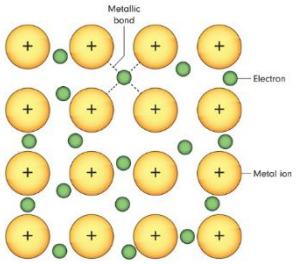
Section A

1 (a) (i) [1] W. It has the highest $\frac{q^+}{r^+}$ value

Note : C is not a metallic element

(ii) [1] V or Cr

(iii) [✓] Giant metallic structure with strong [✓] electrostatic forces of attraction between cations and sea of delocalised electrons.



[1]

2[✓] = 1m

(iv) [1] Adding carbon atoms into the space between the iron atoms in the lattice will prevent the iron atoms from sliding over each other easily and hence do not go out of shape easily.

(b) $FeCl_2$ has a [✓] giant ionic structure while [✓] $SiCl_4$ and SiI_4 have simple molecular structures.

Between Fe^{2+} and Cl^- ions, there are [✓] strong ionic bonds while between $SiCl_4$ molecules and between SiI_4 molecules, there are [✓] weak instantaneous dipole-induced dipole attractions (id-id). Hence [✓] more energy is required to overcome the strong ionic bonds than the weak id-id attractions resulting in a high m.p. for $FeCl_2$.

SiI_4 has a [✓] bigger electron cloud compared to $SiCl_4$ resulting in [✓] greater polarization leading to [✓] stronger id-id attractions between SiI_4 molecules. Hence [✓] more energy required to overcome the id-id attractions resulting in higher m.p. for SiI_4.

3[✓] = [1]

2 **(a)** [1] The product of reduction of H_2O_2 is water/oxygen which is clean / non-pollutants / environmentally friendly.

Note: accept O_2

(b) [✓] Sufficient energy is released from the formation of [✓] hydrogen bonds between water and H_2O_2 to overcome the [✓] hydrogen bonds between water molecules and hydrogen bonds between H_2O_2 molecules.

[✓] Insufficient energy is released from the formation of [✓] instantaneous dipole-induced dipole interactions between anthraquinone and water to overcome the hydrogen bonds between water molecules.

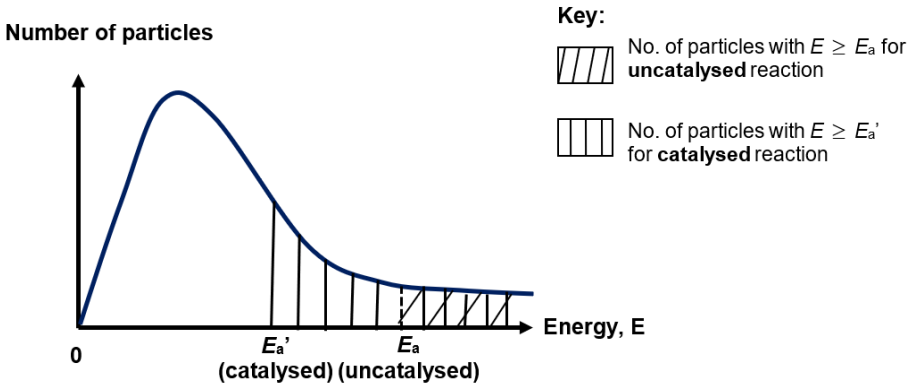
[✓] H_2O_2 dissolve in water / anthraquinone cannot dissolve in water.

3[✓] = [1]

(c) **(i)** [1] Palladium catalyst is not in the same phase as the reactants.

(ii) The reactant molecules are [✓] adsorbed unto the surface of the solid catalyst.

This [✓] lowers the activation energy by [✓] increasing the surface concentration of reactant molecules (or: reactant molecules are brought closer together) and [✓] weakens the covalent bonds of/within the reactant molecules. [✓] Number of particles with energy greater than or equal to E_a' increases.



The [✓] frequency of effective collisions is increased. [✓] Rate constant increases and hence the rate of the reaction increases.

After the reaction, [✓] desorption of product molecules occur at the catalyst surface. The product molecules eventually [✓] break free and diffuse away from the catalyst surface. Other reactant molecules may then approach the catalyst surface.

3[✓] = [1] ; Diagram = [1]

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

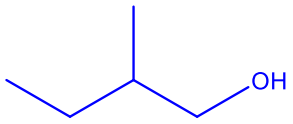
(ii) [1] Finely dividing the palladium into nanoparticles increases its surface area to volume ratio. Hence, there are more active sites on the catalyst surface for adsorption of reactants.

(iii) [1] Due to their small size, nanoparticles can enter human body through pores on skin, breathing/respiratory system, or ingestion (by digestive system).

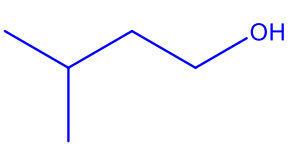
These particles can travel around the body via the circulatory system, get deposited in body tissues/cells/organs and cause the latter to be damaged/inflamed/develop cancer/cause immune response.

(iv) [1] Gold particles are larger and the deposition of the nanoparticles decreases the chances / prevents them from being inhaled or ingested.

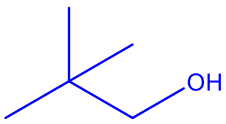
3 (a) (i) Either one (accept any form of structural formula):



2-methylbutan-1-ol



3-methylbutan-1-ol



2.2-dimethylpropan-1-ol

[1] correct structure ; **[1]** name

Note: Answer must be a primary alcohol.

(ii) methanol, conc. H_2SO_4, heat **[1]**

(b) (i) $K_a = \frac{[H^+][CH_3(CH_2)_3CO_2^-]}{[CH_3(CH_2)_3CO_2H]}$ **[1]**

Reject use of round brackets

(ii) $pK_a = -\log_{10}K_a$

$K_a = 10^{-4.82}$

$= 1.51 \times 10^{-5}$ mol dm^{-3} **[1]** both value and units

(iii) A **buffer solution** is a solution that **resists changes in pH** upon addition of a **small amount of an acid or base**. **[1]**

Comments : must mention small amounts of acid or base

(iv) $CH_3(CH_2)_3CO_2^- + H_3O^+ \rightarrow CH_3(CH_2)_3CO_2H + H_2O$ **[1]**

Reject if reversible arrow is used or H^+ used

(v) Amount of KOH reacted = amount of valeric acid = $0.05 \times \frac{22}{1\,000}$ = **0.00110 mol** **[1]**

Amount of valeric acid in 250 cm^3 buffer = 0.00110 x 10 = **0.0110 mol** **[1]**

(vi) **Initial amount** of valeric acid = amount in 250 cm^3 buffer + amount reacted with NaOH

$= 0.0110 + 0.1 \times \frac{100}{1\,000}$ = **0.0210 mol** **[1]**

Initial molar concentration of valeric acid = $\frac{0.0210}{0.150}$ = **0.140 mol dm^{-3}** **[1]**

Note : the initial amount of valeric acid would include the unreacted acid (from (v)) and the amount of acid that reacted with NaOH to form the salt.

(c) Heat released = $mc\Delta T$

$= (100 + 100) \times 4.18 \times 5.5$ = **4598 J** **[1]**

Since valeric acid is the limiting reagent

Amount of H_2O formed = amount of valeric acid reacted = $0.9 \times \frac{100}{1\,000}$ = **0.09 mol**

$\Delta H_n = -\frac{4598}{0.09}$ = **–51.1 kJ mol^{-1}** **[1]** with sign and units

4 **(a)** **(i)** PVAc is a thermoplastic as there are **no cross links** ✓ between the polymer chains.

The **weak permanent dipole-permanent dipole interactions** ✓ (OR **instantaneous dipole induced dipole interactions**) between polymer chains **are easily overcome** ✓ hence it **can be remolded / soften when heated** ✓.

Two ✓ **[1]**

(ii) PVAc will **not** have a weak absorption peak from **1635 to 1690 cm^{-1}** as it does not contain **C=C bonds**. **[1]**

Note : Need to quote IR absorption values and specify which functional gp is present.

(iii) Step 1: **ethanolic NaOH, heat [1]**

V: **CH_3CH_2OH [1]**

(iv) **$C_2H_4 + CH_3COOH + ½O_2 \rightarrow CH_3CO_2CHCH_2 + H_2O$ [1]**

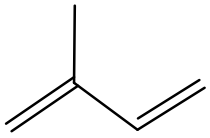
(v) **CH_3CHO [1]**

(b) **acid: $CH_3CHC/COOH$ and conjugate base: CH_3CHC/COO^- [1]**

base: NH_3 and conjugate acid: NH_4^+ [1]

[1] each both pairs correctly identified

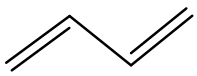
5 **(a)**



[1] accept allene

Comments : Answer must be a non-cyclic branched HC with only 5 C atoms. Also, there must be 2 C=C based on the reaction with Br_2.

(b)



[1]

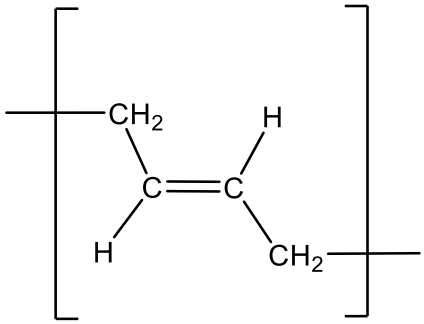
Systematic name: buta-1,3-diene

(c) **(i)** Cis-trans isomerism. [1]

There is restricted rotation about the C=C bond and each carbon of the C=C bond is bonded to two different groups. [1]

Comments : Must clearly state that the 2 different groups are attached to each of the C of the double bond.

(ii)



Structure of polymer **Y** (trans isomer), need to show extended bonds [1].

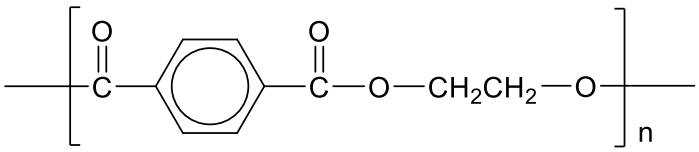
Diagram must show trigonal planar around C=C.

(iii) polymer **Z** (cis isomer) [1]

(d) Carbon-carbon bonds are non-polar / too strong / not attacked by nucleophiles / cannot by hydrolysed. [1 with explanation]

(note: the focus is on C-C bonds not C-H bonds as need to break these bonds in order to degrade the polymer)

(e) **(i)**



PET

[1] with n indicated and bonds extended

Comment: Not repeat unit and must be open-ended

(ii) Reactions with a high percentage atom economy are more efficient and less wasteful of resources / less pollution. [1]

Accept: maximises the use of raw materials in the process into useful products, saves resources

(iii) The percentage atom economy of the reaction to form PET is lower than that to form polymer X as H_2O / another molecule is also formed during the condensation or reaction while all the monomers are used to form polymer X. [1]

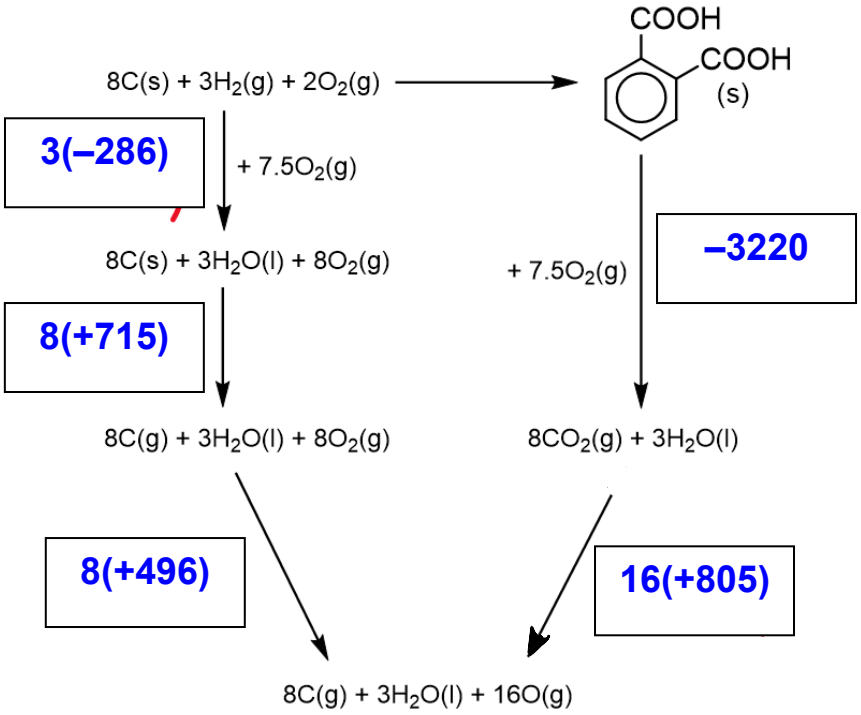
Comment: insufficient to just mention addition vs condensation polymer

(f) **(i)** Benzene-1,4-dicarboxylic acid is more energetically stable as it has a less exothermic standard enthalpy change of combustion. [1]

Note: Benzene-1,4-dicarboxylic acid is more stable than benzene-1,2-dicarboxylic acid due to less steric repulsion between the –COOH groups as they are further apart.

(ii) standard enthalpy change of formation of benzene-1,2-dicarboxylic acid. [1]

(iii)



5[✓] = 3 marks 3-4[✓] = 2 marks 2[✓] = 1 mark

(iv) $\Delta H_1^\ominus$ = (–286 x 3) + (+715 x 8) + (496 x 8) + (–805 x 16) – (–3220)

= – 830 kJ mol^{-1} [1] ecf (iv)

(g) [✓] |lattice energy| $\alpha \left|\frac{q_+q_-}{r_+ + r_-}\right|$

q_+ and r_+ are constant for both compounds.

The ionic radius of the anion of KHP is larger [✓] than O^{2-} and the charge of the anion of KHP is smaller [✓] than O^{2-} [1]. Hence, the ionic bonds in KHP are weaker than the ionic bonds in K_2O. Therefore, the [✓] magnitude of lattice energy of KHP is smaller than that of K_2O. [1]

Comments:

- Both compounds are ionic compounds.
- Must quote the correct species.
- Terms such as atomic radius are incorrect.

Section B

6 (a) (i) [1] Atoms of same element with the same number of protons but different number of neutrons.

(ii) [1] A_r of copper = [5(63)+2(65)]/7 = 63.5714

(iii)

atomic mass unit at 114	[✓] $^{79}Br^{35}Cl$
atomic mass unit at 116	[✓] $^{79}Br^{37}Cl$ and [✓] $^{81}Br^{35}Cl$
atomic mass unit at 118	[✓] $^{81}Br^{37}Cl$

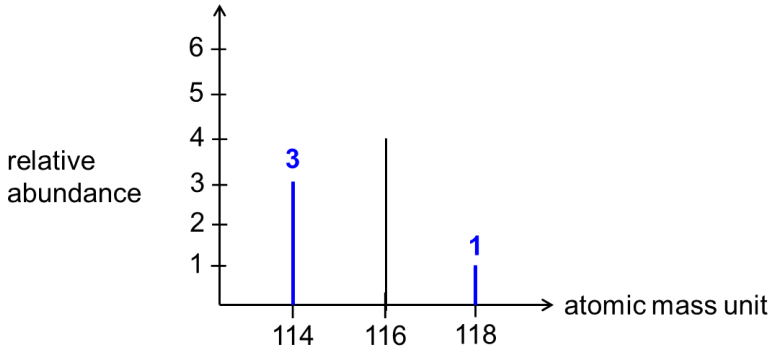
2[✓] = [1]

(iv) Percentage of sample with $^{79}Br^{35}Cl$ = (1/2)(3/4) = 3/8 = 0.375 = 37.5%

Percentage of sample with $^{81}Br^{37}Cl$ = (1/2)(1/4) = 1/8 = 0.125 = 12.5%

Percentage of sample with $^{79}Br^{37}Cl$ and $^{81}Br^{35}Cl$ = (1/2)(1/4) + (1/2)(3/4) = 4/8 = 50%

[1] correct answers



[1] correct plots (no ecf)

(b) (i) [1] Oxidising agent.

[1] Oxidation state nitrogen decreases from +5 in HNO_3 to +4 in NO_2.

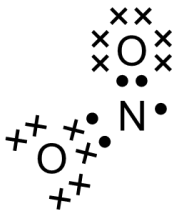
(ii) amt of sulfur precipitate: = $\frac{64.2}{32.1}$ = 2 mol

amt of NO_2 gas = $\frac{114}{22.7}$ = 5 mol

[1] correct number of moles of S and NO_2

Comparing mole ratio, y = 2 and x = 1 [1]

(c) (i)



[1]

N and O are period 2 elements hence should not accommodate more than 8 electrons

(ii) Amt of manganate used = 44.8/1000 x 0.02 = 0.000896 mol

Amt of iron(II) produced = 0.000896 x 5 = 0.00448 mol

$Fe^{2+} \equiv Fe^{3+}$

Amt of iron(III) reacted with hydroxylamine = 0.00448 mol [1]

(iii) Amt of hydroxylamine used = 0.074 / 33 = 0.00224 mol

Hence $2Fe^{3+} \equiv NH_2OH \equiv 2e$

Oxidation of 1 NH_2OH loses 2e, so final oxidation state of nitrogen in product

[1] = – 1 + 2 = +1

[1] N_2O

(iv) $Fe^{3+} + e \rightarrow Fe^{2+}$ (x4)

$2NH_2OH \rightarrow N_2O + H_2O + 4H^+ + 4e$ (x1)

[1] $4Fe^{3+} + 2NH_2OH \rightarrow 4Fe^{2+} + N_2O + H_2O + 4H^+$

(d) **(i)** [1] Minimum energy required to completely remove one mole of valence electrons from

[1] one mole of ground-state gaseous **F^+** ions to form 1 mole of gaseous **F^{2+}** ions /

$\mathbf{F}^+(g) \rightarrow \mathbf{F}^{2+}(g) + e$

(ii) [1] Large decrease in 2nd IE from **D** to **E** implies that the 2nd electron in **E** is in the outer shell.

E belongs to Group 2 and **B** belongs to group 17.

[1] **B** is fluorine

(iii) **A**: s^2p^4 **A^+**: s^2p^3

B: s^2p^5 **B^+**: s^2p^4

[1] The removal of 2nd electron in **B** comes from a paired electron which experiences interelectronic repulsion, so less energy is needed to remove.

DO NOT WRITE IN THIS MARGIN

7 **(a)** **(i)** Electronegativity refers to the ability of an atom to attract the shared electron pair in a covalent bond/molecule. [1]

(ii) Comparing sodium and chlorine, [✓] chlorine has a higher nuclear charge due to larger number of protons, [✓] Screening effect remains approximately constant as electrons are added to the same electronic shell.

[✓] As there is stronger attraction between the nucleus and the bonding electrons in the outer shell, chlorine has higher [✓] electronegativity, resulting in a larger EN value.

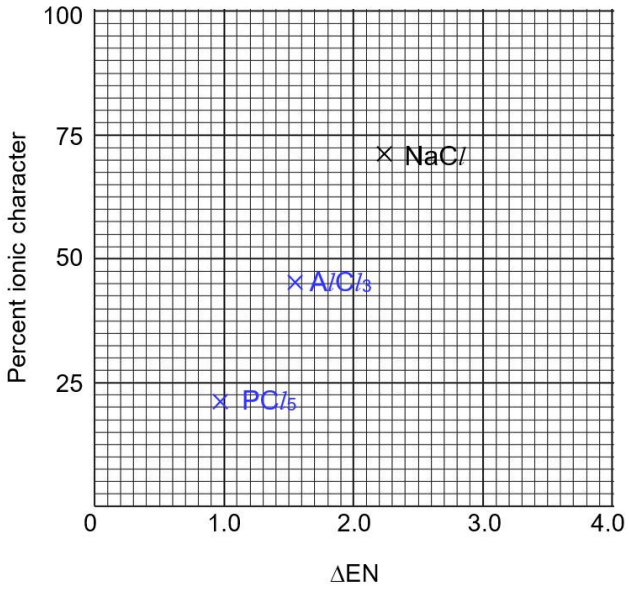
2[✓]= [1]

(iii) ΔEN for $AlCl_3$ = 3.16 – 1.61 = 1.55 [✓]

ΔEN for PCl_5 = 3.16 – 2.19 = 0.970 [✓]

2[✓] = [1]

[1] Correct relative order for percent ionic character for the three compounds



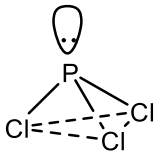
(iv) [1] Ionic bonds exist in NaCl due to large ΔEN (or large difference in electronegativities) between Na and Cl.

[1] Covalent bonds exist in PCl_5 due to small ΔEN (or small difference in electronegativities) between P and Cl.

(b) Ionic character of bond: [1] SeF_4 > BrF_3

Br is more electronegative than Se hence ΔEN between Br and F is smaller than that between Se and F i.e. Se and F have larger ΔEN hence higher ionic character.

(c) There are [✓] 3 bond pairs and 1 lone pair in the valence shell of P atom. [✓] To minimise repulsion and maximise stability, the shape of PCl_3 is [✓] trigonal pyramidal.



[✓]

Since [✓] lone pair – bond pair repulsion > bond pair – bond pair repulsion, the [✓] bond angles is 107° *(accept other bond angles < 109.5°).*

2[✓] = [1]

(d) By Le Chatelier's Principle, the [✓] position of equilibrium will shift right to [✓] decrease the concentration of Cl_2. The equilibrium mixture will contain [✓] more PCl_5, less PCl_3 and [✓] more Cl_2.

2[✓] = [1]

Comment: Even though the equilibrium position shifted to remove chlorine, there will still be more Cl_2 than before when the new equilibrium is established.

(e) **(i)** [1] $K_c = \frac{[PCl_5]}{[PCl_3][Cl_2]}$, $mol^{-1}dm^3$

(ii) $K_c = \frac{[PCl_5]}{[PCl_3][Cl_2]} = \frac{\left(\frac{1.2}{2}\right)}{\left(\frac{0.4}{2}\right)\left(\frac{0.25}{2}\right)}$ = 24.0 $mol^{-1}dm^3$ [1]

(iii)

	$PCl_3(g)$ +	$Cl_2(g)$ ⇌	$PCl_5(g)$
Initial amount /mol	0.4	0.25 **+ x**	1.2
Change in amount /mol	-y	-y	+y
Equilibrium amount /mol	0.4 – y	0.25 + x – y	1.28
	= 0.32	= 0.17 + x	

[1] ICE Table Working

y = 1.28 – 1.2 = 0.08

$K_c = \frac{[PCl_5]}{[PCl_3][Cl_2]} = \frac{\left(\frac{1.28}{2}\right)}{\left(\frac{0.32}{2}\right)\left(\frac{0.17+x}{2}\right)}$ = 24

x = 0.163 mol [1]

(f) Na_2O [✓] reacts vigorously with water to give a strongly alkaline solution of NaOH(aq) with a [✓] pH = 13.

[✓] **$Na_2O + H_2O \rightarrow 2NaOH$**

P_4O_{10} [✓] reacts vigorously with water to give a strongly acidic solution of H_3PO_4(aq) with a [✓] pH = 2.

[✓] **$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$**

[✓] Al_2O_3 does not react with water due to its high lattice energy. [✓] pH = 7

3[✓] = [1]

6[✓] = [2]

8[✓] = [3]

DO NOT WRITE IN THIS MARGIN