Paper 2

1 (a) One mole of a substance contains exactly 6.02×10^{23} elementary entities. [1]

(b) (i) $Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$ [1]

(ii) Oxidising agent. The oxidation state of Mn in MnO_4^- decreases from +7 to +2 in Mn^{2+} and the oxidation state of Fe in Fe^{2+} increases from +2 to +3 in Fe^{3+}. [2]

(iii) The aliquot changes from yellow to orange. [1]

(iv) $MnO_4^- + 8H^+ + 5e \rightarrow Mn^{2+} + 4H_2O$

$Fe^{2+} \rightarrow Fe^{3+} + e \quad \times 5$

$MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$ [1]

(v) amount of MnO_4^- used = $32.00/1000 \times 0.025 = 8.00 \times 10^{-4}$ mol [1]

(vi) amount of Fe^{2+} in 25.0 cm^3 = $8.00 \times 10^{-4} \times 5 = 4.00 \times 10^{-3}$ mol

amount of Fe^{2+} in 250 cm^3 = $4.00 \times 10^{-3} \times 250/25.0$

$= 4.00 \times 10^{-2}$ mol [1] [1]

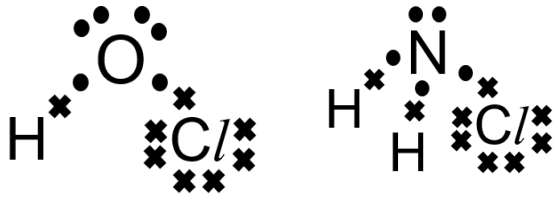
(vii) Mass of Fe in wire = $4.00 \times 10^{-2} \times 55.8 = 2.232$ g

% by mass of Fe in wire = $2.232/3.35 \times 100$ % = 66.6 %

The % of Fe in the ore is >60%, more ores can be purchased. [3]

[Total: 11]

2 (a) (i)



[2]

(ii) There are 2 lone pairs of electrons and 2 bond pairs of electrons around O in HOCl whereas there are only 1 lone pair of electrons and 3 bond pairs of electrons in around N in NH_2Cl. To minimise repulsion, HOCl has a bent shape while NH_2Cl has a trigonal pyramidal shape.

Since the lone pair – lone pair repulsion is greater in HOCl than the lone pair – bond pair repulsion in NH_2Cl, the bond angle in HOCl is smaller at 104.5° than 107° in NH_2Cl. [3]

(iii) Yes, HOC*l* is a polar molecule.

C*l* is more electronegative than H, O−C*l* is less polar than O−H. There is a net dipole moment in the HOC*l* molecule. [1]

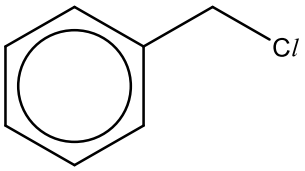
(b) CsC*l* has a giant ionic lattice structure while HOC*l* has a simple covalent structure. More energy is required to overcome the stronger electrostatic forces of attraction between Cs^+ and Cl^- ions than the weaker hydrogen bonds between HOC*l* molecules.

[2]

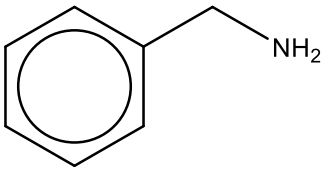
[Total: 8]

3 **(a)**

Intermediate 1:



Intermediate 2:



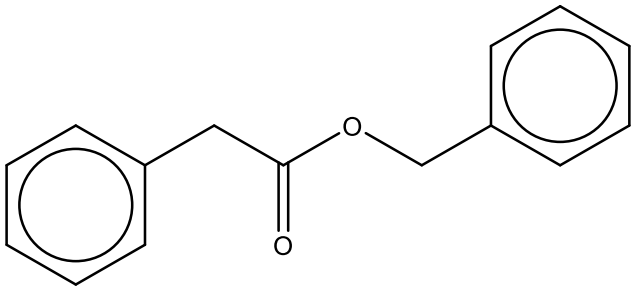
[2]

(b) Step 1: HC*l*, heat or PCl_3 or $SOCl_2$ or PCl_5

Step 2: ethanolic NH_3, heat in a sealed tube

Step 3: CH_3COOH, DCC [3]

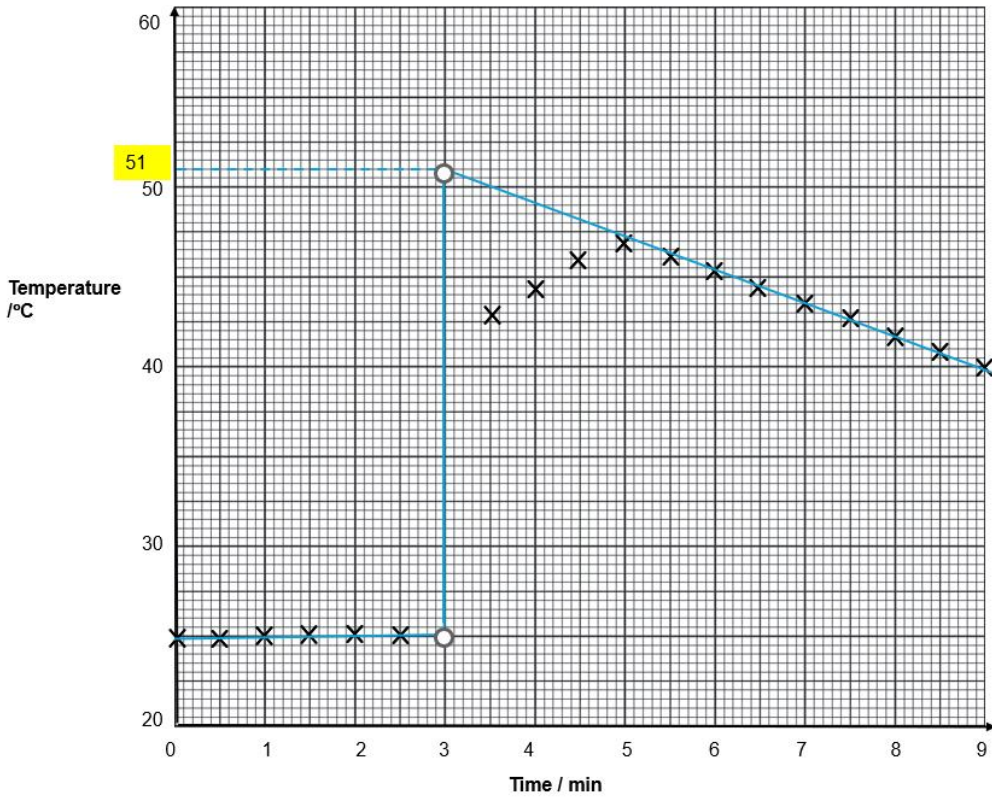
(c)



[1]

[Total: 6]

4 (a) (i)



Maximum temperature = 51.0 °C

2 BFL drawn to extrapolate to 3 min [2]

(ii) Highest temperature rise = 51.0 – 25.0

= 26.0 °C [1]

(iii) Heat evolved = 4.18 × 25.0 × 26.0

= 2717J

= 2.72 kJ (3.s.f) [1]

(iv) Amount of Mg in mass of **FA 1** added into cup = $\frac{1.00}{24.3}$

= 4.115×10^{-2} mol

Amount of $CuSO_4$ in 25.0 cm^3 of **FA 2** $= 1.00 \times \frac{25.0}{1000} = 2.50 \times 10^{-2}$ mol

$CuSO_4$ is the limiting reagent.

$\Delta H = -\frac{2.717}{2.50 \times 10^{-2}}$

= -108.68 kJ mol^{-1}

= -109 kJ mol^{-1} [2]

(b) $Na_2O(s)$ <u>reacts vigorously</u> with water to form NaOH(aq), which is a <u>strongly alkaline, pH = 13.</u>

$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$ [2]

(c) Down the Group, the atomic radius of rubidium is larger than sodium. The increase in nuclear charge is largely cancelled by the increase in shielding effect by the inner shells electrons. As a result, ionisation energy decreases in rubidium than in sodium, i.e. increasing ease of losing electrons by the metal. Thus, the tendency of the metal to be oxidised increases.

[2]

[Total: 10]

5 (a) (i) Comparing experiments 1 and 2, when [CO] is constant, $[NO_2]$ increases to 2.0 times as rate also increases to 2.0 times.

$\Rightarrow$ Order of reaction with respect to NO_2 is **1**. OR

Using the substitution method,

$$\frac{(\text{Rate})_1}{(\text{Rate})_2} = \frac{k\,[NO_2]_1^m[CO]_1^n}{k\,[NO_2]_2^m[CO]_2^n}$$

$$\frac{(\text{Rate})_1}{(\text{Rate})_2} = \left(\frac{[NO_2]_1}{[NO_2]_2}\right)^m \text{ since [CO] is constant.}$$

$$\frac{1.80 \times 10^{-3}}{3.60 \times 10^{-3}} = \left(\frac{1.50 \times 10^{-3}}{3.00 \times 10^{-3}}\right)^m$$

m=1

Comparing Experiments 2 and 3, when $[NO_2]$ is constant [CO] increases to 1.5 times as rate also increases to 1.5 times.

$\Rightarrow$ Order of reaction with respect to I^- is **1**.

$$\frac{(\text{Rate})_2}{(\text{Rate})_3} = \frac{k\,[NO_2]_2^m[CO]_2^n}{k\,[NO_2]_3^m[CO]_3^n}$$

$$\frac{(\text{Rate})_2}{(\text{Rate})_3} = \left(\frac{[CO]_2}{[CO]_3}\right)^n \text{ since } [NO_2]$$

$$\frac{3.60 \times 10^{-3}}{5.40 \times 10^{-3}} = \left(\frac{2.50 \times 10^{-3}}{3.75 \times 10^{-3}}\right)^n$$

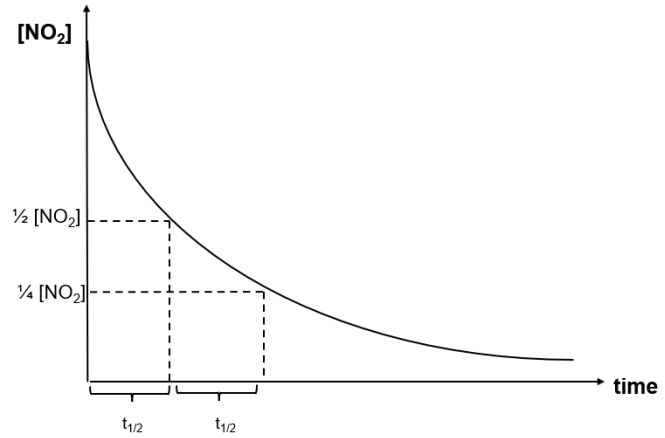
n=1

[2]

(ii) Rate = $k[NO_2][CO]$

[1]

(iii)



correct shape with $t_{1/2}$ constant for 1st order [1]

(iv) Adsorption:

CO and NO_2 molecules form weak bonds with the active sites on the platinum catalyst surface. This interaction weakens the internal bonds within the CO and NO_2 molecules, making them more chemically reactive.

Reaction:

The adsorbed CO and NO_2 molecules are held close together on the catalyst surface in the correct orientation. This allows the oxygen from NO_2 to react with CO, forming CO_2 and NO.

Desorption:

The weak bonds between the product molecules (CO_2 and NO) and the platinum surface are broken. These products then diffuse away from the catalyst surface, freeing the active sites for more CO and NO_2 molecules to be adsorbed and reacted. [3]

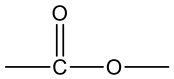
[Total: 7]

6 **(a)** Polymers are macromolecules with at least 100 repeat units of monomers and average molar mass of at least 1000 g mol^{-1}. [1]

(b) More items are made of PE and PP, so more will be thrown away as garbage.
OR

Low density (PE: 0.92, PP: 0.90) is less than seawater (1.03 g/ cm^3), so they float easily and persist on the surface. [1]

(c) As the number of electrons is much lesser / electron cloud size is smaller in PE and PP than PS, less energy is required to overcome the weaker instantaneous dipole- induced dipole interactions between PE and PP molecules than PS molecules. [1]

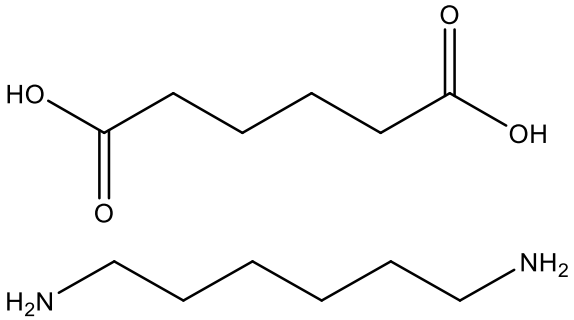
(d) In the presence of alkali, PET, containing the ester bonds,  can undergo hydrolysis. [1]

(e)

LDPE	HDPE
Plastic bags Cling wrap	Crates Bottles

Plastic bags and cling wrap are LDPE because they have lower tensile strength but greater ductility and flexibility while HDPE products have higher tensile strength and are more rigid. [2]

(f)



[2]

(g) Environment Advantage:

- Reduce oil usage and emissions of greenhouse gases associated with the production of plastics.
- When PET is recycled, it does not go into landfill, which can run out over time.
- PET does not become ocean waste and pollute the water.

Either 1

Trade-off:

- recycling process may generate more toxic materials. For example, when bleach is used during recycling, noxious Cl_2 may be released to the atmosphere and this in turn may contribute to air pollution.
- Leeching of toxic chemicals to the waterways.
- Energy required to recycle plastics

Either 1

[2]

[Total: 10]

7 **(a)** **(i)** Nanoparticles are defined as particles with all dimensions between 1–100 nm on the nanoscale. [1]

(ii) As the surface area to volume ratio is high, a greater amount of sunscreen is in contact with the nanoparticles. The denser packing covers the skin more evenly/ does not leave bulky residue behind. [2]

(iii) Due to the small size, nanoparticles can easily (either 1)

- pass through the pores on the skin / absorb into the blood stream through the skin (AND cause cancer / become toxic to cells.)
- Volatility is high for TiO_2, increased the possibility of inhaling. [1]

(b) Graphene is a single layer of carbon atoms arranged in hexagons as they are in graphite (or a single layer of graphite). Each carbon atom in the layer is covalently bonded with 3 other carbon atoms resulting in a hexagonal lattice structure.

Graphene has high tensile strength because of the strong covalent bonds between carbon atoms.

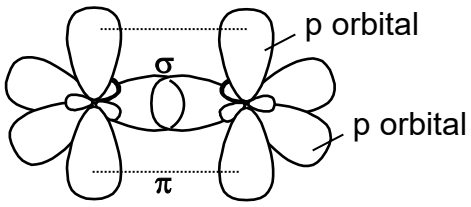
Each carbon atom has a 2p orbital that has a single electron that is not involved in bonding. This p orbital overlap sideways with its neighbouring carbon atom, resulting in an extended π-electron cloud of delocalised electrons above and below the plane.

Graphene is an excellent conductor of electricity because it has delocalised mobile electrons over the layer which serves as charge carriers and can carry electric current. [4]

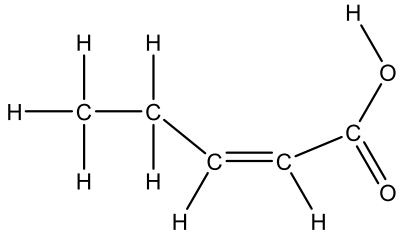
[Total: 8]

8 **(a)** **(i)** Pent-2-enoic acid is a compound that dissolves in water to yield H^+ and $CH_3CH_2CH{=}CHCOO^-$ ions. [1]

(ii) [2]

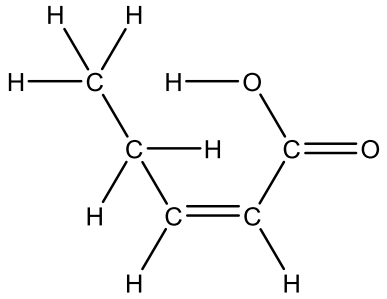


(iii) [2]

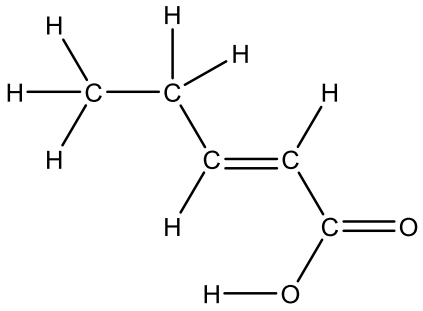


14 σ, 2 π bond

(iv) [2]



cis



trans

(v) $Br_2(l)/Br_2$ in $CCl_4/Br_2(aq)$ [1]

(vi) Reddish-brown $Br_2(l)$/ Orange-red Br_2 (in CCl_4)/ Orange Br_2 (aqueous) will be decolourised. [1]

(b) (i) Temperature increase favours endothermic reaction to absorb some of the added heat. From the graph, when temperature increases, K_w increases, position of equilibrium shift right. Hence the dissociation of water is endothermic. [2]

(ii) $K_w = [H^+][OH^-]$ [1]

(iii) The numerical value of K_w is 5.50×10^{-14} at 50 ºC.

$[H^+] = \sqrt{5.50 \times 10^{-14}} = 2.345 \times 10^{-7}$ mol dm^{-3}

pH= −lg (2.345×10^{-7}) = 6.63 (3 s.f) [2]

(iv) I do not agree. Pure water is neutral as the $[H^+] = [OH^-]$ [1]

(c) (i) A buffer solution is one that can resist a change in pH (pH changes only very slightly) when a small amount of acid or base is added to it. [1]

(ii) The pH of blood will decrease. [1]

(iii) When $[H^+]$ in the blood increases (e.g. from lactic acid produced during vigorous exercise), the large amount of HCO_3^- present removes the small amount of additional H^+. Hence, $[H^+]$ does not increase appreciably and the pH is kept approximately constant.

$$HCO_3^-(aq) + H^+(aq) \rightarrow H_2CO_3(aq)$$ [3]

[Total: 20]

9 (a) **X** belongs to group 17.

There is a large difference in ionisation energies of the 7th and 8th electron, indicating that the 8th electron is removed from an inner principal quantum shell. [2]

(b) (i) **W**: −2 ; **X**: −1 ; **Z**: +1 [1]

(ii) $W^{2-} > X^{-} > Z^{+}$ [1]

(c) The halogens have simple covalent structure; between discrete non-polar molecules there exist weak instantaneous dipole induced dipole interactions.

Down group 17, the number of electrons in the molecules increases , leading to an increase in the strength of the instantaneous dipole induced dipole interactions between the molecules.

Thus, group 17 elements are less volatile down the group. [2]

(d) Purple/violet vapour of I_2 will be observed. [1]

(e) From HC*l* to HI, the ease of decomposition of HX increases.

The atomic radius of the halogen atom increases and the valence orbitals become more diffuse, resulting in less effective overlap of the orbitals between the H atom and halogen atom and less energy is required to overcome the weaker H—X bond. [3]

(f) condition 1: low temperature

explanation: A lower in temperature will favour the forward exothermic reaction. The position of equilibrium lies to the right. Hence this will cause the yield of methanol to increase.

condition 2: high pressure

explanation: a high pressure will favour the side with lesser gaseous molecules. The position of equilibrium lies to the right. Hence this will cause the yield of methanol to increase. [4]

(g) **(i)** Dynamic equilibrium refers to a reversible process at equilibrium in which the rate of the forward reaction is equal to the rate of the backward reaction, where there is no net change in concentration of reactants and products. [1]

(ii) $K_c = \dfrac{[C_3H_5(OH)_3][RCOOCH_3]^3}{[(RCOO)_3C_3H_5][CH_3OH]^3}$ [1]

(iii)

	$(RCOO)_3C_3H_5$ (l)	+	$3CH_3OH$(l)	⇌	$C_3H_5(OH)_3$ (l)	+	$3RCOOCH_3$ (l)
initial amt / mol	0.50		1.50		0		0
change / mol	−0.4		−1.2		+0.4		+1.2

eqm amt / mol	0.1	0.3	0.4	1.2
eqm conc / mol dm^{-3}	$\frac{0.1}{V}$	$\frac{0.3}{V}$	$\frac{0.4}{V}$	$\frac{1.2}{V}$

$$K_c = \frac{[C_3H_5(OH)_3][RCOOCH_3]^3}{[(RCOO)_3C_3H_5][CH_3OH]^3}$$

$$= \frac{(\frac{0.4}{V})(\frac{1.2}{V})^3}{(\frac{0.1}{V})(\frac{0.3}{V})^3}$$

$$= \frac{(0.4)(1.2)^3}{(0.1)(0.3)^3}$$

= <u>256</u> [3]

(iv) - Biodiesels produces less pollutants when burned.
- Biodiesels are biodegradable. [1]

[Total: 20]