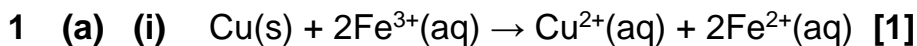
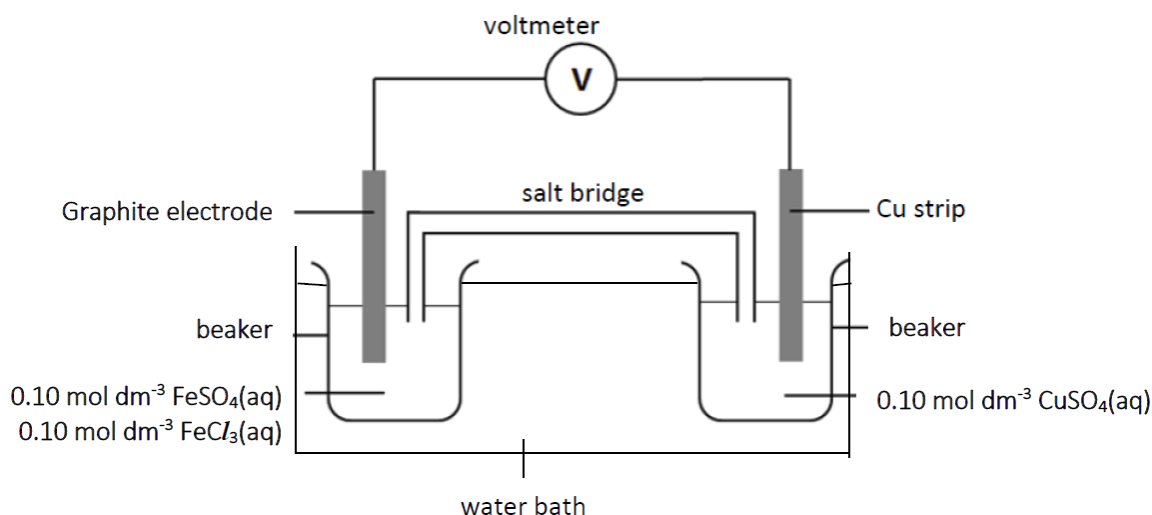


## Paper 2



- (ii) Positive. More aqueous ions produced and thus more ways that energy can be distributed in the system through the motion of ions. [1]

1 (b)



<b>M1</b>	[1/2] voltmeter and salt bridge
	[1/2] a single water bath or hot plate (not separate)
<b>M2</b>	Correct $\text{Fe}^{3+}/\text{Fe}^{2+}$ half cell: [1/2] electrode + [1/2] solutions (with correct concentration)
<b>M3</b>	Correct $\text{Cu}^{2+}/\text{Cu}$ half cell: [1/2] electrode + [1/2] solution (with correct concentration)
<b>M4</b>	[1/2] 5.56 g of solid  [1/2] details for weighing – electronic balance, weighing bottle/beaker, reweigh <u>or</u> tare and rinse out all solid
<b>M5</b>	<u>Preparation of acidified <math>\text{FeSO}_4</math> solution:</u> [1/2] adding acid <u>before</u> topping up to $100 \text{ cm}^3$ mark  [1/2] $100 \text{ cm}^3$ volumetric flask
<b>M6</b>	<u>Preparation of <math>\text{FeSO}_4</math> solution:</u> <ul style="list-style-type: none"> <li>• Transfer solid to beaker</li> <li>• Dissolve solid in beaker</li> <li>• Transfer solution to volumetric flask</li> </ul>

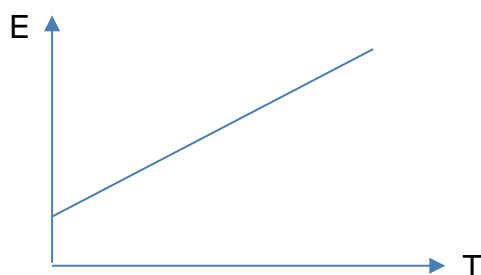
	<ul style="list-style-type: none"> <li>• Transfer washings to volumetric flask</li> <li>• Top up volumetric flask</li> <li>• Shake</li> </ul> <p><b>[1/2]</b> any 3 – 5 points  <b>[1]</b> all 6 points</p>
<b>M7</b>	<p><b>[1/2]</b> measure volumes of solutions used for both half-cells (minimum volume of electrolyte in each half-cell: 20 cm<sup>3</sup>)</p> <p><b>[1/2]</b> use appropriate apparatus e.g. measuring cylinder for measurement of solutions for both half-cells</p>
<b>M8</b>	<p><b>[1/2]</b> measure temperature using thermometer or set temperature of thermostatically controlled water bath</p> <p><b>[1/2]</b> range of temperature used at least 30 °C – should have at least 5 readings with at least 5 °C intervals (lowest temperature should not be below 20 °C)</p>
<b>M9</b>	<p>Sketch of graph:</p> <p><b>[1/2]</b> Correct choice of axes – E vs T (ignore units)</p> <p><b>[1/2]</b> Linear graph with positive gradient</p> <p>Allow a plot of <math>\Delta G</math> vs T. In this case, a linear graph with negative gradient would be obtained. Candidate needs to explain clearly how <math>\Delta G</math> can be obtained.</p>
<b>M10</b>	<p><b>[1]</b> explain how entropy change could be obtained from the graph – e.g. Gradient = <math>\Delta S / nF</math> (for E vs T graph)</p> <p>Gradient = <math>-\Delta S</math> (for <math>\Delta G</math> vs T graph)</p>

### Sample procedure

1. Using an electronic weighing balance, weigh accurately 5.56g of FeSO<sub>4</sub>·7H<sub>2</sub>O in a weighing bottle.
2. Transfer this solid into a 100 cm<sup>3</sup> beaker. Reweigh the weighing bottle to account for any residual solid. Record the mass of the solid used.
3. Dissolve the solid using about 20 cm<sup>3</sup> of 0.50 mol dm<sup>-3</sup> H<sub>2</sub>SO<sub>4</sub>(aq).
4. Transfer this solution into a 100 cm<sup>3</sup> volumetric flask. Rinse the beaker thoroughly and transfer all washings into the flask. Top up to the mark with deionised water/H<sub>2</sub>SO<sub>4</sub>(aq) and shake well to obtain a homogeneous solution. Label this solution as FA1.

5. Transfer 15 cm<sup>3</sup> of FA1 and 15 cm<sup>3</sup> of 0.20 mol dm<sup>-3</sup> FeCl<sub>3</sub> into a 100 cm<sup>3</sup> beaker using separate burettes.
6. Transfer 30 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> CuSO<sub>4</sub> into a 100 cm<sup>3</sup> beaker using a burette.
7. Set up the apparatus as shown in the diagram above.
8. Ensure that the water bath is maintained at 25°C by measuring the temperature with a thermometer.
9. Record the cell potential using a voltmeter.
10. Record the cell potential at different temperatures: 30°C, 35°C, 40°C, 45°C, 50°C, 55°C.

Plot a graph of E against T.



$$\Delta S = \text{gradient of the graph} \times F \times n$$

2 (a) (i) ½m each:

- ✓ O atom has more protons (or higher nuclear charge than C atom)
- ✓ shielding effect is similar (or almost the same)
- ✓ O has higher effective nuclear charge
- ✓ its outer electrons are pulled (or attracted) more closely to the nucleus

(ii) 1m: S atom has 1 more occupied quantum shell than O and C.

2 (b) (i) 1m: blood red

(ii) ½m each:

- ✓ [Fe(CN)<sub>6</sub>]<sup>3-</sup> has (much) higher  $K_{\text{stab}}$  than [Fe(H<sub>2</sub>O)<sub>5</sub>(SCN)]<sup>2+</sup>
- ✓ SCN<sup>-</sup> (and H<sub>2</sub>O) unable to replace CN<sup>-</sup> as the ligands attached to Fe<sup>3+</sup> i.e. no ligand exchange

(iii) 1m:

[Fe(edta)]<sup>-</sup> has (much) higher  $K_{\text{stab}}$  than [Fe(edta)]<sup>2-</sup>.

So [Fe(edta)]<sup>-</sup> is less likely to be reduced to [Fe(edta)]<sup>2-</sup>.

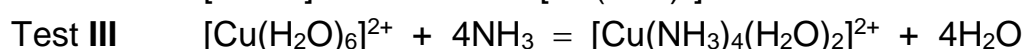
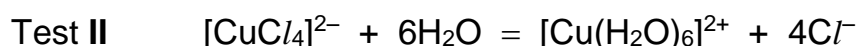
OR reduction equilibrium [Fe(edta)]<sup>-</sup> + e<sup>-</sup> ⇌ [Fe(edta)]<sup>2-</sup> lies more to the left.

OR edta ligand stabilises +3 oxidation state of Fe relative to +2 state.  
 $\therefore$  reduction potential for Fe(III)/Fe(II) with edta as ligands or for  $[\text{Fe}(\text{edta})]^-/[\text{Fe}(\text{edta})]^{2-}$  would be lower than +0.77 V.

2 (c) (i)  $\frac{1}{2}$ m each:

- ✓ yellow solution:  $[\text{CuCl}_4]^{2-}$
- ✓ blue solution:  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$
- ✓ pale blue ppt:  $\text{Cu}(\text{OH})_2$  or  $[\text{Cu}(\text{OH})_2(\text{H}_2\text{O})_4]$
- ✓ dark blue solution:  $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$

(ii) 1m each:



Accept  $\rightarrow$

2 (d) (i)  $\frac{1}{2}$ m each:

- ✓  $E^\ominus(\text{H}_2\text{O}/\text{H}_2) = -0.83 \text{ V}$  and  $E^\ominus(\text{Al}^{3+}/\text{Al}) = -1.66 \text{ V}$   
or  $E^\ominus(\text{H}^+/\text{H}_2) = 0 \text{ V}$  and  $E^\ominus(\text{Al}^{3+}/\text{Al}) = -1.66 \text{ V}$
- ✓  $E^\ominus(\text{H}_2\text{O}/\text{H}_2)$  is higher or less negative, so  $\text{H}_2\text{O}$  would be preferentially reduced to  $\text{H}_2$ ,  $\text{Al}^{3+}$  would not be reduced to give  $\text{Al}$ .  
or  $E^\ominus(\text{H}^+/\text{H}_2)$  is higher or less negative, so  $\text{H}^+$  would be preferentially reduced to  $\text{H}_2$ ,  $\text{Al}^{3+}$  would not be reduced to give  $\text{Al}$ .

(ii) 1m:  $2\text{AlO}_2^- \rightarrow \text{Al}_2\text{O}_3 + \frac{1}{2}\text{O}_2 + 2\text{e}^-$   
or  $4\text{AlO}_2^- \rightarrow 2\text{Al}_2\text{O}_3 + \text{O}_2 + 4\text{e}^-$

(iii) 1m: calculates no. of moles of electrons  
1m: calculates time in hours

$$\text{Amount of Al deposited} = \frac{1000 \times 10^3}{27} = 3.704 \times 10^4 \text{ mol}$$

$$\text{Amount of electrons passed} = 3 \times 3.704 \times 10^4 = 1.111 \times 10^5 \text{ mol}$$

$$Q = It = 1.111 \times 10^5 \times 96500 = 1.072 \times 10^{10} \text{ C}$$

$$t = \frac{1.072 \times 10^{10}}{10^4} = 1.072 \times 10^6 \text{ s} = 298 \text{ h} \quad (\text{or } 297.8 \text{ h})$$

2 (e) 1m: concludes +6

1m: calculates 0.00225 mol  $\text{XeF}_2$  and 0.00150 mol Cr(III)

1m: explains how to conclude +6, e.g. 1 mol Cr(III) loses 3 mol electrons

Sample working:

$$\text{Amount of XeF}_2 = \frac{15.2}{1000} \times \frac{25}{169} = 0.002249 \text{ mol}$$

XeF<sub>2</sub> reduced to Xe, oxidation state of Xe changes from +2 to 0

$$\text{Amount of electrons transferred} = 2 \times 0.002249 = 0.004497 \text{ mol}$$

$$\text{Amount of Cr(III)} = \frac{10}{1000} \times 0.150 = 0.00150 \text{ mol}$$

$$\frac{0.004497}{0.00150} = 3 \text{ mol of electrons lost from 1 mol of Cr(III)}$$

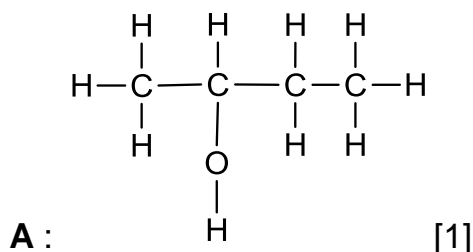
∴ oxidation state of Cr increases by 3 units

∴ oxidation state of Cr is +6 after reaction

- 3 (a) The carbon atom of the reactant (but-2-ene) in the C=C bond is sp<sup>2</sup> hybridised [1/2] and the bond angle around the carbon atom is 120° [1/2].

The carbon atom of the product (butane) in the C–C bond is sp<sup>3</sup> hybridised [1/2], and the bond angle around the carbon atom is 109.5°.  
(accept 109°) [1/2]

- (b) (i) Steam, 300°C, 70 atm (or 60 atm), (conc) H<sub>3</sub>PO<sub>4</sub> [1]  
OR conc H<sub>2</sub>SO<sub>4</sub> followed by warming with water.



- (ii) Both but-2-ene and alcohol are simple covalent compounds /simple, discrete molecules /have simple molecular structure. [1/2]

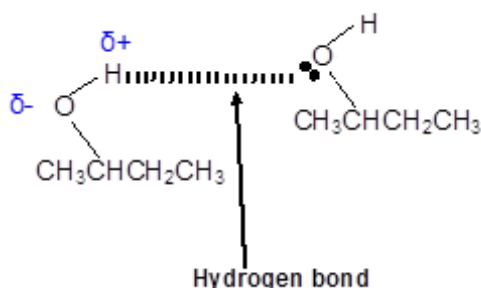
For but-2-ene, there are weak dispersion forces between its molecules. For alcohol **A** (butan-2-ol) with polar O–H bond, there are strong intermolecular hydrogen bonding between its molecules. [1/2]

More energy is required to overcome the stronger intermolecular hydrogen bonding in alcohol **A** than the weak dispersion forces in but-2-ene which is therefore in gaseous state. [1/2]

OR

the energy provided by room temperature is insufficient to overcome the strong hydrogen bonds between alcohol **A** molecules,

Hence alcohol **A** exists as a liquid at room temperature and but-2-ene exists as gas. [1/2]

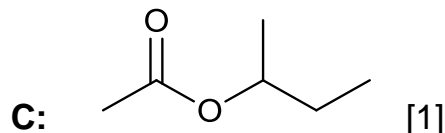
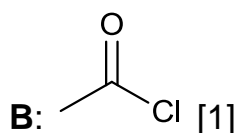


*Diagram [1]*

- showing correct hydrogen bond (must be oxygen atom and the H atom from the OH group)
- labelling hydrogen bond
- showing lone pair of electrons on oxygen
- labelling  $\delta+$  and  $\delta-$  for the O–H group forming H bond.

Each mistake minus 1/2 mark

(iii)

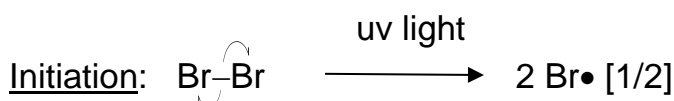


3 (c) (i) Ratio of 1-bromobutane : 2-bromobutane = 1 : 3 [1]

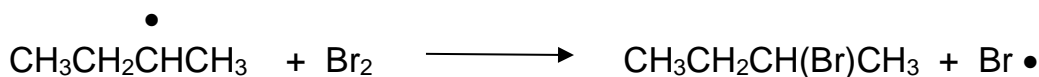
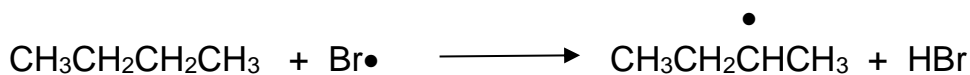
In 1-bromobutane: there are 6 possible primary ( $1^\circ$ ) H atoms for substitution and in 2-bromobutane: there are only 4 secondary ( $2^\circ$ ) H atoms for substitution [1/2]

Relative rate of substitution suggests that the mole ratio of 1-bromobutane : 2-bromobutane =  $1 \times 6 : 4.5 \times 4 = 6 : 18$  [1/2] for working

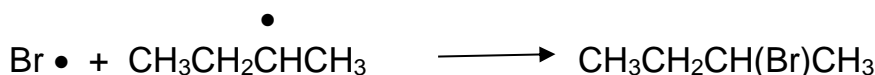
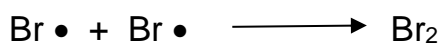
(ii) Type of mechanism: Free radical substitution [1]

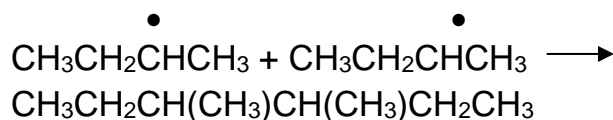


Propagation: [1]



Termination [1/2]





- 4 (a) The thermal stability of the hydrogen halides **decreases** down the group [1/2] as the **bond energy of H-X** decreases accordingly from +562 (HF) to +431 (HCl) to +366 (HBr) to +299 kJ mol<sup>-1</sup> (HI) [1/2].  
Down the group, **less energy is required** to break the bond [1/2] as the **bond strength decreases** [1/2].

- (b) Step 1: To 1 cm<sup>3</sup> of each reagent in separate test tubes, add a few drops of **aqueous lead(II) nitrate** and shake. [1/2]  
If yellow ppt (of PbI<sub>2</sub>) is obtained, the test tube contains NaI. If white ppt is obtained, the test tube contains KBr or KCl. [1]

Step 2: To 1 cm<sup>3</sup> of each reagent that gave white ppt in step 1, add a few drops of **acidified sodium chlorate(I)** OR **Cl<sub>2</sub>(aq)** and shake. [1/2]  
If the solution turned yellow-orange, the test tube contains KBr. If the solution remained colourless, the test tube contains KCl. [1]

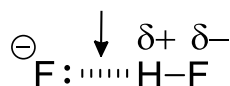
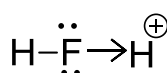
OR

Step 1: To 1 cm<sup>3</sup> of each reagent in separate test tubes, add a few drops of **acidified sodium chlorate(I)** OR **Cl<sub>2</sub>(aq)**, followed by 1 cm<sup>3</sup> of **hexane**. Shake well and leave to stand. [1]  
If both layers remained colourless, the test tube contains KCl.  
If the aqueous layer turned yellow-orange, while the organic layer turned reddish-brown, the test tube contains KBr.  
If the aqueous layer turned brown, while the organic layer turned violet, the test tube contains KI. [3 obs correct:2m; 2 obs correct:1m]

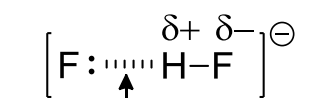
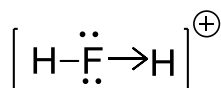
- 4 (c) (i)  $2\text{HF} + \text{H}_2\text{O} = \text{H}_3\text{O}^+ + \text{HF}_2^-$  [1]  
 $K = K_1 \times K_2 = (1.1 \times 10^{-3})(2.6 \times 10^{-1}) = 2.86 \times 10^{-4}$  [1]

- (ii) NaOH, Na<sub>2</sub>CO<sub>3</sub>, etc. Base reacts with acid, lowers [H<sub>3</sub>O<sup>+</sup>] and shifts position of equilibrium forward. [2]

- (d) (i) hydrogen bonding



OR



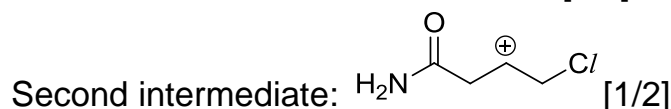
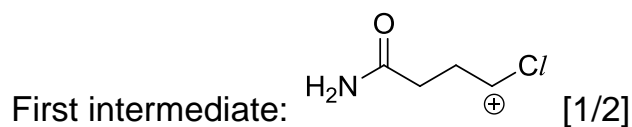
hydrogen bonding [1] x 2

(ii)  $[H_2F^+] = [HF_2^-] = \sqrt{(8.0 \times 10^{-12})} = 2.83 \times 10^{-6} \text{ mol dm}^{-3}$  [1]  
 $[HF] = \frac{1.002 \times 10^3}{1.0 + 19.0} = 50.1 \text{ mol dm}^{-3}$

The auto-dissociation causes a negligible change in [HF], hence the

requested fraction is  $\frac{[H_2F^+]}{[HF]} = \frac{2.83 \times 10^{-6}}{50.1} = 5.65 \times 10^{-8}$  [1]

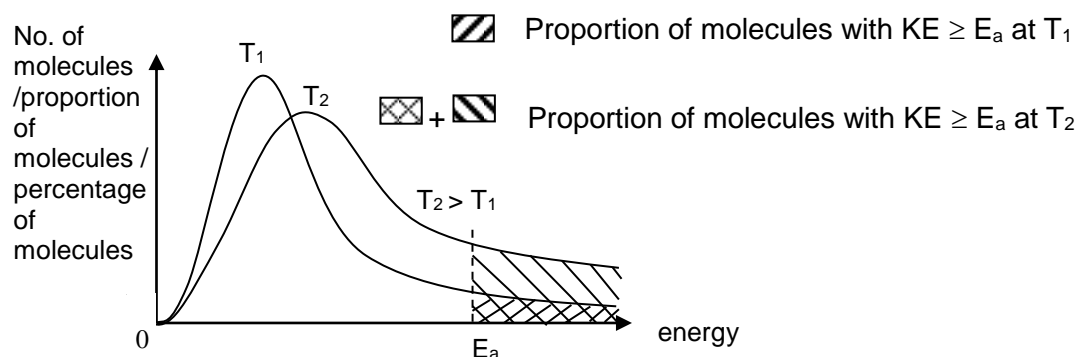
5 (a) (i)



Product formed is from the first intermediate which is less stable than second intermediate. [1/2]

This is because the positive charge is intensified by electron withdrawing chlorine through inductive effect. [1/2]

(ii) Boltzmann distribution diagram: [1]



At higher temperatures, the proportion of molecules with kinetic energy greater than or equal to activation energy increases [1].

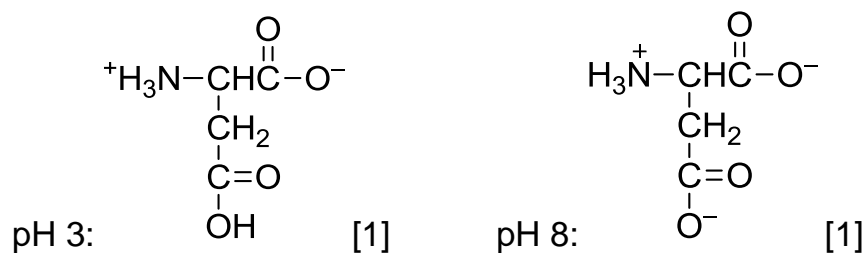
Thus, frequency of effective collision increases [0.5], reaction rate increases [0.5]

(iii) The prolinamide is synthesised as a racemic mixture containing equal proportions of two enantiomers. [1/2]

Hence only 50% of the synthesised prolinamide can fit into / would possess the correct 3D shape to bind to the active site of the enzyme. [1/2]



5 (b) (i)



(ii)

aspartic acid	lysine	<b>Ionic interaction</b>
isoleucine	phenylalanine	<b>dispersion forces / van der Waals interaction</b>
serine	asparagine	<b>Hydrogen bond</b>

3 correct = [2], 2 correct = [1], 1 correct = [1/2]

(iii) Mercury ion disrupts the disulfide bridge by binding tightly with –SH of cysteine residue

OR

Mercury ion disrupts the ionic interaction by forming ionic interaction with –CO<sub>2</sub><sup>–</sup> side chain of aspartic acid. [1]

The tertiary structure / shape of the enzyme is altered, and hence its function is lost. [1]

5 (c) Asp-lys-ser-phe-lys-gly-cys-asn-phe [1]

(d) (i) Glycine [1/2], cysteine [1/2]

(d) (ii)

