

Module 1

THE IDENTIFICATION AND PRODUCTION OF MATERIALS

CHAPTER 1: ETHENE

Review exercise 1.1

- 1 Any chemical that has been derived from petroleum.

2

Energy source	Advantages	Disadvantages
Ethanol	clean burning, renewable	production not yet commercially viable
Hydrogen	less polluting	expensive
Solar energy	renewable	expensive installation
Hydroelectric	renewable, cheap	environmental damage

Review exercise 1.2

- 1 Boiling point.
- 2 Weak dispersion forces caused by temporary induced dipoles.
- 3 Increasing molecular mass in larger molecules causes greater dispersion forces due to a greater number of electrons.
- 4 Hexane is non-polar and therefore immiscible in water. It will form a layer above water as it is less dense.

Review exercise 1.3

- 1 Alkenes have a reactive double bond.
- 2
 - a Catalytic cracking produces lower mass hydrocarbons from high mass petroleum fractions. Thermal cracking converts ethane and propane to ethene.
 - b Catalytic cracking uses zeolites (catalysts) to control the cracking process at lower temperatures. Thermal cracking uses high temperatures to break the hydrocarbon.
 - c $\text{C}_9\text{H}_{20} \rightarrow \text{C}_7\text{H}_{16} + \text{C}_2\text{H}_4$

- 3 Zeolites. These solid crystalline substances absorb the gaseous reactants therefore weakening their bonds.

Review exercise 1.4

- 1
 - i Reaction with bromine solution. 1-hexene would decolourise the bromine solution while hexane would show no reaction.
 - ii Oxidation with cold, dilute potassium permanganate (KMnO_4). 1-hexene would decolourise the KMnO_4 . Hexane would show no reaction.
- 2
 - a $\text{C}_3\text{H}_6 + \text{Cl}_2 \rightarrow \text{C}_3\text{H}_6\text{Cl}_2$ 1,2-dichloropropane
 - b $\text{C}_7\text{H}_{14} + \text{HBr} \rightarrow \text{C}_7\text{H}_{15}\text{Br}$ 2-bromoheptane, 1-bromoheptane
 - c $\text{C}_6\text{H}_{12} \rightarrow \text{C}_6\text{H}_{13}\text{OH}$ 3-hexanol
- 3 Chlorination of 2-butene.
- 4 Oxidation of ethene using cold, dilute KMnO_4 .
- 5 The fermentation of natural sources of starch or sugar is yet to become a commercially viable method of producing ethanol.

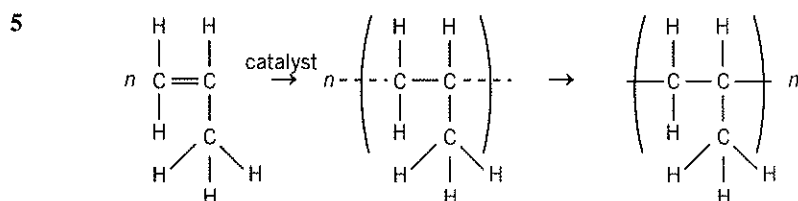
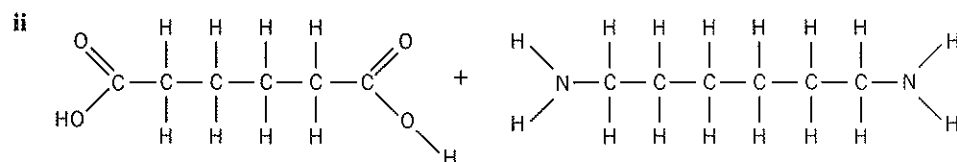
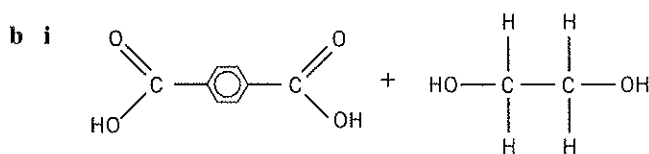
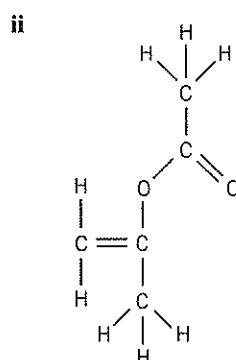
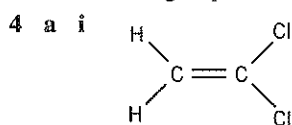
Chapter 1 — Application and research

- 1 Research
- 2
 - a A: C_8H_{18} B: CH_4 C: C_4H_{10}
 - b Advantage: easier to clean up.
 - Disadvantages: damage to marine life and birds. Less likely to become dilute.
- 3
 - a
 - i To produce hydrocarbons with lower molecular mass which have greater market demand, eg petrol, branch-chained alkanes to improve the performance of petrol.
 - ii To produce ethene which can be used as a starting material for many organic compounds.
 - b
 - i Petrol, branched chain alkanes which improve petrol performance, alkenes used as starting blocks for synthesis and hydrogen.
 - ii Ethene and hydrogen. Used as building blocks for organic substances.
 - c Catalytic cracking uses zeolite crystals as catalysts to lower the activation energy in the cracking of high molecular mass hydrocarbons. Thermal cracking uses very high temperatures to crack hydrocarbons such as ethane and propane.
- 4
 - a $\text{C}_9\text{H}_{20} \rightarrow \text{C}_7\text{H}_{16} + \text{C}_2\text{H}_4$
 - b $\text{C}_3\text{H}_8 \rightarrow \text{CH}_4 + \text{C}_2\text{H}_4$
- 5 Research
- 6 The reactive double bond readily undergoes addition reactions in order to gain a more stable single bond.
- 7
 - a 1,2-dichloropropane
 - b 1-chlorobutane; 2-chlorobutane
 - c ethanol
- 8
 - a 2-butene with HCl
 - b 2-butene with Cl_2
 - c propene with H_2O in the presence of a catalyst
- 9 Cyclohexene undergoes an addition reaction with Br_2 across the double bond. The bonds in benzene react similarly to the saturated hydrocarbon cyclohexane, and thus do not undergo addition reactions.
- 10 Research

CHAPTER 2: POLYMERS

Review exercise 2.1

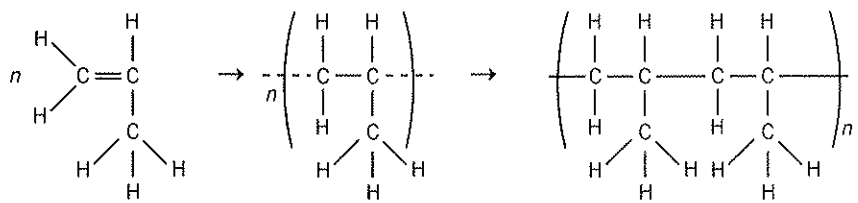
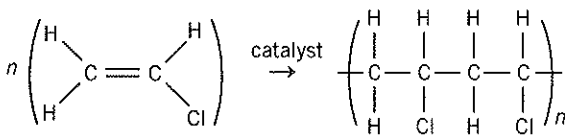
- 1 The chemical reaction whereby monomers link together to form polymers.
- 2 **Addition polymerisation:** all atoms in monomer are present in polymer chain.
Involves unsaturated monomers joining together via breaking of the C = C double bond.
Condensation polymerisation: reaction between two monomers, which can be different, during which a small molecule, such as water, is eliminated.
- 3 **a** monomers have C = C double bond.
b Monomers contain two functional groups which may be different.
Common groups are -COOH (carboxylic acid), -OH (alcohol) or -NH₂ (amine) group.



Review exercise 2.2

- 1 Nylon's structure consists of many long chains with weak dispersion forces between the chains. These chains slide easily when heated. Therefore nylon can be remoulded but hardens on cooling.
Phenol-formaldehyde is a hard plastic which does not soften on heating. This is due to strong covalent bonds present between chains in its structure.
Vulcanised rubber. Crosslinking and overlapping of long chains allows vulcanised rubber to return to its original shape after distortion.
- 2
 - a reduced
 - b increased
 - c increased
 - d increased
 - e increases hardness

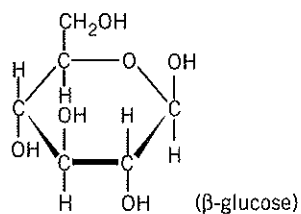
Review exercise 2.3

- 1
 - a 
 - b
$$n(\text{HOOC} - \text{C}_6\text{H}_4 - \text{COOH}) + \text{HO} - (\text{CH}_2)_2 - \text{OH} \rightarrow \text{H} - \text{OC} - \text{C}_6\text{H}_4 - \text{COO} - (\text{CH}_2)_2 - \text{O} - \text{H} + 2n\text{H}_2\text{O}$$
 - c 
- 2 LDPE is softer and more flexible due to greater branching of chains causing reduced dispersion forces.
HDPE has fewer branched chains causing greater dispersion forces and hence greater hardness and strength.
- 3 1 monomer unit has molar mass of 62.5, so 15 000 monomer units have molar mass of 937 500 a.m.u.
- 4
 - a polystyrene
 - b High Density Polyethene HDPE
 - c polypropene/nylon
 - d LDPE
 - e HDPE
 - f HDPE
 - g Teflon
 - h polyethene terephthalate (PET)

Review exercise 2.4

1 a cellulose

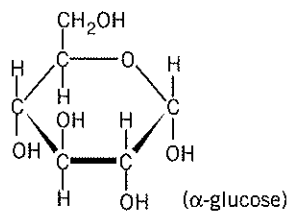
i



ii condensation

b starch

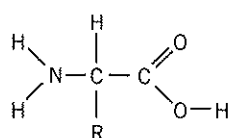
i



ii condensation

c proteins

i



ii condensation

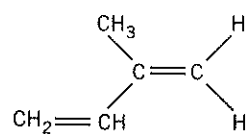
d DNA

i nucleotide

ii condensation

e rubber

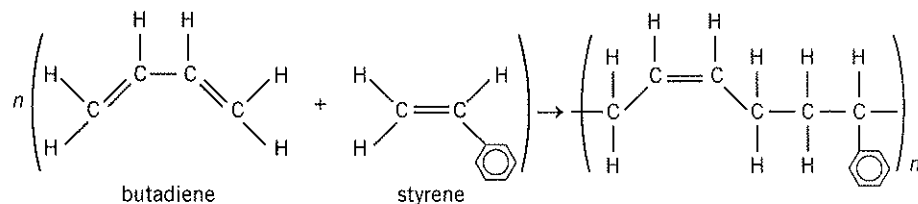
i



ii addition

- 2 Natural rubber is soft and not very elastic. The presence of double bonds means it is chemically reactive.
Vulcanised rubber contains sulfur atoms which crosslink the polymer chains.
This increases hardness and elasticity.

3



Review exercise 2.5

- 1
 - a Nature's decomposers do not possess the enzymes needed to break down the bonds within the synthetic polymers.
 - b Plastics such as PVC and PAN produce toxic HCl(g) and HCN(g) when burnt. If incineration is carried out at about 700°C without oxygen, the plastics can be reduced to simple raw materials such as methane, ethane, propene and benzene.
 - c High temperature incineration produces useful raw materials from plastics. Energy is also produced. This process is expensive but may become more economical in the future.
 - d Inclusion of smaller polymer chain fragments in plastics which will be more susceptible to biological degradation may have a dangerous impact on the environment.
- 2 Plastics: properties, demand, cost efficient manufacture vs recycling, use of non-renewable resources, pollution.

Review exercise 2.6

- 1 Advantages are that biopolymers come from plant material which is a renewable resource and that plastics made from biopolymers are easily broken down by bacteria and fungi.
Disadvantages include the cost of production and that they are easily biodegradable which is not useful in some applications.
- 2
 - a Rayon: Cellulose fibres from wood pulp are treated with NaOH and CS_2 to break them down into smaller units. The resultant 'syrup' called viscose is extruded into a sulfuric acid solution through a nozzle with small holes to form filaments. These filaments harden, are made into yarns, and then can be woven into fabric.

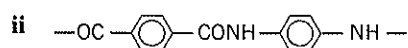
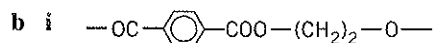
Chapter 2 — Application and research

- 1 Monomer: small repeating units which join by covalent bonds to form a polymer, eg ethene.
Polymer: large chain molecule consisting of small repeating units called monomers, eg poly(ethene).
Polymerisation: the chemical reaction by which monomers link together to form polymers, eg formation of poly(ethene) by addition reaction.
- 2 Research
- 3
 - a thermosetting plastic
 - b thermoplastic
 - c thermoplastic
 - d thermosetting plastic
- 4
 - a Melamine-formaldehyde is a hard plastic which contains covalent bonds crosslinking between the chains.
PVC is soft and flexible when heated but becomes hard when cooled. This flexibility is due to the weak intermolecular forces between chains.
 - b Thermosetting plastic (melamine-formaldehyde):
 - hard
 - used in laminates for kitchen benches, cupboards, light switchesThermoplastic (PVC):
 - able to be remoulded
 - softer
 - used in upholstery, hoses, pipes, bottles
- 5
 - a Elastomers are able to be stretched but return to their original shape.
 - b Partially coiled chains with some crosslinking between chains.
- 6
 - a some
 - b significant
 - c none
 - d some

- 7 cling wrap: allows O_2 and CO_2 through but not H_2O , tough
 wire insulation: non-conductor and flexible
 buckets/bins: tough and durable
 chemical containers: chemically resistant

8 Molecular mass of 1 monomer = 28, so $84\,500 \div 28 = 3018$ monomer units

9 Research



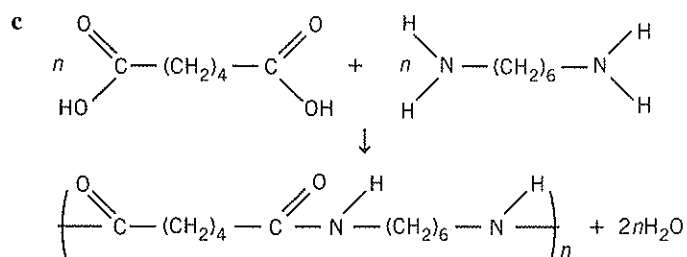
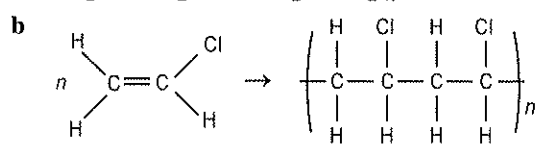
11 a $HC(C_6H_5) = CH_2$

b $H_2C = CHCN$

c $HOOC-C_6H_4-COOH + H_2N-C_6H_4-NH_2$

d $HOOC-C_6H_4-COOH + HO-CH_2C_6H_4CH_2-OH$

12 a $n(H_2C = CH_2) \rightarrow -(H_2C-CH_2)_n-$



13 a $nH_2N-(CH_2)_5-COOH \rightarrow -[HN-(CH_2)_5-CONH-(CH_2)_5-CO]_n- + nH_2O$

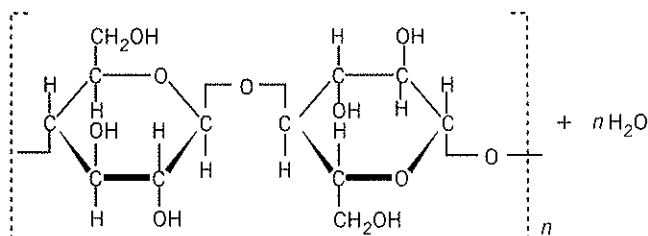
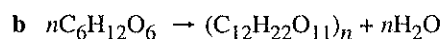
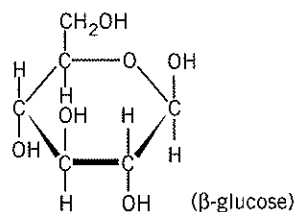
b condensation

14 a A polymer in which one of the monomers contains the amine group ($-NH_2$).

b Synthetic polymers: nylon, Kevlar. Biopolymers: nucleic acids, proteins.

15 Research

16 a $C_6H_{12}O_6$



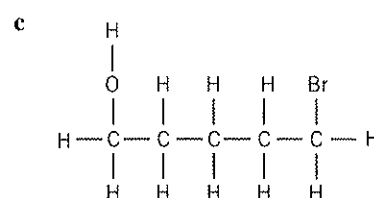
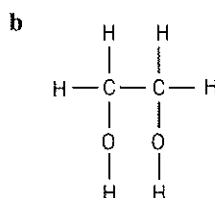
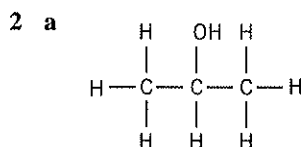
- c Cellulose is a monomer of β -glucose while starch is a monomer of α -glucose. In cellulose the glucose monomers alternate their alignment so that the monomers can pack more tightly together. In starch the geometry of the links between the glucose units is different.

17–24 Research

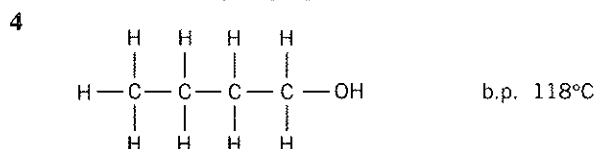
CHAPTER 3: ETHANOL

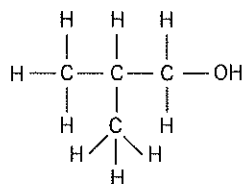
Review exercise 3.1

- 1 a 1-propanol
- b 4-chloro-2-pentanol
- c 1,4-butanediol
- d 2-methyl-2-propanol

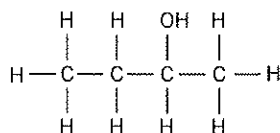


- 3 In primary alcohols the carbon to which the $-OH$ group is attached is joined to only one other carbon atom, eg 1-propanol.
In secondary alcohols, this carbon atom is attached to two other carbon atoms, ie in the middle of the chain, eg 2-propanol.
In tertiary alcohols the carbon attached to the $-OH$ is joined to three carbon atoms, eg 2-methyl-2-propanol.

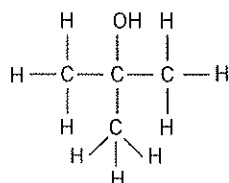




b.p. 108°C



b.p. 100°C



b.p. 83°C

Review exercise 3.2

- 95% ethanol 5% methanol and small quantities of foul tasting chemicals. The additives are used to discourage people from drinking it.
- Ethanol molecule contains the polar -OH end and the non-polar hydrocarbon chain. Hence it is able to be used as a solvent for non-polar substances such as perfumes and aftershaves.
- Cars using ethanol produce fewer pollutants. Ethanol is a renewable resource. However, no commercially viable method of obtaining ethanol is available and cars will need to be significantly modified to run on pure ethanol.
- | | | |
|---|---|---|
| Mass of methanol burned | = | 1.10 g |
| Mass of water | = | 100 g |
| Mass of copper | = | 200.0 g |
| Temperature change | = | 5°C |
| Specific Heat Capacity water | = | 4.18 J K ⁻¹ g ⁻¹ |
| Specific Heat Capacity copper | = | 0.387 J K ⁻¹ g ⁻¹ |
| Heat released per 1.10 g methanol = -(mCΔT(copper) + mCΔT(water)) | | |
| = -(200 × 0.387 × 5 + 100 × 4.18 × 5) | | |
| = -2477 J released by 1.10 g methanol | | |
| Heat released per mole of methanol = -2477 × $\frac{32}{1.10}$ | | |
| = -72058 J mol ⁻¹ | | |
| ∴ Heat of combustion | = | 72 kJ mol ⁻¹ |

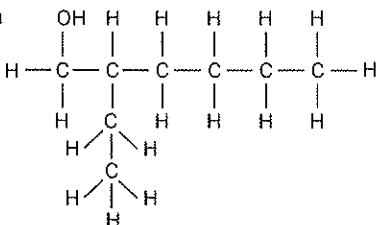
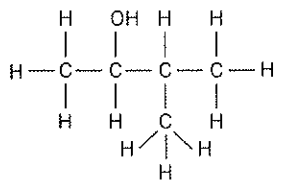
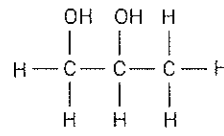
Review exercise 3.3

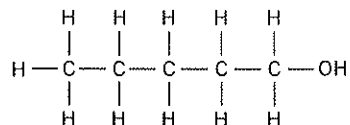
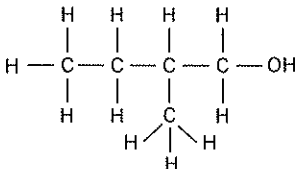
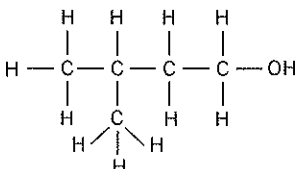
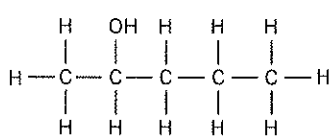
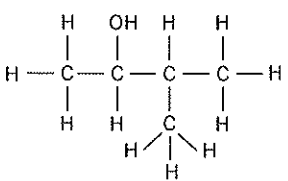
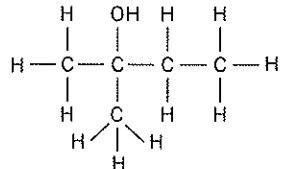
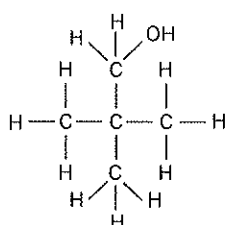
- The catalyst is needed to cause the water molecule to attack the double bond in ethene.
- $\text{CH}_2 = \text{CH}-\text{CH}_3(\text{g}) + \text{H}_2\text{O}(\text{g}) + \xrightarrow{\text{H}^+} \text{CH}_2\text{OH}-\text{CH}_2-\text{CH}_3(\text{g})$
- carbohydrates, eg glucose, sucrose, starch, plus water and yeast.
 - The yeasts produce enzymes which act as catalysts in the conversion of glucose to ethanol and carbon dioxide.
 - ethanol and carbon dioxide
 - exothermic
 - Once the ethanol concentration reaches 15% in the fermentation container, the yeast is killed and the reaction ceases. Therefore naturally fermented wines have ethanol concentrations from 12–15%.

Review exercise 3.4

- 1 $\text{C}_2\text{H}_5\text{OH}(g) \xrightarrow{\text{conc H}_2\text{SO}_4} \text{C}_2\text{H}_4(g) + \text{H}_2\text{O}(g)$
- 2 It is possible to produce ethene from ethanol and vice versa as this reaction is reversible via a reaction which is acid catalysed.
- 3
 - a $\text{C}_2\text{H}_5\text{OH}(l) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l)$
 - b $\text{C}_2\text{H}_5\text{OH}(aq) \rightarrow \text{CH}_3\text{CHO}(aq) + 2\text{H}^+(aq) + 2\text{e}^-$
 - c $\text{C}_2\text{H}_5\text{OH}(aq) + \text{H}_2\text{O}(l) \rightarrow \text{CH}_3\text{COOH}(aq) + 4\text{H}^+ + 4\text{e}^-$

Chapter 3 — Application and research

- 1
 - a 
 - b 
 - c 
- 2
 - a 2-methyl-1-butanol
 - b 1,4-butanediol
- 3

	1-pentanol: primary alcohol
	2-methyl-1-butanol: primary alcohol
	3-methyl-1-butanol: primary alcohol
	2-pentanol: secondary alcohol
	3-methyl-2-butanol: secondary alcohol
	2-methyl-2-butanol: tertiary alcohol
	2,2-dimethyl-1-propanol: tertiary alcohol

4 Research

- 5 Water will act as a solvent for polar substances only while hexane will dissolve non-polar substances only.
Ethanol is used as a solvent for food essences as its chain contains both a polar and non-polar section and therefore it can dissolve the essences.

- 6 Assume heat absorbed by copper is negligible.

Mass of fuel	=	2.00 g
Mass of water	=	500 g
Change in temp	=	18.4°C
Specific heat water	=	4.18 J K ⁻¹ g ⁻¹

Methanol

$$\begin{aligned}
 \text{Heat released by 2 g} &= -mC\Delta T \\
 &= -(500 \times 4.18 \times 18.4) \\
 &= -38456 \text{ J} \\
 \text{a Heat of combustion/g} &= \frac{38456}{2} \\
 &= 19228 \text{ J g}^{-1} = 19.2 \text{ k J g}^{-1} \\
 \text{b Heat of combustion/mole} &= 38456 \times \frac{32}{2} \\
 &= 615296 \text{ J mol}^{-1} \\
 &= 615 \text{ kJ mol}^{-1}
 \end{aligned}$$

1-Propanol

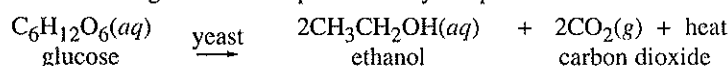
$$\begin{aligned}
 \text{Change in temp} &= 28.5^\circ\text{C} \\
 \text{Heat released} &= -(500 \times 4.18 \times 28.5) \\
 &= -59565 \text{ J}
 \end{aligned}$$

$$\begin{aligned}
 \text{a Heat of combustion/gram} &= \frac{59565}{2} \\
 &= 29782.5 \text{ J g}^{-1} \\
 &= 29.8 \text{ kJ g}^{-1} \\
 \text{b Heat of combustion/mole} &= 59565 \times \frac{60}{2} \\
 &= 1786950 \text{ J mol}^{-1} \\
 &= 1787 \text{ kJ mol}^{-1}
 \end{aligned}$$

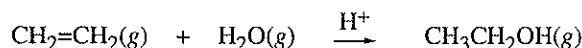
1-Butanol

$$\begin{aligned}
 \text{Change in temp} &= 31.5^\circ\text{C} \\
 \text{Heat released} &= -(500 \times 4.18 \times 31.5) \\
 &= -65835 \text{ J} \\
 \text{a Heat of combustion/gram} &= \frac{65835}{2} \\
 &= 32917.5 \text{ J g}^{-1} \\
 &= 32.9 \text{ kJ g}^{-1} \\
 \text{b Heat of combustion/mole} &= 65835 \times \frac{74}{2} \\
 &= 2435895 \text{ J mol}^{-1} \\
 &= 2436 \text{ kJ mol}^{-1}
 \end{aligned}$$

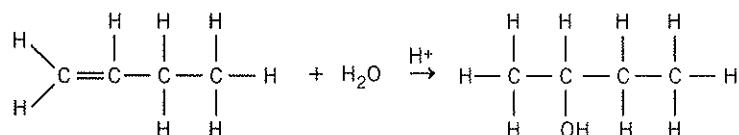
- 7 Fermentation of glucose in the presence of yeast produces ethanol.



Ethanol is produced industrially by the hydration of ethene in acidic conditions.



- 8 a



- b acid conditions

9 Research

- 10 Ethanol concentration in the breath would cause a colour change of orange to green in the tube of crystals. Greater concentration would favour the products of the reaction resulting in more intense green.

CHAPTER 4: ELECTROCHEMISTRY

Review exercise 4.1

- 1
 - a

CO_2	:	C = +4	O = -2
O_2	:	elemental state \therefore 0	
NH_3	:	N = -3	H = +1
H_2S	:	S = -2	H = +1
HCl	:	H = +1	Cl = -1
 - b

SO_2	:	S = +4	O = -2
SO_3^{2-}	:	S = +4	O = -2
$\text{H}_2\text{S}_2\text{O}_7$:	H = +1	S = +6 O = -2
$\text{S}_2\text{O}_8^{2-}$:	S = +7	O = -2
HSO_3^-	:	H = +1	S = +4 O = -2
S	:	0	
 - c

NH_4^+	:	N = -3	H = +1
ClO_4^-	:	Cl = +7	O = -2
Cu_2S	:	Cu = +1	S = -2
MgH_2	:	Mg = +2	H = -1
PO_4^{3-}	:	P = +5	O = -2
- 2
 - a redox reaction : Zn oxidised ($0 \rightarrow +2$), H^+ reduced ($+1 \rightarrow 0$)
 - b not a redox reaction
 - c not a redox reaction
 - d redox reaction : Fe^{2+} oxidised ($+2 \rightarrow +3$), Cr^{6+} reduced ($+6 \rightarrow +3$)
- 3
 - a

NO	: +2	NO_2	: +4	N_2O	: +1	N_2O_3	: +3	N_2O_4	: +4
N_2O_5	: +5	HNO_3	: +5	HNO_2	: +3	NO_2^-	: +3	NO_3^-	: +5
NH_2^-	: -3	NH_4^+	: -3	N_2	: 0	N_2H_4	: -2	NH_3	: -3
NH_2OH	: -1	NH_4Cl	: -3						
 - b Nitrogen has 5 electrons in its outer shell, therefore it can lose 5 electrons (+5) or gain up to 3 electrons (-3).

Review exercise 4.2

- 1
 - a The blue colour of the copper sulfate solution will fade. Copper metal will form on the steel wool as a pink-brown deposit.
 - b $\text{Fe}(s) + \text{Cu}^{2+}(aq) \rightarrow \text{Fe}^{2+}(aq) + \text{Cu}(s)$
 - c

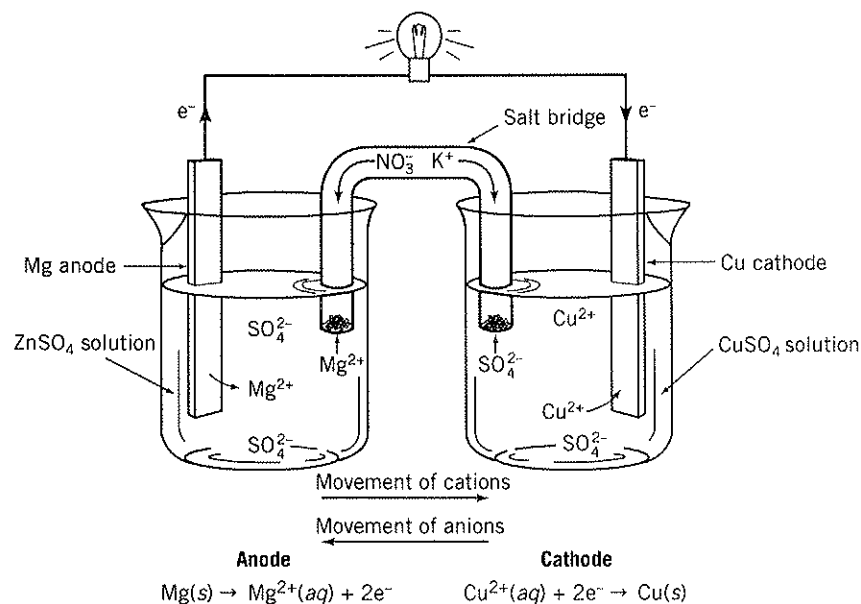
$\text{Fe}(s)$	\rightarrow	$\text{Fe}^{2+}(aq) + 2e^-$	oxidation
$\text{Cu}^{2+}(aq) + 2e^-$	\rightarrow	$\text{Cu}(s)$	reduction
- 2
 - a $\text{Fe}(s) + \text{Sn}^{2+}(aq) \rightarrow \text{Fe}^{2+}(aq) + \text{Sn}(s)$
Steel wool (iron) should get smaller. Sn should deposit as a grey solid.
 - b $\text{Pb}(s) + \text{Hg}^{2+}(aq) \rightarrow \text{Pb}^{2+}(aq) + \text{Hg}(s)$
 - c No change
 - d $\text{Cr}(s) + \text{Fe}^{2+}(aq) \rightarrow \text{Cr}^{2+}(aq) + \text{Fe}(s)$
- 3 Fe is more reactive than Ni, so the iron container will oxidise, displacing Ni from Ni^{2+} .
- 4
 - a No reaction.
 - b

$\text{Sn}(s)$	\rightarrow	$\text{Sn}^{2+}(aq) + 2e^-$	oxidation, tin dissolves
$\text{Cu}^{2+}(aq) + 2e^-$	\rightarrow	$\text{Cu}(s)$	reduction, deposit of copper forms on the tin
 - c

$\text{Sn}(s)$	\rightarrow	$\text{Sn}^{2+}(aq) + 2e^-$	oxidation, tin dissolves
$2\text{Ag}^+(aq) + 2e^-$	\rightarrow	$2\text{Ag}(s)$	reduction, black deposit of silver forms on the tin

Review exercise 4.3

- 1 The salt bridge allows ions to move between each half cell.



- 3 a $3\text{Pb}^{2+}(\text{aq}) + 6\text{e}^- \rightarrow 3\text{Pb(s)}$ cathode
 $2\text{Cr(s)} \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 6\text{e}^-$ anode
 b $\text{Cu(s)} \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$ anode
 $2\text{Ag}^+(\text{aq}) + 2\text{e}^- \rightarrow 2\text{Ag(s)}$ cathode

Review exercise 4.4

- 1 a Ca^{2+} , Pb^{2+} , Cu^{2+} , Ag^+
 b Ag, Sn, Cr, Mg
 c strongest oxidising agent Ag^+
 strongest reducing agent Mg
- 2 a MnO_4^-
 b acidified MnO_4^-
 c Fe^{3+}
 d Cl_2
- 3 a As the $\text{H}^+(\text{aq})$ concentration decreases, the tendency of the half-reactions to proceed as written becomes less. Hence the E° values decrease down the series.
 b As the $\text{OH}^-(\text{aq})$ concentration increases, the tendency of the half-reactions to proceed as written becomes less. Hence the E° values decrease (increase negatively) down the series.

Review exercise 4.5

- 1 a $\text{Pb}^{2+} + 2\text{e}^- \rightarrow \text{Pb(s)}$ $E^\circ = -0.13 \text{ V}$ cathode
 $\text{Zn(s)} \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{e}^-$ $E^\circ = +0.76 \text{ V}$ anode
 e.m.f. = $-0.13 + 0.76$
 = 0.63 V
- b $\text{Cl}_2(\text{g}) + 2\text{e}^- \rightarrow 2\text{Cl}^-(\text{aq})$ $E^\circ = +1.36 \text{ V}$ cathode
 $2\text{I}^-(\text{aq}) \rightarrow \text{I}_2(\text{s}) + 2\text{e}^-$ $E^\circ = -0.54 \text{ V}$ anode
 e.m.f. = $+1.36 - 0.54$
 = 0.82 V
- c $2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$ $E^\circ = 0 \text{ V}$ cathode
 $\text{Mg(s)} \rightarrow \text{Mg}^{2+}(\text{aq}) + 2\text{e}^-$ $E^\circ = +2.37 \text{ V}$ anode
 e.m.f. = $0 + 2.37$
 = 2.37 V

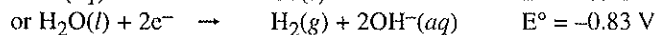
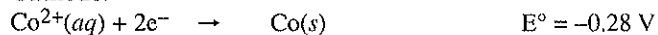
- 2 $\text{Pb(s)} + \text{PbO}_2\text{(s)} + 4\text{H}^+\text{(aq)} + 2\text{SO}_4^{2-}\text{(aq)} \rightarrow 2\text{PbSO}_4\text{(s)} + 2\text{H}_2\text{O(l)}$
 $E^\circ(\text{cell}) = +2.04 \text{ V}$
 anode: $\text{Pb(s)} + \text{SO}_4^{2-}\text{(aq)} \rightarrow 2\text{PbSO}_4\text{(s)} + 2\text{e}^-$
 $E^\circ = +0.36 \text{ V}$
 cathode: $\text{PbO}_2\text{(s)} + 4\text{H}^+\text{(aq)} + \text{SO}_4^{2-}\text{(aq)} + 2\text{e}^- \rightarrow \text{PbSO}_4\text{(s)} + 2\text{H}_2\text{O(l)}$
 $E^\circ = 2.04 - 0.36 = +1.68 \text{ V}$
- 3 a $2\text{I}^-\text{(aq)} \rightarrow \text{I}_2\text{(s)} + 2\text{e}^-$ $E^\circ = -0.54 \text{ V}$
 $\text{MnO}_4^-\text{(aq)} + 8\text{H}^+\text{(aq)} + 5\text{e}^- \rightarrow \text{Mn}^{2+}\text{(aq)} + 4\text{H}_2\text{O(l)}$ $E^\circ = +1.51 \text{ V}$
 Add equations.
 $10\text{I}^-\text{(aq)} + 2\text{MnO}_4^-\text{(aq)} + 16\text{H}^+\text{(aq)} \rightarrow 5\text{I}_2\text{(s)} + 2\text{Mn}^{2+}\text{(aq)} + 8\text{H}_2\text{O(l)}$
 e.m.f. $= -0.54 + 1.51$
 $= +0.97 \text{ V}$
 Positive cell e.m.f. therefore reaction can occur.
- b $\text{Cl}_2\text{(g)} + \text{H}_2\text{S(aq)} + 2\text{e}^- \rightarrow 2\text{Cl}^-\text{(aq)} + \text{S(s)} + 2\text{H}^+\text{(aq)} + 2\text{e}^-$
 $\text{Cl}_2\text{(g)} + 2\text{e}^- \rightarrow 2\text{Cl}^-\text{(aq)}$ $E^\circ = +1.36 \text{ V}$
 $\text{H}_2\text{S(aq)} \rightarrow \text{S(s)} + 2\text{H}^+\text{(aq)} + 2\text{e}^-$ $E^\circ = -0.14 \text{ V}$
 e.m.f. $= +1.36 - 0.14$
 $= +1.22 \text{ V}$
 Positive e.m.f. therefore reaction can occur.
- c $2\text{Cu}^+\text{(aq)} + \text{e}^- \rightarrow \text{Cu}^{2+}\text{(aq)} + \text{Cu(s)} + \text{e}^-$
 $\text{Cu}^+\text{(aq)} \rightarrow \text{Cu}^{2+}\text{(aq)} + \text{e}^-$ $E^\circ = -0.16 \text{ V}$
 $\text{Cu}^+\text{(aq)} + \text{e}^- \rightarrow \text{Cu(s)}$ $E^\circ = +0.52 \text{ V}$
 e.m.f. $= -0.16 + 0.52$
 $= +0.36 \text{ V}$
 Positive e.m.f. therefore reaction can occur.
- 4 a $\text{H}_2\text{O}_2\text{(aq)} + 2\text{H}^+\text{(aq)} + 2\text{e}^- \rightarrow 2\text{H}_2\text{O(l)}$ $E^\circ = +1.78 \text{ V}$
 $\text{H}_2\text{C}_2\text{O}_4\text{(aq)} \rightarrow 2\text{CO}_2\text{(g)} + 2\text{H}^+\text{(aq)} + 2\text{e}^-$ $E^\circ = +0.48 \text{ V}$
 $E^\circ(\text{cell}) = +1.78 + 0.48$
 $= +2.26 \text{ V}$
- b A high activation energy may be necessary for this reaction to occur.
- c Mix the H_2O_2 and $\text{H}_2\text{C}_2\text{O}_4$ at a higher temperature and/or add catalyst.

Review exercise 4.6

- 1 a If the Zn and MnO_2 were in direct contact the overall cell reaction would occur.
 $\text{Zn(s)} + 2\text{H}^+\text{(aq)} + 2\text{MnO}_2\text{(s)} \rightarrow \text{Zn}^{2+}\text{(aq)} + \text{Mn}_2\text{O}_3\text{(s)} + \text{H}_2\text{O(l)}$
 ie zinc is oxidised and manganese dioxide is reduced.
- b The cell would be useless because electron transfer would occur directly between the reactants and not through an external circuit.
- 2 $\text{Zn(s)} + \text{Ag}_2\text{O(s)} + \text{H}_2\text{O(l)} \rightarrow \text{Zn(OH)}_2\text{(s)} + 2\text{Ag(s)}$
- 3 $\text{Pb(s)} + \text{SO}_4^{2-}\text{(aq)} \rightarrow \text{PbSO}_4\text{(s)} + 2\text{e}^-$
 (0) (+2) oxidation
 $\text{PbO}_2\text{(s)} + 4\text{H}^+\text{(aq)} + \text{SO}_4^{2-}\text{(aq)} + 2\text{e}^- \rightarrow \text{PbSO}_4\text{(s)} + 2\text{H}_2\text{O(l)}$
 (+4) (+2) reduction
- 4 The hydrometer measures the electrolyte density in the battery. Higher density indicates greater degree of charge, as recharging generates sulfuric acid which is denser than water.
- 5 Fuel cells have higher fuel efficiency and run continuously at constant e.m.f. Conventional cells lose e.m.f. as products accumulate and reactants are used.
- 6 If the O_2 has to come from the air, it would be difficult to have enough O_2 in contact with the Al to create a sufficient current to be useful. Replacement of Al as used. Sufficient surface area of Al for reaction rate.

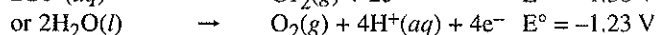
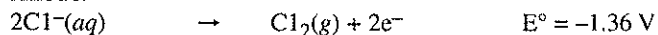
Review exercise 4.7

1 a Cathode:



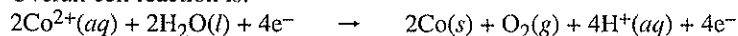
\therefore Cathode reaction will be $\text{Co}^{2+} \rightarrow \text{Co}(\text{s})$ as more positive.

Anode:

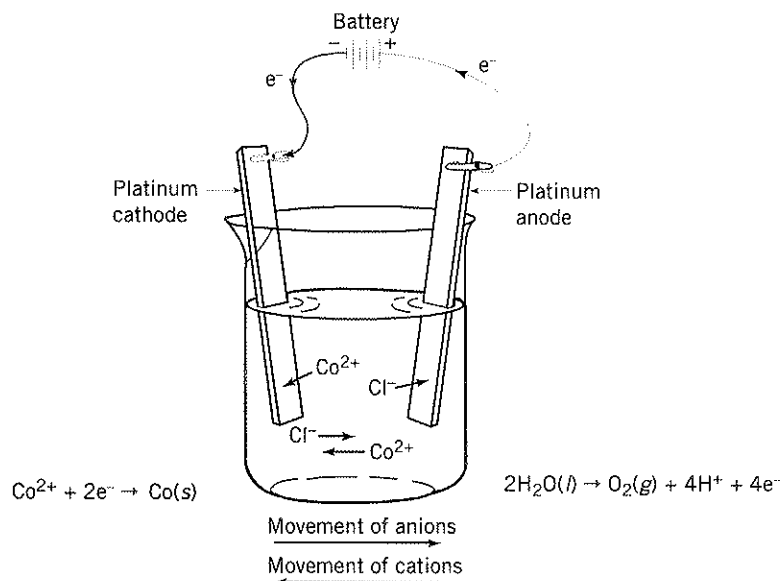


\therefore Anode reaction is the oxidation of H_2O to $\text{O}_2(\text{g})$.

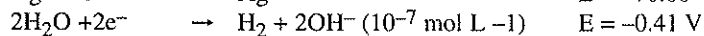
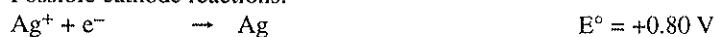
Overall cell reaction is:



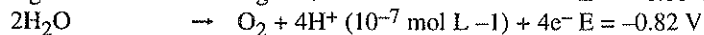
b



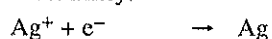
2 Possible cathode reactions:



Possible anode reactions:



Most likely:



Overall:



This constitutes a transfer of silver from the anode to the cathode.

- 3 a cathode: $\text{Ca}^{2+}(\text{l}) + 2\text{e}^- \rightarrow \text{Ca}(\text{l})$
 anode: $2\text{I}^-(\text{l}) \rightarrow \text{I}_2(\text{l}) + 2\text{e}^-$
 b cathode: $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$
 anode: $\text{Cu}(\text{s}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$
 c cathode: $2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$
 anode: $4\text{OH}^-(\text{aq}) \rightarrow \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^-$

Review exercise 4.8

- The reactive metal impurities are oxidised and remain in solution until removed. The inert metal impurities fall to the bottom of the cell as the anode dissolves.
- Anode possibilities:

$$4\text{OH}^-(\text{aq}) \rightarrow \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) \quad 4\text{e}^- \quad E^\circ = -0.40$$

$$\text{Au}(\text{s}) \rightarrow \text{Au}^{3+}(\text{aq}) + 3\text{e}^- \quad E^\circ = -1.50$$
 Most positive E° value is oxidation of $\text{OH}^-(\text{aq}) \rightarrow \text{O}_2(\text{g})$
 $(-2) \rightarrow (0)$
 Cathode:

$$[\text{Au}(\text{CN})_2]^-(\text{aq}) \rightarrow \text{Au}(\text{s}) + 2\text{CN}^-(\text{aq})$$
 $(+1) \rightarrow (0)$
 - $4[\text{Au}(\text{CN})_2]^-(\text{aq}) + 4\text{OH}^-(\text{aq}) \rightarrow 4\text{Au}(\text{s}) + 8\text{CN}^-(\text{aq}) + \text{O}_2(\text{s}) + 2\text{H}_2\text{O}(\text{l})$
- The increased concentration of CN^- favours the forward reaction therefore maintaining a low concentration of Ag^+ .

$$\text{Ag}^+(\text{aq}) + 2\text{CN}^-(\text{aq}) \rightleftharpoons [\text{Ag}(\text{CN})_2]^-(\text{aq})$$
 As Ag^+ deposits at the cathode, complex ions dissociate to regenerate more Ag^+ .
 The concentration of Ag^+ stays fairly constant.
- The anode would be made of pure nickel, the master compact disc would be the cathode and the electrolyte would be a nickel salt solution, eg nickel nitrate $\text{Ni}(\text{NO}_3)_2$.

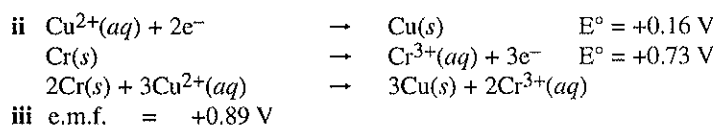
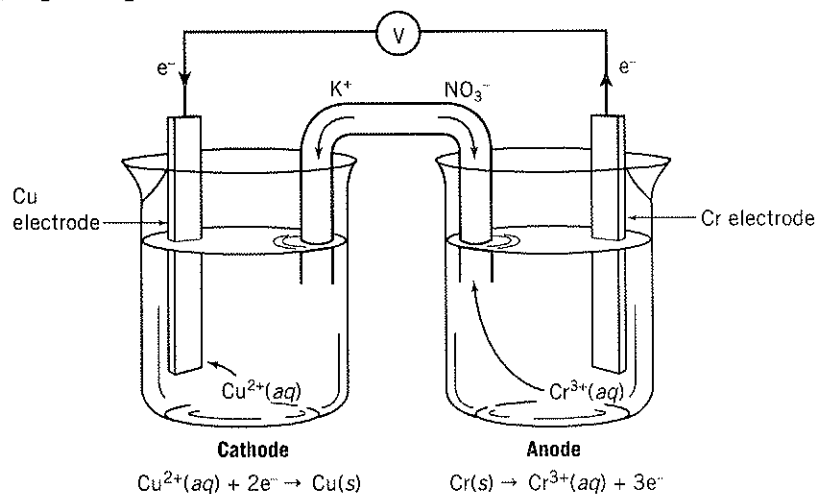
Chapter 4 — Application and research

- Cl_2 : 0 P_4 : 0 SO_2 : +4, -2 H_2S : +1, -2
 - MnO_4^- : Mn; +7 O; -2
 ZnO_2^{2-} : Zn; +3 O; -2
 HSO_4^- : H; +1 S; +6 O; -2
 NH_4^+ : N; -3 H; +1
 - MgCO_3 : Mg; +2 C; +4 O; -2
 KClO_4 : K; +1 Cl; +7 O; -2
 NaIO_4 : Na; +1 I; +7 O; -2
 Na_3PO_4 : Na; +1 P; +5 O; -2
- $\text{HNO}_3(\text{aq}) \rightarrow \text{NO}_2(\text{g})$ reduction
 $+5 \quad +4$
 - $\text{Cl}_2(\text{g}) \rightarrow \text{ClO}_3^-(\text{aq})$ oxidation
 $0 \quad +5$
 - $\text{NH}_3(\text{g}) \rightarrow \text{N}_2(\text{g})$ oxidation
 $-3 \quad 0$
 - $\text{Fe}_2\text{O}_3(\text{s}) \rightarrow \text{FeO}(\text{s})$ reduction
 $+3 \quad +2$
 - $\text{SO}_2(\text{g}) \rightarrow \text{SO}_4^{2-}(\text{aq})$ oxidation
 $+4 \quad +2$
 - $\text{MnO}_4^-(\text{aq}) \rightarrow \text{MnO}_2(\text{s})$ reduction
 $+7 \quad +4$
- Br^- : -1 BrO^- : +1 HBr : -1 BrO_4^- : +7 HBrO_3 : +5
 Br_2 : 0 Br_2O : +1 HBrO_2 : +3
 \therefore 2 pairs with same oxidation state are Br^- and HBr ;
 BrO^- and Br_2O .
- $$\text{Fe}(\text{s}) + \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{FeSO}_4(\text{s})$$

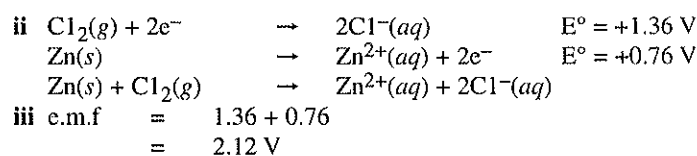
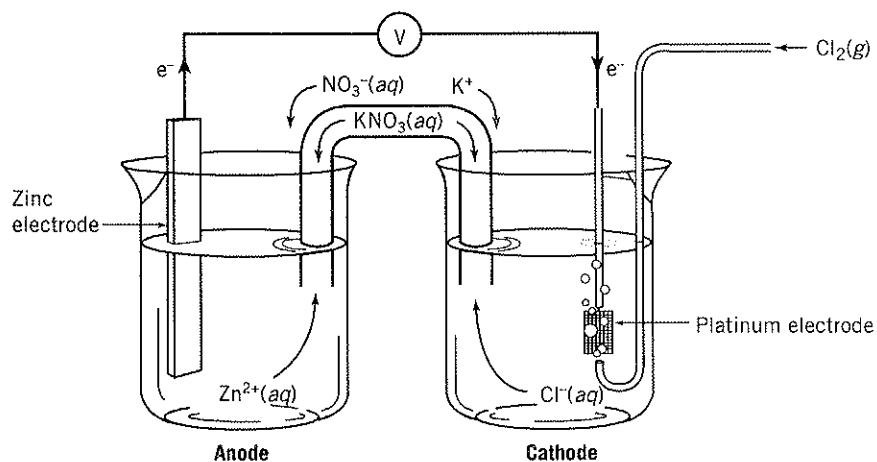
$$0 \quad +4 \quad -2 \quad 0 \quad +2 \quad +6 \quad -2$$
 Fe oxidised; S oxidised; O reduced
 - $$4\text{FeSO}_4(\text{s}) + \text{O}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow 2\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}(\text{s}) + 4\text{H}_2\text{SO}_4(\text{aq})$$

$$+2 \quad +6 \quad -2 \quad 0 \quad +1 \quad -2 \quad +3 \quad -2 \quad +1 \quad -2 \quad +1 \quad +6 \quad -2$$
 Fe oxidised; O_2 reduced
- $\text{Zn}(\text{s}) + \text{CuSO}_4(\text{aq}) \rightarrow \text{ZnSO}_4(\text{aq}) + \text{Cu}(\text{s})$
 - $\text{Zn}(\text{s}) + \text{NiSO}_4(\text{aq}) \rightarrow \text{ZnSO}_4(\text{aq}) + \text{Ni}(\text{s})$

- 6 a i Yes. Fe^{2+} ions will not oxidise Ni.
 ii No. Fe^{3+} will be reduced to Fe^{2+} and Ni oxidised to Ni^{2+} .
 b No. The steel will dissolve and displace the copper.
 7 a All the E° values would be 2.93 V higher.
 b Calculated e.m.f. values for cells are based on the difference in E° between two half-cell reactions. These would be unchanged.
 8 a H_2O_2 , HClO , MnO_4^- , $\text{Cr}_2\text{O}_7^{2-}$
 b Mg, H_2 , Zn, H_2S
 9 a i

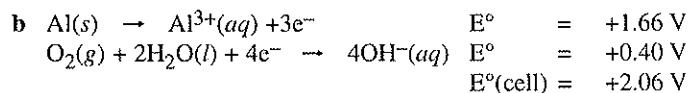


b i



- 10 a In order to generate a current flow in the external circuit.
 b A salt bridge allows ions to move between each half cell and complete the circuit.
 11 a anode: $\text{Zn}(\text{s}) \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{e}^-$ $E^\circ = +0.76 \text{ V}$
 cathode: $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$ $E^\circ = +0.34 \text{ V}$
 cell: $\text{Zn}(\text{s}) + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{Cu}(\text{s})$ $E^\circ(\text{cell}) = +1.10 \text{ V}$

- b As the cell operates the concentration of Cu^{2+} decreases and the Zn^{2+} concentration increases. Both changes would decrease the tendency of the forward reaction to take place and hence the cell e.m.f. would decrease.
- c i Transfer of electrons cannot occur, therefore the reaction between the two half-cells will cease.
ii Transfer of charged ions between half-cells cannot occur.
- 12 The reduction potential of +1.7 V for Au^+ is higher than that for the reduction of O_2 , therefore O_2 would not oxidise the gold. The reduction potential for $[\text{Au}(\text{CN})_2]^- (\text{aq})$ is lower than that for O_2 , therefore in the presence of cyanide ion, gold can be oxidised.
- 13 a $\text{Ni}^{2+}(\text{aq})$ or $\text{Co}^{2+}(\text{aq})$ or $\text{Cd}^{2+}(\text{aq})$
b $\text{Mn}(\text{s})$ or $\text{Al}(\text{s})$ or $\text{Zn}(\text{s})$
c Check gallium's position in the order of reactivity by attempting to oxidise it using the ions of the other metals.
- 14 a i $\text{Fe}^{2+} \rightarrow \text{Fe}^{3+} + \text{e}^-$ $E^\circ = -0.77 \text{ V}$
 $\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}$ $E^\circ = +1.51 \text{ V}$
 $E^\circ(\text{cell}) = +0.74 \text{ V}$
 ii $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$ $E^\circ = -1.36 \text{ V}$
 $\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}$ $E^\circ = +1.51 \text{ V}$
 $E^\circ(\text{cell}) = +0.15 \text{ V}$
 iii $\text{Fe}^{2+} \rightarrow \text{Fe}^{3+} + \text{e}^-$ $E^\circ = -0.77 \text{ V}$
 $\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{e}^- \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$ $E^\circ = +1.33 \text{ V}$
 $E^\circ(\text{cell}) = +0.56 \text{ V}$
 iv $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$ $E^\circ = -1.36 \text{ V}$
 $\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{e}^- \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$ $E^\circ = +1.33 \text{ V}$
 $E^\circ(\text{cell}) = -0.03 \text{ V}$
- Reaction should occur in i, ii and iii.
- b iv above shows that $\text{Cr}_2\text{O}_7^{2-}$ will not oxidise the Cl^- ion of HCl , but ii shows that MnO_4^- will. Hence, it is inappropriate to use HCl to acidify solutions involving permanganate titrations.
- 15 a $\text{H}_2\text{O}_2 \rightarrow \text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^-$ $E^\circ = -0.68 \text{ V}$
 $\text{H}_2\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightarrow 2\text{H}_2\text{O}$ $E^\circ = +1.78$
 $2\text{H}_2\text{O}_2(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g})$ $E^\circ(\text{cell}) = +1.10 \text{ V}$
 b The activation energy for normal decomposition must be quite high. This is lowered significantly by using MnO_2 as a catalyst.
- 16 a The anode is the electrode at which oxidation takes place. The cathode is the electrode at which reduction takes place.
b The salt bridge allows the flow of ions between the two half cells. The external circuit allows the flow of electrons from anode to cathode.
c Secondary cells are able to be recharged while primary cells are not.
d The reduction potential is the measure of the tendency of a substance to be reduced, relative to $2\text{H}^+(\text{aq}) \rightarrow \text{H}_2(\text{g})$. The cell e.m.f. is the difference between the reduction potentials of the anode and cathode half reactions.
- 17 a i anode: $\text{Pb}(\text{s}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{PbSO}_4(\text{s}) + 2\text{e}^-$
 cathode: $\text{PbO}_2(\text{s}) + 4\text{H}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) + 2\text{e}^- \rightarrow \text{PbSO}_4(\text{s}) + 2\text{H}_2\text{O}(\text{l})$
 ii anode: $\text{PbSO}_4(\text{s}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow 2\text{e}^- + \text{SO}_4^{2-}(\text{aq}) + 4\text{H}^+(\text{aq}) + \text{PbO}_2(\text{s})$
 cathode: $\text{PbSO}_4(\text{s}) + 2\text{e}^- \rightarrow \text{Pb}(\text{s}) + \text{SO}_4^{2-}(\text{aq})$
 b i On discharging the density decreases.
 ii On recharging the density increases.
 c Chemical potential energy is transformed into electrical energy and some heat energy as the battery is discharged. On charging, electrical energy is transformed into chemical potential energy and some heat energy.
- 18 a Anode: $\text{Al}(\text{s}) \rightarrow \text{Al}^{3+}(\text{aq}) + 3\text{e}^-$
 Cathode: $\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^- \rightarrow 4\text{OH}^-(\text{aq})$

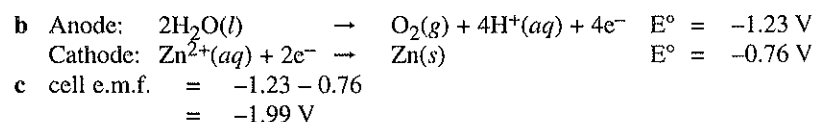
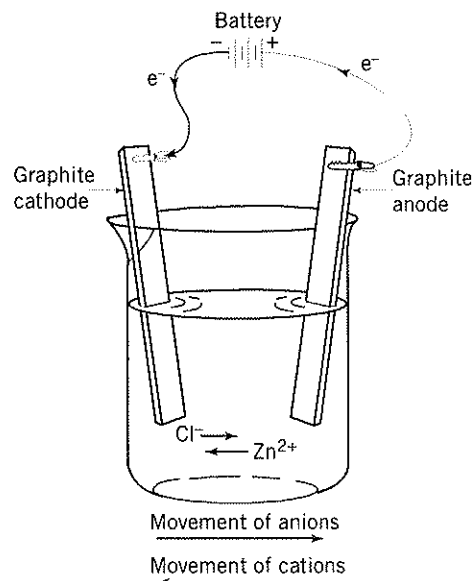


Cell e.m.f. would be 2.06 V.

- c** They would weigh much less.
 Avoids use of corrosive H_2SO_4 .
 Uses O_2 from air as cathode.

19–22 Research

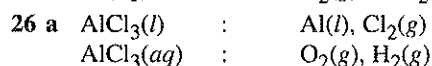
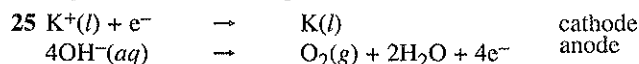
23 a



24 Metal: electric current is carried by the mobile sea of electrons.

Molten ionic compound: once molten the charged ions are mobile and therefore can carry the electric current.

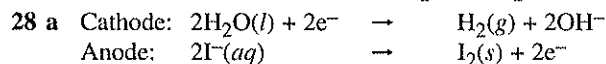
Aqueous solution: charged ions conduct the electric current.



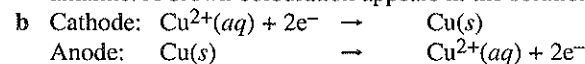
- b** In aqueous solution the water is more easily oxidised and reduced than the ions $\text{Al}^{3+}(\text{aq})$ and $\text{Cl}^-(\text{aq})$.

27 a O_2, H_2

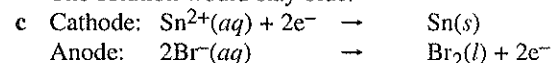
- b** There would be twice as much $\text{H}_2(\text{g})$ as $\text{O}_2(\text{g})$.



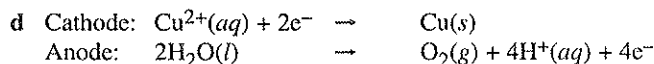
Colourless gas is evolved at the cathode. The surrounding solution becomes alkaline. A brown colouration appears in the solution around the anode.



The cathode would increase in size and the anode would decrease in size. The solution would stay blue.



The cathode would increase in size as tin is deposited on it. The solution around the anode would become yellow-brown as bromine was produced.



The cathode would increase in size as copper is deposited on it. The solution would fade slightly as Cu^{2+} are removed. A colourless gas is evolved at the anode. The surrounding solution becomes acidic (use indicator).

- 29 The construction bolts can be cadmium plated by using a pure cadmium anode, the bolt as the cathode and an electrolyte which is a cadmium cyanide complex.
 30 Research

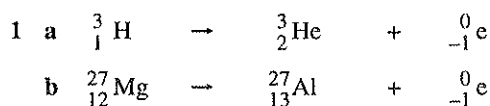
CHAPTER 5: NUCLEAR CHEMISTRY

Review exercise 5.1

- 1
 - a Atoms are not conserved in nuclear reactions.
 - b Chemical reactions involve changes in electrons between atoms. Nuclear reactions involve the particles in the nucleus.
 - c Temperature, pressure/concentration and catalysts have no effect on nuclear reactions.
 - d Far more energy obtained from nuclear reactions.
- 2
 - a
 - i ^{17}O : 8 protons; 9 neutrons
 - ii ^{52}Fe : 26 protons; 26 neutrons
 - iii ^{137}I : 53 protons; 84 neutrons
 - iv ^{258}Md : 101 protons; 157 neutrons
 - b

i	$^{150}_{62}\text{Sm}$	ii	$^{93}_{41}\text{Nb}$	iii	$^{208}_{82}\text{Pb}$
---	------------------------	----	-----------------------	-----	------------------------
- 3
 - a α large mass; β very small mass; γ no mass
 - b α 2+ charge; β 1- charge; γ no charge
 - c α least penetrating, about 5 cm through air;
 β about 1 m through air, stopped by aluminium;
 γ can pass through several cm of lead
- 4
 - a ^4_2He
 - b $^0_{-1}\text{e}$
 - c ^1_0n
 - d ^1_1p
 - e ^0_1e
- 5
 - a Photographic film becomes dark on exposure. Darkness increases with length of exposure and greater intensity of radiation.
 - b Geiger counter: The argon gas inside a metal tube is ionised into positive ions and electrons. These move towards electrodes which conduct a current measured by a recording device.
 - c Scintillation counter: Electrons in substances such as zinc sulfide are excited by radiation and emit photons of light as they return to lower energy states. Radiation is measured by counting flashes of light.

Review exercise 5.2



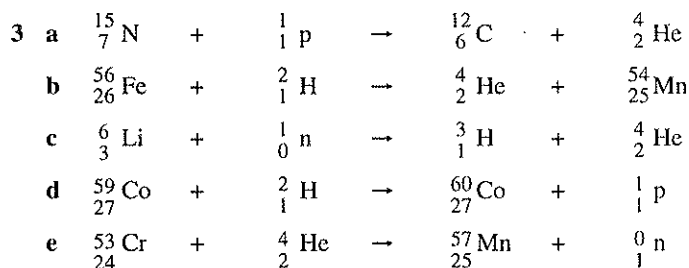
- c ${}_{11}^{26}\text{Na} \rightarrow {}_{12}^{26}\text{Mg} + {}_{-1}^0\text{e}$
- 2 a ${}_{86}^{210}\text{Rn} \rightarrow {}_{84}^{206}\text{Po} + {}_2^4\text{He}$
 b ${}_{94}^{239}\text{Pu} \rightarrow {}_{92}^{235}\text{U} + {}_2^4\text{He}$
 c ${}_{92}^{234}\text{U} \rightarrow {}_{90}^{230}\text{Th} + {}_2^4\text{He}$
- 3 a ${}_{7}^{12}\text{N} \rightarrow {}_6^{12}\text{C} + {}_1^0\text{e}$
 b ${}_{5}^8\text{B} \rightarrow {}_4^8\text{Be} + {}_1^0\text{e}$
 c ${}_{23}^{48}\text{V} \rightarrow {}_{22}^{48}\text{Ti} + {}_1^0\text{e}$
- 4 a ${}_{4}^7\text{Be} + {}_{-1}^0\text{e} \rightarrow {}_3^7\text{Li}$
 b ${}_{93}^{232}\text{Np} + {}_{-1}^0\text{e} \rightarrow {}_{92}^{232}\text{U}$
 c ${}_{46}^{103}\text{Pd} + {}_{-1}^0\text{e} \rightarrow {}_{45}^{103}\text{Rh}$
- 5 a Beta emission
 b Positron emission
 c Alpha emission
 d Positron emission
- 6 a positron or electron capture
 b β decay
 c α decay
- 7 With reference to Figure 5.7.
 a No, the neutron : proton ratio is too high and outside the zone of stability.
 b No, the neutron : proton ratio is too low and outside the zone of stability.
 c Yes, the neutron : proton ratio is in the zone of stability.
- 8 a ${}_{92}^{235}\text{U} \rightarrow {}_{90}^{231}\text{Th} \rightarrow {}_{91}^{231}\text{Pa} \rightarrow {}_{89}^{227}\text{Ac} \rightarrow {}_{90}^{227}\text{Th} \rightarrow {}_{88}^{223}\text{Ra} \rightarrow {}_{86}^{219}\text{Rn} \rightarrow {}_{84}^{215}\text{Po} \rightarrow {}_{82}^{211}\text{Pb} \rightarrow {}_{83}^{211}\text{Bi} \rightarrow {}_{81}^{207}\text{Tl} \rightarrow {}_{82}^{207}\text{Pb}$
 b lead-207

Review exercise 5.3

- 1 After 1st 2.6 hours: $0.1/2 = 0.05$ g
 After 5.2 hours: 0.025 g
 After 7.8 hours: 0.0125 g
- 2 1st half-life: $0.120/2 = 0.06$ g
 \therefore 3 half lives in 24 days
 2nd half-life: $0.06/2 = 0.03$ g
 I-131 has half-life of 8 days
 3rd half-life: $0.03/2 = 0.015$ g
- 3 a 2.1 g = 21%
 b 164 g \rightarrow 20.5 g in 3 half-lives, \therefore 84 years
 c Half-life is 28 years.

Review exercise 5.4

- 1 To overcome the electrostatic repulsion alpha particles and protons will encounter in the nuclide. Neutrons do not carry a charge and therefore do not need to be accelerated.
- 2 They are produced synthetically.

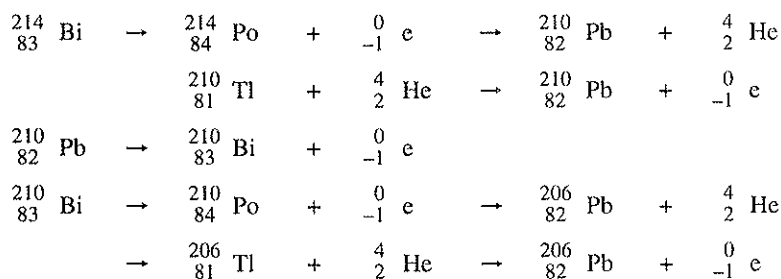


- 4 The nuclear transformations in a, b, d and e would all take place in a cyclotron as the charged particles are used to bombard the nucleus.
 Nuclear transformation c would take place in a nuclear reactor as it involves bombardment by neutrons.



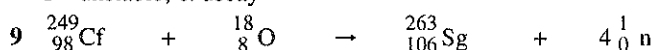
Chapter 5 — Application and research

- 1 a 90 protons; 140 neutrons
 b 96 protons; 148 neutrons
 c 77 protons; 115 neutrons
- 2 Chemical reactions involve changes in the arrangements of electrons around the nucleus. Nuclear reactions involve changes within the nucleus.
- 3 a β decay
 b α decay, positron emission, electron capture
- 4 a ${}^{241}_{94}\text{Pu} \rightarrow {}^{237}_{92}\text{U} + {}^4_2\text{He}$
 b ${}^{210}_{86}\text{Rn} \rightarrow {}^{210}_{87}\text{Fr} + {}^0_{-1}\text{e}$
 c ${}^{48}_{23}\text{V} \rightarrow {}^{48}_{22}\text{Ti} + {}^0_1\text{e}$
 d ${}^{107}_{48}\text{Cd} + {}^0_{-1}\text{e} \rightarrow {}^{107}_{47}\text{Ag}$
 e ${}^{234}_{92}\text{U} \rightarrow {}^{230}_{90}\text{Th} + {}^4_2\text{He}$
 f ${}^{26}_{11}\text{Na} \rightarrow {}^{26}_{12}\text{Mg} + {}^0_{-1}\text{e}$
 g ${}^{12}_7\text{N} \rightarrow {}^{12}_6\text{C} + {}^0_1\text{e}$
 h ${}^{232}_{93}\text{Np} + {}^0_1\text{e} \rightarrow {}^{232}_{92}\text{U}$
- 5 Uranium and thorium undergo alpha emission spontaneously.
 Therefore helium is found within the ore.
- 6 ${}^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^4_2\text{He}$
 ${}^{234}_{90}\text{Th} \rightarrow {}^{234}_{91}\text{Pa} + {}^0_{-1}\text{e}$
 ${}^{234}_{91}\text{Pa} \rightarrow {}^{234}_{92}\text{U} + {}^0_{-1}\text{e}$
 ${}^{234}_{92}\text{U} \rightarrow {}^{230}_{90}\text{Th} + {}^4_2\text{He}$
 ${}^{230}_{90}\text{Th} \rightarrow {}^{226}_{88}\text{Ra} + {}^4_2\text{He}$
 ${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^4_2\text{He}$
 ${}^{222}_{86}\text{Rn} \rightarrow {}^{218}_{84}\text{Po} + {}^4_2\text{He}$
 ${}^{218}_{84}\text{Po} \rightarrow {}^{218}_{85}\text{At} + {}^0_{-1}\text{e} \rightarrow {}^{214}_{83}\text{Bi} + {}^4_2\text{He}$
 \searrow
 $\rightarrow {}^{214}_{82}\text{Pb} + {}^4_2\text{He} \rightarrow {}^{214}_{83}\text{Bi} + {}^0_{-1}\text{e}$



7 Elements with high neutron-to-proton ratios emit β -particles. Elements with low neutron-to-proton ratios undergo either positron emission or electron capture.

- 8 a unstable; β decay
 b unstable; positron emission or electron capture
 c unstable; positron emission or electron capture
 d unstable; β decay
 e stable
 f unstable; α decay

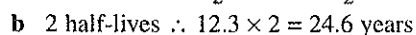
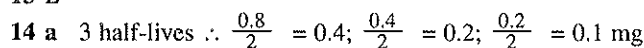


10 Research

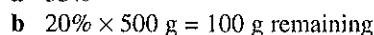
11 Research

- 12 a Californium-252: used to measure mineral content of coal ash and moisture within silos.
 b Iodine-123: diagnose thyroid disorders.
 c Oxygen-18 was used to track the reaction mechanism for photosynthesis.

13 B



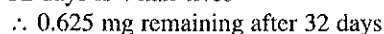
15 a 35%



c 84 days

d 25 days

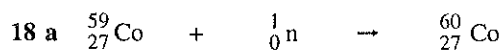
16 a 32 days is 4 half-lives



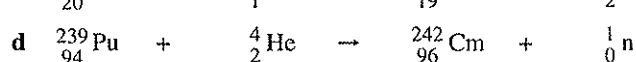
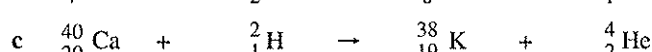
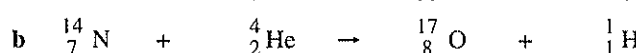
b 5 half-lives drop to 0.312 g, so $<0.5 \text{ g}$ in 36 days

17 a Inert gas in the tube is ionised by the radiation into electrons and positive ions. These charged particles travel to electrodes which conduct a current to a measuring device.

b Substances such as zinc sulfide are struck by radiation and their electrons become excited. When the electrons return to a lower energy level they emit photons of light. These light flashes are measured to determine level of radiation.



b ${}^{60}\text{Co}$ would be made in a nuclear reactor as it involves the capture of a neutron. In a nuclear reactor atoms are bombarded with neutrons. A cyclotron is used to bombard atoms with charged particles.



20 α particles can cause serious damage to cells.

Module 1

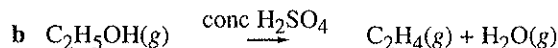
REVIEW

- 1 a
- 2 d
- 3 b
- 4 b
- 5 d
- 6 a
- 7 b
- 8 d
- 9 c
- 10 a

- 11 a Ethene is more reactive due to the presence of the double bond.
 - b addition
 - c poly(ethene)
 - d HI

- 12 Spirit burners containing ethanol and 1-butanol respectively are weighed and used to heat a set mass of water through a temperature change of 10°C. The spirit burners are weighed again and the mass of fuel used is recorded. The specific heat capacity of water is known and therefore the heats of combustion for the two fuels can be calculated. Precautions must be taken not to allow the fuels to come in direct contact with a naked flame.

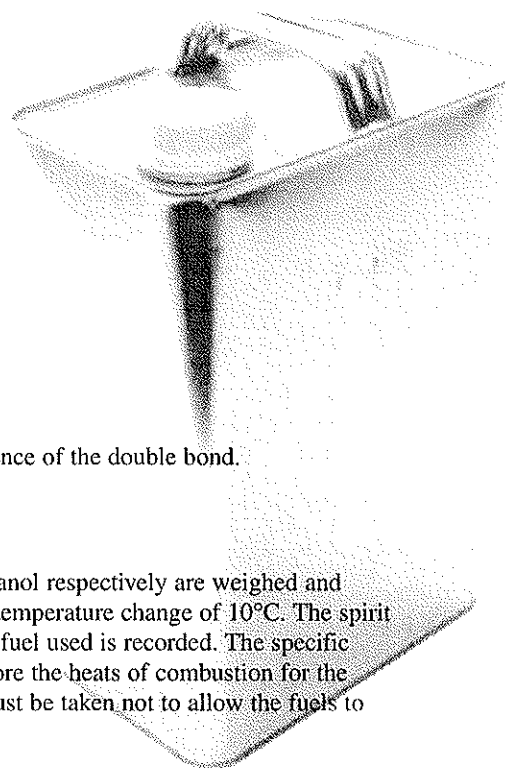
- 13 a i
$$\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) \xrightarrow{\text{yeast}} 2\text{CH}_3\text{CH}_2\text{OH}(\text{aq}) + 2\text{CO}_2(\text{g}) + \text{heat}$$
 - ii Sugar (sucrose) is first extracted from the sugar cane by crushing. The sucrose mixture is warmed and yeast is added. The yeast contains enzymes which convert sucrose to glucose as well as ferment the glucose. Fermentation is promoted by temperatures around 37°C. The ethanol must be separated from the ethanol/water mixture by fractional distillation.



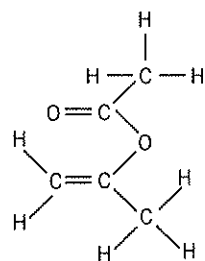
This reaction is carried out industrially at 350°C. Lower pressures would favour the production of ethene.

- 14 a
$$\text{C}_{10}\text{H}_{22}(\text{g}) \rightarrow \text{C}_8\text{H}_{18}(\text{g}) + \text{C}_2\text{H}_4(\text{g})$$
 - b Zeolites

- 15 a To lower the activation energy for the reaction by providing an alternative pathway.
 - b At low temperatures the reaction rate would be low and the process would not be economically viable. Higher temperatures cause a higher reaction rate.
 - c High pressure, acidic conditions.



16 a



- b vinyl chloride
i chloroethene
ii polyvinylchloride (PVC)

iii PVC is a thermoplastic with long chains with weak dispersion forces between them. This allows the polymer to be heated and remoulded. With additives, PVC can be used as a rigid plastic eg guttering, water pipes, or as a flexible plastic eg garden hoses.

17 a LDPE has a greater degree of branching between its polymer chains, reducing the dispersion forces between the chains. HDPE has less branching, resulting in a stronger and more dense plastic.

b cling wrap, insulation for wires.

c LDPE: Organic peroxides are used as catalysts to attack the ethene double bond and form a covalent bond with a carbon atom. This new molecule then attacks another ethene molecule causing the chain to grow (propagate). Branches are formed when the chain curls back and removes a H from a carbon in the chain, which will in turn react with another ethene molecule. The reaction terminates when two polymer radicals react together.
HDPE: Ionic catalysts (Ziegler-Natta catalysts) are used. Ethene molecules are added to the polymer on the surface of the catalyst which reduces the amount of branching.

d The polymer chains in HDPE are packed tightly together due to less branching of the chains. This gives HDPE greater strength and toughness but reduces its flexibility.

18 No commercially viable method of producing ethanol from crops is yet available. Fuel mixtures containing greater than 15% ethanol require some modification to the car before being used.

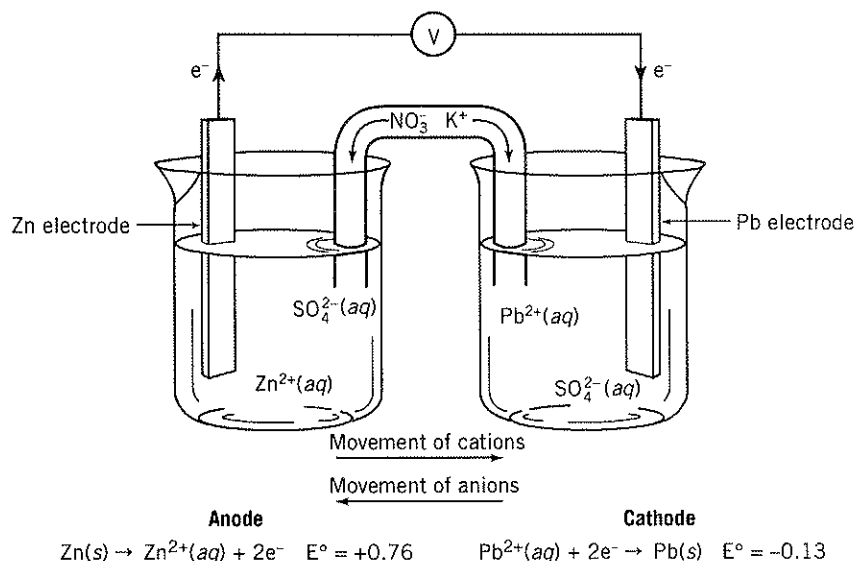
Ethanol is a renewable fuel and petroleum is not.

19 a $\text{Li}(s) \rightarrow \text{Li}^+(aq) + e^-$

b $\text{I}_2(s) + 2e^- \rightarrow 2\text{I}^-(aq)$
Iodine ions as iodine is reduced.

c Size of the button cell is compact.

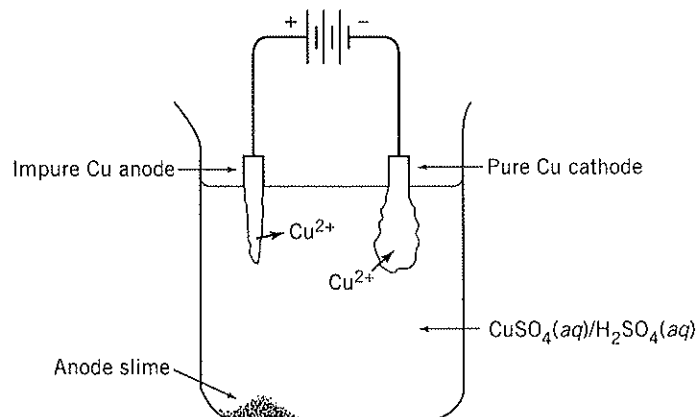
20 a



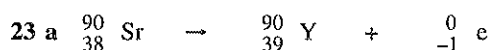
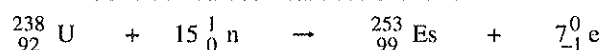
b Cell potential = $+0.76 - 0.13 = 0.63 \text{ V}$

c Zinc

- 21 Refining of copper. Impure copper is the anode and pure copper is the cathode. Acidified copper sulfate solution is the electrolyte. The copper and impurities are oxidised and form ions in the solution. Pure copper deposits at the cathode. The inert impurities fall to the bottom and form an 'anode slime'.



- 22 Uranium-238 is bombarded with neutrons to form einsteinium.



b Sr is in the same periodic group as calcium and therefore is chemically similar.

c 85.3 years is 3 half-lives; $\therefore > 0.125 \text{ g}$ remains at 85 years.

- 24 a Iodine-131 is used in the diagnosis of thyroid misfunction and in treatment of thyroid tumours.

b I-131 is produced by neutron bombardment in a reactor.

c Short half-life therefore only in the body for a short time.

I-131 can destroy some healthy cells when used for radiation.