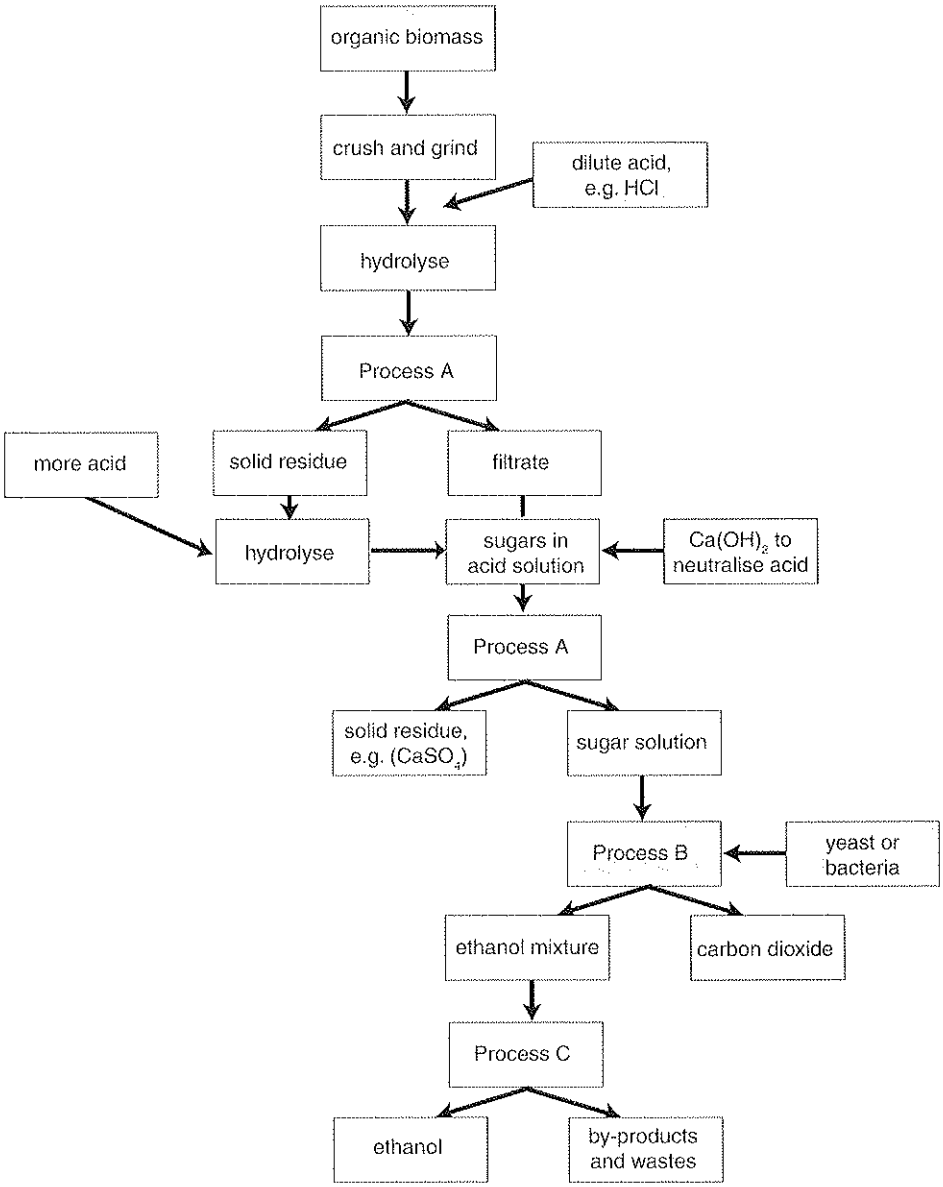
3.4.2 The following flow chart summarises the industrial production of ethanol from biomass.



Identify the processes that occur at:

A .....

B .....

C .....

3.5 Describe and account for the many uses of ethanol as a solvent for polar and non-polar substances.

3.5.1

(a) Identify the type of bonding within a molecule of ethanol.

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(b) Explain why ethanol is a polar molecule.

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(c) Identify the intermolecular forces between molecules of ethanol.

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(d) Use a diagram to show a hydrogen bond between atoms in adjacent ethanol molecules.

3.5.2 Describe and account for the many uses of ethanol as a solvent for polar and non-polar substances.

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3.6 Outline the use of ethanol as a fuel and explain why it can be called a renewable resource.

3.6.1 Outline the use of ethanol as a fuel.

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3.6.2 Justify the classification of ethanol as a renewable resource.

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3.6.3 Distinguish between the terms renew, reuse and recycle.

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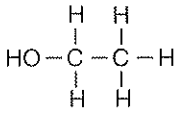
3.7 Identify the IUPAC nomenclature for straight-chained alkanols from C1 to C8.

3.7.1

(a) Complete the following table to revise the structure and nomenclature of the first eight alkanols.

Name of alkanol	Molecular formula	Structural formula
Methanol		
		
Propanol		
	C_4H_9OH	
Pentanol		
Hexanol		
	$C_7H_{15}OH$	
Octanol		

(b) Show the structural formulas of:

(i) 3-hexanol

(ii) 2-propanol

3.8 Identify data sources, choose resources and perform a first-hand investigation to determine and compare heats of combustion of at least three liquid alkanols per gram and per mole.

3.8.1

(a) Identify the three liquid alcohols you used when performing a first-hand investigation to determine and compare heats of combustion of alkanols.

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(b) Use a labelled diagram to show the method you used.

(c) Comment on the accuracy of your results.

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(d) Suggest ways you could improve the accuracy of your results.

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(e) Explain one safety precaution you applied when carrying out this experiment.

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3.9 Define the molar heat of combustion of a compound and calculate the value for ethanol from first-hand data.

3.9.1 Define the molar heat of combustion of a compound.

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3.9.2 The following table shows the heats of combustion for a number of fuels.

(a) Complete the following table by calculating the heat of combustion in kJ g^{-1} for each of the fuels shown.

Fuel	Formula	Heat of combustion (kJ/mole)	Heat of combustion (kJ/gram)
Hydrogen	H_2	285	
Coke (carbon)	C	393	
Methane	CH_4	890	
Ethane	C_2H_6	1560	
Propane	C_3H_8	2220	
Methanol	CH_3OH	727	
Ethanol	C_2H_5OH	1367	

(b) Identify the fuel that would produce the most heat by the combustion of 1 g of fuel.

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(c) Consider which has the lower heat of combustion, ethanol or methanol. Using this information, which would be more expensive to use as a fuel?

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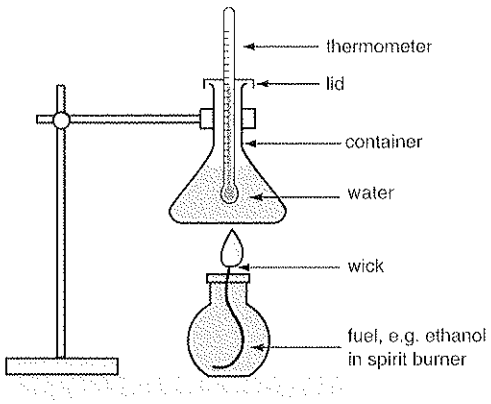
3.9.3 A group of Year 12 students performed a first-hand investigation of the heat of combustion of ethanol. They burned ethanol in a spirit burner, and used it to heat 100 mL of water, as shown in the diagram below.



The results they obtained were:

Initial temperature of 100 mL water = 22.6°C

Final temperature of 100 mL water = 35.9°C

Initial mass of spirit burner + ethanol = 235.56 g

Final mass of spirit burner + ethanol = 234.23 g

Specific heat of water = 4.2×10^3 J kg^{-1} K^{-1}

Use these results to calculate the experimental molar heat of combustion of ethanol.

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3.10 Process information from secondary sources to summarise the use of ethanol as an alternative car fuel, evaluating the success of current usage.

3.10.1 Describe and evaluate the use of ethanol as a fuel in cars.

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3.10.2 Identify one secondary source you used to obtain this information and evaluate the validity of the information obtained from this source.

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3.11 Assess the potential of ethanol as an alternative fuel and discuss the advantages and disadvantages of its use.

3.11.1 Assess the potential of ethanol as an alternative fuel and discuss the advantages and disadvantages of its use.

3.12 Solve problems, plan and perform a first-hand investigation to carry out the fermentation of glucose and monitor mass changes.

3.12.1 Describe the first-hand investigation you carried out to ferment glucose and monitor mass changes.

3.12.2

(a) Write an equation for the fermentation of glucose.

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(b) Identify a potential problem in the fermentation of glucose and outline the method you used to overcome this problem.

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(c) Explain any mass changes that occur during fermentation.

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3.13 Describe conditions under which fermentation of sugars is promoted.

3.13.1 Describe conditions under which fermentation of sugars is promoted.

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3.14 Summarise the chemistry of the fermentation process.

3.14.1 Summarise the chemistry of the fermentation process.

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3.15 Present information from secondary sources by writing a balanced equation for the fermentation of glucose to ethanol.

3.15.1 Write a balanced equation for the fermentation of glucose to ethanol.

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4. Oxidation-reduction reactions are increasingly important as a source of energy.

4.1 Perform a first-hand investigation to identify the conditions under which a galvanic cell is produced.

4.1.1 Identify the conditions under which a galvanic cell is produced.

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4.1.2

(a) Describe a galvanic cell that you set up.

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(b) Identify any observations you made.

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4.2 Perform a first-hand investigation and gather first-hand information to measure the difference in potential of different combinations of metals in an electrolyte solution.

4.2.1 During this topic you performed a first-hand investigation in which you measured the difference in potential of different combinations of metals in an electrolyte solution.

(a) Identify two combinations of metals that you used in this investigation.

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(b) Identify the electrolytes you used.

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(c) For one of the pairs of metals used, draw a labelled diagram to show how you performed the experiment.

(d) Outline one possible source of error in this investigation and describe how you could overcome this.

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(e) Outline one safety issue involved in the carrying out of this experiment and describe how you would handle this issue.

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(f) Describe what you used as a salt bridge and indicate the direction of flow of ions over this salt bridge.

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4.3 Explain the displacement of metals from solution in terms of transfer of electrons.

4.3.1 Explain the displacement of metals from solution in terms of transfer of electrons.

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4.4 Identify the relationship between displacement of metal ions in solution by other metals to the relative activity of metals.

4.4.1 Identify the relationship between displacement of metal ions in solution by other metals to the relative activity of metals.

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4.4.2 List the following metals in order of activity from most active to least active: iron, magnesium, sodium, silver, zinc, lead, aluminium, calcium, copper.

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4.4.3

(a) A series of solutions is set up and pieces of metal are placed in each solution as shown in the table below. Complete the table to show where displacement reactions will occur.

Solution	Metal added	Any displacement reaction
Calcium chloride	Zinc	
Zinc chloride	Calcium	
Lead chloride	Magnesium	
Lead chloride	Silver	

(b) Which would cause the more vigorous displacement reaction, placing magnesium metal in zinc nitrate or in silver nitrate solution? Explain.

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(c) A piece of zinc is placed into a copper sulfate solution. The copper sulfate loses its blue colour, copper is deposited on the bottom of the beaker and the zinc disappears. What can you deduce about the relative reactivity of copper and zinc?

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4.5 Account for changes in the oxidation state of species in terms of their loss or gain of electrons.

4.5.1 Account for changes in the oxidation state of species in terms of their loss or gain of electrons. (*Hint:* Show the connection between an increase or decrease in oxidation state and the processes of oxidation and reduction.)

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4.5.2 State the rules for working out oxidation states/numbers.

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4.5.3 Identify the oxidation states of the following:

(a) Iron in $FeSO_4$ .....

(b) Iron in $FeCl_3$ .....

(c) Iron metal .....

(d) Oxygen in CO_2 .....

(e) The nitrate ion NO_3^-.....

(f) Manganese in $KMnO_4$ .....

4.6 Describe and explain galvanic cells in terms of oxidation/reduction reactions.

4.6.1 What is meant by a galvanic cell?

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4.6.2 Define the terms:

(a) oxidation

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(b) reduction

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(c) redox reaction

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(d) oxidant

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(e) reductant

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4.6.3 Explain galvanic cells in terms of oxidation/reduction reactions.

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4.7 Outline the construction of galvanic cells and trace the direction of electron flow.

4.7.1 Outline the construction of galvanic cells.

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4.7.2

(a) Describe the direction of electron flow in a galvanic cell.

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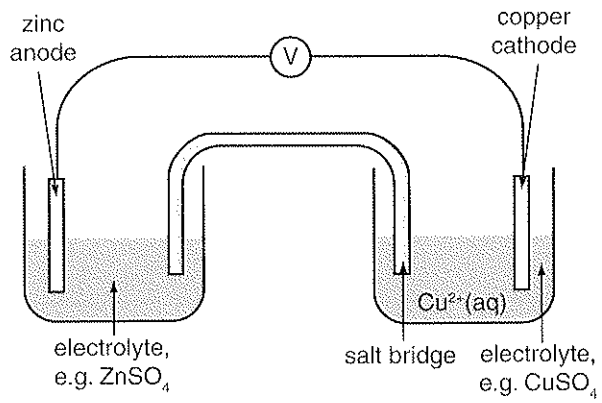
(b) Add arrows to show:

(i) the flow of electrons in the following galvanic cell

(ii) the movement of ions in the salt bridge



4.8 Define the terms anode, cathode, electrode and electrolyte to describe galvanic cells.

4.8.1 Define the following terms:

(a) electrode

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(b) electrolyte

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(c) anode

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(d) cathode

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4.8.2

(a) Identify the purpose of galvanic cells in society today.

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(b) In terms of oxidation/reduction, explain the purpose of separating the reactions into two half-cells.

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4.9 Solve problems and analyse information to calculate the potential $E^{\ominus}$ requirement of named electrochemical processes using tables of standard potentials and half equations.

4.9.1

(a) What is meant by a standard reduction potential?

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(b) Define a standard hydrogen half-cell. Include a diagram in your answer.

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(c) Identify the instrument used to measure the potential difference between two half-cells.

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4.9.2

(a) What is meant by the redox table?

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(b) Complete the following prose passage to describe the redox table.

In the redox table, forward reactions are written as ..... reactions. The higher the reduction potential the more easily the species is ..... .

Oxidations are shown by ..... the reactions and changing the sign.

Oxidising agents are on the ..... side of the table, and they increase in strength as you move ..... the table.

The strongest oxidising agent is ..... . Fluorine is most likely to accept ..... from another species, thus causing the oxidation of that species.

Reducing agents are found on the right side of the table, the strongest reducing agent is at the ..... of the table.

Potassium and barium are the strongest reducing agents, so they are the metals most likely to ..... electrons to another species, thus causing that species to be ..... .

A metal higher in the redox series will displace a metal ..... from a solution of its ions.

All metals above hydrogen will displace ..... from a solution of its ions.

A reducing agent will react with an ..... agent lower in the table.

4.9.3 Use the redox table in the back of this book to answer the questions below.

(a) What is the reduction potential for $Fe^{2+} + 2e^- \rightleftharpoons Fe(s)$? .....

(b) Convert the following reduction reactions to oxidation reactions:

(i) $Al^{3+} + 3e^- \rightleftharpoons Al(s)$ -1.66 V

(ii) $Cu^{2+} + 2e^- \rightleftharpoons Cu(s)$ $+0.35$ V

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(c) An iron electrode is placed in a beaker of aluminium sulfate solution. Another iron electrode is placed in copper sulfate solution. Write equations to show in which beaker a redox reaction is occurring.

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(d) A galvanic cell is set up containing a copper electrode in copper sulfate solution connected to a zinc electrode in zinc sulfate solution.

Calculate the $E^{\ominus}$ potential for this cell if standard conditions apply.

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4.10 Gather and present information on the structure and chemistry of a dry cell or lead-acid cell and evaluate it in comparison to one of the following:

- **button cell**
- **fuel cell**
- **vanadium redox cell**
- **lithium cell**
- **liquid junction photovoltaic device (e.g. the Gratzel cell)**

in terms of:

- **chemistry**
- **cost and practicality**
- **impact on society**
- **environmental impact**

4.10.1

(a) Draw a diagram of either a dry cell OR a lead acid cell and describe its chemistry.

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(b) Draw a diagram of either a button cell, fuel cell, vanadium redox cell, lithium cell OR a liquid junction photovoltaic device (e.g. the Gratzel cell) and describe its chemistry.

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4.10.2 For the two cells chosen in Question 4.10.1, complete the following table to compare them.

	Dry cell or lead acid cell	Button cell, fuel cell, vanadium redox cell, lithium cell, OR Gratzel cell
Cost and practicality		
Impact on society		
Environmental impact		

4.10.3 Assess a dry cell or a lead-acid cell in comparison to one of the following:

- button cell
- fuel cell
- vanadium redox cell
- lithium cell
- liquid junction photovoltaic device (e.g. the Gratzel cell).

5. Nuclear chemistry provides a range of materials.

5.1 Distinguish between stable and radioactive isotopes and describe the conditions under which a nucleus is unstable.

5.1.1

(a) Define isotope.

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(b) Distinguish between a stable and a radioactive isotope.

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(c) Describe the conditions under which the nucleus of atoms is unstable.

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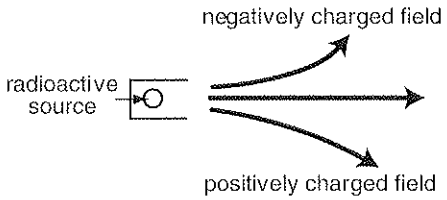
5.1.2 Complete the following table to compare alpha, beta and gamma radiation.

	Alpha radiation	Beta radiation	Gamma radiation
Structure	Particles		
Consist of		Electron from the nucleus	
Charge	+2		
Ionising ability		Fair	
Penetration	Poor (2-10 cm in air)		
Deflection in electric field		Towards positive plate	

5.1.3 Label the three types of radiation shown in the following diagram as alpha, beta or gamma radiation.



5.1.4

(a) Describe radioactive decay.

(b) What is meant by the half-life of a radioactive isotope?

5.2 Process information from secondary sources to describe recent discoveries of elements.

5.2.1 Describe recent discoveries of elements.

5.2.2 Identify two recently discovered elements and outline their method of production.

5.3 Describe how transuranic elements are produced.

5.3.1

(a) What is meant by a transuranic element?

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(b) Briefly outline how transuranic elements are produced.

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(c) Describe the production of two transuranic elements. Include equations.

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5.4 Describe how commercial radioisotopes are produced.

5.4.1

(a) Identify some commercial radioisotopes.

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(b) Describe how commercial radioisotopes are produced.

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5.5 Identify instruments and processes that can be used to detect radiation.

5.5.1 Identify instruments that can be used to detect radiation.

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5.5.2 For two of the instruments named above, outline the processes involved.

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5.6 Identify one use of a named radioisotope:

- **in industry**
- **in medicine.**

5.6.1

(a) Identify one use of a named radioisotope in industry.

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(b) Identify one use of a named radioisotope in medicine.

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5.7 Describe the way in which the above named industrial and medical radioisotopes are used and explain their use in terms of their chemical properties.

5.7.1 Describe the way in which the radioisotopes named in Question 5.6.1 are used.

(a) industrial radioisotope

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(b) medical radioisotope

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5.7.2 For one of the radioisotopes described in Question 5.7.1, explain its use in terms of its properties.

5.8 Use available evidence to analyse benefits and problems associated with the use of radioactive isotopes in identified industries and medicine.

5.8.1 Analyse benefits associated with the use of radioactive isotopes in identified industries and medicine.

5.8.2 Analyse problems associated with the use of radioactive isotopes in identified industries and medicine.

Notes