

ignore state symbols

(ii) [2]

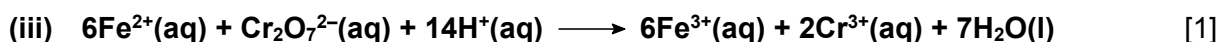
|   |       |              |              |
|---|-------|--------------|--------------|
| titration number                        | 1     | 2            | 3            |
| initial burette reading / $\text{cm}^3$ | 0.00  | 19.95        | 2.10         |
| final burette reading / $\text{cm}^3$   | 19.95 | 39.05        | 22.15        |
| titre / $\text{cm}^3$                   | 19.95 | <u>20.00</u> | <u>20.05</u> |

$$\begin{aligned}\text{average volume of KI used} &= \frac{1}{3}(19.95 + 20.00 + 20.05) \\ &= \underline{20.00 \text{ cm}^3}\end{aligned}$$

$$\begin{aligned}n(\text{K}_2\text{Cr}_2\text{O}_7) \text{ required} &= \frac{20.00}{1000} \times 0.100 \\ &= \underline{0.00200 \text{ mol}}\end{aligned}$$

[1]: correctly determine the titre for run 2 and 3 and used all 3 titres to find the average titre (accept if students used any 2 titres which are within  $0.05 \text{ cm}^3$ )

[1]:  $n(\text{K}_2\text{Cr}_2\text{O}_7)$



ignore state symbols

(iv) [2]

$$\begin{aligned}n(\text{Fe}^{2+}) \text{ in } 25.0 \text{ cm}^3 \text{ of solution} &= 6 \times 0.00200 \\ &= 0.0120 \text{ mol} \\ n(\text{Fe}^{2+}) \text{ in } 250 \text{ cm}^3 \text{ of solution} &= 0.0120 \times 10 \\ &= \underline{0.120 \text{ mol}}\end{aligned}$$

$$\begin{aligned}\text{mass of Fe present} &= 0.120 \times 55.8 \\ &= 6.696 \text{ g}\end{aligned}$$

$$\begin{aligned}\% \text{ by mass of iron in the sample of iron ore} &= \frac{6.696}{11.05} \times 100\% \\ &= \underline{60.6 \%}\end{aligned}$$

[1]:  $n(\text{Fe}^{2+})$  originally present in  $250 \text{ cm}^3$  (scaling)

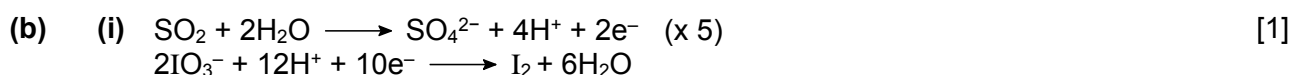
[1]: % by mass of iron in iron ore (ecf)

2 (a) (i)  $\text{PSI of PM}_{10} = \frac{200-100}{350-150}(320-150)+100 = \underline{185}$  [2]  
 $\text{PSI of CO} = \frac{300-200}{34-17}(20-17)+200 = \underline{218}$

[1] each

(ii) overall PSI is the maximum value out of 185, 218, 112, 133 and 150. [1]  
Hence overall PSI is 218. ecf

(iii) I would advise the PE teacher to avoid strenuous physical exertion / conduct the lesson indoor (words to the effect based on valid reasoning). [1]  
ecf



$$\begin{aligned} n(\text{NaOH}) \text{ reacted} &= 0.01 \times 0.005 \\ &= 5 \times 10^{-5} \text{ mol} \end{aligned}$$

$$n(\text{H}^+) \text{ reacted with NaOH} = 5 \times 10^{-5}$$

$$\begin{aligned} n(\text{SO}_2) \text{ in } 1 \text{ m}^3 \text{ sample of air} &= 5 \times 10^{-5} \times \frac{5}{8} \\ &= \underline{3.125 \times 10^{-5} \text{ mol}} \end{aligned}$$

$$\begin{aligned} \text{mass of SO}_2 \text{ in } 1 \text{ m}^3 \text{ sample of air} &= 3.125 \times 10^{-5} \times 64.1 \\ &= 0.00200 \text{ g} \\ &= 2000 \mu\text{g} \end{aligned}$$

$$\text{concentration of SO}_2 = \underline{2000} \mu\text{g m}^{-3}$$

[1]:  $[\text{SO}_2]$  in  $\text{mol m}^{-3}$

[1]:  $[\text{SO}_2]$  in  $\mu\text{g m}^{-3}$

(c) (i) In  $1 \text{ m}^3$ , [1]  
mass of air is 1 kg

$$\text{mass of PM}_{10} \text{ is } \frac{2 \times 10^{-5}}{100} \times 1 = 2 \times 10^{-7} \text{ kg} = 0.0002 \text{ g} = 200 \mu\text{g}$$

$$\text{Hence concentration of PM}_{10} \text{ is } \underline{200} \mu\text{g m}^{-3}$$

(ii) Since concentration calculated in (c)(i) is more than 180, the sample of air has [1]  
exceeded the limit. ecf

The German city of Leipzig will be fined.

- 3 (a) (i) carboxylic acid [1]  
aldehyde

[1] both correct

- (ii) Add Tollens' reagent / 2,4-dinitrophenylhydrazine, warm (accept Fehling's) [2]

For aldehyde, a silver mirror (or grey ppt) is formed / orange ppt formed.  
No ppt formed for carboxylic acid.

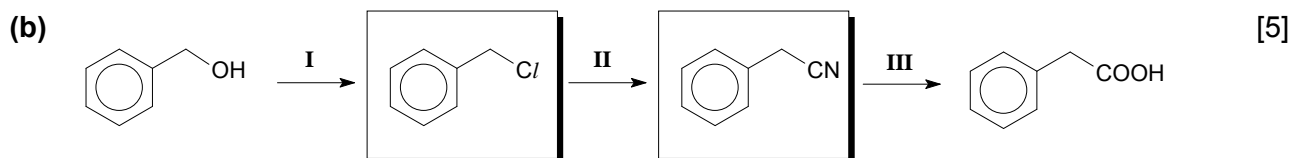
Add Na or Mg metal.

For aldehyde, no gas evolved.

For carboxylic acid, effervescence observed, gas gives a 'pop' sound with lighted splint.

[1]: reagent and condition

[1]: observation



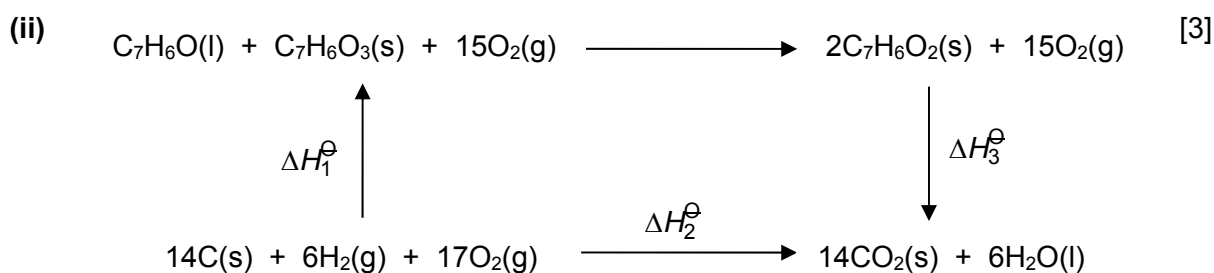
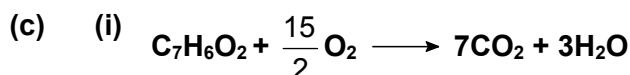
stage I: anhydrous  $\text{PCl}_5$ , room temp (accept  $\text{SOCl}_2$ ,  $\text{PCl}_3$  (w heat) or Br analogous,  $\text{NaBr}$  in concentrated  $\text{H}_2\text{SO}_4$  (w heat))

stage II: ethanolic  $\text{KCN}$ , heat under reflux

stage III: dilute  $\text{H}_2\text{SO}_4$ , heat (accept dil.  $\text{HCl}$ )

[1] each intermediate

[1] each set of reagent and condition



$$\begin{aligned}\Delta H_1^\ominus &= \Delta H_f^\ominus \text{C}_7\text{H}_6\text{O}(\text{l}) + \Delta H_f^\ominus \text{C}_7\text{H}_6\text{O}_3(\text{s}) \\ &= (-87) + (-367) \\ &= \underline{-454 \text{ kJ mol}^{-1}}\end{aligned}$$

$$\begin{aligned}\Delta H_2^\ominus &= 14\Delta H_c^\ominus \text{carbon} + 6\Delta H_c^\ominus \text{hydrogen} \\ &= 14(-393.5) + 6(-285.8) \\ &= \underline{-7223.8 \text{ kJ mol}^{-1}}\end{aligned}$$

$$\begin{aligned}\Delta H_3^\ominus &= 2\Delta H_c^\ominus \text{C}_7\text{H}_6\text{O}_2(\text{s}) \\ &= 2(-3228) \\ &= \underline{-6456 \text{ kJ mol}^{-1}}\end{aligned}$$

[1] each unknown enthalpy change

(iii) By Hess' Law,

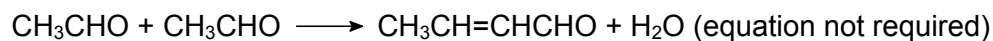
$$\begin{aligned}\Delta H_r^\ominus \text{ for reaction 1} &= -\Delta H_1^\ominus + \Delta H_2^\ominus - \Delta H_3^\ominus \\ &= -(-454) + (-7223.8) - (-6456) \\ &= \underline{-314 \text{ kJ mol}^{-1}}\end{aligned}$$

[1]

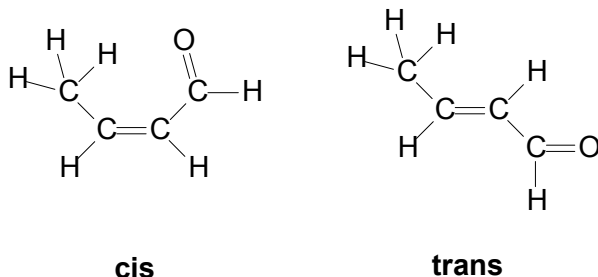
- 4 (a) (i) stage I:  $\text{K}_2\text{Cr}_2\text{O}_7$ , dilute  $\text{H}_2\text{SO}_4$ , warm with immediate distillation [2]  
 stage III:  $\text{H}_2$ , Pt / Pd, room temperature (accept Ni, with or w/o warm/heat)

[1] each

- (ii) condensation [1]



- (iii) cis-trans isomerism [2]



[1]: type of isomerism with correct label

[1]: displayed structure

- (iv)  [2]

**G** is reduced to **H** (an alcohol) which reacts with sodium metal to give effervescence of  $\text{H}_2$ . **H** reacts with aqueous  $\text{Br}_2$  because of the  $\text{C}=\text{C}$  bond present.

[1]: structure of **H**

[1]: explanation

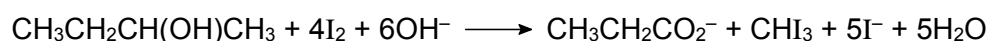
- (b) (i) compounds with the same molecular formula but different structural formula / structure [1]

- (ii) [2]
- |   |   |                             |
|---|---|-----------------------------|
| $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$ | $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{OH}$ | $(\text{CH}_3)_3\text{COH}$ |
| <b>J</b>  | <b>K</b>  | <b>L</b>                    |
| $2^\circ$   | $1^\circ$   | $3^\circ$                   |

[1]: all 3 structural isomers correctly identified and labelled (in any order)

[1]: corresponding classification of 3 alcohols

- (iii) **J** reacts with alkaline aqueous iodine [2]



[1]: correctly identified the alcohol with positive reaction with  $\text{I}_2/\text{OH}^-$

[1]: balanced equation

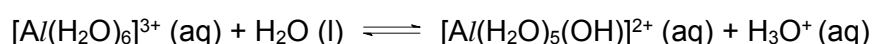
- 5 (a) (i) NaCl exists as a giant ionic lattice with strong electrostatic forces of attraction between  $\text{Na}^+$  and  $\text{Cl}^-$  ions. A lot of energy is required to break these strong ionic bonds in order to melt NaCl. Hence, it has a very high melting point. [1]

$\text{AlCl}_3$ ,  $\text{CCl}_4$  and  $\text{SiCl}_4$  are simple molecular molecules with weak instantaneous dipole-induced dipole attraction between the molecules. Hence, they have low melting points. [1]

- (ii) NaCl dissolves in water without further reaction to give a neutral solution (pH 7). [6]  
Hydrolysis does not occur for  $\text{Na}^+$  and  $\text{Cl}^-$ . max



$\text{AlCl}_3$  dissolves in water with some hydrolysis (due to the large polarising power of  $\text{Al}^{3+}$  ions) to give an acidic solution (pH 3)



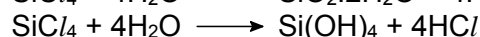
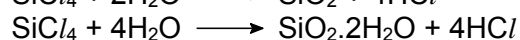
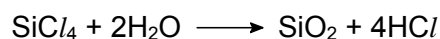
$\text{CCl}_4$  will not undergo hydrolysis. (pH 7)

This is because  $\text{CCl}_4$  has no vacant low-lying (energetically accessible) d-orbitals to accept the lone pair of electrons from the water molecules.

or

(steric hindrance) it is difficult for the water molecule to attack the carbon atoms due to the large chlorine atoms present.

$\text{SiCl}_4$  undergo complete hydrolysis in water to give a strongly acidic solution due to the presence of empty low-lying 3d orbitals to accommodate the lone pair of electrons from water molecules. (pH 1)



[1] each description with correct pH

[1] each balanced equation

- (b) (i) Valence electron pairs (bond pairs and lone pairs) around an atom of a molecule arrange themselves as far apart as possible to minimise inter-electronic repulsion. [1]

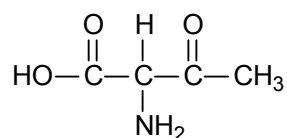
The strength of repulsion between electron pairs decreases in the order: lp-lp > lp-bp > bp-bp. [1]

Since there are 2 bond pairs and 1 lone pair around N atom, bond angle will be 117°. (accept  $110^\circ < \text{angle} < 120^\circ$ ) [1]

- (ii) Type: substitution [1]  
Conditions:  $\text{Br}_2$ ,  $\text{AlBr}_3$  or  $\text{FeBr}_3$  catalyst [1]

- (iii) instantaneous dipole-induced dipole / permanent dipole-permanent dipole / van der Waals [1]

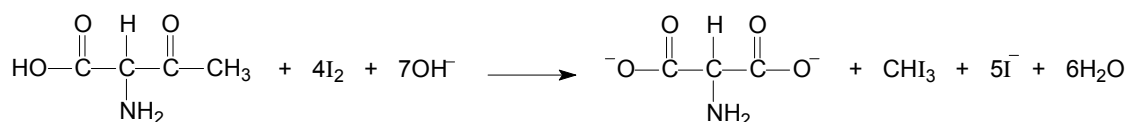
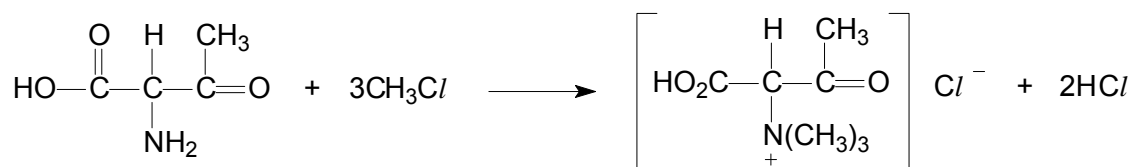
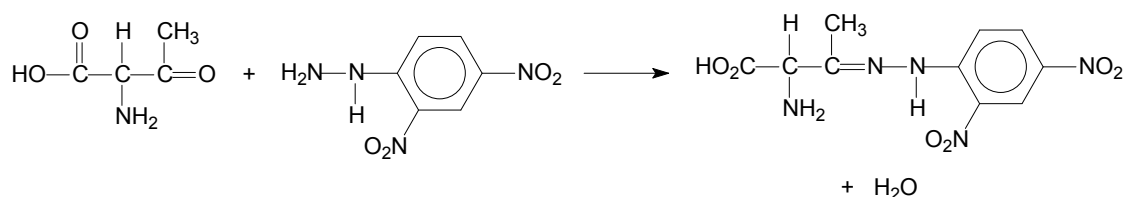
(c)

**W**

| Observations   | Type of reaction | Deduction  |
|--|------------------|--|
| Compound <b>W</b> contains a primary amine functional group.   |                  | <b>W</b> contains R-NH <sub>2</sub> .  |
| <b>W</b> gives an orange precipitate when treated with 2,4-DNPH but it has no reaction with Tollens' reagent.                        | condensation     | <b>W</b> is a ketone not an aldehyde.  |
| <b>W</b> gives a yellow precipitate when warmed with alkaline aqueous iodine.  | (mild) oxidation | <b>W</b> contains the structure RCOCH <sub>3</sub> or RCH(OH)CH <sub>3</sub> . |
| <b>W</b> has a proton chemical shift (δ) of 13.0 ppm.  |                  | from page 34 of the <i>Data Booklet</i> ,<br><b>W</b> contains -COOH.          |
| <b>W</b> is heated with excess CH <sub>3</sub> Cl, it gives C <sub>7</sub> H <sub>14</sub> NO <sub>3</sub> Cl, as the major product. | substitution     | further / multi-substitution occurs / product is a substituted amine           |

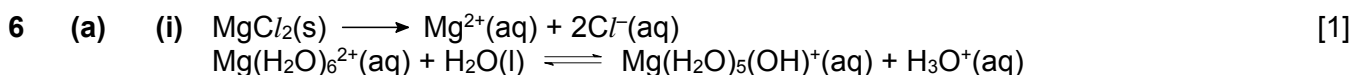
[2]: 5–8 points

[1]: 2–4 points

(accept if -CO<sub>2</sub>H is not neutralised, i.e. 6OH<sup>-</sup>/5H<sub>2</sub>O)[1]: structure of **W**

[2]: deductions and types of reactions

[1] each balanced equation



(ignore state symbol and if 1<sup>st</sup> equation is not given)

(ii)  $K_a = \frac{[\text{Mg}(\text{H}_2\text{O})_5(\text{OH})^{+}][\text{H}_3\text{O}^{+}]}{[\text{Mg}(\text{H}_2\text{O})_6^{2+}]}$  [1]

(iii) from the graph, pH = 6 [1]  
 $[\text{H}^{+}] = 10^{-6}$   
 $= 1 \times 10^{-6} \text{ mol dm}^{-3}$

- (iv) (I) yellow [1]  
 (II) yellowish pink / pinkish yellow  
 (III) orange pink

(b) (i) Activation energy of reverse reaction =  $9.6 + 173.2$  [1]  
 $= 182.8 \text{ kJ mol}^{-1}$

(ii) High pressure [6]  
 Position of equilibrium (P.O.E.) remains unchanged since there are equal number of moles of gaseous reactants and products particles.  
 Rate will increase since there are more gaseous particles per unit volume thus increases the frequency of effective collisions.

High temperature

P.O.E. shifts left, since backward endothermic reaction is favoured to remove the excess heat.

Rate will increase as the average kinetic energy of particles is increased, leading to greater frequency of effective collisions.

Presence of catalyst

P.O.E. remains unchanged, as the rate of the forward and reverse reaction increase by the same extent.

Rate of reaction will increase since the presence of catalyst provides an alternative pathway of lowered activation energy. More reactant molecules will possess energy greater than or equal to the activation energy, leading to greater frequency of effective collisions.

[1] each effect on P.O.E.

[1] each effect on rate of reaction

(d) (i) Taking gradient at  $t = 0$ , [1]  
 set 1 =  $\frac{0.004}{8}$   
 $= 5 \times 10^{-4} \text{ mol dm}^{-3} \text{ min}^{-1}$

set 2 =  $\frac{0.004}{4}$   
 $= 1 \times 10^{-3} \text{ mol dm}^{-3} \text{ min}^{-1}$

[1] both correct (accept 6–8 min for set 1, 3–4min for set 2)



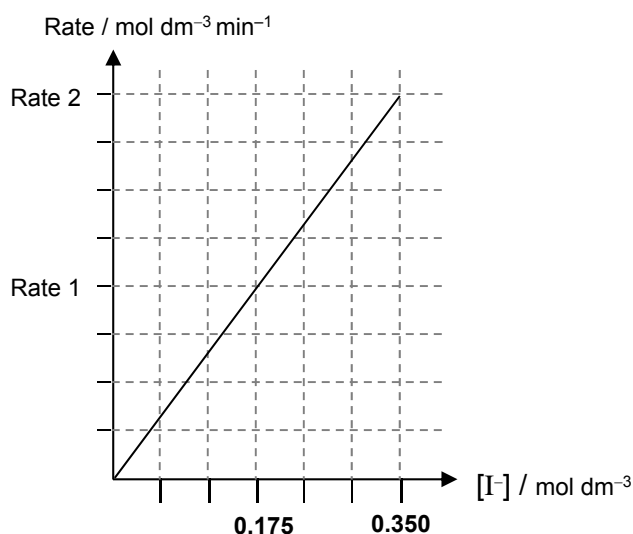
- (ii) When  $[H^+]$  decreases from  $0.004 \text{ mol dm}^{-3}$  to  $0.002 \text{ mol dm}^{-3}$ , time taken is 3 min [2]  
 When  $[H^+]$  decreases from  $0.002 \text{ mol dm}^{-3}$  to  $0.001 \text{ mol dm}^{-3}$ , time taken is 3 min  
 Since  $t_{1/2}$  is constant at 3 min, order of reaction wrt  $H^+$  is 1.

|              | $[H_2O_2] / \text{mol dm}^{-3}$ | $[I^-] / \text{mol dm}^{-3}$ | $[H^+] / \text{mol dm}^{-3}$ | initial rate / $\text{mol dm}^{-3} \text{ min}^{-1}$ |
|--------------|---------------------------------|------------------------------|------------------------------|--|
| <b>Set 1</b> | 0.200                           | 0.175                        | 0.004                        | 0.0005   |
| <b>Set 2</b> | 0.200                           | 0.350                        | 0.004                        | 0.001  |

Comparing **Set 1** and **Set 2**, when concentration of  $[I^-]$  is doubled, the rate is also doubled. Since rate is directly proportional to  $[I^-]$ , order of reaction wrt  $[I^-]$  is 1.

[1] each order of reaction

- (iii) [2]



[1]: straight line passing thru the origin

[1]: labels using both sets of data

- (iv) Based on student's guess, rate =  $k [H_2O_2]^2 [H^+] [I^-]$  [2]

$$\frac{\text{rate}_3}{\text{rate}_1} = \frac{(0.3)^2 (0.004) (0.10)}{(0.2)^2 (0.004) (0.175)}$$

$$\text{rate}_3 = 1.28 \times 0.0005$$

$$= \underline{6.43 \times 10^{-4} \text{ mol dm}^{-3} \text{ min}^{-1}}$$

Alternative

|               | $[H_2O_2] / \text{mol dm}^{-3}$ | $[I^-] / \text{mol dm}^{-3}$ | $[H^+] / \text{mol dm}^{-3}$ | initial rate / $\text{mol dm}^{-3} \text{ min}^{-1}$ |
|---------------|---------------------------------|------------------------------|------------------------------|--|
| <b>Set 1</b>  | 0.2                             | 0.175                        | 0.004                        | 0.0005   |
| <b>Set 1a</b> | 0.2                             | 0.10                         | 0.004                        | 0.000286   |
| <b>Set 3</b>  | 0.3                             | 0.10                         | 0.004                        | 0.000644   |

When  $[I^-]$  is decreased from 0.175 to 0.10  $\text{mol dm}^{-3}$ ,

$$\text{rate} = 0.0005 \times \left( \frac{0.10}{0.175} \right) = 0.000286 \text{ mol dm}^{-3}.$$

When  $[\text{H}_2\text{O}_2]$  is increased from 0.2 to 0.3  $\text{mol dm}^{-3}$ ,

$$\text{rate} = 0.000286 \times \left(\frac{0.30}{0.20}\right)^2 = \underline{0.000644 \text{ mol dm}^{-3}}$$

[1]: proportional decrease in rate when  $[\text{I}^-]$  decreases by 1.75.

[1]: rate increases by  $(1.5)^2$  when  $[\text{H}_2\text{O}_2]$  increases by 1.5.

(v)  $\text{Rate} = k [\text{H}_2\text{O}_2] [\text{I}^-] [\text{H}^+]$   
 $4.4 \times 10^{-5} = k(0.002)(0.2)(0.2)$   
 $k = \underline{0.550 \text{ mol}^{-2} \text{ dm}^6 \text{ s}^{-1}}$

[2]

[1]: value of  $k$

[1]: units

7 (a) (i) I.E. decreases down the group [2]  
Nuclear charge increases, the number of electron shells also increases and  
valence electrons are further away from the nucleus.  
nuclear charge attraction experienced by the valence electron decreases.

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[1]: trend
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[1]: explanation in terms of weaker attraction due to valence electron being further from nucleus / at a higher energy level

(ii) I.E. of Se is lower [2]  
Se has one proton less (smaller nuclear charge) but relatively constant shielding effect and effective nuclear charge is smaller in Se  
nuclear charge attraction experienced by the valence electron is weaker.

[1]: I.E. of Se is lower

[1]: explanation in terms of ENC

(b)      (i) no. of protons = 52  
                      = no. of electrons  
no. of neutrons =  $128 - 52$   
                      = 76

electronic configuration of Te:  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^4$

electronic configuration of Te:  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^2$

(accept abbreviated electronic configuration: [Kr] 4d<sup>10</sup> 5s<sup>2</sup> 5p<sup>2</sup>)

[1]: no. of protons and electrons

[1]: no. of neutrons

[1]: electronic configuration

(ii) TeO<sub>3</sub> [1]

(iii)  $\text{TeO}_3$  has a simple molecular structure with weak intermolecular forces (id-id / vdW) [2]

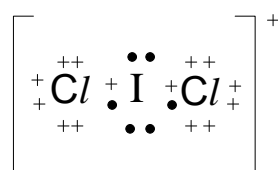
hence likely to be a volatile liquid or solid with low bp / m.p. that does not conduct electricity in all states

[1]: either physical property

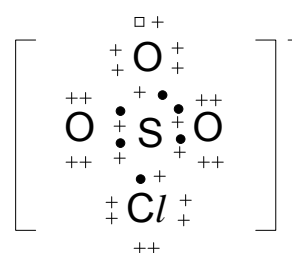
[1]: structure and bonding

(iv) Hydrolysis [1]  
 $\text{TeO}_3 + \text{H}_2\text{O} \longrightarrow \text{H}_2\text{TeO}_4$

(c) (i)  $ICl_2^+$   $SO_3Cl^-$  [4]



shape: bent



shape: tetrahedral

[1] each dot-and-cross

[1] each shape

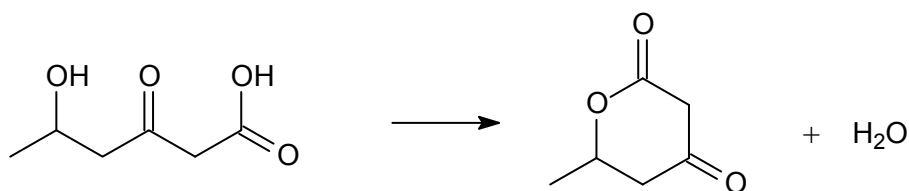


The  $\text{HSO}_4^-$  conjugate base has an additional electronegative O atom. This results in a greater electron-withdrawing effect which allows the negative charge on the anion is to be dispersed to a larger extent, stabilizing the anion.

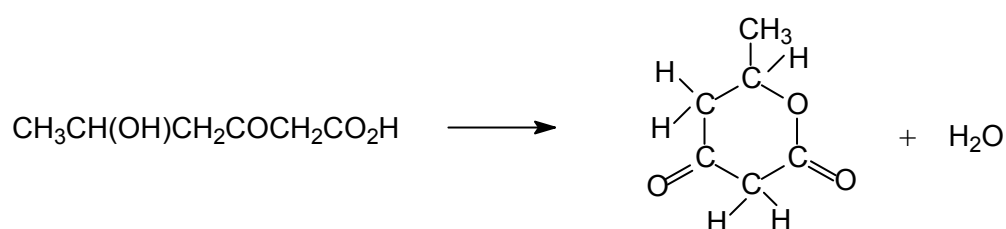
The dissociation of  $\text{H}_2\text{SO}_4$  is more favoured, POE will be shifted more to the right.

[1]: identify presence of an additional O atom in  $\text{HSO}_4^-$

[1]: greater dispersal of charge



OR



[1]: structural formula of organic product

[1]: balanced equation