SUGGESTED ANSWERS

CHAPTER 1

REDOX EQUILIBRIUM

Activity 1A

(page 5)

1. (a) $2CuO + C \rightarrow 2Cu + CO_2$

(b) (i) Reduction reaction (ii) Oxidation reaction

(c) (i) Carbon
(ii) Copper(II) oxide
(iii) Copper(II) oxide
(iv) Carbon

Activity 1B

(page 6)

(a) (i) Ammonia
(ii) Copper(II) oxide
(iii) Copper(II) oxide
(iv) Ammonia

(b)
- Ammonia is oxidised because it loses hydrogen
- Copper(II) oxide is reduced because it loses oxygen.
- Copper(II) oxide is an oxidising agent because it causes ammonia to undergo oxidation reaction.
- Ammonia is a reducing agent because it causes copper(II) oxide to undergo reduction reaction.

Laboratory Activity 1A

(page 7)

1. X : $2I^- \rightarrow I_2 + 2e$
Y : $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

2. X : Oxidation
Y : Reduction

3. $10I^- + 2MnO_4^- + 16H^+ \rightarrow 5I_2 + 2Mn^{2+} + 8H_2O$

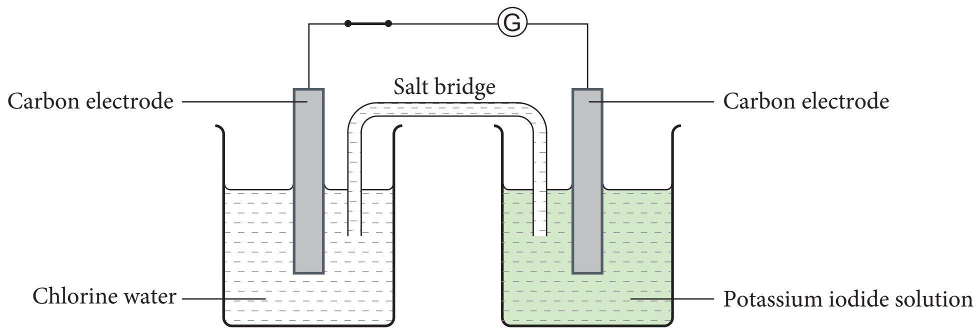
4.
- I^- ions are oxidised because they lose electrons.
- MnO_4^- ions are reduced because they gain electrons.
- Oxidising agent is MnO_4^- ions because MnO_4^- ions are the electron acceptors.
- Reducing agent is I^- ions because I^- ions are the electron donors.

5. Electrons move from X electrode to Y electrode through the connecting wires.

6. Positive terminal is Y electrode and negative terminal is X electrode.

7. To allow the transfer of ions and to complete the curcuit.

8.



Activity 1C

(page 12)

1. +7
2. +2
3. -1
4. +1
5. +1
6. +3
7. +4
8. 0

ACTIVITY 1D

(page 13)

$CuO + H_2 \rightarrow Cu + H_2O$

(a) A redox reaction occurs because the oxidation number of copper in copper(II) oxide decreases from +2 to 0, while the oxidation number of hydrogen increases from 0 to +1.

(b) (i) H_2 is oxidised and CuO is reduced.

(ii) Oxidising agent is CuO and reducing agent is H_2.

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

(a) A redox reaction occurs because the oxidation number of magnesium increases from 0 to +2, while the oxidation number of hydrogen decreases from +1 to 0.

(b) (i) Mg is oxidised and HCl is reduced.

(ii) Oxidising agent is HCl and reducing agent is Mg.

ACTIVITY 1E

(page 14)

1. (a) Copper(I) oxide
(b) Copper(II) oxide
(c) Mercury(I) chloride
(d) Mercury(II) chloride
(e) Potassium chromate(VI)

2. (a) V_2O_5 (b) Na_2O (c) $PbCO_3$

3. Fe_2O_3 : Iron(III) oxide
Al_2O_3 : Aluminium oxide
- The nomenclature of compound Fe_2O_3 has a Roman numeral, while Al_2O_3 does not have a Roman numeral.
- Iron has more than one oxidation number and the Roman numeral of iron(III) oxide shows the oxidation number of iron is +3, while aluminium has only one oxidation number and does not need a Roman numeral.

Laboratory Activity 1B

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Result:

Table to record all observations in Sections A and B.

Mixture	Observation
Iron(II) sulphate solution + Bromine water	
Iron(III) chloride solution + Zinc powder	

1. Section A:

(a) Fe^{2+} ions are oxidised because the oxidation number of iron in iron(II) sulphate increases from +2 to +3, while bromine water is reduced because the oxidation number of bromine decreases from 0 to -1.

(b) Fe^{2+} ions are oxidised because Fe^{2+} ions lose electrons to form Fe^{3+} ions and bromine water is reduced because bromine molecule, Br_2 gains electrons to form bromide ion, Br^-.

Section B:

(a) Zinc is oxidised because the oxidation number of zinc increases from 0 to +2, while Fe^{3+} ion is reduced because the oxidation number of iron decreases from +3 to +2.

(b) Zinc is oxidised because zink atom, Zn loses electrons to form Zn^{2+} ion, and Fe^{3+} ion is reduced because Fe^{3+} gains an electron to form Fe^{2+} ion.

2. - Bromine water is an oxidising agent because bromine is the electron acceptor.
- Zinc is a reducing agent because zinc is the electron donor.

3. Iron(II) sulphate solution is easily oxidised to become iron(III) sulphate.

4. Sodium hydroxide solution.

5. Section A : Chlorine water
Section B : Magnesium powder

Procedure:

1. Using the sand paper, clean the magnesium ribbons, lead plates and copper plates.
2. Put the magnesium ribbons into two difference test tubes.
3. Pour 0.5 mol dm^{-3} lead(II) nitrate solution into the first test tube and 0.5 mol dm^{-3} copper(II) nitrate solution into the second test tube until each magnesium ribbon is immersed.
4. Repeat step 2 using lead plates and copper plates.
5. Pour 0.5 mol dm^{-3} magnesium(II) nitrate solution into the third test tube and 0.5 mol dm^{-3} copper(II) nitrate solution into the fourth test tube until each lead plate is immersed.
6. Pour 0.5 mol dm^{-3} magnesium(II) nitrate solution into the fifth test tube and 0.5 mol dm^{-3} lead(II) nitrate solution into the sixth test tube until each copper plate is immersed.
7. Put all the test tubes on the test tube rack.
8. Record all observations.

Result:

Table to record all observations and inferences of metal displacement reactions.

Metal	Salt solution	Observation	Inference
Magnesium	Lead(II) nitrate		
	Copper(II) nitrate		
Lead	Magnesium nitrate		
	Copper(II) nitrate		
Copper	Magnesium nitrate		
	Lead(II) nitrate		

Experiment: $Mg + Pb(NO_3)_2$

(a) Oxidation half equation: $Mg \rightarrow Mg^{2+} + 2e^-$
Reduction half equation: $Pb^{2+} + 2e^- \rightarrow Pb$
Overall ionic equation: $Mg + Pb^{2+} \rightarrow Mg^{2+} + Pb$

(b) (i) Magnesium
(ii) Lead(II) nitrate
(iii) Lead(II) nitrate
(iv) Magnesium

(c) (i) Magnesium atoms lose electrons to form Mg^{2+} ions.
(ii) Pb^{2+} ions gain electrons to form lead, Pb atoms.
(iii) Pb^{2+} ions are the electron acceptors
(iv) Mg is the electron donor

Experiment: $Mg + Cu(NO_3)_2$

(a) Oxidation half equation: $Mg \rightarrow Mg^{2+} + 2e^-$
Reduction half equation: $Cu^{2+} + 2e^- \rightarrow Cu$
Overall ionic equation: $Mg + Cu^{2+} \rightarrow Mg^{2+} + Cu$

(b) (i) Magnesium
(ii) Copper(II) nitrate
(iii) Copper(II) nitrate
(iv) Magnesium

(c) (i) Magnesium atoms lose electrons to form Mg^{2+} ions.
(ii) Cu^{2+} ions gain electrons to form copper, Cu atoms.
(iii) Cu^{2+} ions are the electron acceptors
(iv) Mg is the electron donor

Experiment: $Pb + Cu(NO_3)_2$

(a) Oxidation half equation: $Pb \rightarrow Pb^{2+} + 2e^-$
Reduction half equation: $Cu^{2+} + 2e^- \rightarrow Cu$
Overall ionic equation: $Pb + Cu^{2+} \rightarrow Pb^{2+} + Cu$

(b) (i) Lead
(ii) Copper(II) nitrate
(iii) Copper(II) nitrate
(iv) Lead

(c) (i) Pb atoms lose electrons to form Pb^{2+} ions.
(ii) Cu^{2+} ions gain electrons to form copper, Cu atoms.
(iii) Cu^{2+} ions are the electron acceptors
(iv) Pb is the electron donor

Result:

Table to record all observations.

Halide solution	Halogen	Observation	
		Aqueous layer	1,1,1-trichloroethane layer
Potassium chloride	Bromine water		
	Iodine solution		
Potassium bromide	Chlorine water		
	Iodine solution		
Potassium iodide	Chlorine water		
	Bromine water		

1. To verify the presence of halogen.

2. (a) No
(b) Chlorine water.
(c) Chlorine water and bromine water.

3. KBr and Cl_2
(a) Oxidation half equation : $2Br^- \rightarrow Br_2 + 2e^-$
Reduction half equation : $Cl_2 + 2e^- \rightarrow 2Cl^-$
(b) Overall ionic equation : $2Br^- + Cl_2 \rightarrow Br_2 + 2Cl^-$
(c) - Br^- ions are oxidised because Br^- ions lose electrons to form bromine, Br_2 molecules, while chlorine is reduced because chlorine, Cl_2 molecules gain electrons to form Cl^- ions.
- Chlorine water is an oxidising agent because chlorine is the electron acceptor, while potassium bromide is a reducing agent because Br^- ions are the electron donors.

KI and Cl_2
(a) Oxidation half equation : $2I^- \rightarrow I_2 + 2e^-$
Reduction half equation : $Cl_2 + 2e^- \rightarrow 2Cl^-$
(b) Overall ionic equation : $2I^- + Cl_2 \rightarrow I_2 + 2Cl^-$
(c) - I^- ions are oxidised because. I^- ions lose electrons to form iodine, I_2 molecules, while chlorine is reduced because chlorine, Cl_2 molecules gain electrons to form chloride, Cl^- ions.
- Chlorine water is an oxidising agent because chlorine is the electron acceptor, while potassium iodide is a reducing agent because I^- ions are the electron donors.

KI and Br_2
(a) Oxidation half equation : $2I^- \rightarrow I_2 + 2e^-$
Reduction half equation : $Br_2 + 2e^- \rightarrow 2Br^-$
(b) Overall ionic equation : $2I^- + Br_2 \rightarrow I_2 + 2Br^-$
(c) - I^- ions are oxidised because I^- ions lose electrons to form iodine, I_2 molecules, while bromine is reduced because bromine, Br_2 molecules gain electrons to form bromide, Br^- ions.
- Bromine water is an oxidising agent because bromine is the electron acceptor, while potassium iodide is a reducing agent because I^- ions are the electron donors.

4. (a) I_2, Br_2, Cl_2
(b) The strength of a halogen as an oxidising agent decreases down Group 17.
(c) Cl^-, Br^-, I^-

Self Assess 1.1

(page 21)

1. A chemical reaction where oxidation and reduction process occur simultaneously.
2. Reaction I
   (a) Oxidation half equation : $Cu \rightarrow Cu^{2+} + 2e^-$
   Reduction half equation : $Ag^+ + e^- \rightarrow Ag$
   (b) - Copper is oxidised because copper, Cu atoms lose electrons to form Cu^{2+} ions, while Ag^+ ions are reduced because Ag^+ gains electrons to form silver, Ag atoms.
   - Ag^+ ions are oxidising agents because Ag^+ ions are the electron acceptors, while copper is a reducing agent because copper is the electron donor.

   Reaction II
   (a) Oxidation half equation : $Pb \rightarrow Pb^{2+} + 2e^-$
   Reduction half equation : $O_2 + 4e^- \rightarrow 2O^{2-}$
   (b) - Lead is oxidised because lead, Pb atoms lose electrons to form Pb^{2+} ions, while oxygen is reduced because oxygen, O_2 molecules gain electrons to form oxide, O^{2-} ions.
   - Oxygen is an oxidising agent because oxygen is the electron acceptor, while lead is a reducing agent because lead is the electron donor.

   Reaction III
   (a) Oxidation half equation : $Al \rightarrow Al^{3+} + 3e^-$
   Reduction half equation : $Cl_2 + 2e^- \rightarrow 2Cl^-$
   (b) - Aluminium is oxidised because aluminium, Al atoms lose electrons to form Al^{3+} ions, while chlorine is reduced because chlorine, Cl_2 molecules gain electrons to form chloride, Cl^- ion.
   - Chlorine is an oxidising agent because chlorine is the electron acceptor, while aluminium is a reducing agent because aluminium is the electron donor.

   Reaction IV
   (a) Oxidation half equation : $2I^- \rightarrow I_2 + 2e^-$
   Reduction half equation : $Br_2 + 2e^- \rightarrow 2Br^-$
   (b) - I^- ions are oxidised because I^- ions lose electrons to form iodine, I_2 molecules while bromine is reduced because bromine, Br_2 molecules gain electrons to form bromide, Br^- ions.
   - Bromine water is an oxidising agent because bromine is the electron acceptor, while iodide ions are reducing agents because I^- ions are the electron donors.

Activity 1F

(page 26)

2. (a) - The standard electrode potential value, E^0 is arranged from the most negative to the most positive.
   $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$ $E^0 = +1.33$ V
   $Cl_2(g) + 2e^- \rightleftharpoons Cl^-(aq)$ $E^0 = +1.36$ V
   - The E^0 value of $Cr_2O_7^{2-}$ is less positive. Therefore, $Cr_2O_7^{2-}$ ions on the left side are weaker oxidising agents. $Cr_2O_7^{2-}$ ions are difficult to gain electrons and reduction reaction does not occur.
   - The E^0 value of Cl^- is more positive. Therefore, Cl^- ions on the right side are weaker reducing agents. Cl^- ions are difficult to lose electrons and oxidation reaction does not occur. Therefore, the reaction between $Cr_2O_7^{2-}$ and Cl^- does not occur.

   (b) - The standard electrode potential value, E^0 is arranged from the most negative to the most positive.
   $Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$ $E^0 = +1.07$
   $H_2O_2(aq) + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O(l)$ $E^0 = +1.77$
   - The E^0 value of H_2O_2 is more positive. Therefore, H_2O_2 on the left side is a stronger oxidising agent. H_2O_2 gains electrons easily and reduction reaction occurs.
   - The E^0 value of Br^- is less positive. Therefore, Br^- ions on the right side are stronger reducing agents. Br^- ions lose electrons easily and oxidation reaction occurs. Therefore, the reaction between H_2O_2 and Br^- occurs.

Self Assess 1.2

(page 26)

1. (a) Arrange the standard electrode potential value, E^0 from the most negative to the most positive.

$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$ $E^0 = -2.38$

$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$ $E^0 = -0.76$

$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$ $E^0 = +0.34$

$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$ $E^0 = +0.80$

Oxidising agent : Mg^{2+}, Zn^{2+}, Cu^{2+}, Ag^+

Reducing agent : Ag, Cu, Zn, Mg

(b) (i) Reaction occur
- Mg is a stronger reducing agent. Mg easily releases electrons and oxidation reaction occurs.
- Magnesium can displace copper from its salt solution because magnesium is a stronger reducing agent compared to copper.

(ii) Reaction occur
- Mg is a stronger reducing agent. Mg easily releases electrons and oxidation reaction occurs.
- Magnesium can displace zinc from its salt solution because magnesium is a stronger reducing agent compared to zinc.

(iii) Reaction does not occur
- Cu is a weaker reducing agent. Cu atom is difficult to lose electrons and oxidation reaction does not occur.
- Copper cannot displace zinc from its salt solution because copper is a weaker reducing agent compared to zinc.

Experiment 1A

(page 29)

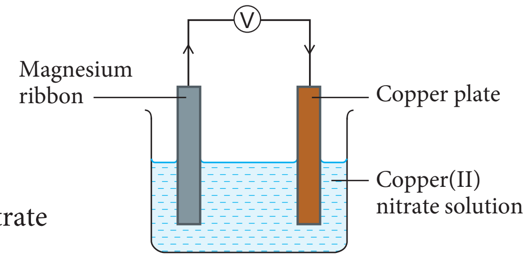
Sample answer: Simple chemical cell

Materials: Magnesium ribbon, iron nail, zinc plate, lead plate, copper plate and copper(II) nitrate solution.

Apparatus: Beaker

Procedure:

1. Using the sand paper, clean the magnesium ribbon, iron nail, zinc plate, lead plate and copper plate.
2. Pour 1.0 mol dm^{-3} of copper(II) nitrate solution into a beaker until half full.
3. Connect magnesium ribbon and copper plate to a voltmeter using a connecting wire.
4. Dip the magnesium ribbon and copper plate into the copper(II) nitrate solution to complete the circuit.
5. Record the voltmeter reading, the metal at the negative terminal and the metal at the positive terminal.
6. Repeat steps 3 to 5 using the iron nail, zinc plate and lead plate to replace magnesium ribbon.



Or

Sample answer: Chemical cell with two half cells.

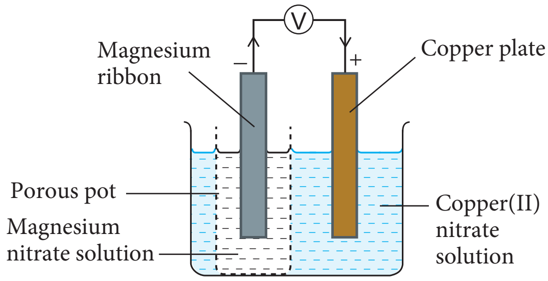
Materials: Magnesium ribbon, iron nail, zinc plate, lead plate, copper plate, magnesium nitrate solution, iron(II) nitrate solution, zinc nitrate solution, lead(II) nitrate solution and copper(II) nitrate solution.

Apparatus: Beaker and porous pot

Prosedure:

1. Using the sand paper, clean the magnesium ribbon, iron nail, zinc plate, lead plate and copper plate.
2. Pour 1.0 mol dm^{-3} of magnesium nitrate solution into a porous pot and 1.0 mol dm^{-3} of copper(II) nitrate solution into a beaker until half full.
3. Place the porous pot into the beaker.

4. Connect the magnesium ribbon and copper plate to a voltmeter using a connecting wire.
5. Dip the magnesium ribbon into the magnesium nitrate solution and the copper plate into the copper(II) nitrate solution to complete the circuit.
6. Record the voltmeter reading, the metal at the negative terminal and the metal at the positive terminal.
7. Repeat steps 2 to 6 using the iron(II) nitrate solution, zinc nitrate solution and lead(II) nitrate solution to replace magnesium nitrate solution in the porous pot, and using the iron nail, zinc plate and lead plate to replace magnesium ribbon.



Discussion:

1. - Pair of Mg/Cu
 Oxidation half equation : $Mg \rightarrow Mg^{2+} + 2e^-$
 Reduction half equation : $Cu^{2+} + 2e^- \rightarrow Cu$
 Overall ionic equation : $Mg + Cu^{2+} \rightarrow Mg^{2+} + Cu$
 - Pair of Fe/Cu
 Oxidation half equation : $Fe \rightarrow Fe^{2+} + 2e^-$
 Reduction half equation : $Cu^{2+} + 2e^- \rightarrow Cu$
 Overall ionic equation : $Fe + Cu^{2+} \rightarrow Fe^{2+} + Cu$
 - Pair of Zn/Cu
 Oxidation half equation : $Zn \rightarrow Zn^{2+} + 2e^-$
 Reduction half equation : $Cu^{2+} + 2e^- \rightarrow Cu$
 Overall ionic equation : $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$
 - Pair of Pb/Cu
 Oxidation half equation : $Pb \rightarrow Pb^{2+} + 2e^-$
 Reduction half equation : $Cu^{2+} + 2e^- \rightarrow Cu$
 Overall ionic equation : $Pb + Cu^{2+} \rightarrow Pb^{2+} + Cu$
2. - Pair of Mg/Cu
 $Mg(s) \,|\, Mg^{2+}(aq, 1\ mol\ dm^{-3}) \,||\, Cu^{2+}(aq, 1\ mol\ dm^{-3}) \,|\, Cu(s)$
 - Pair of Fe/Cu
 $Fe(s) \,|\, Fe^{2+}(aq, 1\ mol\ dm^{-3}) \,||\, Cu^{2+}(aq, 1\ mol\ dm^{-3}) \,|\, Cu(s)$
 - Pair of Zn/Cu
 $Zn(s) \,|\, Zn^{2+}(aq, 1\ mol\ dm^{-3}) \,||\, Cu^{2+}(aq, 1\ mol\ dm^{-3}) \,|\, Cu(s)$
 - Pair of Pb/Cu
 $Pb(s) \,|\, Pb^{2+}(aq, 1\ mol\ dm^{-3}) \,||\, Cu^{2+}(aq, 1\ mol\ dm^{-3}) \,|\, Cu(s)$
3. - Pair of Mg/Cu
 $E^0_{cell} = (+0.34) - (-2.38) = +2.72\ V$
 - Pair of Fe/Cu
 $E^0_{cell} = (+0.34) - (-0.44) = +0.78\ V$
 - Pair of Zn/Cu
 $E^0_{cell} = (+0.34) - (-0.76) = +1.10\ V$
 - Pair of Pb/Cu
 $E^0_{cell} = (+0.34) - (-0.13) = +0.47\ V$
4. The greater the difference of E^0 value for the pair of metals, the greater the voltage of the cell.

Activity 1G

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1. (a) (i) Negative terminal: Iron
 Positive terminal : Silver
 (ii) $Fe(s) \,|\, Fe^{2+}(aq) \,||\, Ag^+(aq) \,|\, Ag(s)$
 (iii) Oxidation half equation : $Fe \rightarrow Fe^{2+} + 2e^-$
 Reduction half equation : $Ag^+ + e^- \rightarrow Ag$
 Overall ionic equation : $Fe + 2Ag^+ \rightarrow Fe^{2+} + 2Ag$
 (iv) $E^0_{cell} = (+0.80) - (-0.44) = +1.24\ V$

Self Assess 1.3

(page 30)

1. (a) $Mg(s) \mid Mg^{2+}(aq) \parallel Sn^{2+}(aq) \mid Sn(s)$
(b) $Pt(s) \mid Cl^{-}(aq)\ ,\ Cl_2(aq) \parallel MnO_4^{-}(aq)\ ,\ Mn^{2+}(aq) \mid Pt(s)$

2. (a) E^0_{cell} = (+0.13) – (-0.25) = + 0.12 V
(b) E^0_{cell} = (+0.80) – (+0.54) = + 0.26 V
(c) E^0_{cell} = (+0.80) – (+0.77) = + 0.03 V
(d) E^0_{cell} = (+1.36) – (+1.07) = + 0.29 V

Activity 1H

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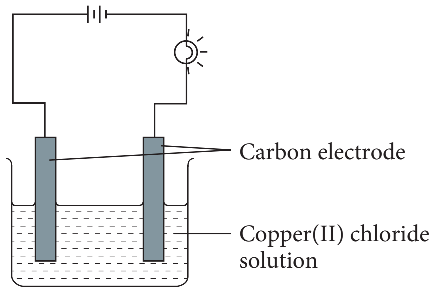
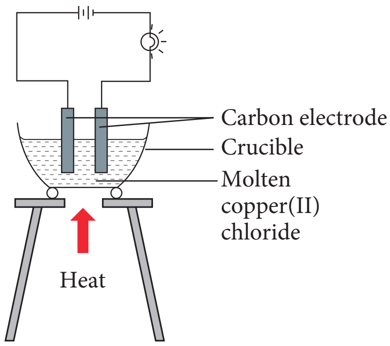
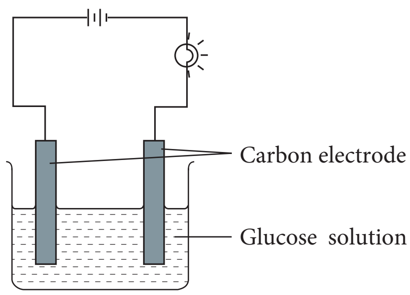
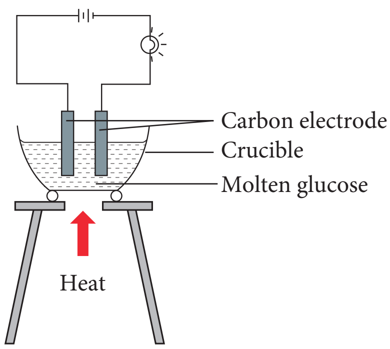
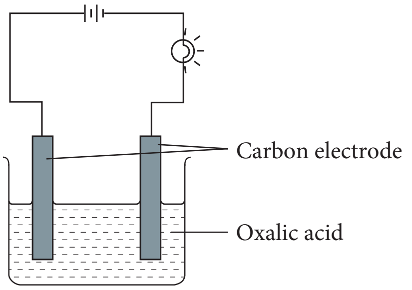
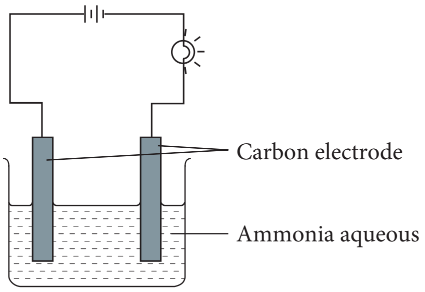
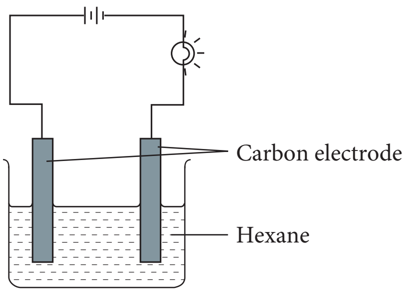
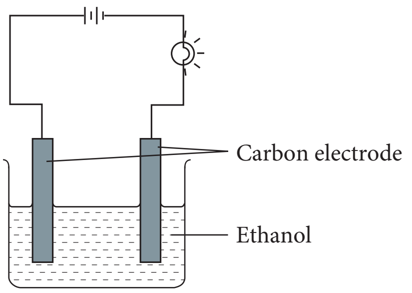
Apparatus set-up	Observation	Inference	Conclusion
	Bulb lights up	Presence of free moving ions	Copper(II) chloride, $CuCl_2$ is an electrolyte
	Bulb lights up	Presence of free moving ions	Copper(II) chloride, $CuCl_2$ is an electrolyte
	Bulb does not light up	No free moving ions	Glucose, $C_6H_{12}O_6$ is a non-electrolyte
	Bulb does not light up	No free moving ions	Glocose, $C_6H_{12}O_6$ is a non-electrolyte

	Bulb lights up	Presence of free moving ions	Oxalic acid, $C_2H_2O_4$ is an electrolyte
	Bulb lights up	Presence of free moving ions	Ammonia, NH_3 is an electrolyte
	Bulb does not light up	No free moving ions	Hexane, C_6H_{14} is a non-electrolyte
	Bulb does not light up	No free moving ions	Ethanol, C_2H_5OH is a non-electrolyte

Laboratory Activity IE

(page 34)

1. Lead(II) ions move to the cathode and bromide ions move to the anode.

2. (a) $Pb^{2+} + 2e^- \rightarrow Pb$

(b) $2Br^- \rightarrow Br_2 + 2e^-$

3. Cathode : Lead

Anode : Bromine

4. Cathode : A lead(II) ion gains two electrons to form a lead atom.

Anode : A bromide ion loses one electron to form a bromine atom. Two bromine atoms combine to form a bromine molecule. (OR two bromide ions lose two electrons to form a bromine molecule)

5. $Pb^{2+} + 2Br^- \rightarrow Pb + Br_2$

Activity 11

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1. (a)

- **Molten zinc oxide, ZnO**
  - **Anode**
    - Colourless gas is released
    - Two oxide ions lose four electrons to form an oxygen molecule
  - **Cathode**
    - Grey solid is deposited
    - A zinc ion gains two electrons to form a zinc atom

(b)

- **Molten Magnesium chloride, $MgCl_2$**
  - **Anode**
    - Greenish yellow gas is released
    - Two chloride ions lose two electrons to form a chlorine molecule
  - **Cathode**
    - Grey solid is deposited
    - A magnesium ion gains two electrons to form a zinc atom

Laboratory Activity 1F

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Result:

Solution	Observation	
	Cathode	Anode
Copper(II) sulphate		
Sulphuric acid		

Discussion:

1. (a) Cu^{2+} ion, SO_4^{2-} ion, H^+ ion, OH^- ion

(b) H^+ion, SO_4^{2-} ion, OH^- ion

2. Copper(II) sulphate solution

	Cathode	Anode
(a)	Cu^{2+} ion and H^+ ion	SO_4^{2-} ion and OH^- ion
(b)	Cu^{2+} ion E^0 value of Cu^{2+} ion is more positive compared to E^0 of H^+ ion	OH^- ion E^0 value of OH^- ion is less positive compared to E^0 of SO_4^{2-} ion
(c)	Copper	Oxygen
(d)	$Cu^{2+} + 2e^- \rightarrow Cu$	$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$
(e)	Cu^{2+} ion gains two electrons to form one copper atom	Four OH^- ions lose four electrons to form one oxygen molecule and two water molecules.

(f) $2Cu^{2+} + 4OH^- \rightarrow 2Cu + O_2 + 2H_2O$

Sulphuric acid

	Cathode	Anode
(a)	H^+ ion	SO_4^{2-} ion and OH^- ion
(b)	H^+ ion Only H^+ ion is present at the cathode	OH^- ion E^0 value of OH- ion is less positive compared to E^0 of SO_4^{2-} ion
(c)	Hydrogen	Oxygen
(d)	$2H^+ + 2e^- \rightarrow H_2$	$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$
(e)	Two H^+ ions gain two electrons to form one hydrogen molecule	Four OH^- ions lose four electrons to form one oxygen molecule and two water molecules.

(f) $4H^+ + 4OH^- \rightarrow 2H_2 + O_2 + 2H_2O$

Experiment 1B

(page 41)

1. Hydrochloric acid, HCl 1.0 mol dm^{-3}
   (a) Chlorine.
   Chloride ions are discharged because the concentration of Cl^- ions is higher than OH^- ions.
   Two chloride ions lose two electrons to form one chlorine molecule.
   (b) $2Cl^- \rightarrow Cl_2 + 2e^-$

   Hydrochloric acid, HCl 0.0001 mol dm^{-3}
   (a) Oxygen
   Hydroxide ions are discharged because the E^0 value of OH^- ions are less positive compared to the E^0 value of Cl^- ions.
   Four OH^- ions lose four electrons to form one oxygen molecule and two water molecules.
   (b) $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$
2. The electrolyte decomposition process produces gas bubbles at the anode when carbon electrodes that are connected to the batteries are dipped into hydrochloric acid.
3. Colourless gas is released. Hydroxide ions are discharged because the E^0 value of OH^- ions is less positive compared to the E^0 value of Cl^- ions. Four OH^- ions lose four electrons to form one oxygen molecule and two water molecules.

Experiment 1C

(page 42)

Hypothesis:
When carbon electrodes are used, colourless gas bubbles are released at the anode, while when copper electrodes are used, the copper at the anode becomes thinner.

Variables:
(a) Manipulated variable : Carbon electrode and copper electrode
(b) Responding variable : Observation at anode
(c) Fixed variable : Copper(II) sulphate solution

Prosedure:
1. Pour 0.5 mol dm^{-3} of copper(II) sulphate solution, $CuSO_4$ into a beaker until half full.
2. Connect the carbon electrodes to the switch and batteries using the connecting wires.
3. Dip the carbon electrodes into the copper(II) sulphate solution to complete the curcuit.
4. Observe and record the changes that occur at the anode and the cathode in a table.
5. Repeat steps 1 to 4 using copper electrodes to replace carbon electrodes.

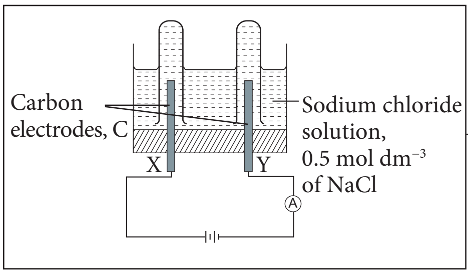
Result:

Type of electrode	Observation	
	Cathode	Anode
Carbon		
Copper		

1. (a) Cathode : Copper
   Anode : Oxygen
   (b) Cathode : Copper
   Anode : Copper(II) ion.
2. (a) Anode : $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$
   (b) Anode : $Cu \rightarrow Cu^{2+} + 2e^-$
3. (a) - The blue colour of copper(II) sulphate solution becomes paler.
   - The concentration of Cu^{2+} ions decreases.
   - Cu^{2+} ions are discharged to form copper atoms at the cathode.
   (b) - The blue colour of copper(II) sulphate solution remains unchanged.
   - The concentration of Cu^{2+} ions remains unchanged.
   - The discharged rate of Cu^{2+} ions to form copper atoms at the cathode is the same as the ionisation rate of copper atoms to form Cu^{2+} ions at the anode.

Activity 1J

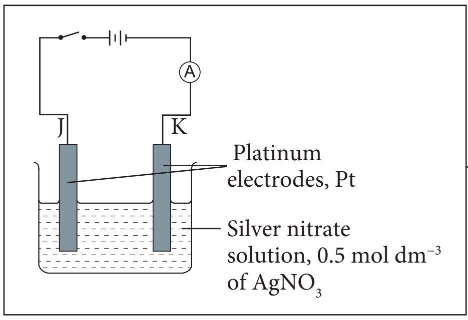
2.



(a) Product
X : Chlorine
Y : Hydrogen

(b) Equation
X : $2Cl^- \rightarrow Cl_2 + 2e^-$
Y : $2H^+ + 2e^- \rightarrow H_2$

(c) Product, if concentration of electrolyte is 0.0001 mol dm^{-3}
X : Oxygen
Y : Hydrogen



(a) Product
J : Oxygen
K : Silver

(b) Equation
J : $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$
K: $Ag^+ + e^- \rightarrow Ag$

(c) Product, if concentration of electrolyte is 0.0001 mol dm^{-3}
J : Oxygen
K: Silver

Activity 1K

1.
- Electrolytic cell:
  Anode(+) : $Cu \rightarrow Cu^{2+} + 2e^-$ Cathode(-) : $Cu^{2+} + 2e^- \rightarrow Cu$
- Chemistry cell:
  Anode(-) : $Zn \rightarrow Zn^{2+} + 2e^-$ Cathode(+) : $Cu^{2+} + 2e^- \rightarrow Cu$
- The blue colour of copper(II) sulphate solution remains unchanged in the electrolytic cell but the blue colour of copper(II) sulphate solution becomes paler in the voltaic cell.
- The concentration of Cu^{2+} ions remains unchanged in the electrolytic cell but the concentration of Cu^{2+} ions decreases in the voltaic cell.
- In the electrolytic cell, the discharge rate of Cu^{2+} ions at the cathode is the same as the ionisation rate of copper atoms at the anode, but in the voltaic cell, Cu^{2+} ions are discharged to form copper atoms at the cathode.

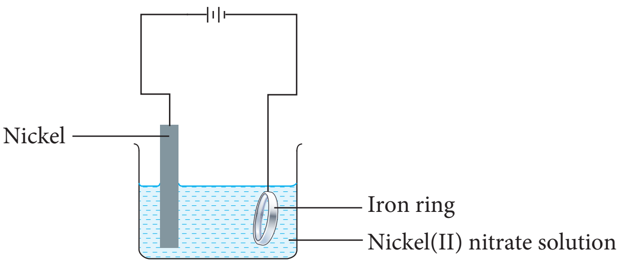
Laboratory Activity 1G

1. (a) Yes.
(b) Oxidation reaction occurs when copper atoms lose electrons to form Cu^{2+} ions at the anode (copper) and reduction reaction occurs at the cathode (iron spoon) when Cu^{2+} ions gain electrons to form copper atoms.

2. The blue colour of copper(II) sulphate solution remains unchanged because the concentration of Cu^{2+} ions remains unchanged.
The discharge rate of Cu^{2+} ions at the cathode is the same as the ionisation rate of copper atoms at the anode.

3.
- Rotate the iron spoon during the electroplating process to get a uniformed layer of plating.
- Use a low current during the electroplating process to get a strong layer of coating on the iron spoon.

4.



Laboratory Activity 1H

(page 46)

1. Yes. Oxidation reaction occurs at the impure copper plate (anode) when copper atoms lose electrons to form Cu^{2+} ions and reduction reaction occurs at the pure copper plate (cathode) when Cu^{2+} ions gain electrons to form copper atoms.
2. The blue colour of copper(II) nitrate solution remains unchanged because the concentration of Cu^{2+} ions remains unchanged. The discharge rate of Cu^{2+} ions at the cathode is the same as the ionisation rate of copper atoms at the anode.
3. The anode is impure copper that contains impurities. When the impure copper ionises and dissolves, the impurities form under the anode. The cathode is pure copper that does not have impurities.
4. The purification of copper metal is carried out through an electrolysis process.

Self Assess 1.4

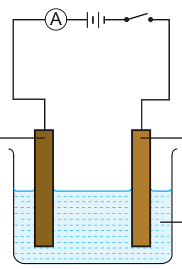
(page 47)

1. (a) Chloride ions and hydroxide ions
   (b) Electrolytic cell I
   - Oxygen gas.
   - Hydroxide ions are discharged because the E^0 value of OH^- ion is less positive compared to the E^0 value of Cl^- ion
   - Four OH^- ions lose four electrons to form one oxygen molecule and two water molecules.

   Electrolytic cell II
   - Chlorine gas
   - Cl^- ions are discharged because the concentration of Cl^- ions are higher than OH^- ions.
   - Two chloride ions lose two electrons to form one chlorine molecule.

   (c) (i) $Cu \rightarrow Cu^{2+} + 2e^-$
   (ii) - Copper is the active electrode.
   - Copper atoms ionise to form Cu^{2+} ions at the anode.

   (d) Oxidation reaction.
   (e) Greenish yellow gas is released
2. (a) Iron key looks more attractive / resistant to corrosion.
   (b) (i) Silver nitrate solution.
   (ii) Connect the iron key to the negative terminal of the batteries and connect the silver plate to the positive terminal of the batteries.
3. (a)



   (b) Anode: Impure nickel metal becomes thinner.
   Cathode: Pure nickel metal becomes thicker.
   (c) $Ni \rightarrow Ni^{2+} + 2e^-$

Activity 1L

(page 49)

2. (a) During the electrolysis of molten aluminium oxide, Al^{3+} ions move to the cathode electrode, while O^{2-} ions move to the anode. Al^{3+} ions are discharged to form aluminium, while O^{2-} ions are discharged to form oxygen gas.
   Half equation at the cathode : $Al^{3+} + 3e^- \rightarrow Al$
   Half equation at the anode : $2O^{2-} \rightarrow O_2 + 4e^-$
   Ionic equation : $4Al^{3+} + 6O^{2-} \rightarrow 4Al + 3O_2$

   (b) Since the electrolysis of molten aluminium oxide is carried out at a high temperature, the oxygen gas produced at the anode reacts with the carbon electrode to form carbon dioxide gas. Therefore, the carbon anode becomes thinner and should be replaced from time to time.
   Chemical equations for the reactions involved:
   $2Al_2O_3 \rightarrow 4Al + 3O_2$
   $O_2 + C \rightarrow CO_2$

   (c) - Yes. Oxidation reaction at the anode and reduction reaction at the cathode occur simultaneously.
   - At the anode, O^{2-} ions undergo oxidation reaction because O^{2-} ions lose electrons to form oxygen molecules.
   - At the cathode, Al^{3+} ions undergo reduction reaction because Al^{3+} ions gain electrons to form aluminium atoms.

Self Assess 1.5

(page 51)

1. Silver and aurum.

2. - Aluminium is more reactive than carbon in the reactivity series of metals.
- Reaction between aluminium oxide and carbon does not occur.
- Carbon cannot reduce aluminium oxide.

3. (a) $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

(b) - At a high temperature, calcium carbonate, $CaCO_3$ decomposes to form calcium oxide, CaO (quicklime) and carbon dioxide, CO_2.
- Calcium oxide, CaO reacts with the impurities in iron ore such as silicone(IV) oxide, SiO_2 to form slag or calcium silicate, $CaSiO_3$.
- This reaction is important to separate the impurities from molten iron.
- The difference in density causes slag to be at the top layer of the molten iron that makes the separation process easier.

4. - Zinc (or Magnesium / Aluminium / Iron / Tin / Lead)
- Zinc is more reactive than copper.
- Zinc can reduce copper(II) oxide to copper.

Experiment 1D

(page 52)

Result:

Metal	Observation	Inference
Copper		
Iron		

1. To detect the presence of Cu^{2+} ions and Fe^{2+} ions.

2. Copper : $Cu \rightarrow Cu^{2+} + 2e^-$

Iron : $Fe \rightarrow Fe^{2+} + 2e^-$

$Fe^{2+} \rightarrow Fe^{3+} + e^-$

3. Metal corrosion occurs when metal atom loses electrons to form metal ions.

Experiment 1E

(page 54)

Result:

Metal	Observation
Fe/Mg	
Fe/Sn	
Fe/Zn	
Fe/Cu	
Fe	

1. Potassium hexacyoanoferrate(III) solution is used to verify the presence of Fe^{2+} ions and phenolphthalein detects the presence of OH^- ions.

2. The blue spots and pink spots can be seen clearly and the colour does not mix.

3. The higher the intensity of the blue colour, the higher the rate of rusting of iron.

4. As control.

5.

Metals that prevent rusting of iron	Metals that accelerate rusting of iron
Magnesium Zinc	Tin Copper

6. Metals that are more electropositive than iron prevent rusting of iron, while metals that are less electropositive than iron accelerate the rate of rusting of iron.

7. Hypothesis accepted. When a more electropositive metal comes into contact with the iron nail, the iron nail does not rust, while when a less electropositive metal comes into contact with the iron nail, the iron nail rusts.

(page 57)

Activity 1M

1. (a) Rusting of iron is a metal corrosion that only occurs to iron, while metal corrosion occurs to all metals.
   (b) - Iron undergo oxidation reaction when iron atoms lose electrons to form Fe^{2+}.
   $Fe \rightarrow Fe^{2+} + 2e^-$
   - Oxygen undergo reduction reaction when oxygen gains electrons to form OH^- ions.
   $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
   - Fe^{2+} ions react with OH^- ions to form iron(II) hydroxide, $Fe(OH)_2$.
   $Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$
   - $Fe(OH)_2$ undergoes continuous oxidation with oxygen to form hydrated iron(III) oxide, $Fe_2O_3 . xH_2O$, rust.
   (c) - A metal that is more electropositive than iron has a higher tendency to lose electrons.
   - A metal that is more electropositive than iron corrodes and rusting of iron is prevented.
   - A metal that is more electropositive than iron becomes a sacrificial metal.
   - Examples: Bridge pillars, ship hulls and underground pipes.

(page 57)

Self Assess 1.6

1. (a) P : Copper
   Q : Zinc
   (b) Experiment I
   - Redox reactions.
   - Iron undergoes oxidation reaction when iron atoms lose electrons to form Fe^{2+} ions.
   $Fe \rightarrow Fe^{2+} + 2e^-$
   - The blue spots in the test tube shows the presence of Fe^{2+} ions.
   - Oxygen undergoes reduction reaction when oxygen gains electrons to form OH^- ions.
   $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
   Experiment II
   - Redox reactions.
   - Zinc undergoes oxidation reaction when zinc atoms lose electrons to form Zn^{2+} ions.
   $Zn \rightarrow Zn^{2+} + 2e^-$
   - Oxygen undergoes reduction reaction when oxygen gains electrons to form OH^- ions.
   $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
   - The pink spots in the test tube shows the presence of OH^- ions.
   - Absence of blue spots in the test tube indicates no Fe^{2+} ions.
   (c) Cu, Fe, Zn
2. - Tin forms a protective oxide layer.
   - The tin oxide layer protects the steel from coming into contact with oxygen and water. Therefore, steel does not oxidise and rusting does not occur.

ACHIEVEMENT TEST

(page 59)

1. Reaction I is a redox reaction.
- The oxidation number of iron before the reaction is +2 and after the reaction is 0.
- The oxidation number of magnesium before the reaction is 0 and after the reaction is +2.
- Magnesium undergoes an oxidation reaction because the oxidation number of magnesium increases from 0 to +2.
- Iron(II) sulphate undergoes a reduction reaction because the oxidation number of iron decreases from +2 to 0.

Reaction II is not a redox reaction.

$$AgNO_3 + NaCl \longrightarrow AgCl + NaNO_3$$

$AgNO_3$			+	$NaCl$		→	$AgCl$		+	$NaNO_3$		
+1	+5	-2		+1	-1		+1	-1		+1	+5	-2

- The oxidation number of all elements: silver, nitrogen, oxygen, sodium and chlorine, remain unchanged before and after the reaction.

2. (a) The oxidation number of iodine decreases from 0 to -1.
The oxidation number of sulphur in sulphur dioxide increases from +4 to +6.
(b) Oxidising agent : Iodine.
Reducing agent : Sulphur dioxide.
(c) $I_2 + 2e^- \rightarrow 2I^-$

3. (a) Copper(II) nitrate solution.
Copper
(b) Oxidation half equation : $Pb \rightarrow Pb^{2+} + 2e^-$
Reduction half equation : $Cu^{2+} + 2e^- \rightarrow Cu$
(c) $Pb + Cu^{2+} \rightarrow Pb^{2+} + Cu$
(d) +2 to 0

4. (a) Bromine
(b) Iodine
(c) Oxidation half equation : $2I^- \rightarrow I_2 + 2e^-$
Reduction half equation : $Br_2 + 2e^- \rightarrow 2Br^-$
Ionic equation : $2I^- + Br_2 \rightarrow I_2 + 2Br^-$

5. Oxidising agent : R^{2+}, Q^{2+}, P^{2+}
Reducing agent : P, Q, R

6. (a) Negative terminal : Tin electrode.
Positive terminal : Platinum electrode.
(b) $Sn(s) \mid Sn^{2+}(aq, 1\ mol\ dm^{-3}) \parallel Cl_2(aq), Cl^-(aq, 1\ mol\ dm^{-3}) \mid Pt(s)$
(c) Oxidation reaction : $Sn \rightarrow Sn^{2+} + 2e^-$
Reduction reaction : $Cl_2 + 2e^- \rightarrow 2Cl^-$
Ionic equation : $Sn + Cl_2 \rightarrow Sn^{2+} + 2Cl^-$
(d) $E^0_{cell} = (+1.36) - (-0.14) = +1.50\ V$

7. (a) Oxygen gas. Hydroxide ion is discharged because the E^0 value of OH^- ion is less positive compared to the E^0 value of NO_3^- ion.
Four OH^- ions lose four electrons to form one oxygen molecule and two water molecules.
(b) Insert a glowing wooden splinter into the test tube. The glowing splinter rekindles.
(c)
- The blue colour of copper(II) sulphate solution becomes paler in Set I, but the blue colour of copper(II) sulphate solution remains unchanged in Set II.
- The concentration of Cu^{2+} ions decreases in Set I, but the concentration of Cu^{2+} ions remains unchanged in Set II.
- Cu^{2+} ions are discharged to form copper atoms at the cathode in Set I, but in Set II, the discharge rate of Cu^{2+} ions to form copper atoms at the cathode is the same as the ionisation rate of copper atoms to form Cu^{2+} ions at the anode.

Enrichment Corner

(page 60)

- Oxidised substance: PbS
- Reduced substance: H_2O_2
- The oxidation number of sulphur before the reaction is -2 and after the reaction is +6
- The oxidation number of oxygen before the reaction is -1 and after the reaction is -2
- PbS undergoes an oxidation reaction because the oxidation number of sulphur in lead(II) sulphide increases from -2 to +6, while H_2O_2 undergoes a reduction reaction because the oxidation number of oxygen decreases from -1 to -2

Reinforcement Exercises in Determining the Oxidation Number

(page 12)

1.	+2
2.	-1
3.	0
4.	+2
5.	+4
6.	+1
7.	-1

8.	0
9.	+4
10.	+4
11.	+5
12.	+2
13.	+5
14.	+6

15.	+6
16.	0
17.	-1
18.	+6
19.	+6
20.	+3
21.	-3

22.	-2
23.	+6
24.	+5
25.	-3
26.	-1
27.	+1
28.	+3

CHAPTER 2

CARBON COMPOUND

Activity 2A

(page 66)

1. (a) Organic
(b) Inorganic
(c) Inorganic
(d) Organic
(e) Organic

2.

(a) Compounds containing the element carbon.	Carbon compounds
(b) Hydrocarbons possessing only single bonds.	Saturated hydrocarbon
(c) Organic compounds containing only hydrogen and carbon.	Hydrocarbon
(d) Carbon compounds derived from living things.	Organic Compound
(e) Hydrocarbons containing at least one double or triple bond between carbon atoms.	Unsaturated hydrocarbon

Laboratory Activity 2A

(page 69)

1. Some porcelain chips are used for uniform heating of petroleum and to avoid bumping of the liquid due to uneven heating.

2. The boiling points of petroleum fractions are in the range of 30 °C – 200 °C. The maximum temperature that a normal thermometer can record is 110 °C. Thus petroleum fractions that have a boiling point exceeding 110 °C cannot be separated.

3. (a) The higher the boiling point, the darker the colour of the fraction.
(b) The higher the boiling point, the higher the viscosity of the fraction.
(c) The higher the boiling point, the higher the quantity of soot formed after combustion.

4. Fraction 1

Self Assess 2.1

(page 70)

1. (a) Carbon compounds are compounds that contain carbon as their constituent element.
(b) - Organic compounds that contain only hydrogen and carbon.
- Organic compounds that contain carbon and hydrogen and other elements, such as oxygen, nitrogen, phosphorus or halogen.

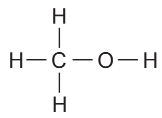
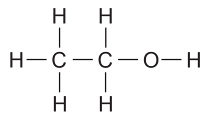
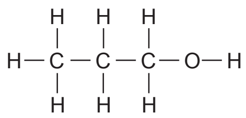
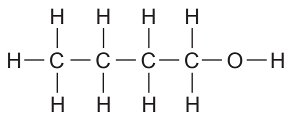
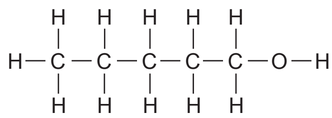
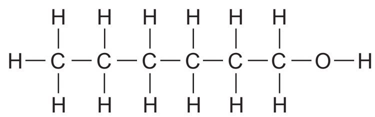
(c) - Hydrocarbons that contain only single bonds between carbon atoms.
- Hydrocarbons that contain at least one double or triple bond between carbon atoms.

2. (a) Cracking is the process of breaking long chain hydrocarbons into smaller hydrocarbons at a high temperature with the presence of a catalyst.
(b) (i) $C_{10}H_{22} \rightarrow C_6H_{14} + C_4H_8$
(ii) $C_{11}H_{26} \rightarrow C_4H_8 + C_3H_6 + C_4H_{12}$
(c) - The demand for small sized hydrocarbons is higher.
- The separation of petroleum into its fractions by fractional distillation does not meet the demand for small-sized hydrocarbons.
- The cracking process produces smaller sized hydrocarbons that can be used as fuel as well as raw materials in the petrochemical industry.

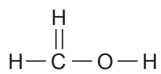
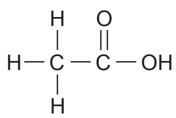
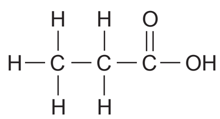
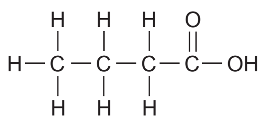
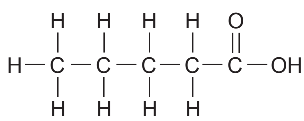
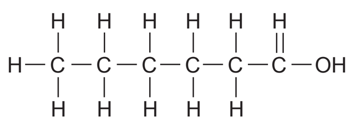
(page 77)

ACTIVITY 2F

1. The first six members of alcohols

n	Molecular formula	Number of carbon atom	Structural formula	Name
1	CH_3OH	1		Methanol
2	C_2H_5OH	2		Ethanol
3	C_3H_7OH	3		Propanol
4	C_4H_9OH	4		Butanol
5	$C_5H_{11}OH$	5		Pentanol
6	$C_6H_{13}OH$	6		Hexanol

The first six members carboxylic acids

n	Molecular formula	Number of carbon atom	Structural formula	Name
0	HCOOH	1		Methanoic acid
1	CH_3COOH	2		Ethanoic acid
2	C_2H_5COOH	3		Propanoic acid
3	C_3H_7COOH	4		Butanoic acid
4	C_4H_9COOH	5		Pentanoic acid
5	$C_5H_{11}COOH$	6		Hexanoic acid

2. Based on the general formula of carboxylic acid $C_nH_{2n+1}COOH$, there is one carbon atom in the functional group —COOH. As the first member of carboxylic acids having one carbon atom, the value of n in the general formula must start with the value of 0.

3. The carboxyl functional group, $-\overset{\overset{\Large O}{||}}{C}-OH$ always exists at the end of the carbon chain because the carbon in the group has formed 3 covalent bonds with O and OH.

ACTIVITY 2G

(page 78)

1.

Molecular formula	Melting point/°C	Boiling point/°C	Physical state at room temperature
CH_4	-182	-162	Gas
C_2H_6	-183	-89	Gas
C_3H_8	-188	-42	Gas
C_4H_{10}	-138	-0.5	Gas
C_5H_{12}	-130	36	Liquid
C_6H_{14}	-95	69	Liquid
C_7H_{16}	-91	98	Liquid

Molecular formula	Melting point/°C	Boiling point/°C	Physical state at room temperature
C_2H_4	-169	-104	Gas
C_3H_6	-185	-47	Gas
C_4H_8	-185	-6	Gas
C_5H_{10}	-165	30	Liquid
C_6H_{12}	-140	63	Liquid
C_7H_{14}	-119	93	Liquid

2. (i) The members in the homologous series of alkanes and alkenes are represented by the same general formula, namely:
   (a) C_2H_{2n+2} for alkanes
   (b) C_2H_{2n} for alkenes
   (ii) The consecutive members in the homologous series of alkanes and alkanes differ by one carbon atom and two hydrogen atoms (CH_2) or relative molecular mass = 14
   (iii) The physical properties of the members of the homologous series of alkanes and alkenes gradually change from one member to the next member from gas to liquid.

Self Assess 2.2

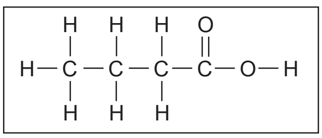
(page 79)

1. Organic compound
- Hydrocarbon
  - Alkane: C_nH_{2n+2}, n = 1,2,3..
  - Alkene: C_nH_{2n}, n = 2,3..
  - Alkyne: C_nH_{2n-2}, n = 2,3..
- Non Hydrocarbon
  - Alcohol: $C_nH_{2n+1}OH$, n = 1,2,3..
  - Carboxylic acid: $C_nH_{2n+1}COOH$, n = 0,1,2..
  - Ester: $C_mH_{2m+1}COOC_nH_{2n+1}$, m = 0,1,2, n = 1,2,3..

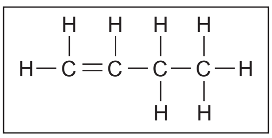
2. (a) (i)

P	Q	R	S	T
Carboxylic acid	Alkene	Alcohol	Alkane	Alkyne

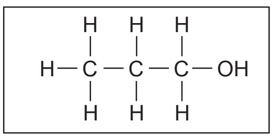
(ii) P



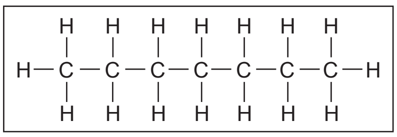
Q



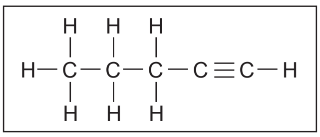
R



S



T



(iii)

P	Q	R	S	T
Butanoic acid	But-1-ene / But-2-ene	Propan-1-ol / Propan-2-ol	Heptana	Pent-1-yne / Pent-2-yne

(b) (i) Substance that exists in the form of gas: Q
(ii) Substances that exist in the form of liquid: P, R, S and T
(c) (i) P and R
(ii) Q, S and T
(d) - Boiling point of S is higher than Q.
- The molecular size of S is larger than Q.
- The van der Waals forces between S molecules are stronger than Q.
- More energy is needed to overcome the attraction between S molecules compared to Q molecules.

Activity 2H

(page 82)

1. (a) $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$
(b) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
(c) $2C_6H_{14} + 19O_2 \rightarrow 12CO_2 + 14H_2O$
(d) $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$
2. (a) $C_2H_6 + Br_2 \rightarrow C_2H_5Br + HBr$
(b) Ethane → Bromoethane

C_2H_5Br Bromoethane	+	Br_2	→	$C_2H_4Br_2$ Dibromoethane	+	HBr
$C_2H_4Br_2$ Dibromoethane	+	Br_2	→	$C_2H_3Br_3$ Tribromoethane	+	HBr
$C_2H_3Br_3$ Tribromoethane	+	Br_2	→	$C_2H_2Br_4$ Tetrabromoethane	+	HBr
$C_2H_2Br_4$ Tetrabromoethane	+	Br_2	→	C_2HBr_5 Pentabromoethane	+	HBr
C_2HBr_5 Pentabromoethane	+	Br_2	→	C_2Br_6 Hexabromoethane	+	HBr

Experiment 2A

(page 86)

1. (a) Hexene burns with more soot than hexane.
(b) %C in hexane = $\frac{6(12)}{6(12) + 14(1)} \times 100\ \% = 83.72\%$

%C in hexene = $\frac{6(12)}{6(12) + 12(1)} \times 100\ \% = 85.71\%$

(c) The higher the percentage of carbon by mass per molecule, the more soot is produced by the flame.
2. (a) - Acidic solution of potassium manganate (VII)
- Bromine water
- Hexane does not decolourise the brown colour of bromine water but hexene decolourises the brown colour of bromine water.
- Hexane does not decolourise the purple colour of acidified potassium manganate (VII) solution, but hexene decolourises the purple colour of acidified potassium manganate (VII) solution.
(b) - Hexane is a saturated hydrocarbon that contains a single covalent bond between carbon atoms. The addition reaction does not occur when an acidic solution of potassium manganate (VII) is added.
- Hexene is an unsaturated hydrocarbon that contains a double covalent bond between carbon atoms, —C=C—. The addition reaction occurs when an acidic solution of potassium manganate (VII) is used to produce hexanadiol.
Balanced equation :
$C_6H_{12} + H_2O + [O] \rightarrow C_6H_{12}(OH)_2$
Hexene → Hexane-1,2-diol
3. When bromine water is dripped into liquid hydrocarbon, the brown colour of bromine water decolourises/ When an acidic solution of potassium manganate (VII) is dripped into the hydrocarbon, the purple colour of potassium manganate (VII) decolourises.

Activity 21

1. - Addition of hydrogen:

$C_2H_4 + H_2 \rightarrow C_2H_6$

- Addition of halogen, Br_2:

$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$

- Addition of hydrogen halide, HBr:

$C_2H_4 + HBr \rightarrow C_2H_5Br$

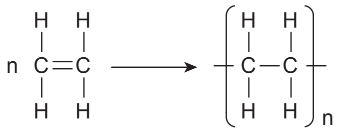
- Addition of water (Hydration):

$$C_2H_4 + H_2O \xrightarrow[300\ °C,\ 60\ atm]{H_3PO_4} C_2H_5OH$$

- Addition of hydroxyl group, acidified $KMnO_4$:

$$C_2H_4(g) + H_2O + [O] \longrightarrow C_2H_4(OH)_2$$

- Addition polymerisation:



where n is any very large integer value.

2. (a) - Hexene burns with more soot than hexane.

$$\%C \text{ in hexane} = \frac{6(12)}{6(12) + 14(1)} \times 100\% = 83.72\%$$

$$\%C \text{ in hexene} = \frac{6(12)}{6(12) + 12(1)} \times 100\% = 85.71\%$$

- The percentage of carbon by mass in hexene is higher than hexane.

(b) 1. Put 2 cm^3 of hexane into the test tube.
2. Add 2 - 3 drops of bromine water in 1,1,1-trichloroethane into hexane.
3. Shake the mixture.
4. Record all observations.
5. Steps 1 to 4 are repeated using hexene to replace hexane.

Observation:
- Hexene decolourises the brown colour of bromine water.
- Hexane does not decolourise the brown colour of bromine water.

Laboratory Activity 2B

1. Yeast contains enzymes that act as a catalyst to break down glucose into ethanol and carbon dioxide.
2. To ensure that the gas released during fermentation is passed through the lime water.
3. Carbon dioxide gas
4. Ethanol
5. - The filtrate is a mixture of ethanol and water that have different boiling points. The boiling point of ethanol is lower than that of water.
- When the mixture is heated, ethanol boils first before water at the temperature of 78 °C.
- The ethanol vapour formed at its boiling point will be condensed in a Liebig condenser and then collected in a test tube.

6. $$\underset{\text{Glucose}}{C_6H_{12}O_6(ce)} \xrightarrow{\text{Yeast}} \underset{\text{Ethanol}}{2C_2H_5OH(ce)} + 2CO_2(g)$$

7. Fruits contain carbohydrates, such as glucose, fructose and sucrose. During fermentation, yeasts that contain the enzyme zymase break down the molecules of these carbohydrates to produce ethanol.

Laboratory Activity 2C

(page 92)

A: Oxidation of ethanol

1. Ethanoic acid

2. 1. Potassium dichromate(VI) solution
2. Potassium manganate (VII) solution

3. $C_2H_5OH + 2[O] \rightarrow CH_3COOH + H_2O$
Ethanol → Ethanoic acid + Water

4. Acidic

B: Dehydration of ethanol

1. Ethene

2. As a catalyst

3. $C_2H_5OH \xrightarrow{\text{Porcelain chips}} C_2H_4 + H_2O$
Ethanol → Ethene + Water

Activity 2J

(page 94)

1. (a) $2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$
(b) $2C_3H_7OH + 9O_2 \rightarrow 6CO_2 + 8H_2O$

2. (a) $C_4H_9OH + 2[O] \rightarrow C_3H_7COOH + H_2O$
Butanol → Butanoic acid + Water
(b) $C_5H_{11}OH + 2[O] \rightarrow C_4H_9COOH + H_2O$
Pentanol → Pentanoic acid + Water

3. (a) $C_4H_9OH \xrightarrow{\text{Porcelain chips}} C_4H_8 + H_2O$
Butanol → Butene + Water
(b) $C_5H_{11}OH \xrightarrow{\text{Porcelain chips}} C_5H_{10} + H_2O$
Pentanol → Pentene + Water

Laboratory Activity 2D

(page 96)

1. Hydrogen Gas

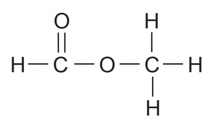
2. (a) Magnesium ethanoate
(b) Sodium ethanoate
(c) Copper(II) ethanoate

3. (a) $2CH_3COOH + Mg \rightarrow (CH_3COO)_2Mg + H_2$
(b) $2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$
(c) $2CH_3COOH + CuO \rightarrow (CH_3COO)_2Cu + H_2O$

Activity 2K

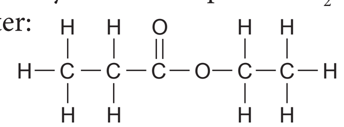
(page 99)

(i) Molecular formula of alcohol component: CH_3OH
Molecular formula of carboxylic acid component: $HCOOH$
Structural formula of ester:



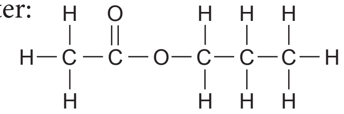
Methyl methanoate

(ii) Molecular formula of alcohol component: C_2H_5OH
Molecular formula of carboxylic acid component: C_2H_5COOH
Structural formula of ester:



Ethyl propanoate

(iii) Molecular formula of alcohol component: C_3H_7OH
Molecular formula of carboxylic acid component: CH_3COOH
Structural formula of ester:



Propyl ethanoate

Laboratory Activity 2E

(page 100)

1. Esterification
2. Ethyl ethanoate and water
3. Ethyl ethanoate is less dense than water
4. As a catalyst
5. $CH_3COOH + C_2H_5OH \rightarrow CH_3COOC_2H_5 + H_2O$

Self Assess 2.3

(page 100)

1. (a) (i)
- Q burns with more soot than P
- Percentage of carbon by mass in molecules P and Q:

$$\%C \text{ in } P = \frac{3(12)}{3(12) + 8(1)} \times 100\% = 81.8\%$$

$$\%C \text{ in } Q = \frac{3(12)}{3(12) + 6(1)} \times 100\% = 85.7\%$$

- The percentage of carbon by mass in molecule Q is higher. Therefore, Q burns with more soot than P.

(ii)
- P is a saturated hydrocarbon that only has a single bond between carbon atoms. Addition reaction does not occur between compound P and bromine water.
- Q is an unsaturated hydrocarbon that has a double bond between carbon atoms. Addition reaction occurs between molecules Q and bromine water:

$C_3H_6 + Br_2 \rightarrow C_3H_6Br_2$

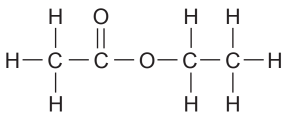
(b) $C_2H_5OH + 3O_2 \rightarrow 4CO_2 + 3H_2O$

$$\text{Mol of } R = \frac{2.3 \text{ g}}{46 \text{ g mol}^{-1}} = 0.05 \text{ mol}$$

From the equation: 1 mol C_2H_5OH : 2 mol CO_2
0.05 mol C_2H_5OH : 0.10 mol CO_2

Volume of CO_2 = 0.10 mol × 24 $dm^3 \, mol^{-1}$
= 2.4 dm^3

(c) R and T



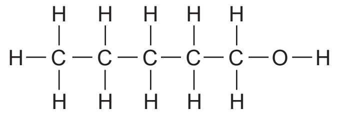
Ethyl ethanote

(d) Acid X is concentrated sulphuric acid
Chemical equation:
$2H_2SO_4 + CaCO_3 \rightarrow CaSO_4 + H_2O + CO_2$

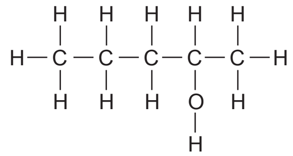
Activity 2N

(page 105)

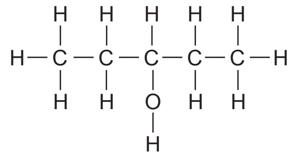
1. $C_5H_{11}OH$
2.



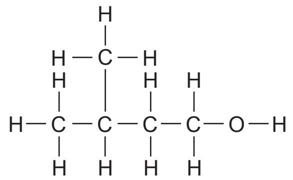
Pentan-1-ol



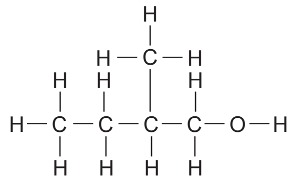
Pentan-2-ol



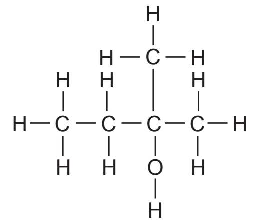
Pentan-3-ol



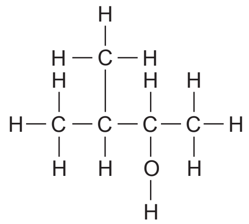
3-methylbutan-1-ol



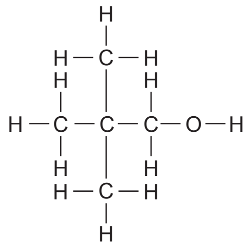
2-methylbutan-1-ol



2-methylbutan-2-ol



3-methylbutan-2-ol

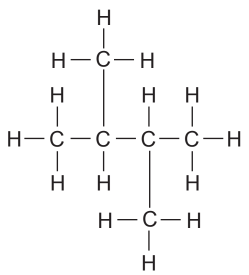


2,2-dimethylpropan-1-ol

SelfAssess 2.4

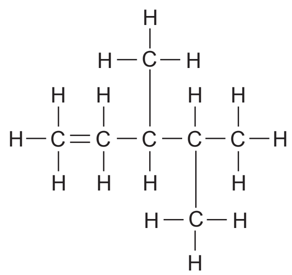
(page 109)

1. (a)



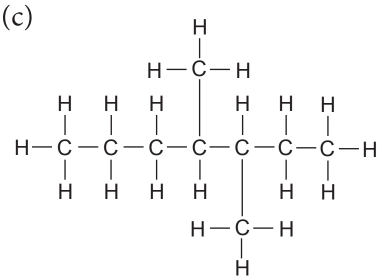
2,3-dimethylbutane

(b)



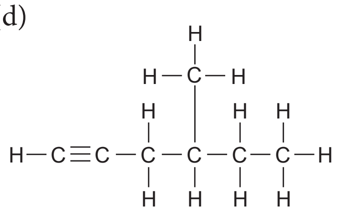
3,4-dimethylpent-1-ene

(c)



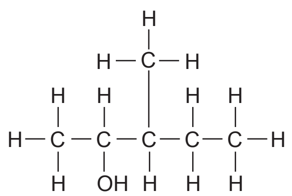
3,4-dimethylheptane

(d)



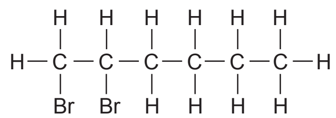
4-methylhex-1-yne

(e)



3-methylpentan-2-ol

(f)



1,2-dibromohexane

2. (a) X : 2-methylbut-2-ene
   Y : Pent-2-ene
   Z : 2-methylbut-1-ene
   (b) - X and Z are isomers
   - X and Z have different structural formulae but the same molecular formula which is C_5H_{10}

ACHIEVEMENT TEST

(page 111)

1. (a) - Petroleum is a mixture of simple or long chain hydrocarbons.
- Fractions in petroleum can be separated because each hydrocarbon fraction has its own boiling point.

(b) (i) B (ii) D (iii) E

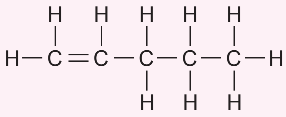
(c) (i) - The X process is the cracking process.
- The catalyst is a mixture of silicon (IV) oxide and aluminum oxide.

(ii) - The cracking process produces smaller sized hydrocarbons that can be used as fuel as well as raw materials in the petrochemical industry.

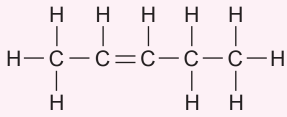
2. (a) (i) - Hydrocarbons that have at least one double or triple bond between carbon atoms.

(ii) Alkene

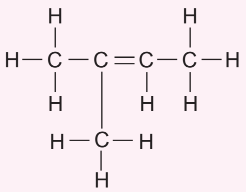
(iii)



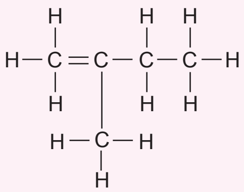
Pent-1-ene



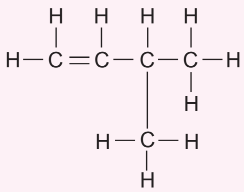
Pent-2-ene



2-methylbut-2-ene



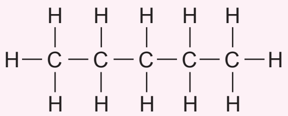
2-methylbut-1-ene



3-methylbut-1-ene

(b) (i) Addition of hydrogen (Hydrogenation)

(ii)



(c) (i) $2C_5H_{10} + 15O_2 \rightarrow 10CO_2 + 10H_2O$

(ii) Number of mol X $= \dfrac{14\text{ g}}{70\text{ g mol}^{-1}}$

$= 0.2$ mol

From the equation: 2 mol C_5H_{10} : 10 mol CO_2

0.2 mol C_5H_{10} : 1.0 mol CO_2

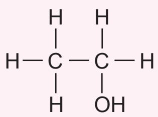
Volume of carbon dioxide = 1.0 mol × 24 dm^3 mol^{-1}

= 24 dm^3

3. (a) (i) Fermentation

(ii) Ethanol

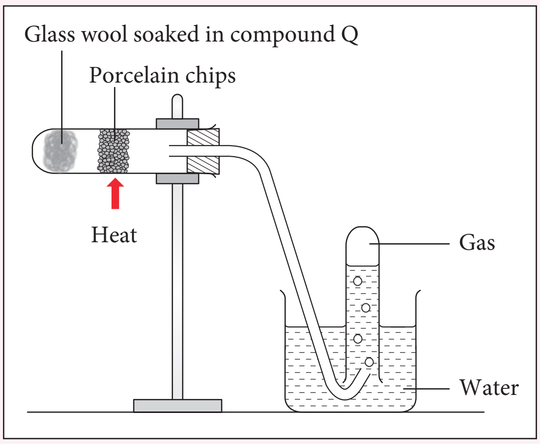
(iii)



(b) $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

(c) (i) Ethene

(ii)



(d) Purple colour is decolourised
(e) (i) Esterification
(ii) Ethyl ethanoate

(page 112)

Enrichment Corner

Aim: To prepare two different esters using the same alcohol and different carboxylic acids and to identify their odour.

(a) **Hypothesis:** The same alcohol that reacts with different carboxylic acids will produce different ester odours.

(b) **Manipulated variables:** Ethanoic acid and butanoic acid (types of carboxylic acids)
Responding variable: Odour of ester
Constant variable: Pentanol (type of alcohol)

(c) **Materials and apparatus:**
Materials: Pentanol, glacial ethanoic acid, butanoic acid, concentrated sulphuric acid and water.
Apparatus: Boiling tube, measuring cylinder, test tube holder, dropper, beaker and Bunsen burner.

(d) **Procedure:**
1. Put 2 cm^3 of glacial ethanoic acid into the boiling tube.
2. Add 2 cm^3 of pentanol into the boiling tube containing glacial ethanoic acid.
3. Add 5 drops of concentrated sulphuric acid by using a dropper to the mixture and shake the boiling tube.
4. Heat the mixture slowly over low heat until it boils for two minutes.
5. Pour the contents of the boiling tube into a beaker half filled with water.
6. Record the odour of the content in the beaker.
7. Repeat steps 1 to 6 by replacing glacial ethanoic acid with butanoic acid.

(e) **Observation:**

Carboxylic acid	Alcohol	Odour
Ethanoic acid	Pentanol	
Butanoic	Pentanol	

(f) **Chemical equation:**
- Reaction between ethanoic acid and pentanol

$$\underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Pentanol}}{C_5H_{11}OH} \rightarrow \underset{\text{Pentyl ethanoate}}{CH_3COO\,C_5H_{11}} + \underset{\text{Water}}{H_2O}$$

- Reaction between butanoic acid and pentanol

$$\underset{\text{Butanoic acid}}{C_3H_7COOH} + \underset{\text{Pentanol}}{C_5H_{11}OH} \rightarrow \underset{\text{Pentyl butanoate}}{C_3H_7COOC_5H_{11}} + \underset{\text{Water}}{H_2O}$$

CHAPTER 3

THERMOCHEMISTRY

Laboratory Activity 3A

(page 117)

Result:

Reactants	Initial temperatue (°C)	Highest or lowest temperature (°C)
Solid sodium hydroxide, NaOH + water		
Solid ammonium nitrate, NH_4NO_3 + water		
Solid sodium thiosulphate, $Na_2S_2O_3$ + water		
Solid anhydrous calcium chloride, $CaCl_2$ + water		

Discussions:

1. (a) Solid ammonium nitrate, solid sodium thiosulphate, solid anhydrous calcium chloride.
(b) Solid sodium hydroxide.

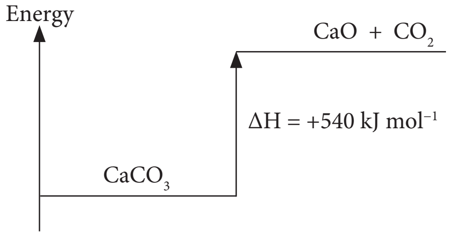
2.

Exothermic reaction	Endothermic reaction
Sodium hydroxide + water	Ammonium nitrate + water Anhydrous calcium chloride + water Sodium thiosulphate + water

Self Assess 3.1

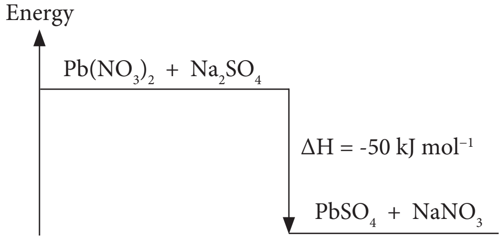
(page 119)

1. (a)



(b) 1. The decomposition of calcium carbonate, $CaCO_3$ is an endothermic reaction.
2. When 1 mole of calcium carbonate, $CaCO_3$ is decomposed, 540 kJ energy is absorbed from the environment.
3. The energy content of the products is higher than the energy content of the reactants.

2. (a) Exothermic reaction
(b) Reactants ($Pb(NO_3)_2$ and Na_2SO_4) undergo bond breaking, while products ($PbSO_4$ and $NaNO_3$) undergo bond formation.
(c) Energy is absorbed during bond breaking, while heat is released during bond formation.
(d)



Result:

Temperature (°C)	Set I	Set II
	Silver nitrate, $AgNO_3$ + sodium chloride, NaCl	**Magnesium nitrate, $Mg(NO_3)_2$ + sodium carbonate, Na_2CO_3**
Initial temperature of nitrate salts		
Initial temperature of sodium salts		
Average temperature of both solutions		
Highest temperature		
Increase in temperature, θ		

Discussions:

1. Double decomposition reaction (Precipitation reaction)

2. Steps in calculations:

(a) Heat of precipitation of silver chloride

(i) Calculate the number of moles or silver chloride, AgCl precipitate formed

Number of moles of silver ions, Ag^+ = number of moles of silver nitrate, $AgNO_3$

$$= 0.5 \text{ mol dm}^{-3} \times \frac{25}{1000} \text{ dm}^3 = 0.0125 \text{ mol}$$

Number of moles of chloride ions, Cl^- = number of moles of sodium chloride, NaCl solution

$$= 0.5 \text{ mol dm}^{-3} \times \frac{25}{1000} \text{ dm}^3 = 0.0125 \text{ mol}$$

Ionic equation: $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

From the ionic equation. 1 mole of silver ions, Ag^+ reacts with 1 mole of chloride ions, ,Cl^- to produce 1 mole of silver chloride, AgCl.

Therefore, 0.0125 moles of silver ions, Ag^+ reacts with 0.0125 moles of chloride ions, Cl^- to produce 0.0125 moles of silver chloride, AgCl.

(ii) Calculate the heat change:

Mass of reacting mixture = Total volume of reacting mixture × density of solution

$= (25 + 25)\text{cm}^3 \times 1 \text{ g cm}^{-3} = 200 \text{ g}$

Change in temperature of mixture, θ = Highest temperature – lowest temperature

Heat released in the reaction $Q = mc\theta$

$= 200 \text{ g} \times 4.2 \text{ J g}^{-1} \text{°C}^{-1} \times \theta$

$= x$ J

(iii) Calculate the heat change for the formation of 1 mole of precipitate

Precipitation of 0.0125 moles of silver chloride releases x J heat

Therefore, the precipitation of 1 mole of silver chloride releases = $x \text{ J} \times \frac{1 \text{ mol}}{0.0125 \text{ mol}}$

$= 80x$ J heat

$= 0.08x$ kJ heat

(iv) Write the heat of precipitation by putting a negative sign for an exothermic reaction

Heat of precipitation of silver chloride = - 0.08 x kJ mol^{-1}

Note: Follow the same steps to calculate the heat of precipitation of magnesium carbonate.

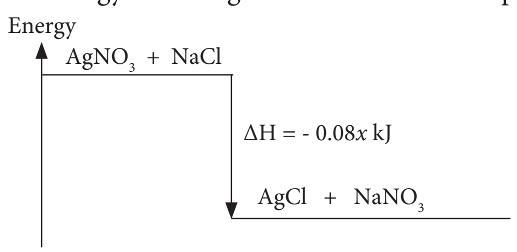
3. The thermochemical equation for the heat of precipitation of silver chloride:

$AgNO_3 + NaCl \rightarrow AgCl + NaNO_3 \qquad \Delta H = -0.08x \text{ kJ mol}^{-1}$

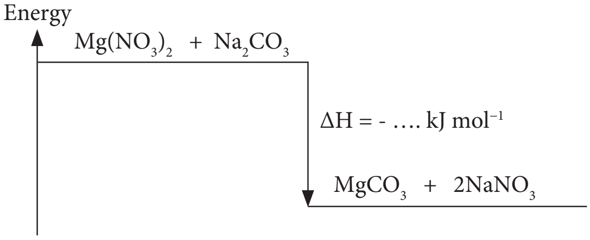
The thermochemical equation for the heat of precipitation of magnesium carbonate:

$Mg(NO_3)_2 + Na_2CO_3 \rightarrow MgCO_3 + 2NaNO_3 \qquad \Delta H = -$ (calculated value) kJ mol^{-1}

4. The energy level diagram for the heat of displacement of silver chloride.



The energy level diagram for the heat of displacement of magnesium carbonate.



5. Different.
Difference due to:
(i) Heat is lost to the surroundings.
(ii) Polystyrene cup absorbs heat.

Laboratory Activity 3C

(page 123)

Procedure:

1. Measure 25 cm^3 of 0.2 mol dm^{-3} copper(II) sulphate, $CuSO_4$ solution and pour it into a polystyrene cup.
2. Dip a thermometer into the solution and leave aside for two minutes.
3. Record the initial temperature of the solution in a table.
4. Add one spatula of magnesium powder, Mg quickly and carefully into the polystyrene cup.
5. Close the polystyrene cup and stir the mixture using the thermometer.
6. Record the highest temperature of the mixture.
7. Repeat steps 1 to 6 by using zinc powder, Zn to replace magnesium powder, Mg.

Result:

Metal	Magnesium	Zinc
Initial temperature of copper(II) sulphate solution (°C)		
Highest tempearute of mixture (°C)		
Temperature change, θ (°C)		

Discussions:

1. (a) Chemical equation: $Mg(s) + CuSO_4(aq) \rightarrow Cu(s) + MgSO_4(aq)$
$Zn(s) + CuSO_4(aq) \rightarrow Cu(s) + ZnSO_4(aq)$

Ionic equation: $Mg(s) + Cu^{2+}(aq) \rightarrow Cu(s) + Mg^{2+}(aq)$
$Zn(s) + Cu^{2+}(aq) \rightarrow Cu(s) + Mg^{2+}(aq)$

(b) Steps in calculations:

(i) Calculate the number of moles of copper, Cu displaced from copper(II) sulphate, $CuSO_4$ solution
Number of moles of copper(II) sulphate, $CuSO_4$ solution

$$= 0.5 \text{ mol dm}^{-3} \times \frac{25}{1000} \text{ dm}^3 = 0.0125 \text{ mol}$$

From the equation, 1 mole of copper, Cu is displaced from 1 copper(II) sulphate, $CuSO_4$ solution.
Therefore, 0.0125 moles of copper, Cu is displaced from 0.0125 moles of copper(II) sulphate, $CuSO_4$ solution.

(ii) Calculate the heat change
Mass of solution, m = 25 cm^3 × 1 g cm^{-3} = 25 g
Heat released in the reaction, Q = mcθ
$= 25 \text{ g} \times 4.2 \text{ J g}^{-1} \text{°C}^{-1} \times \theta$
$= x$ J

(iii) Calculate the heat of displacement
Displacement of 0.0125 moles of copper, Cu releases x J heat

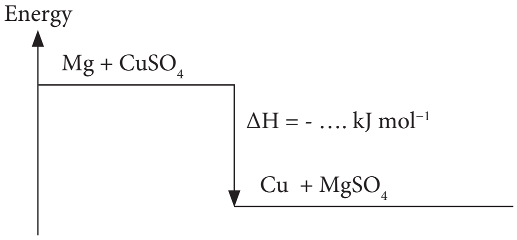
Therefore, 1 mole of copper, Cu will release $= x \text{ J} \times \frac{1 \text{ mol}}{0.0125 \text{ mol}} = y \text{ J} = z \text{ kJ}$ heat

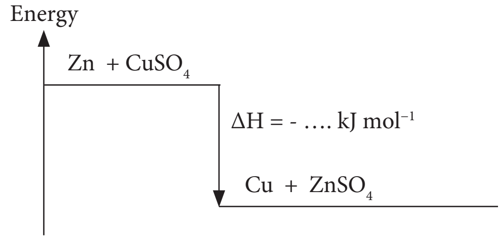
(iv) Write the heat of displacement by putting a negative sign for an exothermic reaction.
Heat of displacement of copper, Cu $= -z$ kJ mol^{-1}

Note: Follow the same steps to calculate the heat of displacement of copper, Cu using zinc, Zn.

(c) Magnesium is a more electropositive metal compared to zinc. Therefore the change in temperature is higher. Thus the value of heat of precipitation is different.

(d)





Note: Put the calculated value of ΔH

2. To ensure that all copper(II) ions are completely displaced to form copper atoms.
3. (i) Brown solid deposited.
   (ii) The blue colour of the solution becomes pale blue.
4. Operational definition of heat of displacement: When magnesium metal is added into the copper(II) sulphate solution to displace 1 mole of copper, the thermometer reading increases.
5. (i) Stirring the solution slowly and continuously throughout the experiment to ensure the temperature of the mixture is uniform.
   (ii) The solid metal is added quickly and carefully.
   (iii) Using metal powder and not granules to ensure the reaction occurs faster.
6. Same. Heat of displacement only involves copper ions that are present in copper(II) nitrate solution.

ACTIVITY 3A

(page 127)

(a) $Cu + 2AgNO_3 \rightarrow 2Ag + Cu(NO_3)_2$ $\Delta H = -105\ kJ\ mol^{-1}$

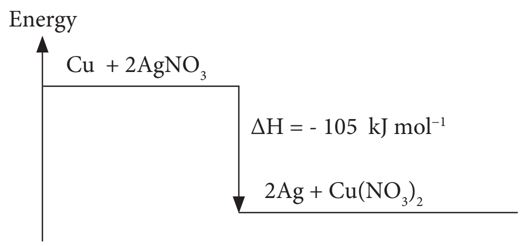
(b) Number of moles of silver ions = $0.5\ mol\ dm^{-3} \times \frac{100}{1000}\ dm^3 = 0.05\ mol$

From the thermochemical equation, 1 mole of silver displaced releases 105 kJ heat
Therefore, 0.05 moles of silver displaced releases $0.05\ mol \times 105\ kJ\ mol^{-1} = 5.25\ kJ$ heat

(c) $Q = mc\theta$ therefore, $\theta = \frac{Q}{mc}$

$\theta = \frac{5.25 \times 1000\ J}{100\ g \times 4.2\ J\ g^{-1}\ °C^{-1}} = 12.5\ °C$

(d)



(e) Number of moles of silver nitrate solution = $1.0\ mol\ dm^{-3} \times \frac{100}{1000}\ dm^3 = 0.1\ mol$

From the thermochemistry equation, displacement of 1 mole of silver releases 105 kJ of heat

Therefore, 0.1 moles of silver displaced releases $0.1\ mol \times 10.5\ kJ\ mol^{-1} = 10.5\ kJ$ heat

$Q = mc\theta$ there fore, $\theta = \frac{Q}{mc}$

$\theta = \frac{10.5 \times 1000\ J}{100\ g \times 4.2\ J\ g^{-1}\ °C^{-1}} = 25\ °C$

The number of moles of solution is twice, thus the change in temperature is also twice.

Experiment 3A

(page 128)

Hypothesis:
The reaction between a strong acid and a weak alkali will produce a higher heat of neutralisation compared to the reaction between a weak acid and a weak alkali.

Discussions:

1. A: $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$
$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$

B: $HCl(aq) + NH_3.H_2O(aq) \rightarrow NH_4Cl(aq) + H_2O(l)$
$CH_3COOH(aq) + NH_3.H_2O(aq) \rightarrow CH_3COONH_4(aq) + H_2O(l)$

Note: Explanation of the neutralisation reaction using aqueous ammonia.
1. Chemical equation: $HCl(aq) + NH_3(aq) \rightarrow NH_4Cl(aq)$
   (NH_4OH molecules do not exist)
2. Neutralisation of acids with alkalis will produce salt and water but in the case of aqueous ammonia, water in the equation is not shown.
3. Aqueous ammonia, NH_3 is a weak alkali that ionises partially in water to produce hydroxide ions, OH^-.
   $NH_3(aq) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$
4. The neutralisation reaction between an acid and aqueous ammonia also produces water and this can be shown in the ionic equation.
5. H^+ ions from the acid reacts with OH^- ions to form ammonia to produce water.
   Ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

2. From the equation, 1 mole of acid reacts with 1 mole of alkali.
Steps in calculating each reaction:
(i) Calculate the number of moles of water produced.
Number of moles of H^+ = Number of moles of acid

$$= 1.0 \text{ mol dm}^{-3} \times \frac{50}{1000} \text{ dm}^3 = 0.05 \text{ mol ion } H^+$$

Number of moles of OH^- = Number of moles of alkali

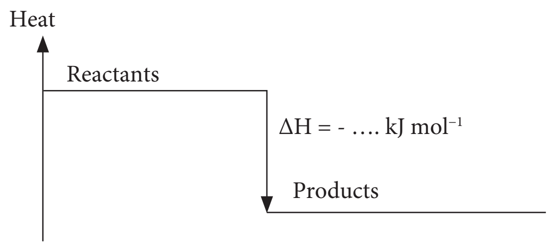
$$= 1.0 \text{ mol dm}^{-3} \times \frac{50}{1000} \text{ dm}^3 = 0.05 \text{ mol ion } OH^-$$

Therefore, 0.05 moles of H^+ ions react with 0.05 moles of OH^- ions to produce 0.05 moles of water.
(ii) Calculate the heat change:
Total volume of solutions = volume of acid + volume of alkali
= ($50 \text{ cm}^3 + 50 \text{ cm}^3$) = 100 cm^3
Mass of mixture, m = $100 \text{ cm}^3 \times 1 \text{ g cm}^3 = 100 \text{ g}$
Change in temperature of the mixture, θ
Heat released in the reaction, $Q = mc\theta$
$= 100 \text{ g} \times 4.2 \text{ J g}^{-1} \text{ °C}^{-1} \times \theta = p \text{ J}$
(ii) Calculate the heat of neutralisation:
0.05 moles of water formed produces p J heat
Therefore, 1 mole of water formed produces

$$p \text{ J} \times \frac{1 \text{ mol}}{0.05 \text{ mol}} = q \text{ J} = r \text{ kJ haba}$$

(iv) Write the heat of neutralisation for the reaction between an acid and an alkali as $-r$ kJ mol^{-1}
Note : The negative sign shows that the neutralisation reaction is exothermic.

3. Construct the energy level diagram as follows:
Note: Write the chemical formulae for the reactants and the products



4. The value of the heat of neutralisation between a strong acid and and a strong alkali is higher than the heat of neutralisation between a strong acid and a weak alkali.
The value of the heat neutralisation between a strong acid and a weak alkali is higher than the heat of neutralisation between a weak acid and a weak alkali.
The value of the heat of neutralisation is the highest for the reaction between a strong acid and a strong alkali.
The value of the heat of neutralisation is the lowest for the reaction between a weak acid and a weak alkali.

5.
- Hydrochloric acid is a strong acid and sodium hydroxide solution is a strong alkali. Both solutions ionise completely in water to produce a high concentration of ions.
- The neutralisation reaction involves only the combination of hydrogen ions and hydroxide ions to form water molecules.
- The heat released is not reabsorbed to ionise strong acids or strong alkalis
- Ethanoic acid is a weak acid and ionises partially in water. The concentration of hydrogen ions is low because most weak acids exist as molecules.
- During neutralisation, a small amount of heat released during the formation of 1 mole of water molecules is reabsorbed by the ethanoic acid molecules to ionise the acid molecules completely.
- Thus, when the released heat decreases, the heat of neutralisation also decreases. The same goes for aqueous ammonia solution that is a weak alkali.

6. The value of heat of neutralisation obtained in this experiment is lower. This is due to:
(a) part of the heat is released to the surroundings.
(b) the polystyrene cup absorbs heat.

ACTIVITY 3B

(page 132)

(a) Mass m $= (100 + 100)\text{cm}^3 \times 1\text{ g cm}^{-3} = 200\text{ g}$
Temperature change, $\theta = (43.5 - 30.0)\ °C = 13.5\ °C$
$Q = 2000\text{ g} \times 4.2\text{ J g}^{-1}\ °C^{-1} \times 13.5\ °C = 11340\text{ J}$
Number of moles of water = Number of moles of hydrogen ions or number of moles of hydroxide ions

$$= 2.0\text{ mol dm}^{-3} \times \frac{100}{1000}\text{ dm}^3 = 0.2\text{ mol}$$

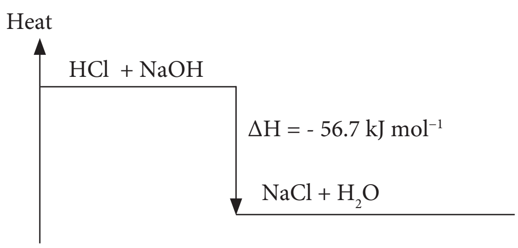
Neutralisation of 0.2 moles of hydrogen ions with 0.2 moles of hydroxides ions releases 11340 J heat.
Therefore, the heat released when I mole of hydrogen ions reacts with 1 mole of hydroxide ions releases

$$= 11340\text{ J} \times \frac{1\text{ mol}}{0.02\text{ mol}} = 5670\text{ J} = 56.7\text{ kJ}$$

Heat of neutralisation, $\Delta H = -56.7\text{ kJ mol}^{-1}$

(b) $HCl + NaOH \rightarrow NaCl + H_2O \qquad \Delta H = -56.7\text{ kJ mol}^{-1}$

(c)



(d) Temperature change is 13.5 °C. Nitric acid is a strong acid and ionises completely in water.

Experiment 3B

(page 133)

Result:

Alcohol	Methanol	Ehtanol	Propanol	Butanol
Initial temperature of water (°C)	T_1			
Highest temperature of water (°C)	T_2			
Increase in temperature (°C)	$(T_2 - T_1) = \theta$			
Mass of lamp before burning (g)	m_1			
Mass of lamp after burning (g)	m_2			
Mass of alcohol burnt (g)	$m_1 - m_2 = m_3$			

Note: Unknown values are given to show steps of calculations.

Discussions:

1. (a) Example : Heat of combustion of methanol, CH_3OH

Molar mass of methanol, CH_3OH =12 + 4(1) + 16 = 32 g mol^{-1}

Number of moles of methanol, CH_3OH burnt = $\frac{m_3}{32}$ mol = p mol

Heat released during the combustion of methanol, CH_3OH = heat absorbed by water

= $mc\theta$

= 200 g × 4.2 J g^{-1} °C^{-1} × θ = q J

Combustion of p mol of methanol, CH_3OH releases q J haba

Therefore, the combustion of 1 mole of methanol, CH_3OH releases = q J × $\frac{1 \text{ mol}}{x \text{ mol}}$ = r J heat

= s kJ heat

The heat of combustion of methanol, CH_3OH is – s kJ mol^{-1}

Using the same method, calculate the heat of combustion of ethanol, propanol and butanol.

(b) The thermochemical equation for the heat of combustion of methanol:

$CH_3OH + \frac{3}{2}O_2 \rightarrow CO_2 + 2H_2O \quad \Delta H = -s \text{ kJ mol}^{-1}$

The thermochemical equation for the heat of combustion of ethanol:

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O \quad \Delta H$ = - ...... kJ mol^{-1}

The thermochemical equation for the heat of combustion of propanol:

$C_3H_7OH + \frac{9}{2}O_2 \rightarrow 3CO_2 + 4H_2O \quad \Delta H$ = - .... kJ mol^{-1}

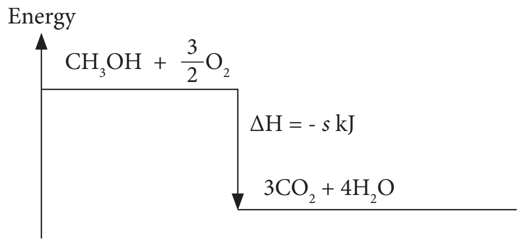
The thermochemical equation for the heat of combustion of butanol:

$C_4H_9OH + 6O_2 \rightarrow 4CO_2 + 5H_2O \quad \Delta H$ = - .... kJ mol^{-1}

Note: Write the value of ΔH calculated for each alcohol.

(c) Energy level diagram for the combustion of alcohol:

Example: methanol



Note: Construct the energy level diagram for other alcohols

2. As the number of carbon atoms per molecule in the alcohol increases, the value of heat of combustion also increases.

3. Operational definition of heat of combustion of alcohol: Temperature rise when 1 mole of alcohol is burned completely.

4. Copper is a good conductor of heat.

5. The bottom of the container turns black. The substance is soot (carbon) due to the incomplete combustion of alcohol.
6. Precautions:
   (i) Use a windshield.
   (ii) Make sure the flame of the lamp touches the bottom of the copper container.
   (iii) Stir the water in the copper container continuously.
   (iv) When the flame of the alcohol is extinguished, the lamp must be weighed immediately as the alcohol is very volatile.

Self Assess 3.2

(page 135)

1. Heat released, $Q = 100\text{ g} \times 4.2\text{ J g}^{-1}\text{°C}^{-1} \times 4\text{ °C} = 1680\text{ J}$
   Ionic equation: $Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3$
   From the equation: 1 mole of Ca^{2+} ions reacts with 1 mole of CO_3^{2-} ions to produce 1 mole of $CaCO_3$ precipitate.
   Number of moles of Ca^{2+} ions = Number of moles of CO_3^{2-} ions
   $$= 2.0\text{ mol dm}^{-3} \times \frac{50}{1000}\text{ dm}^3 = 0.1\text{ mol}$$
   The formation of 0.1 moles of $CaCO_3$ releases 16800 J heat.
   Therefore, the formation of 1 mole of $CaCO_3$ releases $16800\text{ J} \times \frac{1}{0.1} = 168000\text{ J} = 168\text{ kJ}$
   Heat of precipitation of $CaCO_3$, $\Delta H = +168\text{ kJ mol}^{-1}$
2. Number of moles of Fe^{2+} ions $= 0.25\text{ mol dm}^{-3} \times \frac{50}{1000}\text{ dm}^3 = 0.0125\text{ mol}$
   Mass of solution, $m = 50\text{ cm}^3 \times 1\text{ g cm}^{-3} = 50\text{ g}$
   Given, $\Delta H = 80.6\text{ kJ mol}^{-1}$
   1 mole of Fe^{2+} ions displaced releases 80.6 kJ of heat.
   Therefore, 0.0125 moles of Fe^{2+} ions releases $80.6\text{ kJ} \times 0.0125 = 1.075\text{ kJ}$ heat = 1075 J heat
   $Q = mc\theta$, Therefore $\theta = \frac{Q}{mc}$
   $$\theta = \frac{1075}{50 \times 4.2} = 5.12\text{ °C}$$
3. Heat of neutralisation using ethanoic acid is less than using hydrochloric acid.
   Ethanoic acid is a weak acid, while hydrochloric acid is a strong acid.
   Some of the heat given out is used to completely ionise ethanoic acid.

Activity 3D

(page 138)

2. The most suitable fuel for frying eggs or making popcorn is natural gas.
3. Justification of selection:
   - Fuel value of natural gas is higher than other fuels.
   - Burning 1 gram of natural gas will produce 50 kJ of heat energy.
   - Although the fuel value of hydrogen is the highest, the handling of hydrogen as fuel for cooking is not suitable because the storage of hydrogen gas as hydrogen liquid is difficult.
   - Furthermore, hydrogen gas is flammable and forms an explosive mixture with air.
   - Natural gas contains propane and butane, which can be compressed under pressure and filled into cylinders of various sizes. This facilitates the storage and transportation of natural gas.
   - The burning of natural gas in sufficient oxygen for cooking does not produce soot or smoke. So, it is clean and environmentally friendly.

Self Assess 3.3

(page 138)

1. The fuel value of a fuel is the amount of heat energy given out when one gram of the fuel is completely burnt in excess oxygen.

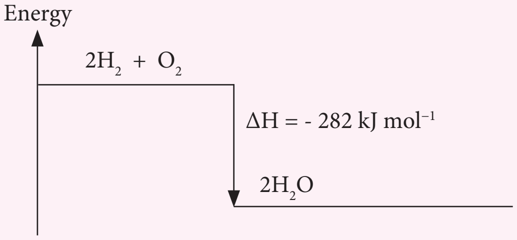
2. (a) Hydrogen gas
   (b) The combustion of hydrogen is clean as it will only produce water. Incomplete combustion of gasoline can produce soot, toxic carbon monoxide gas and carbon dioxide gas. These will increase air pollution.

ACHIEVEMENT TEST

(page 140)

1. m = 200 g θ = 7 °C
   $Q = 200\ g \times 4.2\ J\ g^{-1}\ °C^{-1} \times 7\ °C = 5880\ J$

2. (a) (i) Exothermic reaction. ΔH is negative
   (ii) $2H_2 + O_2 \rightarrow 2H_2O \quad \Delta H = -282\ kJ\ mol^{-1}$
   (iii)



   (b) (i) Number of moles of hydrogen $= \frac{50}{2} = 25$ mol

   (ii) 1 mole of hydrogen releases 282 kJ heat.
   Therefore, 25 moles of hydrogen releases 25 mol $\times$ 282 kJ mol^{-1} = 7050 kJ heat

   (c) Hydrogen can be used as fuel because a large amount of energy is released when 1 g of hydrogen is burned. It is also a clean fuel because its combustion only produces water. Hydrogen fuels are also renewable energy. Hydrogen, on the other hand, is a flammable gas and its storage is difficult. The cost of producing hydrogen fuel is also expensive.

Enrichment Corner

(page 140)

Sodium metal is a highly reactive metal and its reaction is very exothermic. Sodium metal is not as easy to handle as other metals because it does not exist freely and it only exists as compounds. Therefore, sodium metal is not suitable to be used in hot packs.

(page 135)

1. (a) Number of moles of butanol, $C_4H_9OH = \frac{0.37}{74}$ mol = 0.005 mol

Heat released, Q = 0.005 mol $\times$ 2671 kJ mol^{-1} = 13.355 kJ

(b) $Q = mc\theta$, therefore $\theta = \frac{Q}{mc}$

Mass of water = 100 cm^3 $\times$ 1 g cm^{-3} = 100 g

$$\theta = \frac{13355 \text{ J}}{100 \text{ g} \times 42 \text{ J g}^{-1}\,°\text{C}^{-1}}$$

= 31.8 °C

2. Calculate the number of moles of methanol, CH_3OH.
Molar mass of methanol, CH_3OH = 12 + 4(1) + 16 = 32 g mol^{-1}
Mass of methanol, CH_3OH used = (145.91 – 144.95) g = 0.96 g

Number of moles of methanol, $CH_3OH = \frac{\text{mass of methanol}}{\text{molar mass of methanol}}$

$= \frac{0.96 \text{ g}}{32 \text{ g mol}^{-1}}$ = 0.03 mol

Calculate the heat released.
Mass of water, m = 200 cm^3 $\times$ 1 g cm^{-3} = 200 g
Temperature change, θ = (59.0 – 29.0) °C = 30.0 °C

Heat released, Q = mcθ
= 200 g $\times$ 4.2 J g^{-1} °C^{-1} $\times$ 30.0 °C = 25200 J = 25.2 kJ
Calculate the heat of combustion of methanol, CH_3OH
Combustion of 0.03 moles of methanol, CH_3OH releases 25.2 kJ heat

Therefore, 1.0 mol of methanol releases $\frac{25.2 \text{ kJ}}{0.03 \text{ mol}}$ = 840 kJ mol^{-1}

Heat of combustion of methanol, ΔH, CH_3OH = - 840 kJ mol^{-1}

3. Calculate the heat released
Mass of water, m = 2150 cm^3 $\times$ 1 g cm^3 = 2150 g
Temperature change, θ = (100.0 – 25.0) °C = 75.0 °C
Heat released, Q = 2150 cm^3 $\times$ 4.2 J g^{-1} °C^{-1} $\times$ 75.0 °C = 677 250 kJ
= 677.25 kJ
Calculate the mass of hexane, C_6H_{14}
Molar mass of hexane, C_6H_{14} = 6(12) + 14(1) = 86 g mol^{-1}
35000 kJ of heat is relapsed by 86 g hexane, C_6H_{14}
Therefore, the mass of hexane, C_6H_{14} needed to release 677.25 kJ = $\frac{86 \text{ g} \times 667.25 \text{ kJ}}{35000 \text{ kJ}}$ = 1.53 g

(page 140)

1. Number of moles of Pb^{2+} ions = Number of moles of SO_4^{2-} ions

$$= 2.0 \text{ mol dm}^{-3} \times \frac{50}{1000} \text{dm}^3$$
$$= 0.1 \text{ mol}$$

Let the heat released is Q J and the volume of solutions are used for comparison.
Therefore, $Q = (50 + 50) \times 4.2 \text{ J g}^{-1} \text{°C}^{-1} \times 10 \text{ °C}$ ....Equation 1

(a) Number of moles of Pb^{2+} ions = Number of moles of SO_4^{2-} ions

$$= 2.0 \text{ mol dm}^{-3} \times \frac{100}{1000} \text{dm}^3$$
$$= 0.2 \text{ mol}$$

The number of moles of subtance used is twice, hence the heat released is also twice.
Therefore, $2Q = (100 + 100) \times 4.2 \text{ J g}^{-1} \text{°C}^{-1} \times \theta$ ....Equation 2
Comparing equation 1 and 2: total volume of solution is also twice
Hence, $\theta = 10$ °C [No change]

(b) Concentration of both solutions is halved.
Number of moles of Pb^{2+} ions = Number of moles of SO_4^{2-} ions

$$= 1.0 \text{ mol dm}^{-3} \times \frac{50}{1000} \text{dm}^3$$
$$= 0.05 \text{ mol}$$

The quantity of substance is half, hence the heat released is also half.

Therefore, $\frac{1}{2}Q = (50 + 50) \times 4.2 \text{ J g}^{-1} \text{°C}^{-1} \times \theta$ ....Equation 3

Comparing equation 1 and 3: total volume of solutions are the same
Hence, $\theta = 5$ °C [Half]

(c) Concentration of solutions are not the same.

Number of Pb^{2+} ions = $2.0 \text{ mol dm}^{-3} \times \frac{50}{1000} \text{dm}^3 = 0.1 \text{ mol}$

Number of SO_4^{2-} ions = $1.0 \text{ mol dm}^{-3} \times \frac{50}{1000} \text{dm}^3 = 0.05 \text{ mol}$

Number of moles of Pb^{2+} ions are in excess. Therefore, the calculation will be based on the number of moles of SO_4^{2-} ions.
The number of moles of SO_4^{2-} ions is half. Hence, the heat released will also be half and the rise in temperature will also be half, which is 5 °C.

(d) Conclusion : The temperature rise depends on the number of moles of ions used.
- The number of moles of ions depends on the volume and concentration of reactants.
- When the moles of ions are the same, the temperature does not change.
- When the number of moles of ions is halved, the temperature rise is also halved.
- The reactant with excess number of moles of ions is not taken into account in the calculation. (also known as limiting factor)

2. $Q = 200 \text{ cm}^3 \times 4.2 \text{ J g}^{-1} \text{°C}^{-1} \times 50 \text{ °C} = 42000 \text{ J} = 42 \text{ kJ}$
1376 kJ of heat is released by 46 g of ethanol

Therefore, 42 kJ of heat is released by $\frac{42 \text{ kJ} \times 46 \text{ g mol}^{-1}}{1376 \text{ kJ mol}^{-1}} = 1.40 \text{ g}$

3. (a) Heat of displacement is the heat change when one mole of a metal is displaced from its salt solution by a more electropositive metal.

(b) (i) Use a polystyrene cup / plastic

(ii) Blue colour of the solution turns pale //
Brown deposit is formed

(c) 1. No heat change

2. No reaction // Silver is less electropositive than copper.

(d) (i) Number of moles of solution $= 0.5 \text{ mol dm}^{-3} \times \dfrac{100}{1000} \text{dm}^3 = 0.05 \text{ mol}$

$$Q = 0.05 \text{ mol} \times 42 \text{ kJ mol}^{-1} = 2.1 \text{ kJ} = 2100 \text{ J}$$

Mass of solution $= 100 \text{ cm}^3 \times 1 \text{ g cm}^3 = 100 \text{ g}$
Using $Q = mc\theta$

$$\theta = \frac{Q}{mc} = \frac{2100 \text{ J}}{100 \text{ g} \times 4.2 \text{ J g}^{-1} \text{°C}^{-1}} = 5 \text{ °C}$$

Highest temperature $= (28 + 5)$ °C $= 33$ °C

(ii) 1. Number of moles of copper(II) sulphate solution $= 0.5 \text{ mol dm}^{-3} \times \dfrac{100}{1000} \text{dm}^3 = 0.05 \text{ mol}$

2. Mass of magnesium $= 0.05 \text{ mol} \times 24 \text{ g mol}^{-1} = 1.2 \text{ g}$

4. (a) (i) 1. Use a metal container, not a beaker.

2. Replace the wire gauze with a pipe clay trangle.

(ii) Heat released, $Q = mc\theta$

$$= 200 \text{ g} \times 4.2 \text{ J g}^{-1} \text{°C}^{-1} \times 30 \text{ °C}$$
$$= 25200 \text{ J} / 25.2 \text{ kJ} \text{ (with units, J / kJ)}$$

(iii) 1. Number of moles $= \dfrac{1.72}{86}$ // 0.02

2. Heat of combustion, $\Delta H = \dfrac{25.2 \text{ kJ}}{0.02 \text{ mol}}$

3. $= -1260 \text{ kJ mol}^{-1}$ negative sign with units (kJ mol^{-1})

(b) 1. Fuel value of ethanol $= \dfrac{1376 \text{ kJ mol}^{-1}}{46 \text{ g mol}^{-1}} = 29.9 \text{ kJ g}^{-1}$

2. Fuel value of butan-1-ol $= \dfrac{2675 \text{ kJ mol}^{-1}}{74 \text{ g mol}^{-1}} = 36.1 \text{ kJ g}^{-1}$

Butan-1-ol is a better fuel because 1 g butan-1-ol releases 36.1 kJ of heat.

CHAPTER 4

POLYMER

Laboratory Activity 4A

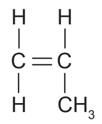
(page 148)

1. (a) Nylon is exceptionally strong.
   The fibres have excellent toughness.
   Resistant to abrasion.
   (b) Very elastic.
   (c) Temperature resistant

2. Uses of nylon:
   - making clothes,
   - reinforcement in rubber materials such as car tyres,
   - as rope or thread,
   - as a substitute for low-strength materials,
   - plastic components in engine compartments of vehicles.

Self Assess 4.1

(page 150)

1. (a) One type
   (b) 
   Propene

2. Synthetic polymers can be used because:
   - Synthetic polymers that are light and strong are used in the production of plastic bags to fill goods or food because they are cheap and easily available.
   - Synthetic polymers also have inert and non-reactive properties that are used in the production of PVC pipes due to their resistance to corrosion.
   - Environmental pollution caused by the use of synthetic polymers can be overcome by using green technology approaches in waste management, adopting 3R measures (reduce, reuse and recycle) and using biodegradable or photodegradable synthetic polymers.

   Alternative:
   The use of synthetic polymers is inappropriate:
   - Most synthetic polymers are durable and non biodegradable.
   - Improper disposal of synthetic polymers, such as plastic bottles and containers, causes the clogging of the drainage system which is one of the reasons why flash floods occur.
   - Burning almost all polymers openly will release acidic and toxic gases that cause air pollution, such as the release of:
     (i) carbon dioxide gas that causes the greenhouse effect.
     (ii) toxic carbon monoxide.

Activity 4D

(page 153)

(i) 2-metylbut-1,3-diene
(ii) Protein membrane on rubber particle is negatively charged that causes rubber particles to repel one another.
(iii) Characteristics of natural rubber
   (a) Soft solid at room temperature for easy usage.
   (b) Elastic to allow gloves to be easily worn.
   (c) Water resistant so that hands are protected from external elements.

Experiment 4A

(page 153)

1. Ethanoic acid causes latex to coagulate, while ammonia solution prevents latex from coagulation.
2. Latex in beaker C coagulate after being left for a while. Bacteria in the air enter the latex and secrete lactic acid that causes latex to colagulate.
3. Methanoic acid and barium hydroxide solution.

Laboratory Activity 4B

(page 155)

1. Rubber gloves
2. No. Products from natural rubber are easily oxidised.
3. (a) Elasticity:
   Less elastic, stretchable but will not return to its original shape.
   (b) Hardness
   Soft and not hard
   (c) Resistance towards heat
   Not heat resistant

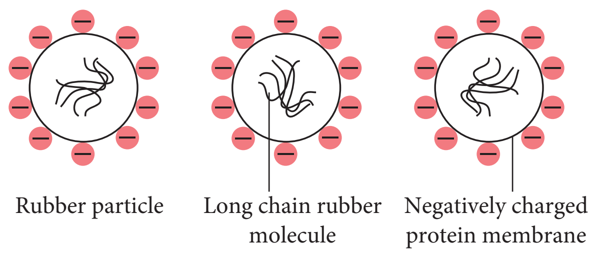
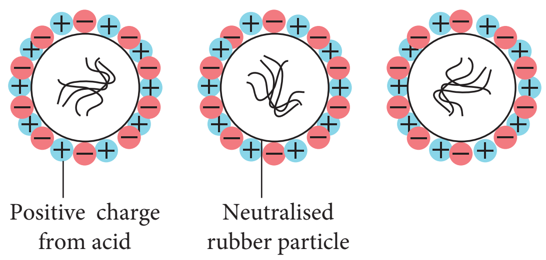
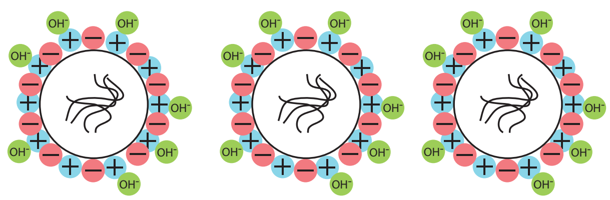
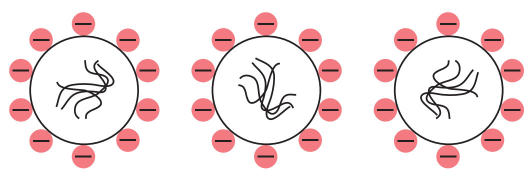
Activity 4E

(page 155)

(a) Coagulant: Formic acid, formaldehyde, vinegar.
Anticoagulant: Ammonia solution, sodium hydroxide solution.

(b) Natural coagulation process is due to the secretion of lactic acid by bacteria. Lactic acid is secreted in a very small quantity and causes coagulation to take place very slowly.

(c) Diagram and description.

	
1. The repulsion between the negatively-charged particles prevents the rubber particles from coming close to each other. Hence, latex will not coagulate.	2. Acid produced by bacteria will neutralise the negative charges on the protein membrane.
	
3. An alkali can be used to prevent the coagulation of latex. The addition of alkalis such as ammonia solution to latex can neutralise any acid produced by the bacteria.This is because ammonia solution consists of negatively charged hydroxide ions.	4. The negative charges on the protein membrane will remain and repel against each other and latex will remain as liquid. Thus, alkali can prevent the coagulation of latex.

Laboratory Activity 4C

(page 156)

Discussion:
1. Ethanoic acid is a coagulant to coagulate the latex.
2. To obtain an even thickness.
3. Rubber strips produced are harder and can withstand high temperature.

Experiment 4B

(page 157)

1. Unvulcanised rubber strip,
2. Vulcanised rubber strip. Able to return to its original length after the weight is removed.
3. Unvulcanised rubber.
4. Conclusion: Hypothesis is accepted. Vulcanised rubber is more elastic than unvulcanised rubber.

Self Assess 4.2

(page 158)

1. Polyisoprene
2. (a) The presence of hydrogen ions, H^+ in the acid neutralises the negatively charged protein membrane.
   (b) - Hydrogen ions, H^+ in the acid neutralise the negatively charged protein membrane.
   - Rubber particles collide with one another that lead the protein membrane to break.
   - Rubber polymers entangle that cause latex to coagulate.
3. Free from sulphur and chemical allergies.
4. Similarity: Vulcanised and unvulcanised rubber originate from latex.

Characteristic	Vulcanised rubber	Unvulcanised rubber
Elasticity	More elastic	Less elactic
Hardness	Hard	Soft
Strength	High	Low
Resistance to heat	Resistant to high heat	Less resistant to high heat
Resistance to oxidation	More resistant to oxidation	More prone to oxidation

Self Assess 4.3

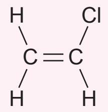
(page 161)

1. A polymer that is elastomeric in nature or elastic polymer.
2. (a) Nitrile rubber
   (b) More resistant to oil and solvent.
3. - Synthetic rubber is more resistant towards heat and abrasion to allow products such as tyres to be manufactured.
   - Synthetic rubber is hard to decompose naturally and can cause pollution.
   - Synthetic rubber needs to be disposed of systematically so that pollution can be prevented.

ACHIEVEMENT TEST

(page 163)

1. (a)



(b) Addition polymerisation.
(c) Production of plastic bottles.
(d) A polymer has a higher boiling point than its monomer due to the high intermolecular force of attraction between polymer chains.

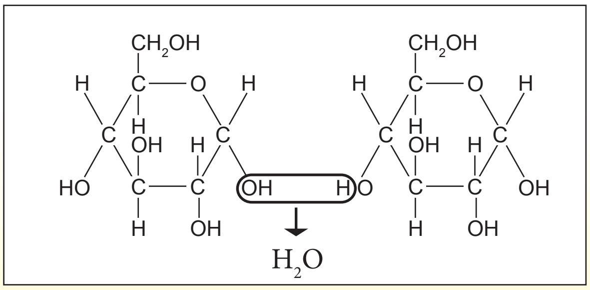
2. (a) Natural polymer: polyisoprene.
Synthetic polymer: Polyvinyl chloride.
(b) Natural polymers can be found in nature, while synthetic polymers are man-made through a chemical reaction.
(c) (i) Thermosetting polymer is a polymer that cannot be remoulded after heating.
(ii) Hard to decompose naturally and difficult to be disposed of.

3. (a) Rubber strip M because natural rubber is softer, easily stretched and less elastic.
(b) Rubber strip M.

Enrichment Corner

(page 163)

- Polymerisation process involved is condensation polymerisation.
- Water molecule is produced.



CHAPTER 5

CONSUMER AND INDUSTRIAL CHEMISTRY

Self Assess 5.1

(page 168)

1. Unsaturated fats are fats that contain unsaturated fatty acids.
2. Ester.
3. Similarity: Consists of the same homologous series.
   Differences:

Aspect	Fats	Oils
Source	Animals	Vegetables
Physical state at room temperature	Solid	Liquid
Melting point	High	Low
Type of fatty acid	High percentage of saturated fatty acids	High percentage of unsaturated fatty acids

4. Use of oils and fats:
   (a) As biofuel.
   (b) Source of nutrition.
   (c) Production of soap and personal care.
   (d) Manufacture of animal feeds.

Experiment 5A

(page 175)

Hypothesis: Detergent is more effective than soap in hard water.

Variables:
Manipulated variable : Soap and detergent
Responding variable : Effectiveness of cleaning
Fixed variable: Volume of hard water

Procedure:
1. Pour 50 cm^3 of hard water into a beaker.
2. Weigh 5 g of soap powder and pour it into the beaker.
3. Put a piece of cloth with grease stains into the beaker.
4. Clean/ Scrub / Wash the cloth.
5. Record the observation.
6. Repeat steps 1 to 5 using liquid detergent.

Result:

Type of cleansing agent	Observation
Soap	
Detergent	

Self Assess 5.2

(page 176)

1. Soaps are sodium or potassium salts of fatty acids.
2. Detergents are sodium or potassium salts of sulphonic acids.
3. Saponification.
4. $CH_3(CH_2)_{16}COOH + NaOH \rightarrow CH_3(CH_2)_{16}COONa + H_2O$
5. Sulphonation or sulphation and neutralisation.
6. Soap bubbles will lower the surface tension of water surface in the following ways:
   - Soap bubbles are a layer of spherical soap film that covers air or gas.
   - The film consists of a thin layer of water trapped between two layers of soap molecules.
   - The hydrophilic part of the soap molecule will dissolve in water, while the hydrophobic hydrocarbon chain part tends to avoid water.
   - The hydrophobic ends of soap molecules accumulate on the surface, avoiding water and stays away from the water molecular layer.
   - As a result, water molecules separate from each other. Increased distances between water molecules will cause a decrease in surface tension, which allows bubbles to form. Thus, soap can wet the surface of the fabric.

Self Assess 5.3

(page 180)

1. Preservatives, emulsifiers, antioxidants, thickeners, flavours, dyes and stabilisers.
2. (a) Antioxidants
   (b) (i) Slows down the oxidation of fats in food.
   (ii) Prevent oily or greasy food from becoming rancid.
   (c) Emulsifiers and dyes / salt / flavouring.

Self Assess 5.4

(page 186)

1. Ginger – removes wind from the body.
   Aloe vera – treats skin diseases
   Tamarind – Juice of the fruit relieves cough
2. Analgesics, antibiotics, psychotic drugs, anti allergies and corticosteroids.
3. Analgesics
4. Makeup cosmetics, treatment cosmetics and fragrances.

Self Assess 5.5

(page 190)

1. Nanoscience is a study of processing of substances at nanoscale, while nanotechnology is the development of substances or gadgets using the properties of nanoparticles.
2. Nanoparticle sizes, ranging from 1 to 100 nanometres, enable various applications to be invented due to their extremely small sizes. For example, health care can be improved with the production of more effective drugs or devices. In the cosmetic fields, for example, the usage of nanoparticles is able to provide more satisfying outcomes as these extremely small particles have the ability to easily penetrate the skin even more.
3. Examples of applications of nanotechnolgy:
   (a) Production of semiconductors and electronics:
   - Smaller and more efficient semiconductors.
   - High conductivity wiring systems.

   (b) Medical:
   - Highly sensitive testing devices.
   - More effective drug delivery systems.

   (c) Energy and electricity:
   - Smaller and more efficient solar cells.
   - Long-lasting batteries.

   (d) Agriculture:
   - More effective pesticides.
   - Highly efficient and thorough fertilisations.

   (e) Textile:
   - Water, fire and dirt resistant fabrics.
   - Anti-wrinkle and UV protective fabrics.

   (f) Food:
   - Nanoscale food additives.
   - Antimicrobial food packaging.
4. Graphene has a high surface area and cavity size that only allows water molecules to pass through it.

Self Assess 5.6

(page 194)

1. Green Technology is a technology developed to reduce the impact of human activities on the environment.
2. To prevent groundwater sources from being polluted.
3. Use of Green Technology in wastewater treatment:
   (a) Use of bacteria to decompose harmful substances.
   (b) Isolation of solid wastes from wastewater treatment
   (c) Use of bacteria in wastewater treatment.
4. The use of solar energy in vehicles can reduce the release of carbon dioxide gas, which contributes to the greenhouse effect.

ACHIEVEMENT TEST

(page 196)

1. (a) Unsaturated fats
   (b) The double covalent bonds in fatty acids P easily react with oxygen in the air and is further oxidised.
2. (a) (i) Saponification
   (ii) Ester
   (b) Potassium hydroxide
3. (a) Cleansing agent A: Detergent   Cleansing agent B: Soap
   (b) Cleansing action of cleansing agent A is more effective in hard water, while cleaning agent B is less effective in hard water.
   Hard water contains Ca^{2+} ions and Mg^{2+} ions.
   Anions in cleansing agent B combine with these ions and form scum that is insoluble salts.
   Cleansing agent A do not form scum.
4. (a) P – Salt   Q – Benzoic acid   R – Pektin
   (b) P – Preservatives or flavourings

   Function:
   - Prevent or delay the growth of bacteria or fungi to make the food last longer

   Flavouring
   - Replace the loss of original flavours during food processing.
     Add flavour or fragrant smell to make food tastier.

   Q – preservative
   Function – Prevent or delay the growth of bacteria or fungi to make the food last longer.

   R – stabiliser
   Function – gives a uniform and smooth texture.
5. (a) Medicine X – antiseptic   Medicine Y – antibiotic
   (b) Drug Y needs to be consumed so that all bacteria are killed. If not consumed, higher doses of the drug is needed if infected with the same disease in the future.
6. (a) Nanotechnology is the development of materials or devices by utilising the characteristics of nanoparticles.
   (b) Apply cream evenly covering the skin for better protection.
   (c) Uses of nanotechnology:
   - Production of unmanned vehicles
   - Production of electrical goods components.
7. (a) Garbage is disposed of using a solvent treatment system that can control the leachate from contaminating groundwater sources.
   (b) Hazardous chemicals can be decomposed first and wastewater treated before they can be discharged into the river. This enables only sufficiently treated and cleaner effluent to flow into the river.
   (c) Sludge materials can be processed into fertilisers or materials for biogas production.

Enrichment Corner

(page 197)

- Virgin coconut oil lasts longer
- Low content of unsaturated fatty acids makes virgin coconut oil more difficult to oxidise and last longer.

(page 197)

1. (a) (i) Preservative
(ii) Slows down or prevent the growth of bacteria or fungi so that food can be kept for a longer period of time.
(b) (i) Natural dye from pandanus leaves.
(ii) Sugar because diabetic patients should not consume too much sugar.
(iii) Artificial sweeteners, for example: stevia / sorbitol / aspartame

2. (i) Analgesic
(ii) Aspirin contains acid which is the -COOH group (carboxylic acid), and is not suitable for children or gastric patients because it will cause stomach ulcers.
Codeine does not contain acids.

3. Suitable because traditional medicines do not contain synthetic chemicals, only natural ingredients.
It is not suitable because if the production does not follow the correct dosage or measurement, it may not be safe to be consumed.
[select any one]

4. Steps that need to be taken:
- Check if the product is approved by the Ministry of Health.
- If there is no approval, check the content of the product to determine that it does not contain prohibited substances, such as hydroquinone, tretinoin or mercury.
- If there is a “tester”, test the product on the back of the wrist. This is to test whether one is allergic to the basic ingredients used in the manufacture of the product.

5. (a) Medicine:
The field of nanomedicine where the use of nanoparticles has been successfully applied. Examples are in assisting with dissolving drug-active molecules, in cargo delivery of drug-active molecules to specific areas of the body that need treatments, as antibacteria and also in disease diagnosis.

(b) Energy
Production of a more efficient and smaller solar cells.
Batteries that last longer.

(c) Agriculture
Manufacture of fertilisers containing ‘nanoactivators’ or ‘nanostimulants’ that act as stimulants for fruit productions.
More effective pesticide productions.

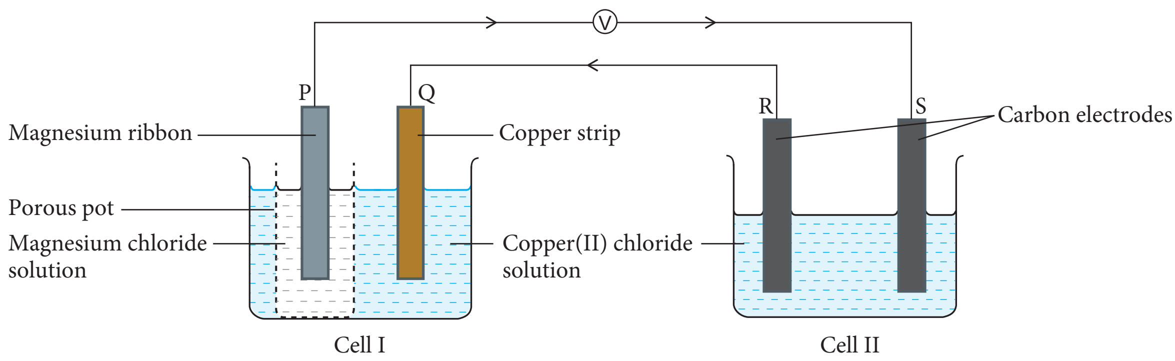
SUGGESTED ANSWERS T&L SUPPORT MATERIALS

OBJECTIVE QUESTIONS

1. A	**2.** D	**3.** C	**4.** C	**5.** A	**6.** D	**7.** C
8. C	**9.** C	**10.** D	**11.** C	**12.** A	**13.** B	**14.** D

STRUCTURED QUESTIONS

1. (a) (i) Chemical energy to electrical energy 1
(ii) Electrical energy to chemical energy 1
(b) Allow the transfer of ions 1
(c) (i) P // Magnesium 1
(ii) $Mg \rightarrow Mg^{2+} + 2e$ 1
(iii) $Mg(s) \mid Mg^{2+}(aq) \parallel Cu^{2+}(aq) \mid Cu(s)$ 1
(iv) $E^0 = +0.34 - (-2.38)$ 1
$= +2.72$ V 1
(v) Reduction 1
(vi) Copper(II) ion // Copper(II) chloride 1
(d) (i) Anode: R 1
Cathode: S 1
(ii) Cu^{2+}, Cl^-, H+, OH^- 1
(iii) Copper(II) ions // Cu^{2+} ion 1
(iv) E^0 of Cu^{2+} ion is more positive than E^0 of H^+ ion 1
Cu^{2+} ion gains 2 electrons to form copper atom 1
(v) $Cu^{2+} + 2e \rightarrow Cu$ 1
(vi) R: Greenish yellow gas bubbles released 1
S: Brown solid deposited 1
(vii) Blue colour becomes paler 1
Concentration of Cu^{2+} ions decreases 1
(e) 1



(f) +2 to 0 1

OBJECTIVE QUESTIONS

1. C	**2.** D	**3.** C	**4.** A	**5.** C	**6.** B	**7.** B
8. B	**9.** C	**10.** C				

STRUCTURED QUESTIONS

1. (a) 1. But-1-ene burns more sooty than butane — 1

2. %C in but-1-ene = $\frac{4(12)}{4(12) + 1(8)} \times 100\% = 85.71\%$ — 1

3. %C in butane = $\frac{6(12)}{4(12) + 10(1)} \times 100\% = 82.76\%$ — 1

4. Percentage of carbon in but-1-ene is higher than butane — 1

(b) $2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$ — 1+1

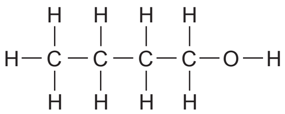
Number of mol of butane $= \frac{0.6\ dm^3}{24\ dm^3\ mol^{-1}} = 0.025$ — 1

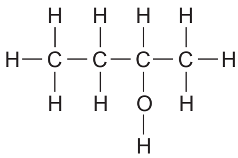
From the equation : 2 mol C_4H_{10} : 8 mol CO_2 — 1
0.025 mol C_4H_{10} : 0.1 mol CO_2

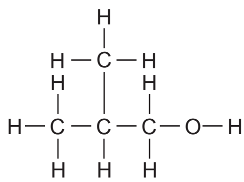
Volume of carbon dioxide = 0.1 mol × 24 $dm^3\ mol^{-1}$ — 1
= 2.4 dm^3

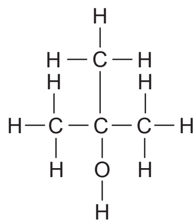
(c) (i) 1. Process I : Hydration — 1
2. Temperature : 300 °C — 1
3. Pressure : 60 atm — 1
4. Catalyst : Phosphoric acid — 1

(ii) (Any 2 isomers) — 1+1, 1+1

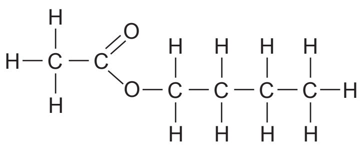

Butan-1-ol


Butan-2-ol


2-metihylpropan-1-ol


2-methylpropan-2-ol

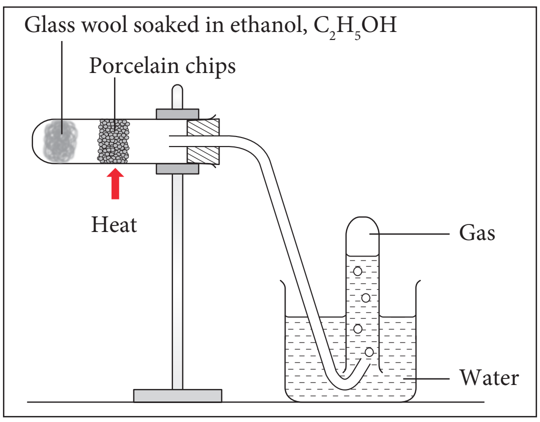
(d) Ester — 1
Butil etanoat — 1

 — 1

2. (a) (i) Molecular formula shows the type and actual number of atoms of each element in a molecule. — 1
(ii) $C_nH_{2n+1}OH$ — 1

(b) (i) Oxidation — 1
(ii) Acidified potassium manganate(VII) solution — 1
(iii) Butanoic acid — 1

(c) (i) — 1+1



(ii) $C_4H_5OH + 2[O] \rightarrow C_3H_7COOH + H_2O$ — 1+1

CHAPTER 3 : THERMOCHEMISTRY

OBJECTIVE QUESTIONS

1. C	**2.** D	**3.** D	**4.** C	**5.** B	**6.** C	**7.** B
8. C	**9.** C	**10.** C	**11.** C	**12.** B	**13.** B	**14.** D
15. D	**16.** B					

STRUCTURED QUESTIONS

1. (a) To decrease heat loss// 1
Polystyrene is heat insulator //
Weak conductor of heat

(b) (i) Exothermic reaction 1
(ii) Is less /smaller // 1
(iii) Add the solution immediately/at once 1
Stir the mixture.

(c) (i) Number of moles of Ag^+ ions = 0.5 mol dm^{-3} × $\frac{25}{1000}$ dm^3 = 0.0125 mol 1

(ii) Q = mcθ
= 50 cm^3 × 4.2 J g^{-1} °C^{-1} × (31.5 – 29.0) °C 1
= 525 J // 0.525 kJ 1

(iii) 0.125 moles of Ag^+ ions releases 0.525 kJ heat

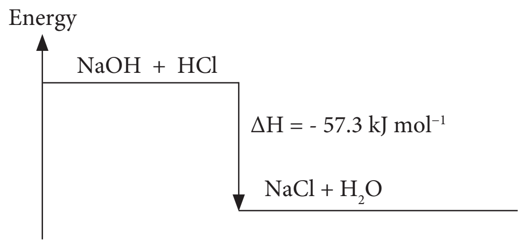
Therefore, 1 mole of Ag^+ ions releases = $\frac{0.525 \text{ kJ}}{0.0125 \text{ mol}}$ = 42 kJ mol^{-1} 1
ΔH = - 42 kJ mol^{-1} 1

(d) Heat is lost to the surroundings //Polysterene cups absorb heat. 1

2. (a) The heat of neutralisation is the heat change when one mole of water is formed from the reaction between an acid and an alkali. 1

(b) (i) The mixture causes the container to become hot// temperature increases// thermometer reading increases. 1
(ii) 1. Heat of neutralisation between sodium hydroxide solution and hydrochloric acid is higher. 1
2. Hydrochloric acid is a strong acid /ionises completely in water, while ethanoic acid is a weak acid/ ionises pertially in water. 1
3. Some of the heat released is used to ionise ethanoic acid molecules completely. 1

(c) 1. Energy axis labelled with 2 differect energy levels correctly drawn for an exothermic reaction. 1
2. Correct formulae of reactants and products. 1
3. Label ΔH with negative sign and correct value. 1



(d) 1. Number of moles of water (ion H^+ or ion OH^-)
2. Heat released, Q
3. Temperature change with the correct unit.

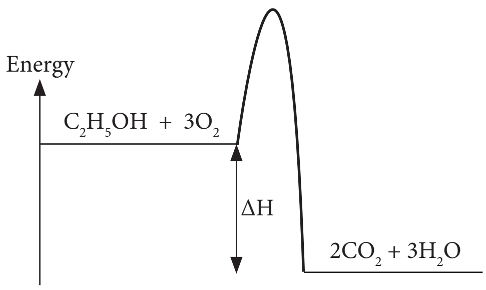
Number of moles of H^+ / OH^- = 1.0 mol dm^{-3} × $\frac{100}{1000}$ dm^3 = 0.1 mol 1

Q = 57.3 kJ mol^{-1} × 0.1 mol = 5.73 kJ = 57300 J 1

Temperature change = $\frac{5730 \text{ J}}{200 \text{ g} \times 4.2 \text{ J g}^{-1} \text{°C}^{-1}}$ = 6.8 °C // 6.82 °C 1

3. (a) A chemical reaction that releases heat to the surroundings. 1

(b) 1



(c) (i) The heat of combustion of propane is higher than methane.// or vice versa. 1

(ii) 1. The number of carbon atoms per molecule of propane is more than methane. 1

2. When the number of carbon atoms increases, the combustion of propane will also produce more carbon dioxide and and water. 1

3. Therefore, more heat is produced. 1

(d) Molar mass of propanol, C_3H_7OH = 60 g mol^{-1}

60 g of C_3H_7OH burnt produces 2016 kJ heat 1

Therefore, 1 g of C_3H_7OH burnt produces = $\frac{2016}{60\text{ g}}$ kJ 1

= 33.6 kJ g^{-1} 1

(e) 1. Put a cold pack on the injured area. 1

2. This will absorb heat from the injured area. 1

3. Blood vessels will constrict and will slow down the blood flow/ fluid formation will be less on the injured area, 1

Note: any endothemic reaction that will relieve the pain on the injured area.

CHAPTER 4 : POLYMER

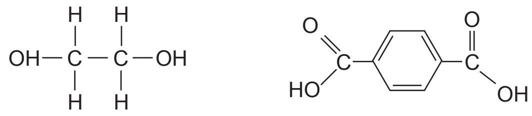
OBJECTIVE QUESTIONS

1. C	**2.** A	**3.** B	**4.** C	**5.** A	**6.** D	**7.** A
8. B	**9.** C	**10.** B	**11.** A	**12.** C		

STRUCTURED QUESTIONS

1. (a) Condensation polymerisation 1

(b) 1+1



(c) (i) Inert 1

Can enable the storage of hazardous chemicals. 1

(ii) Long lasting and hard to decompose naturally. 1

It takes a very long time for the polymer to disintegrate once disposed of and can cause pollution. 1

2. (a) (i) Hydrogen ion 1

(ii) Ethanoic acid 1

(b) (i) Rubber particles collide with one another and break the protein membrane. 1

Rubber polymers combine that cause latex to coagulate. 1

(ii) Add ammonia solution into the latex. 1

CHAPTER 5 : CONSUMER AND INDUSTRIAL CHEMISTRY

OBJECTIVE QUESTIONS

1.	A	**2.**	B	**3.**	B	**4.**	B	**5.**	B	**6.**	C	**7.**	C
8.	A	**9.**	D	**10.**	D	**11.**	C						

STRUCTURED QUESTIONS

1. (a) (i) Fats are esters produced through the reaction between fatty acids and glycerol 1

(ii) 2

Characteristics	**Fats**	**Oil**
Source	Animal	Vegetable
Physical state at room temperature	Solid	Liquid
Melting point	High	Low
Fatty acid content	High percentage of saturated fatty acids	High percentage of unsaturated fatty acids

(any two)

(iii) 1. Supplying energy, 2
2. Providing body temperature insulation and
3. Helping with the absorption of important vitamins.
(any two)

(iv) 1. Excessive intake in our diet can contribute to heart related problems. 1
2. Weight issues or obesity. 1
3. The risk for arteriosclerosis or hardening of the arteries if excessive fat intakes are sourced from animals or saturated fats. 1

2. (a) (i) X: Soap Y: Detergent 2
(ii) Cleaning agent Y. 1
Does not form scum. 1
(iii) Cleaning agent X. 1
Made from natural resources. 1
(iv) Hydrophilic part 1
(b) Biological enzyme- To remove protein stains, such as blood, milk and sugar. 1
Whitening agent-To change dirt to colourless substances. 1

3. (a) (i) Type of food additive: Preservatives 1
Function: Prevent or delay the growth of bacteria or fungi to make the food last longer. 1
(ii)
- allergies
- nerve disorder
- cancer
- asthma
- rashes
- hyperactivity in children 1

(any one)

(b) (i) Salt will draw out water from the cells of microorganisms and will retard the growth of bacteria or fungi so that food can be kept longer 1
(ii)
- Sugar 1
- Vinegar

(any one)

(c) (i) Pectin/ Lecitin 1
Pectin- stabiliser 1
Lecitin -emulsifier
(d) Growth of bacteria or fungi 1
Oxidation of food 1

4. (a) (i) • Helps in the treatment of hair problems 1
• Thickens the hair
• Blacken the hair
(ii) Analgesic 1
(iii) Paracetamol 1
(iv) Liver damage 1
(b) Mercury 2
Hydroquinone
Betamethasone valerate
Tretinoin
(any two)
(e) Mercury - Skin irritation and damage to the kidney and nervous system if absorbed into the bloodstream. 2
Hydroquinone - Hypersensitive skin and exposure to harmful UV rays caused by reduced pigmentation.
Betamethasone valerate - Skin irritation and changes to skin pigmentation.
Tretinoin - Redness and peeling of skin

5. (a) (i) 1. Diamond 1
2. Graphite 1
(ii) 1. Hard and strong 2
2. Transparent
3. Good conductor of heat and electricity
4. Elastic
5. Impermeable
6. Low electrical resistance
(any two)
(iii) 0.1 nm 1
(iv) Electronic - Conductor 2
Polymer and composite - Polymer composite materials.
Membrane - Water filtration, separating water from gaseous mixtures
Energy - Batteries that last longer, flexible and strong, supercapacitor
Censor - Graphene has high surface area.
Biomedical - Censors, tissue engineering, medicine delivery system
(any two)
(b) (i) 1. Ensuring more efficient waste management 2
2. Reduction in greenhouse gases.
3. Emission and removal of cleaner wastewater.
(any two)
(ii) Electrocoalgulation 1
(iii) Copper / Carbon 1