

Section A

- 1 (a) (i) Ionic radius of Si^{4+} is smaller than that of Na^+ . [3]
This is because both cations have the same number of electrons / electrons experience same screening effect,
but Si^{4+} has more protons than Na^+ .
Hence attraction of the electrons to the nucleus is stronger for Si^{4+} .
- (ii) P^{3-} has a larger ionic radius than Si^{4+} .
This is because P^{3-} has an additional quantum shell of electrons.

[1]: stating difference in (i) and (ii)
[1]: explanation in (i)
[1]: explanation in (ii)

- (b) (i)

	<u>Structure</u>	<u>Bonding</u>
A	Giant	Ionic
B	Giant	Covalent
C	Giant	Ionic
D	Simple	Covalent

 [2]

[1] for every 2 correct structures with corresponding bonding

- (ii)

	<u>Identity</u>
A	MgO
B	SiO_2
C	Na_2O
D	P_4O_{10}

 [2]

[1] for every 2 correct identities
(do not accept SO_2/SO_3 for D, both are gases at rtp)

Explanation:

A and C has good electrical conductivity when molten

⇒ giant ionic (i.e. can be Na_2O , MgO or Al_2O_3)

Since C reacts with water to form a strongly alkaline solution, C must be Na_2O .

Since A reacts very little with water to form a weakly alkaline solution, A must be MgO.

Note: Al_2O_3 does not dissolve in water!

B and D has poor electrical conductivity when molten

⇒ giant covalent (i.e. SiO_2) or simple molecular (i.e. oxides of P or S)

Since B does not dissolve in water, B must be SiO_2 .

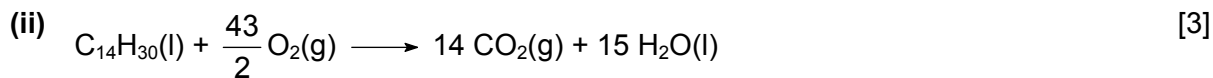
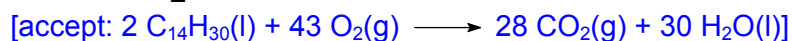
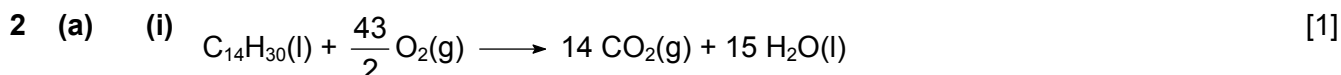
Since D reacts with water to form a strongly acidic solution, D must be P_4O_{10} , SO_2 or SO_3 (cannot be SO_2/SO_3 due to the high m.p. given).

Note: P_4O_6 reacts with water to form an acidic solution of around pH 2.

- (c) NaCl has a giant ionic structure with strong electrostatic forces of attraction between Na^+ and Cl^- ions. A lot of energy is required to break these strong ionic bonds in order to melt NaCl . Hence, it has a very high melting point. [2]

SiCl_4 has a simple molecular structure with weak van der Waals' forces between SiCl_4 molecules. Hence, they have low melting points.

[1] for one correct structure and bonding + comparison of energy and mp



Bonds broken	Energy	Bonds formed	Energy
13 C–C	13 × 350	14×2 C=O	14 × 2 × 740
30 C–H	30 × 410	15×2 O–H	15 × 2 × 460
$\frac{43}{2} \text{O}=\text{O}$	$\frac{43}{2} \times 496$		34520 kJ mol ⁻¹
	27514 kJ mol ⁻¹		(given out)
	(taken in)		

$$\Delta H_f^\circ (\text{kerosene}) = +27514 - 34520$$

$$= -7006 \text{ kJ mol}^{-1}$$

[1] for the 5 bonds and their correct bond energies

[1] for correct no of bonds broken and formed

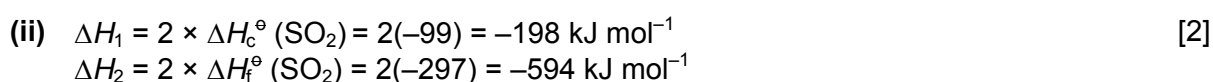
[1] for final answer

- (iii) 1 mol of kerosene produces 7006 kJ of energy [2]
 \Rightarrow 198 g of kerosene produces 7006 kJ of energy
 \Rightarrow 1 g of kerosene produces $7006 \div 198 = 35.4$ kJ of energy

Diesel fuel is more efficient, as it produces more energy per unit mass/gram.

[1] for calculation – allow ecf from (ii)

[1] for conclusion (correct choice of fuel + explanation)



$$\Delta H_3 = \Delta H_2 + \Delta H_1 = -792 \text{ kJ mol}^{-1}$$

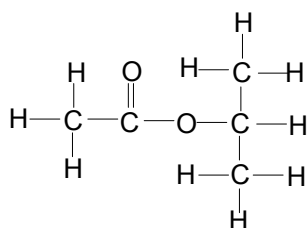
$$\Delta H_f^\circ (\text{SO}_3) = \frac{1}{2} \Delta H_3 = -396 \text{ kJ mol}^{-1}$$

[1] for application of Hess' Law (allow ecf from (i))

[1] for $\Delta H_f^\circ (\text{SO}_3)$

3 (a) (i) $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$ [1]

(ii) [1]



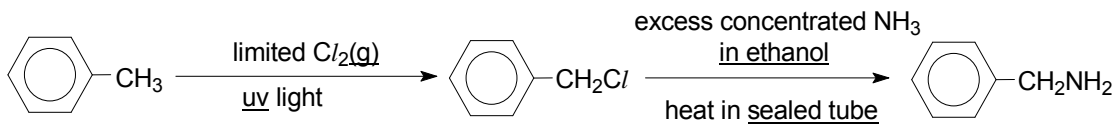
(iii) $\text{CH}_3\text{CO}_2\text{CH}(\text{CH}_3)_2 + \text{OH}^- \longrightarrow \text{CH}_3\text{COO}^- + (\text{CH}_3)_2\text{CHOH}$ [1]

(iv) $\text{CH}_3\text{CH}=\text{CH}_2$ / propene [1]

(v) Add aq. Br_2 to a sample of the reaction mixture. [1]

Orange aq. Br_2 solution will be decolourised in the presence of an alkene. [1]

(b) [3]



[1]: correct intermediate

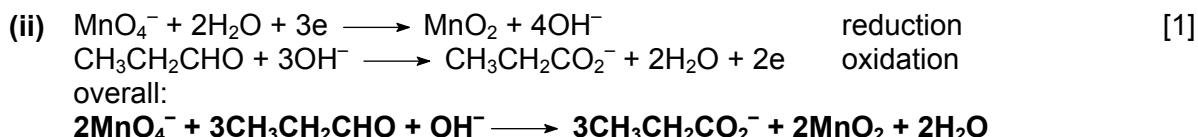
[1]: correct reagents and conditions for each step

4 (a) $n(\text{ethanol}) = 9.2 \div 46.0$ [1]
 $= 0.200 \text{ mol}$

(b) (i) To keep the temperature constant so that the position of equilibrium will not shift due to changes in temperature. [1]

(ii) To quench the reaction mixture by reacting away the H_2SO_4 catalyst [1]

(c) (i) redox / oxidation [1]



(iii)

	propanal(l)	ethanol(l)	acetal F(l)	water(l)
initial amount / mol	0.1	0.2	0	0
change in amount / mol	$-x$	$-2x$	$+x$	$+x$
equilibrium amount / mol	$0.1 - x$	$0.2 - 2x$	x	x

[1]

(iv) $n(\text{KMnO}_4)$ used in the titration $= 0.0253 \times 1.00$ [1]
 $= 0.0253 \text{ mol}$

(v) 1 mol of propanal requires $\frac{2}{3}$ mol of MnO_4^- for reaction. [3]

Hence $(0.1 - x)$ mol of propanal requires $\frac{0.2 - 2x}{3}$ mol of MnO_4^- for reaction.

1 mol of alcohol requires $\frac{4}{3}$ mol of MnO_4^- for reaction.

Hence $(0.2 - 2x)$ mol of ethanol requires $\frac{0.8 - 8x}{3}$ mol of MnO_4^- for reaction.

$$\text{Total } n(\text{MnO}_4^-) \text{ used in the titration} = \frac{0.2 - 2x}{3} + \frac{0.8 - 8x}{3} = 0.0253$$

$$\Rightarrow x = 0.09241$$

equilibrium amount of:

propanal	$= 0.1 - 0.09241$	$= 0.00759 \text{ mol}$
ethanol	$= 0.2 - 2(0.09241)$	$= 0.0152 \text{ mol}$
acetal	$= 0.0924 \text{ mol}$	
water	$= 0.0924 \text{ mol}$	

[1] for using mole ratio and total $n(\text{KMnO}_4)$ in working

[1] for x

[1] for propanal and ethanol

(d)
$$K_c = \frac{[\text{acetal}][\text{H}_2\text{O}]}{[\text{propanal}][\text{ethanol}]^2}$$

$$= \frac{\left(\frac{0.0924}{0.0250}\right)\left(\frac{0.0924}{0.0250}\right)}{\left(\frac{0.00759}{0.0250}\right)\left(\frac{0.0152}{0.0250}\right)^2}$$

$$= \frac{(0.0924)(0.0924)}{(0.00759)\left(\frac{0.0152^2}{0.0250}\right)}$$

$$= 122 \text{ mol}^{-1} \text{ dm}^3$$

[3]

[1] for expression

[1] for K_c value

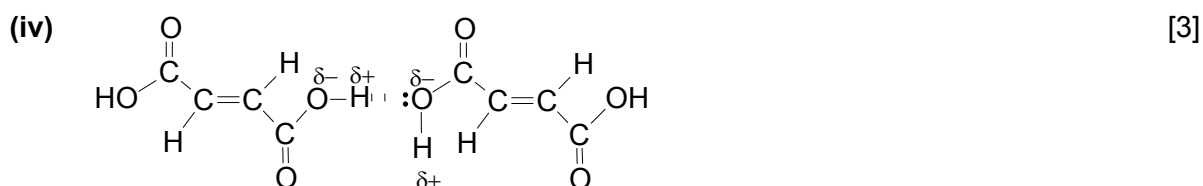
[1] for units

- 5 (b) (i) Reaction I: dilute H₂SO₄, heat (under reflux) [4]
 Reaction II: excess concentrated H₂SO₄, 170 / 180 °C



G

- (iii) The presence of π bond in the C=C double bond prevent free rotation about the double bond. [1]



[1] correct O–H bond
 [1] one lone pair in correct place in H bond
 [1] correct dipoles on at least one O–H bond

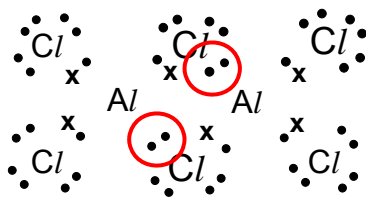
- (v) **G** can form intramolecular hydrogen bonding leading to less extensive intermolecular hydrogen bonding than fumaric acid, resulting in lower melting point. [1]
- (b) (i) $n(\text{NaOH}) = 0.05 \times 32 \div 1000 = 1.6 \times 10^{-3} \text{ mol}$ [2]
 $n(\text{fumaric acid}) = 1.6 \times 10^{-3} \div 2 = 8.0 \times 10^{-4} \text{ mol}$
 $[\text{fumaric acid}] = 8.0 \times 10^{-4} \div 20/1000$
 $= \mathbf{0.0400 \text{ mol dm}^{-3}}$

- (ii) Phenolphthalein. [3]
- The pH at the end (equivalence) point for this titration is around 8.5. Phenolphthalein has a working pH range that lies within the range of rapid pH change for the titration.

- (c) (i) $K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{CO}_2\text{H}]}$ [1]
- (ii) $1.84 \times 10^{-5} = \frac{[\text{H}^+](0.20)}{0.30}$ [2]
 $[\text{H}^+] = 1.84 \times 10^{-5} \times \frac{0.30}{0.20} = 2.76 \times 10^{-5} \text{ mol dm}^{-3}$
 $\text{pH} = -\lg(2.76 \times 10^{-5}) = \mathbf{4.56}$
- (iii) $\text{H}^+ + \text{CH}_3\text{CO}_2^- \rightarrow \text{CH}_3\text{CO}_2\text{H}$ [2]
 $\text{OH}^- + \text{CH}_3\text{CO}_2\text{H} \rightarrow \text{CH}_3\text{CO}_2^- + \text{H}_2\text{O}$ (no mark for using “HA”)

6 (a) (i) Al_2Cl_6

[2]



[1]: correct dot and cross diagram

[1]: with two dative bonds (circled) between Cl and Al (each with 2 dots or 2 crosses) clearly indicated

- (ii) Increasing the temperature favours the forward endothermic reaction. Position of equilibrium shifts right to absorb the increase of heat energy. This results in an increase in amount of $AlCl_3$ and decrease in amount of Al_2Cl_6 .

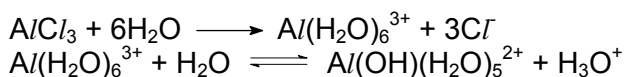
[1]

[1]

- (b) An orange solution with pH 3 is observed.

[3]

$AlCl_3$ dissolves with slight hydrolysis



[1]: correct colour (accept yellow)

[1]: correct pH

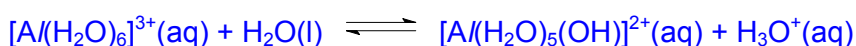
[1]: correct equations

Explanation not required

$AlCl_3$ dissolves in water where Al^{3+} ions form complex ions $[Al(H_2O)_6]^{3+}$.



Al^{3+} has a high charge density, hence a high polarizing power. It polarises the O–H bond in water molecules and weakens it to produce a proton, making the solution acidic.



- (c) (i)

Particle	Mass number	Number of		
		protons	electrons	neutrons
L^{2+}	111	49	47	62
M^{2-}	51	25	27	26

[1]

- (ii) Must be less than sum of 1st IE + 2nd IE of Ga = 577 + 1980 = 2557

[1]

[1]: any specific value < 2557 (must be shown)

In is below Ga in the Period Table so the sum of its 1st and 2nd ionisation energies is less than that of Ga. As the no. of quantum shell increases down the group / valence electrons of In are further away from the nucleus and experience less electrostatic attraction by the nucleus, hence requiring less energy to remove it.

[1]

- (iii) angle of deflection $\propto \frac{\text{charge}}{\text{mass}} \left(\frac{z}{m} \right)$ [2]

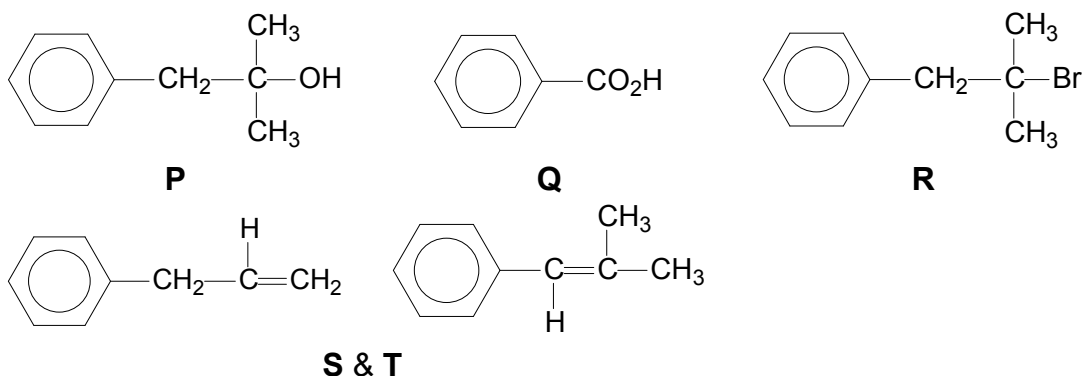
Particle	z/m ratio	angle of deflection
Ca^{2+}	$\frac{+2}{40}$	$+10.0^\circ$
M^{2-}	$\frac{-2}{51}$	$\left[\frac{-2}{51} \div \frac{+2}{40} \right] \times (+10.0^\circ)$ $= -7.84^\circ$

[1]: correct sign (u/c)

[1]: correct magnitude with working

(d) [8]

Observation	Type of reaction	Deduction
Compound P has the molecular formula of $\text{C}_{10}\text{H}_{14}\text{O}$.	–	A contains a benzene ring since the C:H ratio is approximately 1:1.
When P is heated with acidified potassium manganate(VII), it forms compound Q , $\text{C}_7\text{H}_6\text{O}_2$.	side-chain oxidation	Q has a side chain COOH P is a mono-substituted benzene.
The solution remains orange when P is heated with acidified potassium dichromate(VI).	absence of oxidation	P is resistant to oxidation. P must be a tertiary alcohol or ketone.
Heating P under reflux with a mixture of sodium bromide and concentrated sulfuric acid gives compound R .	substitution	P is an alcohol R is bromoalkane
When R is heated under reflux with ethanolic sodium hydroxide, a mixture of two different isomeric alkenes S and T is formed.	elimination (of HBr)	



2–4pt = 1m

5–7pt = 2m

8–11pt = 3m

[1]: each correct structures

7 (a) (i)

[4]

experiment number	volume of $I_2(aq) / \text{cm}^3$	time taken / s	rate
1	20	21	$\frac{20}{21}$
2	20	42	$\frac{20}{42}$
3	40	84	$\frac{40}{84}$
4	40	112	$\frac{40}{112}$

Comparing experiment. 1 and 2,
When volume of HCl used is halved, rate is halved.
 \Rightarrow order of reaction with respect to HCl is 1

Comparing experiment 2 and 3,
When volume of I_2 used is doubled, rate remains the same
 \Rightarrow order of reaction with respect to I_2 is 0

Comparing experiment 3 and 4,

$$\frac{\text{rate}_3}{\text{rate}_4} = \frac{k [\text{CH}_3\text{COCH}_3]_3^x [I_2]_3^0 [HCl]_3}{k [\text{CH}_3\text{COCH}_3]_4^x [I_2]_4^0 [HCl]_4}$$

$$\frac{40/84}{40/112} = \frac{[\text{CH}_3\text{COCH}_3]_3^x [HCl]_3}{[\text{CH}_3\text{COCH}_3]_4^x [HCl]_4}$$

$$\frac{112}{84} = \frac{(40)^x (20)}{(20)^x (30)} \Rightarrow x = 1$$

\Rightarrow order of reaction with respect to CH_3COCH_3 is 1

Therefore, rate equation for this equation is $\text{rate} = k [\text{CH}_3\text{COCH}_3] [H^+]$.

[1]: correct determination of rate for Expt 1 to 4
[1]: each correct deduction of order

(ii) $\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$

[1]

(iii) 84 s

[1]

Working not required:

Notice that the total volume for experiment 5 is halved. Hence the concentration is doubled.

Expt	vol. of propanone / cm^3	vol. of $I_2(aq)$ / cm^3	vol. of HCl / cm^3	vol. of water / cm^3	time taken / s	rate
5	10	20	20	0	t_5	
5'	20	40	40	0	t_5	
4	20	40	30	10	112	$\frac{40}{112}$

Comparing experiment 4 and 5', where [propanone] and [I₂] are constant,

$$\frac{\text{rate}_{5'}}{\text{rate}_4} = \frac{[\text{HCl}]_{5'}}{[\text{HCl}]_4}$$

$$\frac{40/t_{5'}}{40/112} = \frac{[\text{HCl}]_{5'}}{[\text{HCl}]_4}$$

$$\frac{112}{t_5} = \frac{40}{30}$$

$$t_5 = 84 \text{ s}$$

(iv)

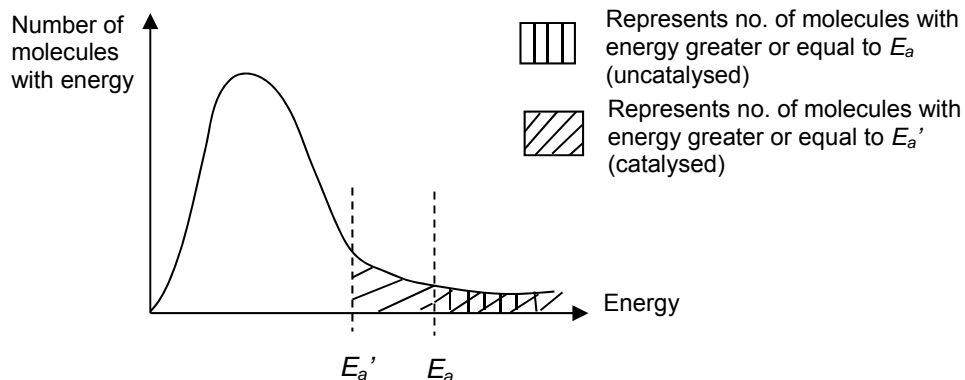


Diagram should have correct label of axes, correct shape of curve, E_a for uncatalysed and catalysed reactions labelled clearly, correct shaded area [1]

The catalyst provide an alternative pathway that has a lower activation energy (E_a' < E_a). [1]

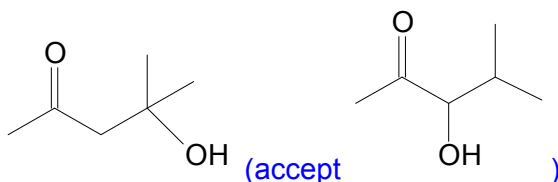
More molecules have energies greater than or equal to the lowered activation energy E_a'. This results in an increase in the frequency of effective collisions and hence rate of reaction increases. [1]

(v) CH₃COO⁻Na⁺ and CHI₃ [2]

[1] each

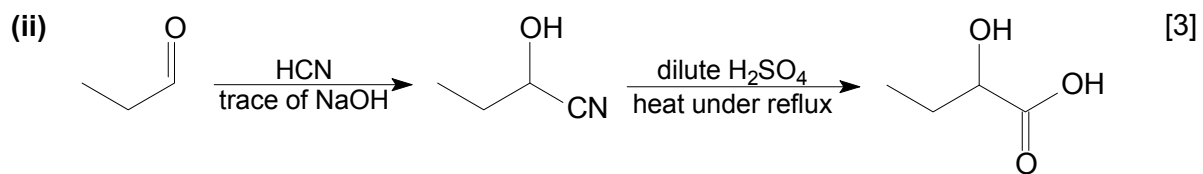
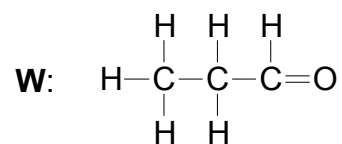
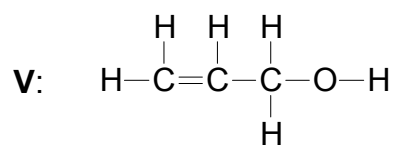
(b) (i) Elimination (of H₂O) [1]

(ii) [1]



(iii) CH₃CH₃CHO [1]

(c) (i) [2]



[1] for reagents and conditions for each step
 [1] for correct intermediate

(iii) [1]

