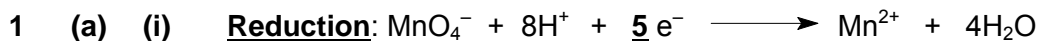


**2014 JC2 Preliminary Exam
H1 Chemistry Paper 2 Mark Scheme**



correct type of reactions [1]

correct no. of electrons [1]

(ii) colourless to pink. [1]

(b) (i) $n(\text{MnO}_4^-) \text{ reacted} = \frac{18.80}{1000} \times \frac{3.65}{158.0} = 4.34 \times 10^{-4} \text{ mol}$

answer + units [1]



$n(\text{C}_2\text{O}_4^{2-}) \text{ in } 25.0 \text{ cm}^3 \text{ of FA 1}$

$= \frac{5}{2} \times 4.34 \times 10^{-4}$

$= 1.09 \times 10^{-3} \text{ mol}$ [ecf only allowed w.r.t. ratio given in (a)(i)]

answer + units [1] (ecf on units)

(iii) $[\text{C}_2\text{O}_4^{2-}] \text{ in FA 1} = \frac{1000}{25.0} \times 1.09 \times 10^{-3} \text{ (ecf)}$
 $= 0.0434 \text{ mol dm}^{-3}$

answer + units [1]

(c) (i) Mass of 1 serving is 100 g.

Or

$n(\text{C}_2\text{O}_4^{2-}) \text{ in 100 g of spinach}$
 $= n(\text{C}_2\text{O}_4^{2-}) \text{ in } 250.0 \text{ cm}^3 \text{ of FA 1}$
 $= 1.09 \times 10^{-3} \times 10$
 $= 1.09 \times 10^{-2} \text{ mol}$

$n(\text{C}_2\text{O}_4^{2-}) \text{ in 100 g of spinach}$
 $= 0.0434 \times 250/1000$
 $= 1.09 \times 10^{-2} \text{ mol}$

Mass of $\text{H}_2\text{C}_2\text{O}_4$ in 100 g of spinach
 $= 1.09 \times 10^{-2} \times 90$
 $= 0.977 \text{ g}$ [1]

(ii) Given oral LD_{50} for oxalic acid = 600 mg/kg body weight
 Minimum mass of oxalic acid consumed by a person with body weight of 65 kg before it becomes toxic
 $= 600 \text{ mg} \times 65$
 $= 39\,000 \text{ mg} = 39 \text{ g}$ [1]

\therefore Minimum servings of spinach needed to be consumed in a meal before oxalic acid toxicity

$= \frac{39}{0.977}$

$= 39.9 \approx 40 \text{ servings}$ [1] (allow actual answer)

(iii) Some oxalic acid may remain dissolved in the inert organic solvent and hence will not react with aqueous KMnO_4 during titration.

[1]

- 2 (a) (i) SiCl_4 forms white HCl fumes / steamy white fumes of HCl with moist air. [1]
- (ii) $\text{PCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_3 + 3\text{HCl}$ [1]
- pH = 1 [1]
- (b) (i) Between **A** and **B**: $\text{CO}_3^{2-} + \text{H}^+ \rightarrow \text{HCO}_3^-$ [1]
- Between **C** and **D**: $\text{HCO}_3^- + \text{H}^+ \rightarrow \text{H}_2\text{CO}_3$ [1]
- (ii) Methyl yellow.
- Yellow to orange.
- [Correct choice + correct colour change]** [1]
- Because its working pH range (pH 2 – 4) lies within the range of rapid pH change. [1]
- (iii) $2\text{HCl} + \text{Na}_2\text{CO}_3 \rightarrow 2\text{NaCl} + \text{CO}_2 + \text{H}_2\text{O}$ [1]
- No. of moles of Na_2CO_3 reacted = $\frac{20.0}{1000} \times 0.10 = 2.00 \times 10^{-3} \text{ mol}$
- No. of moles of HCl in $19.0 \text{ cm}^3 = 2 \times 2.00 \times 10^{-3} = 4.00 \times 10^{-3} \text{ mol}$ [1]
- $[\text{HCl}] = 0.0040 \div \frac{19.0}{1000} = \underline{\underline{2.11 \times 10^{-4} \text{ mol dm}^{-3}}}$
- (iv) No. of moles of HCl in $19.0 \text{ cm}^3 = 4.00 \times 10^{-3} \text{ mol}$
- No. of moles of HCl in $250 \text{ cm}^3 = 4.00 \times 10^{-3} \times \frac{250}{19} = 5.26 \times 10^{-2} \text{ mol}$
- Moles of HCl in 10.0 cm^3 of 'fuming hydrochloric acid' = $5.26 \times 10^{-2} \text{ mol}$ [1]
- Concentration of 'fuming hydrochloric acid'
- $= \frac{5.26 \times 10^{-2}}{10} \times 1000 = \underline{\underline{5.26 \text{ mol dm}^{-3}}}$
- OR
- $[\text{HCl}]$ in solution **X** = $2.11 \times 10^{-4} \text{ mol dm}^{-3}$
- $[\text{Fuming HCl}] = 2.11 \times 10^{-4} \times \frac{250}{10} = \underline{\underline{5.26 \text{ mol dm}^{-3}}}$

3 (a) (i)

Particle	Mass number	Number of		
		protons	electrons	neutrons
A	53	24	22	29
B	50	24	24	26
C	51	25	27	26

[1]

[1]

[1]

(ii) A and B

[1]

(iii) 25 electrons
 $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$

[1]

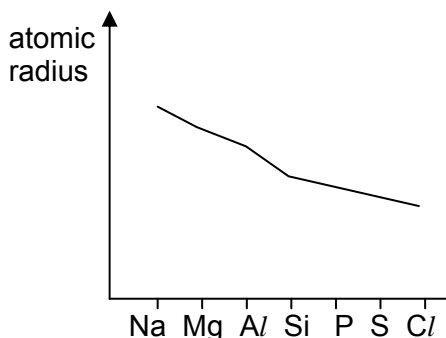
(iv) angle of deflection $\propto \frac{q}{m}$

Particle	z/m ratio	angle of deflection
Ca^{2+}	+2/40.1	+10.0°
C^{2-}	-2/51	$[(-2/51) / (+2/40)] \times (+10.0) = -7.86^\circ$

correct magnitude [1]

correct sign [1]

(b) (i)



[1]

[downward sloping straight line is also accepted](ii) This is due to the fact that the **nuclear charge increases (increasing number of protons)** and **screening effect** remains **relatively constant** since electrons are added to the same shell. (increase in effective nuclear charge.)

[1]

Hence the **attraction between the nucleus and the valence electrons increases**. As a result, atomic radius decreases across the period.

[1]

- 4 (a) (i) The amount of heat **evolved** when **one mole** of propane in its standard state is **completely burned** in excess oxygen under standard conditions of **298 K and 1 atm / standard conditions**. [1]



- (ii) The energy change when **one mole** of a $\text{CO}_2(\text{g})$ is formed **from C(s) and $\text{O}_2(\text{g})$ / constituent elements in their standard states** at **298 K and 1 atm / standard conditions**. [1]



[1] for correct quantity and correct B.E of bonds broken.

[1] for correct quantity and correct B.E of bonds formed.

Bonds broken:	Energy / kJ mol ⁻¹	Bonds formed	Energy / kJ mol ⁻¹
6 x C=C (benzene)	6 x 520	6 x 2 x C=O	12 x 740
6 x C-H	6 x 410	3 x 2 x O-H	6 x 460
15/2 O=O	15/2 x 496		
	= 9300		= 11640

Enthalpy change of combustion, $\Delta H_1 = 9300 - 11640 = -2340 \text{ kJ mol}^{-1}$

[1] for correct enthalpy change of combustion + '-' sign + units

- (ii) $\Delta H_2: 3 \times (-286) = -858 \text{ kJ mol}^{-1}$ [1]

$\Delta H_3: -3920 \text{ kJ mol}^{-1}$ [1]

- (iii) Applying Hess' Law,

$$\begin{aligned} \Delta H_1 + \Delta H_2 &= \Delta H_{\text{hydrogenation}} + \Delta H_3 \\ -2340 + 3(-286) &= \Delta H_{\text{hydrogenation}} + (-3920) \\ \Delta H_{\text{hydrogenation}} &= 3920 - 2340 - 858 = +722 \text{ kJ mol}^{-1} \end{aligned}$$

[1] correct answer + '-' sign + units

Section B

5 (a) (i) The *first ionisation energy* of an element is the energy required to remove one mole of electrons from one mole of the gaseous atom of the element to form one mole of singly charged gaseous cations. [1]

(ii) Si: $1s^2 2s^2 2p^6 3s^2 3p^2$ P: $1s^2 2s^2 2p^6 3s^2 3p^3$ S: $1s^2 2s^2 2p^6 3s^2 3p^4$ [1]

Comparing Si and P

– P has a **higher proton number** than Si, hence P has higher nuclear charge. [1]

– Electron to be removed in Si and P experiences similar shielding effect as the number of inner shell electrons is the same

– Stronger (electrostatic) attraction between electron and nucleus in P [1]

– P has a higher first I.E.

Comparing P and S

– Electron to be removed in S comes from paired electrons in 3p orbital and hence experiences interelectronic repulsion from the paired electron [1]

– Less energy required to remove this electron

(iii) To form Mg^{3+} , ionisation energy required = $736 + 1450 + 7740 = 9926 \text{ kJ mol}^{-1}$
To form Al^{3+} , ionisation energy required = $577 + 1820 + 2740 = 5137 \text{ kJ mol}^{-1}$

[1] for both values (ignore units)

The 3rd IE of Mg is much higher than Al as it involves removing an electron from the inner 2p orbital which is closer to the nucleus.

Since the sum of I.E to form Mg^{3+} is greater than Al^{3+} , Mg^{3+} compounds do not exist. [1]

(b) (i) – Mg_3P_2 solid has a **giant ionic lattice** with **strong electrostatic forces of attraction** between the **Mg^{2+} and P^{3-} ions**.
– Hence a large amount of heat energy is required to overcome the attraction resulting in a high melting point for Mg_3P_2 . [1]

(ii) High melting point

– Large amount of heat energy required to break the strong / large number / extensive network of covalent bonds

[1]

Covalent bond with ionic character

– Phosphorus is more electronegative than aluminium, hence the bonding electrons in Al–P are attracted to phosphorus, resulting in $Al^{\delta+}-P^{\delta-}$ / or **polar Al–P bond** [1]

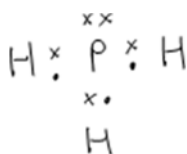
(iii) $Mg_3P_2 + 6H_2O \rightarrow 3Mg(OH)_2 + 2PH_3$
($Mg_3P_2 + 3H_2O \rightarrow 3MgO + 2PH_3$) [1]

$Mg_3P_2 + 6HCl \rightarrow 3MgCl_2 + 2PH_3$ [1]

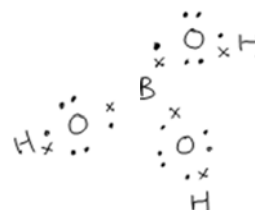
OR

$AlP + 3H_2O \rightarrow Al(OH)_3 + PH_3$
($2AlP + 3H_2O \rightarrow Al_2O_3 + 2PH_3$) [1]

$AlP + 3HCl \rightarrow AlCl_3 + PH_3$ [1]

(c) (i) PH_3 B(OH)_3 

[1]



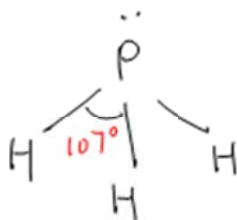
[1]

- (ii) **B** in B(OH)_3 is **2 electrons short of octet** hence it is able to **accept one lone pair of electrons** from **P** in PH_3 forming a **dative / coordinate bond** to achieve an octet configuration.

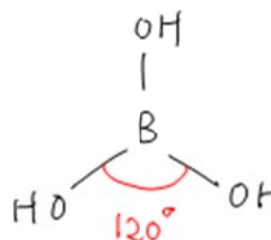
Hence **one** PH_3 molecule reacts with **one** B(OH)_3 molecule.

[1]

(iii)

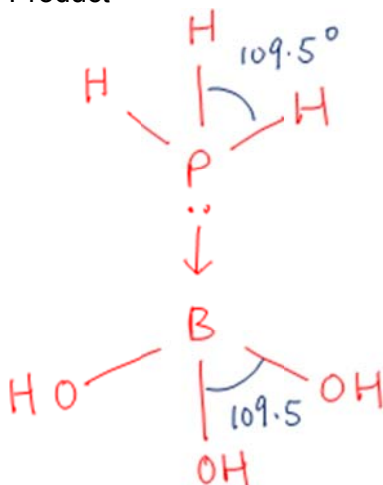


trigonal pyramidal



trigonal planar

Product



tetrahedral w.r.t. both P and B

[1] show the shape of PH_3 clearly (name not required)

[1] show the shape of B(OH)_3 clearly (name not required)

[1] show the shape of product clearly (name not required)

Show change of bond angles: $107^\circ \rightarrow 109.5^\circ$ [1] and $120^\circ \rightarrow 109.5^\circ$ [1]

- (iv) The $-\text{OH}$ groups in product (containing trapped PH_3) **form hydrogen bonds with water**, hence product **dissolves (readily) in water** and thus can be removed from the body

[1]

- 6 (a) (i) $4\text{Na} + \text{O}_2 \rightarrow 2\text{Na}_2\text{O}$ [1]
- $4\text{Al} + 3\text{O}_2 \rightarrow 2\text{Al}_2\text{O}_3$ [1]
- $\text{S} + \text{O}_2 \rightarrow \text{SO}_2$ [1]
(SO_3 is not formed due to high activation energy)
- (ii) $\text{Na}_2\text{O (s)} + \text{H}_2\text{O (l)} \rightarrow 2\text{NaOH (aq)}$
- Na_2O **dissolves readily** in water to give a strongly alkaline NaOH solution of **pH \approx 13**. NaOH (aq) formed **dissociates completely**. [1]
- Al_2O_3 is **insoluble in water**. pH = 7 [1]
- $\text{SO}_2 \text{ (g)} + \text{H}_2\text{O (l)} \rightarrow \text{H}_2\text{SO}_3 \text{ (aq)}$
- SO_3 **dissolves readily** in water to give a **strongly acidic solution**, H_2SO_3 , of **pH = 1**. [1]

(b)

Description	Type of reaction	Deduction
M is heated under reflux with dilute sulfuric acid	Hydrolysis [1]	Acid, N , and alcohol P , is produced.
N , $C_8H_8O_2$, reacts with hot concentrated potassium manganate (VII) to form a white precipitate, Q , $C_7H_6O_2$	(side chain) oxidation [either 1]	Since C:H ratio of N is 1, benzene ring is present.
1 mole of Q reacts with excess aqueous sodium carbonate to produce 0.5 mole of gas.	Acid-base [1]	CO_2 is produced. Q contains one $-COOH$ group. [1]
When P is warmed and distilled with acidified potassium dichromate, compound R is formed.	Oxidation of P [or 1]	P is a 1° or 2° alcohol. [1]
R produces an orange precipitate with 2,4-dinitrophenylhydrazine	Condensation [1]	R is a carbonyl compound or is an aldehyde or ketone. [a]
and produces a silver mirror with Tollens' reagent.	(Mild) oxidation [1]	R is an aldehyde. [b] [a + b = 1]
R reacts with alkaline aqueous iodine to produce a yellow precipitate.	(Mild) oxidation [1] Or tri-iodomethane reaction	R has a structure of $\begin{array}{c} O \\ \\ CH_3-C- \end{array}$ [1]

[5] 9 – 10 points

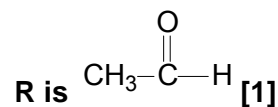
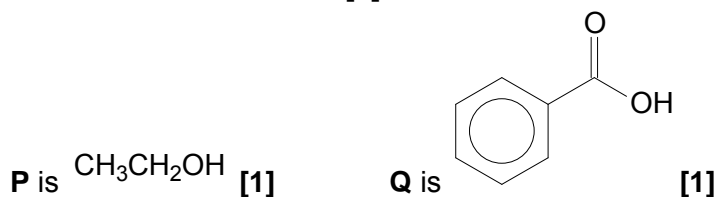
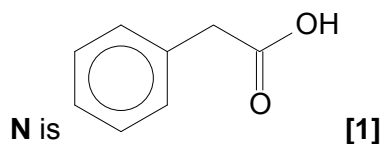
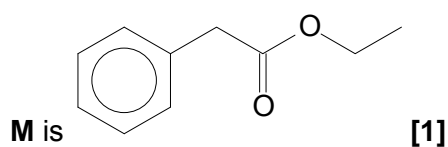
[4] 7 – 8 points

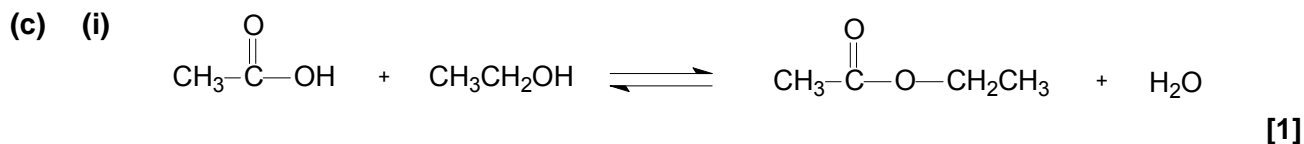
[3] 5 – 6 points

[2] 3 – 4 points

[1] 1 – 2 points

Maximum of 5 marks.





(ii)
$$K_c = \frac{[\text{CH}_3\text{COOCH}_2\text{CH}_3][\text{H}_2\text{O}]}{[\text{CH}_3\text{COOH}][\text{CH}_3\text{CH}_2\text{OH}]}$$
 [1]

(iii) Let the number of moles of acid and alcohol reacted be x mol.

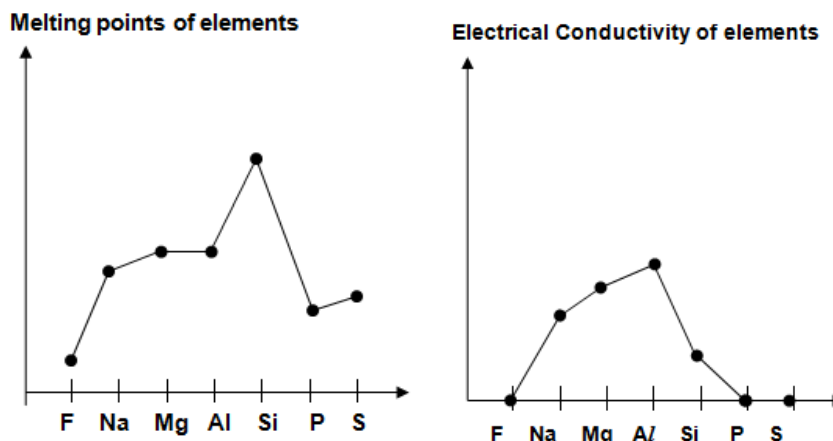
	CH_3COOH	$+ \text{CH}_3\text{CH}_2\text{OH}$	\rightleftharpoons	$\text{CH}_3\text{COOCH}_2\text{CH}_3$	$+ \text{H}_2\text{O}$
I / mol	x	x		0	0
C / mol	$-0.67x$	$-0.67x$		$+0.67x$	$+0.67x$
E / mol	$0.33x$	$0.33x$		$0.67x$	$0.67x$
Conc / mol dm ⁻³	$\frac{0.33x}{V}$	$\frac{0.33x}{V}$		$\frac{0.67x}{V}$	$\frac{0.67x}{V}$

[students can also work in mol dm⁻³, in this case they do not need to introduce the arbitrary volume V]

$$K_c = \frac{\left(\frac{0.67x}{V}\right)\left(\frac{0.67x}{V}\right)}{\left(\frac{0.33x}{V}\right)\left(\frac{0.33x}{V}\right)} = 4.1$$

Correctly substitute equilibrium concentrations [1] + correct K_c value with no units [1]

7 (a) (i)



Correct shape and trend from fluorine to sulfur [1] each.

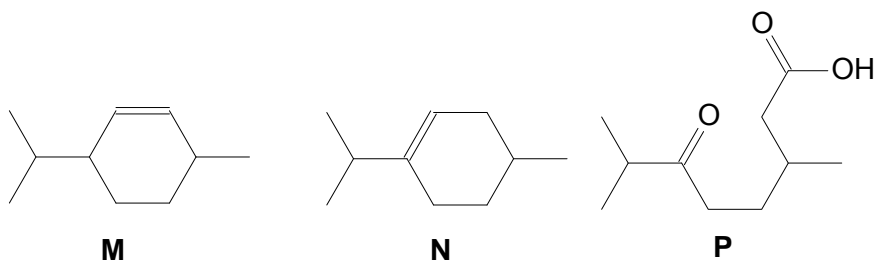
- (ii) Na, Mg and Al form giant metallic lattice with metallic bonds. Melting points increase from Na to Al because more delocalised electrons are available for metallic bonding. Thus, larger amount of energy is needed to break the stronger electrostatic forces of attraction between cations and delocalised electrons. [1]

Si has the highest melting point as large amount of energy is needed to break the strong, extensive covalent bonds between Si atoms in the giant molecular structure. [1]

P₄, S₈ and F₂ form simple molecular structures with weak van der Waals' forces of attraction between the molecules. Thus, they have very low melting points. [1]

- (b) (i) Ethanolic KOH or NaOH, heat under reflux [1]

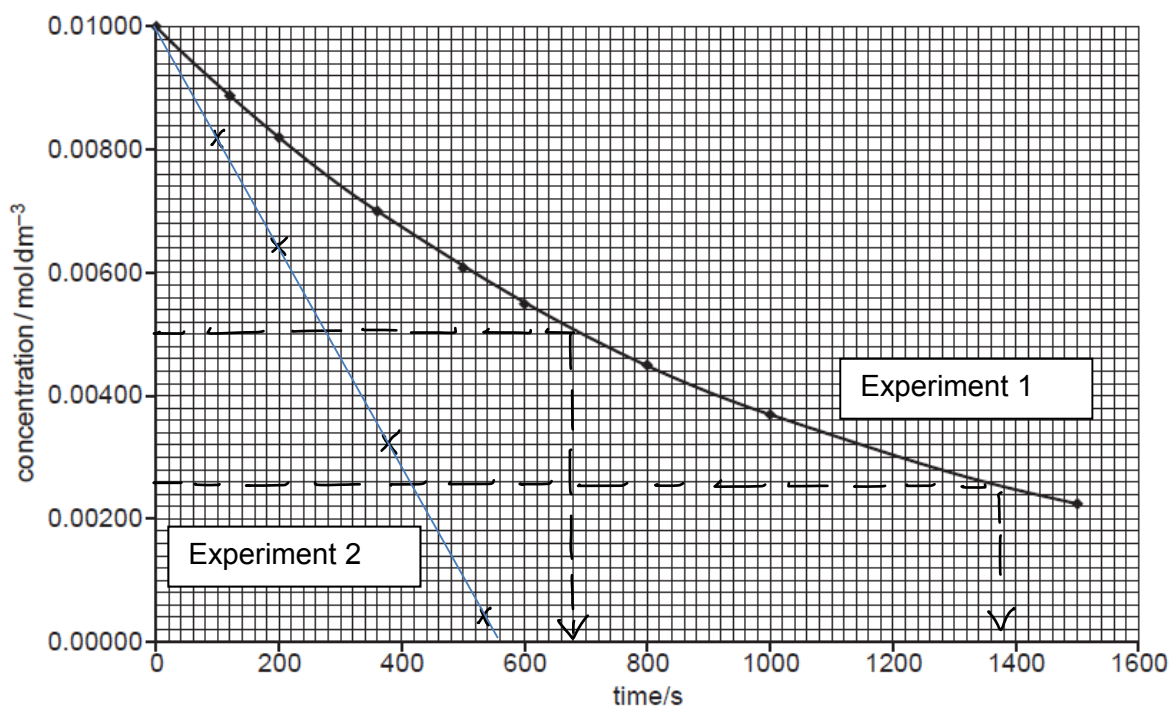
(ii)



Each correct structure [1]

- (iii) Structural isomerism [1]

(c) (i)



Points correctly plotted.

Best fit straight line. [1]

(ii) Show clear construction lines to obtain two half lives.

Two approximately constant half-lives obtained $\approx 690 \pm 10$ s

[1]

Order of reaction w.r.t 2-iodo-2-methylpropane = 1

[1]

(iii) From experiment 2,
[NaOH] vs time graph is a straight line \Rightarrow constant gradient \Rightarrow constant rate $(\Rightarrow \text{rate is independent of } [\text{NaOH}])$

[1]

Hence order of reaction w.r.t. NaOH = 0

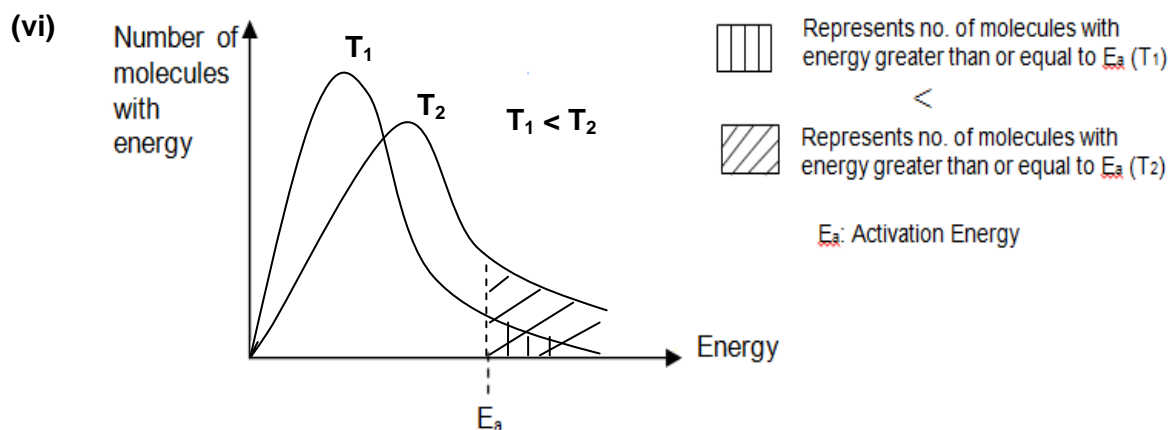
[1]

(iv) rate = k [2-iodo-2-methylpropane]

[1]

(v) **More energy** is required to break the **stronger C-Cl bond** than the C-I bond.
(Hence activation energy is higher for 2-chloro-2-methylpropane and its rate of reaction is slower.)

[1]



- correct label of axes
- correct shape of for both curves.
- label temperature and clearly indicate which curve represent the higher/lower T
- label E_a
- correct shaded area for both curves
- legend to explain the shades areas

[1]

As shown in the diagram above, at a higher temperature, the average kinetic energy of the molecules increases resulting in more reactant molecules with energy greater than or equal to the activation energy, E_a . [1]

Hence there is increase in the frequency of effective collisions and rate of reaction increases. [1]