

Section A

1 (a) (i) **B** and **D** (both have same number of protons) [1]

(ii) Cu
 $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$ [1] correct element + electronic configuration

(b) (i)	sub-atomic particles	relative mass	relative charge
	proton	1	+1
	neutron	1	0
	electron	1/1840	-1

All correct [1]

(ii) ${}^3_3\text{E}$. **E** is an isotope of lithium. [1]

Accept ${}^3_3\text{E}^+$

(c) (i) $\text{Z}^+(\text{g}) \longrightarrow \text{Z}^{2+}(\text{g}) + \text{e}$ [1]

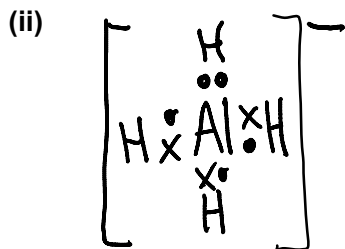
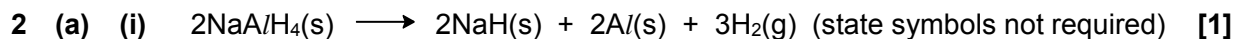
(ii) **W**. Its 1st I.E. is the highest. [1]

(iii) +1 [1]

(iv) **YO** and **Y₃N₂** [1]

(v) **Y** is a Group II element / Mg. [1]

If **A** were among the elements, then its 1st I.E. must be smaller than Mg which is not the case. Only the 1st I.E. of **X** is smaller, but **X** is a Group I element / Na. [1]



[1] 1 dative bond; 3 covalent bonds; negative charge

(b)	compound	pH of solution formed	equation to show reaction with water, if any
	AlCl_3	3	$\text{AlCl}_3(\text{s}) + 6\text{H}_2\text{O}(\text{l}) \longrightarrow [\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq}) + 3\text{Cl}^-(\text{aq})$ $[\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons [\text{Al}(\text{H}_2\text{O})_5(\text{OH})]^{2+} + \text{H}_3\text{O}^+(\text{aq})$
	SiCl_4	1	$\text{SiCl}_4(\text{l}) + 2\text{H}_2\text{O}(\text{l}) \longrightarrow \text{SiO}_2(\text{s}) + 4\text{HCl}(\text{aq})$
	PCl_3	1	$\text{PCl}_3(\text{l}) + 3\text{H}_2\text{O}(\text{l}) \longrightarrow \text{H}_3\text{PO}_3(\text{aq}) + 3\text{HCl}(\text{aq})$

[1] for each compound (correct pH and balanced equation)

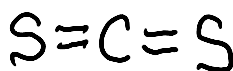
- (c) (i) Na_2S is a giant ionic compound with strong electrostatic forces of attraction [1] while the other two are simple molecular compounds with weak intermolecular forces of attraction. [1]

More energy is required to break the strong electrostatic forces of attraction in Na_2S .

(ii)



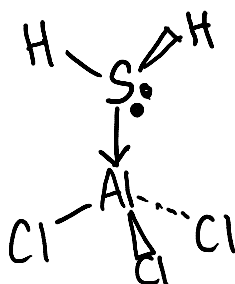
bent; 104.5°



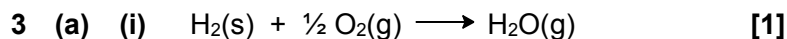
linear; 180°

[1] for each molecule with correct diagram, shape and bond angle

(iii)



[1] dative bond from S to Al; tetrahedral shape w.r.t. Al and trigonal pyramidal w.r.t. S; lone pair on S



(ii) By Hess's law,

$$\Delta H_f^\ominus(\text{CH}_3\text{COOCH}_3) = 3\Delta H_f^\ominus(\text{CO}_2) + 3\Delta H_f^\ominus(\text{H}_2\text{O}) - \Delta H_c^\ominus(\text{CH}_3\text{COOCH}_3)$$

$$= 3(-393.5) + 3(-285.8) - (-1592.1)$$

$$= \underline{\underline{-446 \text{ kJ mol}^{-1}}}$$

[1] correct application of Hess' Law

[1] correct answer, – sign and units

(b) (i) Heat energy gained by copper can = $mc\Delta T$

$$= (250)(0.384)(10)$$

$$= \underline{\underline{960 \text{ J}}}$$

Heat energy gained by water = $(300)(4.18)(10)$

$$= \underline{\underline{12540 \text{ J}}}$$

Total heat energy gained by copper can and water = 13500 J = 13.5 kJ

[1] calculate heat energy gained by both copper can and water correctly

[1] calculate total heat energy gained correctly in kJ

(ii) $n(\text{methyl ethanoate}) = \frac{0.98}{74.0} = 0.01324 \text{ mol}$

Heat energy released = $0.01324 \times 1592.1 = \underline{\underline{21.1 \text{ kJ}}}$ (3 s.f.)

[1] correct answer + unit

(iii) Percentage efficiency of heat transfer = $\frac{13500}{21100} \times 100 \% = \underline{\underline{64.0 \%}}$ [1]

(iv) Heat energy gained by copper can = $mc\Delta T$

$$= (250)(0.384)(11.5)$$

$$= 1104 \text{ J}$$

Heat energy gained by water = $(300)(4.18)(11.5)$

$$= 14421 \text{ J}$$

Total heat energy gained by copper can and water = 15525 J (64% efficient)

Total possible theoretical heat energy gained by copper can and water = $\frac{15525}{64.0} \times 100\%$

$$= \underline{\underline{24258 \text{ J}}}$$
 (100% efficient)

$n(\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3) = \frac{0.948}{88.0} = 0.01077 \text{ mol}$

Standard enthalpy change of combustion of ethyl ethanoate = $-\frac{24258}{0.01077}$

$$= \underline{\underline{-2250 \text{ kJ mol}^{-1}}}$$

[1] take into account % efficiency

[1] calculate standard enthalpy change of combustion of ethyl ethanoate correctly

- (v) Total energy released per gram of ethyl ethanoate
 $= 24258 / 88.0$
 $= \underline{276 \text{ J g}^{-1}}$ or $\underline{0.276 \text{ kJ g}^{-1}}$ [1] allow ecf

4 (a) (i) Comparing experiment 1 and 2.

When [RBr] is tripled, rate is tripled. Rate is directly proportional to [RBr].

Hence reaction is 1st order with respect to RBr. [1]

Comparing experiment 1 and 3.

$$\frac{4 \times 10^{-4}}{8.0 \times 10^{-4}} = \frac{k(0.005)(0.10)^x}{k(0.010)(0.20)^x} \Rightarrow x = 0$$

Hence reaction is zero order with respect to OH⁻. [1]

(ii) Rate = $k [\text{RBr}]$ [1]

(iii) Comparing experiment 1 and 4,

$$\frac{4 \times 10^{-4}}{x} = \frac{k(0.005)}{k(0.018)}$$

Solving, $x = \underline{1.44 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}}$ [1]

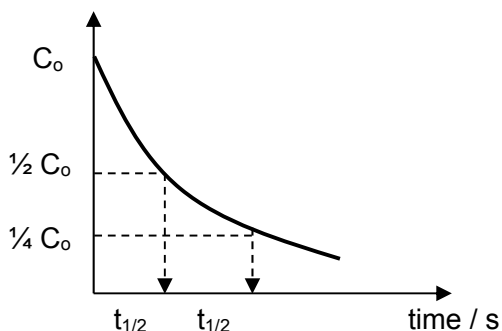
(iv) Using experiment 1

$$\text{Rate constant, } k = \frac{4 \times 10^{-4}}{0.005} = \underline{0.0800 \text{ s}^{-1}}$$

[1] correct value

[1] correct units

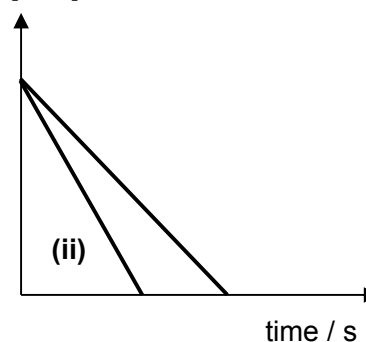
(b) (i) [RBr] / mol dm⁻³



[1] decreasing curve

[1] 2 consecutive half-lives

[OH⁻] / mol dm⁻³



[1] straight line

(ii) Straight line with steeper gradient [1]

[3]

Section B

- 5 (a) (i) Butane is an elongated molecule while 2-methylpropane is a branched molecule.

There is greater surface area in butane molecules for stronger instantaneous dipole – induced dipole attractions to operate. [1]

More energy is required to break the stronger instantaneous dipole – induced dipole attractions in butane. Hence butane has a higher boiling point than 2-methylpropane. [1]

- (ii) Chloropropane is polar while butane is non-polar. More energy is required to break the stronger permanent dipole – permanent dipole attractions in chloropropane [1]

compared to weaker instantaneous dipole – induced dipole attractions in butane. [1]

Hence chloropropane has a higher boiling point than butane.

- (iii) Both compounds can form hydrogen bonds. [1]

However, cyclohexanol has a bigger electron cloud that contributes to stronger instantaneous dipole – induced dipole attractions than in ethanol. [1]

More energy is required to break the additional instantaneous dipole – induced dipole attraction in cyclohexanol. Hence cyclohexanol has a higher boiling point.

- (iv) 1,2-cyclohexadiol can form intramolecular hydrogen bonds so there is less extensive intermolecular hydrogen bonding. [1]

Less energy is required to break the less extensive hydrogen bonds in 1,2-cyclohexadiol. Hence 1,2-cyclohexadiol has a lower boiling point. [1]

- (b) (i) The two carbon atoms form double bond (one sigma bond and one pi bond) with each other.

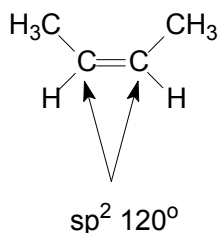
The sp² hybrid orbitals of the carbon atoms overlap head on to form a sigma bond. [1]

The unhybridised p orbitals of the carbon atoms overlap sideways to form a pi bond. [1]

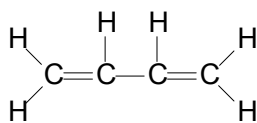
- (ii) Absence of light; room temperature [1]

- (iii) $\text{C}_2\text{H}_4 + \text{Br}_2 \longrightarrow \text{CH}_2\text{BrCH}_2\text{Br}$ [1]

- (c) (i) sp^3 109.5° sp^3 109.5°

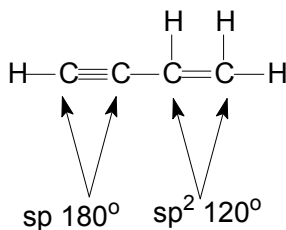


(ii)



$\text{sp}^2 120^\circ$

(iii)



$\text{sp } 180^\circ$

$\text{sp}^2 120^\circ$

Answers only accepted for organic compounds that exist.

For each part:

[1] clearly label the type of hybridisation

[1] clearly label bond angle with respect to each carbon atom in the structures.

- (d) CO is very toxic because it forms a stable compound with haemoglobin, resulting in ineffective transporting of oxygen around the body. [1]

Unburnt hydrocarbons are carcinogenic (cancer causing) and contribute to photochemical smog, which can bring about respiratory problems. [1]

6 (a) (i)

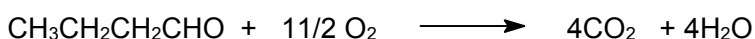
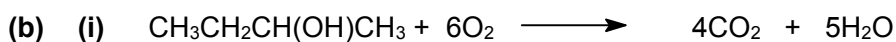
	compound	Tollens' reagent	2,4-DNPH	aq I ₂ /OH ⁻
A	CH ₃ CH ₂ CH(OH)CH ₃	No ppt	No ppt	Yellow ppt
B	CH ₃ CH ₂ CH ₂ CHO	Silver mirror	Yellow/orange ppt	no ppt
C	CH ₃ COCH ₂ CH ₃	No ppt	Yellow/orange ppt	Yellow ppt
D	(CH ₃) ₃ COH	No ppt	No ppt	No ppt

[1] for every 2 correct observations

Total: [6]

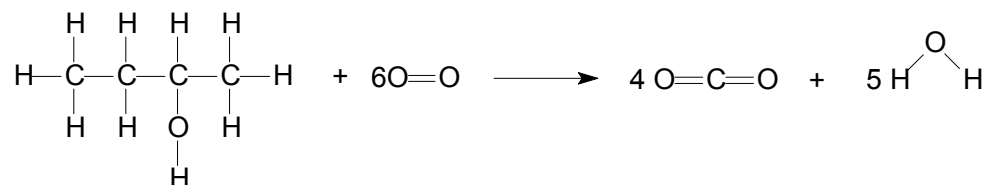
(ii)

	reagents & conditions	observations	organic product
A and D	KMnO ₄ , dil. H ₂ SO ₄ , heat or K ₂ Cr ₂ O ₇ , dil. H ₂ SO ₄ , heat [1]	A : purple colour turns colourless (or orange solution turns green) D : purple colour remains (or orange colour remains) [1]	CH ₃ CH ₂ COCH ₃ [1]
C and D	anhydrous PCl ₅ /SOCl ₂ , room temperature [1]	C : no gas produced D : white fumes (of HCl) [1]	(CH ₃) ₃ CCl [1]

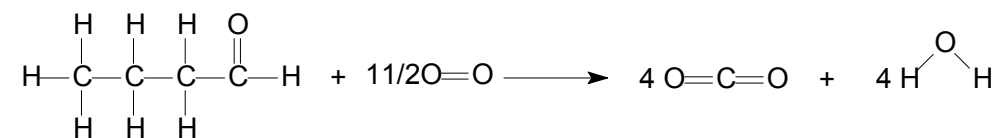


[1] for each correct and balanced equation

(ii)



$$\begin{aligned} \Delta H_c \text{ of A, CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3 &= \sum \text{B.E. (broken)} - \sum \text{B.E. (formed)} \\ &= 3(350) + 9(410) + 1(360) + 1(460) + 6(496) - (4 \times 2 \times 805) - (5 \times 2 \times 460) \\ &= \underline{\underline{-2500 \text{ kJ mol}^{-1}}} \end{aligned}$$



$$\begin{aligned} \Delta H_c \text{ of B, CH}_3\text{CH}_2\text{CH}_2\text{CHO} &= 3(350) + 8(410) + 1(740) + 11/2(496) - (4 \times 2 \times 805) \\ &\quad - (4 \times 2 \times 460) \\ &= \underline{\underline{-2320 \text{ kJ mol}^{-1}}} \end{aligned}$$

Combustion of **A** releases **more** heat energy.

[1] correct application of formula $\sum \text{B.E. (broken)} - \sum \text{B.E. (formed)}$ for A

[1] correct application of formula $\sum \text{B.E. (broken)} - \sum \text{B.E. (formed)}$ for B

[1] correctly calculate ΔH_c of A (allow e.c.f.)

[1] correctly calculate ΔH_c of B (allow e.c.f.)

[1] correct deduction based on answers

- (iii) Compound **A** and **B** are **liquids at room temperature**, however BE values used for calculations assume the compounds are in the gaseous state. [1]

Or, BE values given in the *Data Booklet* are only **average bond energies**. [1]

- 7 (a) (i) A Bronsted acid is a **proton donor**.
A Bronsted base is a **proton acceptor**. [1]

- (ii) $[\text{H}^+] = 10^{-2.4} = \underline{3.98 \times 10^{-3}} \text{ mol dm}^{-3}$

Since $[\text{H}^+] \ll 0.10 \text{ mol dm}^{-3}$, lactic acid is partially dissociated hence it is a **weak acid**.

[1] Correct value of $[\text{H}^+] = 3.98 \times 10^{-3} \text{ mol dm}^{-3}$

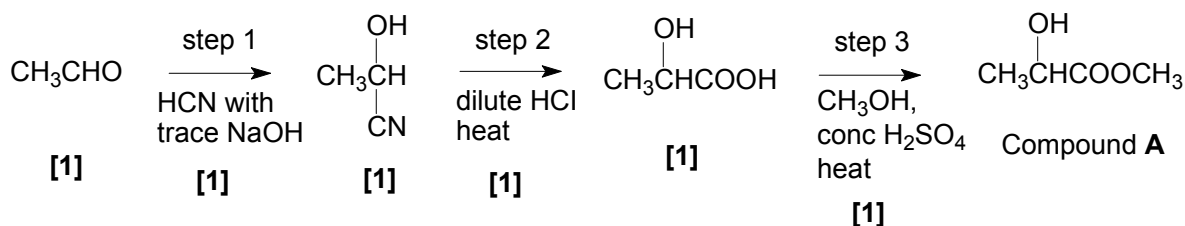
[1] Correct deduction that lactic acid is a weak acid.

- (iii) A buffer solution **resists changes in pH** when **small** quantities of an acid or an alkali are added to it. [1]

- (iv) When a small amount of OH^- is added,
 $\text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{OH}^- \longrightarrow \text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}_2\text{O}$ [1]

When a small amount of H^+ is added,
 $\text{CH}_3\text{CH}(\text{OH})\text{COO}^- + \text{H}^+ \longrightarrow \text{CH}_3\text{CH}(\text{OH})\text{COOH}$ [1]

(b)



- (c) (i) $K_c = \frac{[\text{NO}]^2 [\text{Cl}_2]}{[\text{NOCl}]^2}$ [1]

(ii)

	2NOCl (g)	\rightleftharpoons	2NO (g)	$+ \text{Cl}_2 \text{ (g)}$
Initial/mol	4		0	0
Change/mol	-2(0.6)		+2(0.6)	+0.6
Eqm/mol	2.8		1.2	0.6

[1] each for correct calculation of equilibrium amount of NOCl and NO

$$K_c = \frac{[\text{NO}]^2 [\text{Cl}_2]}{[\text{NOCl}]^2} = \frac{\left(\frac{1.2}{2}\right)^2 \left(\frac{0.6}{2}\right)}{\left(\frac{2.8}{2}\right)^2} = 5.51 \times 10^{-2} \text{ mol dm}^{-3}$$

[1] calculate concentration of species

[1] correct value of K_c and units

- (iii) 1. Position of equilibrium (POE) is **unchanged**. [1]

The catalyst **increases both the rate of forward and backward reactions to the same extent**. Hence, POE is unaffected just that the equilibrium is achieved faster. [1]

2. When temperature increases, the position of equilibrium shifts to the **right** to **favour the forward endothermic** reaction to absorb the extra heat. [1]