ANDERSON SERANGOON JUNIOR COLLEGE

2024 JC 2 Preliminary Paper

NAME:____________________________ (   ) **CLASS:** 24 / ___

CHEMISTRY **8873/02**

Higher 1 **11 Sept 2024**

2 hours

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and register number in the spaces provided at the top of this page.
Write in dark blue or black pen.
You may use a pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.
The number of marks is given in brackets [ ] at the end of each question or part question.

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Section A

Answer **all** the questions in this section in the spaces provided.

1 **(a)** Phosphorus, sulfur and chlorine are Period 3 elements of the Periodic Table.

Table 1.1 shows some properties of the elements P to C*l*.

Table 1.1

	P	**S**	**C*l***
number of electrons in 3p subshell			
number of unpaired electrons			

Complete Table 1.1 to show the number of electrons in the 3p subshell and the number of unpaired electrons in an atom of P, S and C*l*.

[2]

	P [Ne]3s^{2}3p^3	**S [Ne]3s^{2}3p^4**	**C*l* [Ne]3s^{2}3p^5**
number of electrons in 3p subshell	3	4	5
number of unpaired electrons	3	2	1

(b) Fig. 1.1 shows successive ionisation energies of sulfur, S.

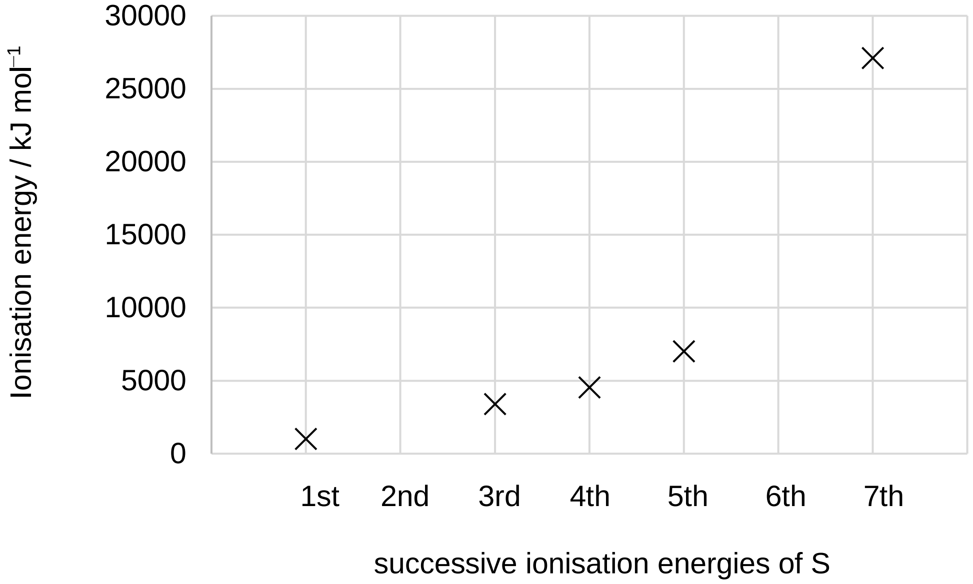


Fig. 1.1

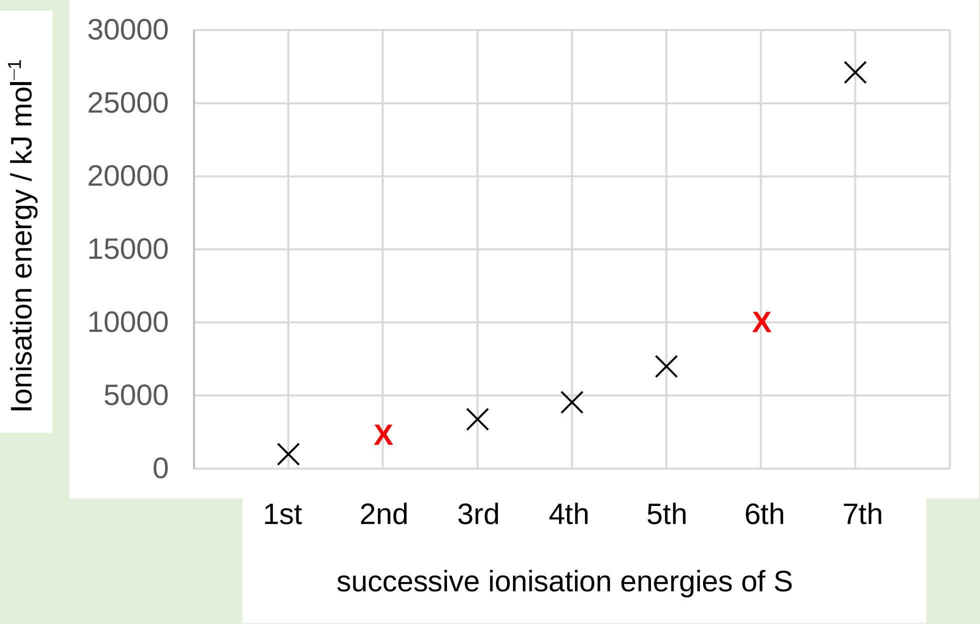
(i) Explain the general increase in successive ionisation energies for any atom.

[2]

- **Nuclear charge remains** unchanged for an atom

- As **electrons are removed from the outermost shell**, there will be a **decrease in shielding effect**.
- **Electrostatic forces of attraction between the nucleus and remaining outer electrons increases**.
- **More energy is required to remove electrons** resulting in a general increase in successive ionisation energies.

(ii) Complete Fig. 1.1 by plotting approximate values for the 2nd successive ionisation energy and the 6th successive ionisation energy of S. [2]



(c) Describe the variation in the electrical conductivity of the elements in the third period, sodium to chlorine. Explain this variation in terms of the structures and bonding of the elements.

[4]

Na, Mg, Al:
Giant metallic structure
Presence of **sea of delocalised electrons** as **mobile charge carriers** to conduct electricity under the influence of an electric current/ field.

Electrical conductivity increases across the period among the metals
Number of valence electrons contributed per atom for metallic bonding **increases** across the period among the metals for **delocalisation**.
More mobile electrons can act as **charge carriers.**

Si:
Giant molecular structure
Strong covalent bonds exist **between atoms** in a giant molecular structure
At **higher** temperatures, more electrons **gain enough energy** to **overcome the nuclear attraction** and electrical conductivity **increases.** Si is a

semiconductor which can only give rise to delocalised electrons at **high temperatures.**

P_4, S_8, Cl_2:

Simple molecular structure

Absence of delocalised electrons or free mobile ions as **mobile charge carriers** because electrons are localised in covalent bonds and not mobile to conduct electricity. They are **non–conductors of electricity.**

[Total: 10]

2 **(a)** When ionic compounds are dissolved in water, the ions form electrostatic attractions with water molecules. These attractions are known as ion–dipole interactions. Enthalpy change of hydration, $\Delta H_{hyd}^{\ominus}$ is a measure of the strength of the ion–dipole attraction.

The ionic radius of the Group 1 ions affects the strength of the attraction between the Group 1 ions and water molecules. The larger the ionic radius, the weaker the electrostatic forces of attraction between the ion and water molecules.

Enthalpy change of hydration, $\Delta H_{hyd}^{\ominus}$ is defined as the amount of heat evolved when one mole of free gaseous ions is dissolved in a large amount of water forming a solution at infinite dilution.

$$Na^+(g) \longrightarrow Na^+(aq)$$

(i) Describe and explain how ionic radius varies down Group 1 ions.

[2]

Down Group 1,

- The **nuclear charge increases.**
- The **number of shells increases** and the **valence electrons are further away from the nucleus** and are **more shielded**.
- The **electrostatic forces of attraction formed between the nucleus and the valence electrons** **decreases**,
- resulting in **increasing ionic radius**.

(ii) Hence, state the trend in the magnitude of enthalpy change of hydration, $\Delta H_{hyd}^{\ominus}$, down the Group 1 ions.

[1]

Magnitude of enthalpy change of hydration would **decrease**.
(Down Group 1, ionic radius increases. Hence, the electrostatic forces of attraction between the Group 1 ion and water molecule would be weaker. Energy released on forming the ion-dipole interactions would decrease.)

(iii) Suggest an equation to represent the enthalpy change of hydration, $\Delta H_{hyd}^{\ominus}$ of sulfide ion, S^{2-}.

[1]

$S^{2-}(g) \longrightarrow S^{2-}(aq)$

(iv) Sodium nitrate, $NaNO_3$ is soluble in water.

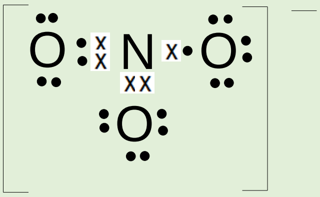
Draw the ‘dot-and-cross’ diagram of the nitrate ion. The ion contains nitrogen as the central atom and all atoms have 8 electrons in its outer shell.

State the shape and bond angle of the nitrate ion.

Shape: ……………………….

Bond angle: ………………..

[3]



Shape: trigonal planar
Bond angle: 120°

(b) Table 2.1 shows the boiling point of three fluorine containing compounds.

Table 2.1

formula	boiling point / °C
NaF	1695
HF	19.5
CH_3CH_2F	–37.1

Explain the difference in the boiling points in terms of the structure and type of bonding in the three compounds.

[4]

NaF has giant ionic structure. Strong electrostatic forces of attraction exist between Na$^+$ and F$^-$ ions as compared to the weak electrostatic forces between molecules with only partial charges. NaF has the highest boiling point since most energy is required to break the strong ionic bonds between Na$^+$ and F$^-$ ions.

CH_3CH_2F and HF have simple molecular structures. Weaker permanent dipole-permanent dipole (pd-pd) forces of attraction exist between CH_3CH_2F molecules as compared to the relatively stronger hydrogen bonds between HF molecules, resulting in least amount of energy required to overcome, hence CH_3CH_2F has the lowest boiling point.

[Total: 11]

3 **(a)** Ammonia is manufactured using the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Table 3.1 shows the number of moles of ammonia at equilibrium at various temperatures at 200 atm. In each case, 1.5 mol of N_2 and 3.0 mol of H_2 are mixed in a vessel initially.

Table 3.1

Temperature / °C	Amount of ammonia at equilibrium / mol
300	1.63
400	1.05
500	0.71

(i) Write the K_c expression for the equilibrium, stating its units.

[2]

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

units = $mol^{-2}\ dm^6$

(ii) Calculate the value of K_c at 200 atm and 300 °C, given that the volume of the vessel is 3 dm^3.

[2]

	$N_2(g)$ +	**$3H_2(g)$ $\rightleftharpoons$**	**$2NH_3(g)$**
initial amt / mol	**1.5**	**3.0**	**0**
change in amt / mol	**–0.815**	**–2.445**	**+1.63**
amt at eqm / mol	**0.685**	**0.555**	**1.63**
conc at eqm / mol dm^{-3}	**0.685/3**	**0.555/3**	**1.63/3**

$K_c = (1.63/3)^2 \div (0.685/3)(0.555/3)^3 = 204\ mol^{-2}\ dm^6$

(iii) State the *Le Chatelier's Principle*.

[1]

Le Chatelier's Principle states that if a change occurs in one of the conditions (concentration, temperature, or pressure) under which a reversible reaction is in dynamic equilibrium, the position of equilibrium shifts so as to minimise that change (and to re–establish equilibrium).

(iv) Using the information in Table 3.1, deduce and explain whether the forward reaction is an endothermic or exothermic reaction.

[2]

According to the data, an increase in temperature causes the amount of ammonia to decrease. The reverse endothermic reaction is favoured.

Equilibrium position will shift to the left to reduce temperature by absorbing the extra heat.
The forward reaction is then exothermic.

(v) Name the catalyst used and explain its role in the production of ammonia.

[2]

Finely divided **iron** catalyst is used to **increase the rate** at which **equilibrium** is achieved.

(b) An unknown alkaline solution with a concentration of 0.010 mol dm^{-3} is thought to be one of the following solutions.

- NaOH
- NH_3 ($K_b = 1.78 \times 10^{-5}$ mol dm^{-3})
- CH_3NH_2 ($K_b = 1.05 \times 10^{-4}$ mol dm^{-3})

(i) Explain what is meant by a *Brønsted-Lowry base*.

[1]

A *BrØnsted-Lowry* base is defined as a **proton acceptor.**

(ii) Identify the *weakest* Brønsted-Lowry base from the list above. Hence, write an equation for its dissociation in water.

[2]

weakest Bronsted-Lowry base: aq. NH_3

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

(iii) The unknown solution has a pH of 12.0.

With suitable calculations, prove that the unknown solution is NaOH.

[2]

pOH = 14 – 12.0 = 2.0
$[OH^-] = 10^{-2.0} = 0.010$ mol dm^{-3}

Since $[OH^-] = [base]$, the unknown solution undergoes complete dissociation. From the given list, NaOH is the only strong base.

[Total:14]

4 Potassium sulfite, K_2SO_3, is used as a food preservative.

The concentration of sulfite ions, SO_3^{2-} is determined by titration using aqueous acidified potassium manganate(VII).

3.40 g of impure K_2SO_3 is dissolved to make a 250 cm^3 solution in a volumetric flask. 25.0 cm^3 of this solution requires 22.40 cm^3 of 0.0250 mol dm^{-3} acidified potassium manganate(VII) to reach the end-point.

Reaction 1 $2MnO_4^- + 6H^+ + 5SO_3^{2-} \longrightarrow 2Mn^{2+} + 3H_2O + 5SO_4^{2-}$

(a) **(i)** Describe the roles of MnO_4^- and SO_3^{2-} in Reaction 1. Explain your answer in terms of electron transfer.

[2]

$$\overbrace{\underset{+7}{2MnO_4^-} + 6H^+ + \underbrace{\underset{+4}{5SO_3^{2-}} \longrightarrow \underset{+2}{2Mn^{2+}}}_{\text{Each } SO_3^{2-} \text{ releases 2 } e^-}}^{\text{Each } MnO_4^- \text{ gains 5 } e^-} + 3H_2O + \underset{+6}{5SO_4^{2-}}$$

<u>SO_3^{2-}</u> is a **<u>reducing agent</u>** as **<u>SO_3^{2-} donates electrons to</u>** MnO_4^- and becomes **<u>oxidised</u>**.

MnO_4^- is an **<u>oxidising agent</u>** as MnO_4^- **<u>accepts electrons from SO_3^{2-}</u>** and becomes **<u>reduced</u>**.

(ii) Calculate the percentage purity of the sample of K_2SO_3. Show your working.

[3]

No of moles of MnO_4^- in 22.40cm^3 = $0.025 \times \frac{22.40}{1000} = 5.6 \times 10^{-4}$ mol

No of moles of SO_3^{2-} in 25.0cm^3 = $5.6 \times 10^{-4} \times \frac{5}{2} = 1.4 \times 10^{-3}$ mol

No of moles of SO_3^{2-} in 250cm^3 = 1.4×10^{-2} mol
= No of moles of K_2SO_3

Mass of K_2SO_3 = $1.4 \times 10^{-2} \times 158.3 = 2.2162$mol

Percentage purity = $\frac{2.2162}{3.4} \times 100$ = <u>65.2%</u>

(b) Potassium manganate(VII) is photosensitive and can be decomposed by sunlight. The solution of acidified potassium manganate(VII) used in the titration was freshly prepared to minimise decomposition.

Comment on the volume of potassium manganate(VII) required in the titration and explain its impact on the calculated value for **(a)(ii)** if the solution of potassium manganate(VII) used is not freshly prepared.

[2]

Higher volume of $KMnO_4$ will be required to fully react with the 25cm^3 sample of SO_3^{2-}.

The percentage purity of the K_2SO_3 calculated will be greater than the actual amount.

[Total: 7]

5 **(a)** Use of *Data Booklet* is relevant in this question.

Using a time of flight (TOF) mass spectrometer, a sample of antimony is found to contain two isotopes – ^{121}Sb and ^{123}Sb. The spectrometer detected the presence of the two isotopes based on the different time taken by the charged isotopes, $^{121}Sb^+$ and $^{123}Sb^+$ to travel through the machine.

(i) State the number of protons, neutrons and electrons in a $^{121}Sb^+$ ion.

sub–atomic particle	no.
protons	
neutrons	
electrons	

[1]

sub–atomic particle	no.
protons	51
neutrons	70
electrons	50

(ii) The mass of an ion is the sum of the masses of the particles it contains.

Calculate the mass, in kg, of one $^{121}Sb^+$ ion. Quote relevant values from the *Data Booklet* and give your answer to three significant figures.

[1]

mass of one $^{121}Sb^+$ ion
$= (51 \text{ X } 1.67 \times 10^{-27}) + (70 \text{ X } 1.67 \times 10^{-27}) + (50 \text{ X } 9.11 \times 10^{-31})$
$= \underline{2.02 \times 10^{-25} \text{ kg}}$

(iii) The relative abundance of the isotopes is analysed by accelerating both $^{121}Sb^+$ and $^{123}Sb^+$ ions to the same kinetic energy of 3.149×10^{-19} J through a 1.05 m long tube in the spectrometer.

The kinetic energy of an ion is given by the equation, $KE = \frac{1}{2}mv^2$
KE = kinetic energy / J
m = mass / kg
v = speed / m s^{-1}

Speed is the distance travelled by an ion per unit time.

Using your answer in **(a)(ii)** and the information given above, calculate the time taken by $^{121}Sb^+$ to travel through the tube.

[1]

Let time taken by $^{121}Sb^+$ to travel through the tube be t,
$3.149 \times 10^{-19} = \frac{1}{2}(2.02 \times 10^{-25})(1.05/t)^2$
$t = \underline{5.95 \times 10^{-4} \text{ s}}$

(iv) A sample of antimony has a relative atomic mass, A_r, of 121.86. Calculate the percentage abundance of ^{121}Sb in this sample of antimony.

[1]

Let x be the percentage abundance of ^{121}Sb

$\frac{x(121) + (100-x)123}{100} = 121.86$

x = 57.0%

(b) (i) Define the term *nanoparticle*.

[1]

Nanoparticles are particles with ALL its dimensions between 1 to 100 nm on the nanoscale.

(ii) Explain how using platinum nanoparticles increases the efficiency of the catalytic converter.

[1]

Platinum nanoparticles have a large surface area to volume ratio.
Hence, there are more active sites on the surface for reaction to occur and reaction occurs at a faster rate so that the harmful gases are efficiently removed.

(iii) Write one balanced chemical equation to show how carbon monoxide is removed in the catalytic converter.

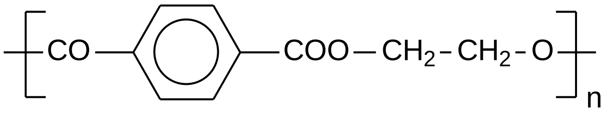
[1]

$CO\,(g) + NO\,(g) \longrightarrow \frac{1}{2} N_2\,(g) + CO_2\,(g)$

$CO\,(g) + \frac{1}{2} O_2\,(g) \longrightarrow CO_2\,(g)$

[Total: 7]

6 (a) The polymer poly(ethylene terephthalate), PET is also known as Terylene. It is often used to make clear beverage bottles and shirts.

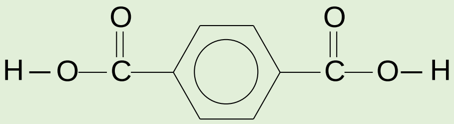


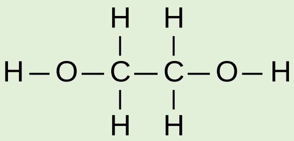
PET

PET is semi-rigid at room temperature but softens when heated to around 70 °C and can be reshaped. One advantage of PET is that it can be recycled.

(i) Draw the **displayed** formula of the two monomers used to make PET.

[2]





(ii) Suggest why Terylene is used to make shirts.

[1]

Terylene, a polyester, is less prone to creasing due to absence of hydrogen bonds in the polymer chain. Hence, it can be used to make shirts that needs little ironing.

(iii) Bottles that are made of PET cannot be used to store alkaline cleaning solution. Bottles that are made of poly(propene) are used instead.

Explain, in terms of the bonds present in both polymers, why the above statements are true.

[2]

PET contains ester bonds which will be hydrolysed in the presence of alkaline solution.

Poly(propene) contains non polar C–C and C–H bonds which are inert to alkaline solution.

(iv) Predict whether PET is a thermosetting or thermoplastic polymer. Explain your answer using the information from the question **and** your knowledge of the structure and bonding in polymers.

[2]

PET is a **thermoplastic** polymer.

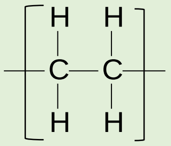
It softens when heated and can be reshaped. This suggests that the polymer can only form **weak instantaneous dipole–induced dipole attractions / permanent dipole-permanent dipole attractions** between the polymer chains. Hence, the **individual chains can slip pass one another easily** when heated.

(b) High density polyethene (HDPE) is a polymer commonly used with PET for liquid or beverage packaging. For example, the bottle cap of a drink bottle is usually made of HDPE while the drink bottle is made of PET.

HDPE is made by polymerising ethene, $CH_2 = CH_2$, monomers.

(i) Draw **one** repeat unit of HDPE.

[1]



$\left[-\mathrm{CH_2}-\mathrm{CH_2}- \right]$

(ii) HDPE is rigid and strong whereas low density polyethene (LDPE) is flexible.

Explain, with the aid of suitable diagrams, how the structure and bonding in HDPE and LDPE result in their different physical properties.

[3]

HDPE

LDPE

LDPE has branched polymer chains;

less close / less regular packing so weaker instantaneous dipole – induced dipole attraction between polymer chains

HDPE has no / little branching in polymer chains;
closer and regular packing so stronger instantaneous dipole – induced dipole attraction between polymer chains

The polymer chains in HDPE will not bend / slide past one another easily.

[Total: 11]

Section B

Answer **one** question in this section in the spaces provided.

7 **(a)** The Ostwald Process is a chemical process used for making nitric acid from ammonia.

During the process, ammonia gas is oxidised by oxygen in the presence of solid alloy platinum-rhodium catalyst.

(i) State and explain the type of catalysis used in the Ostwald process. [1]

Heterogeneous catalysis.

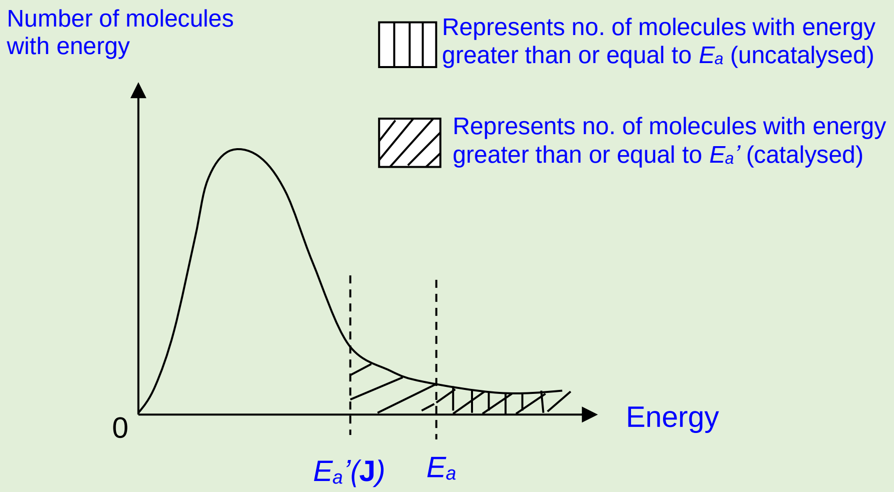
Platinum-rhodium catalyst is a solid but **ammonia and oxygen are gases** so they are of different phases in the reaction.

(ii) Define the term *activation energy*. [1]

Activation energy, E_a, is the **minimum amount of energy** that **molecular collisions must possess** in order for a chemical reaction to occur.
OR
Activation energy, E_a is the **minimum amount of energy that reactants must possess in order for a chemical reaction to occur**.

(iii) Draw a Boltzmann distribution curve for the molecular energies of a sample of a gaseous reaction mixture of ammonia and oxygen.

On your diagram, draw a line to represent the activation energy. Label this line E_a. [2]



(iv) On the Boltzmann distribution curve in **(a)(iii),** show the change that would happen when platinum-rhodium catalyst is added to the reaction mixture. The temperature and pressure of the reaction mixture are kept constant.

Label the change **J**.

[1]

Line for J correctly drawn and labelled

(b) There are several stages to the Ostwald Process, but the following equation is a summary of the overall process.

$$NH_3(g) + 2O_2(g) \longrightarrow HNO_3(l) + H_2O(l)$$

(i) It was found that the *order of reaction with respect to oxygen is zero*.

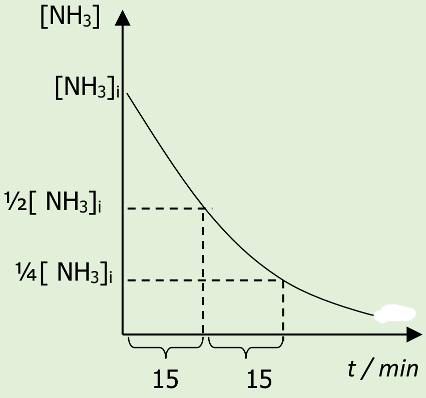
Explain the words in italics.

[1]

The rate of the reaction is independent of the concentration of oxygen.

(ii) The reaction to produce nitric acid is an overall first order reaction with a half-life of 15 minutes. Using this and the information in **(b)(i)**, sketch a well-labelled graph of $[NH_3]$ against time.

[2]



Show downward sloping curve with two half-lives clearly labelled at 15min each.

(iii) Write an expression for the rate equation.

[1]

rate = $k[NH_3]$

(iv) Calculate the rate constant, giving its units.

[1]

$$t_{1/2} = \frac{\ln 2}{k}$$

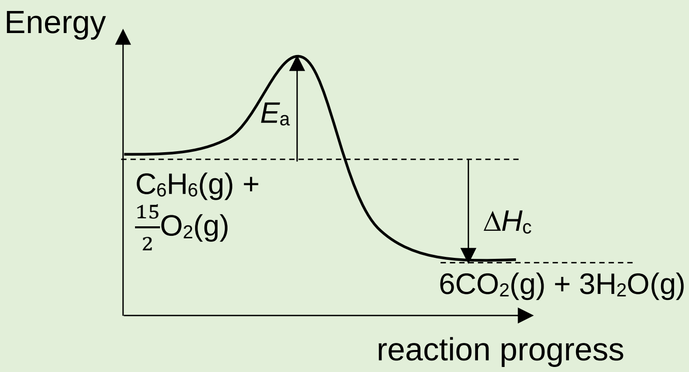
k = (ln 2) / 15 = <u>**0.0462 min^{-1}**</u>

(c) The equation for the complete combustion of liquid benzene is shown.

$$C_6H_6(l) + \frac{15}{2}O_2(g) \longrightarrow 6CO_2(g) + 3H_2O(g) \qquad \Delta H_c = -3267 \text{ kJ mol}^{-1}$$

(i) On the axes below, draw a labelled energy profile diagram for the combustion of benzene. Label the activation energy, E_a, and the enthalpy change of combustion, ΔH_c.

[2]



(ii) Calculate a value for enthalpy change of combustion of gaseous benzene using bond energy values from the *Data Booklet* and the energy cycle shown below.

$$\begin{tikzcd}
C_6H_6(g) + \frac{15}{2}O_2(g) \arrow[rr, "\Delta H_c"] \arrow[dr] & & 6CO_2(g) + 3H_2O(g) \arrow[dl] \\
& 6C(g) + 6H(g) + 15O(g) &
\end{tikzcd}$$

[3]

$\Delta H_c = 6BE(C\text{-}C)(\text{benzene}) + 6BE(C\text{-}H) + \frac{15}{2}BE(O{=}O) - [12BE(C{=}O) + 6BE(O\text{-}H)]$

$= 6(520) + 6(410) + \frac{15}{2}(496) - [12(805) + 6(460)]$

$= \underline{\mathbf{-3120}}$ kJ mol^{-1}

(iii) The accepted value for the standard enthalpy change of combustion of benzene, $\Delta H_c^{\ominus}$ is different from the value of ΔH_c calculated in **(c)(ii)**.

One reason is that the bond energy values are only average values.

Suggest another reason why the accepted value for the enthalpy change of combustion of benzene obtained under standard conditions is different from the value of ΔH_c calculated in **(c)(ii)**.

[1]

This is because **benzene and water are liquids at room temperature.** The **enthalpy change of vaporisation of benzene and H_2O are not taken into consideration**.

(d) **(i)** Hydrofluoric acid, HF, is a weak acid.

A buffer solution **A** can be made from sodium fluoride, NaF and hydrofluoric acid, HF.

Write two equations to show how solution **A** behaves as a buffer when small amounts of OH^- (aq) and H_3O^+ (aq) are separately added to portions of **A**.

[2]

$HF + OH^- \rightarrow F^- + H_2O$

$F^- + H_3O^+ \rightarrow HF + H_2O$

(ii) The buffer solution **A** can be used to maintain an almost constant pH of 7.4. The equilibrium that applies to this buffer solution is shown.

$$HF\text{ (aq)} \rightleftharpoons F^-\text{ (aq)} + H^+\text{ (aq)} \qquad K_a = 5.62 \times 10^{-4}\text{ mol dm}^{-3}$$

Write the K_a expression and use it to calculate the $\frac{[HF]}{[F^-]}$ ratio that gives a pH of 7.4.

[2]

$$HF(aq) \rightleftharpoons F^-(aq) + H^+(aq)$$

$$K_a = \frac{[F^-][H^+]}{[HF]}$$

$$5.62\times10^{-4} = \frac{[F^-]}{[HF]}\times10^{-7.4}$$

$$\frac{[HF]}{[F^-]} = \frac{10^{-7.4}}{5.62\times10^{-4}} = 7.08\times10^{-5}$$

[Total: 20]

8 **(a)** Magnesium oxide reacts with hydrochloric acid in an exothermic reaction.

$$MgO(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l) \qquad \Delta H_{\text{reaction 1}}$$

In an experiment to determine the maximum change in temperature of the above reaction, solid magnesium oxide is added to 50.0 cm^3 of hydrochloric acid in a polystyrene cup. HC*l* is in excess.

The initial temperature of the hydrochloric acid before magnesium oxide is added is measured and recorded at a regular interval for 3 minutes.

At **exactly the fourth minute**, 0.500 g of solid magnesium oxide is added into the polystyrene cup and the mixture is quickly covered with a lid and stirred.

The temperature of the mixture was measured and recorded at the 5th min, and at regular time intervals until 10 min.

The results are as shown in Fig. 8.1.

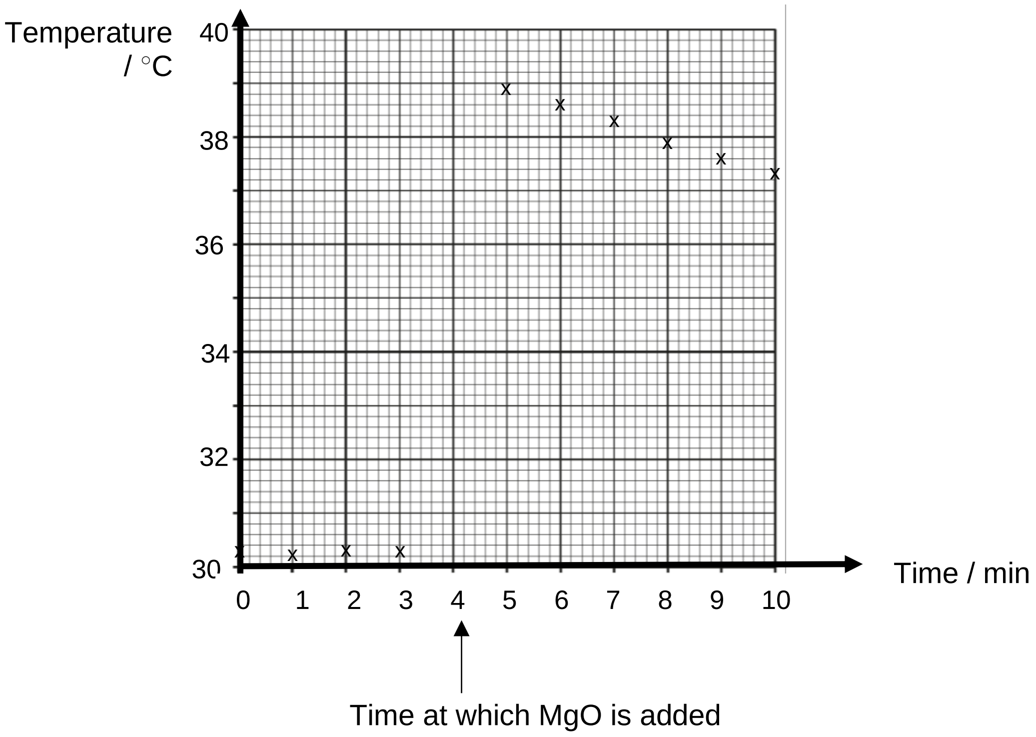


Fig. 8.1

(i) Draw two separate straight lines of best fit.

The first line should take into account the temperatures for the points before 4.0 min. Extend this line to the 4.0 min mark.

The second line should take into account the decreasing temperatures for the points after 4.0 min. Extend this line to the 4.0 min mark.

Use your graph to determine the minimum temperature, maximum temperature and temperature rise, ΔT, of the experiment at the fourth minute.

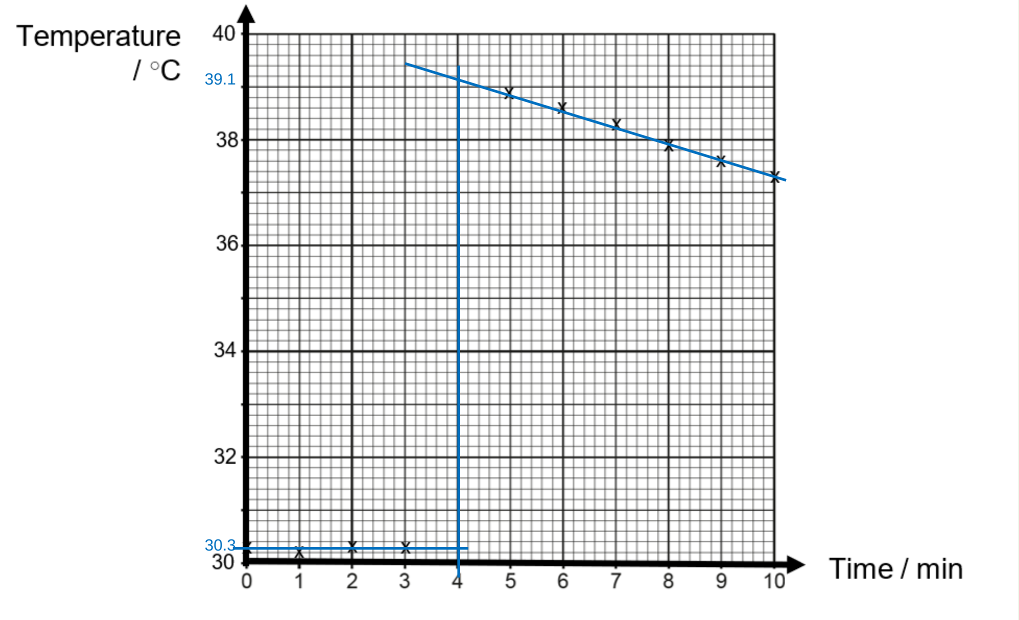
Temperature at the fourth minute:

minimum = ………..°C

maximum = ………..°C

temperature rise, Δ*T* = ………. °C

[3]



minimum = …30.3….°C
maximum = …39.1….°C
temperature rise, ΔT_{max} = ….8.8… °C

(ii) Using your results from **(a)(i)**, calculate the energy, in J, evolved during the reaction.

You should assume that the specific heat capacity of the reaction mixture is 4.18 J g^{-1} K^{-1} and its density is 1.00 g cm^{-3}.

[1]

Heat change of solution = 50 cm^3 x 1.00 g cm^{-3} x 4.18 J g^{-1} K^{-1} x 8.8 K
= **<u>1840 J</u>**

(iii) Calculate the number of moles of magnesium oxide used in the experiment and hence calculate the enthalpy change for the reaction, $\Delta H_{\text{reaction 1}}$.

[2]

n(MgO) = $\frac{0.500}{24.3+16.0} = 0.01241\ mol$

$$\Delta H_{\text{reaction 1}} = -\frac{\text{heat change of solution}}{\text{n(MgO)}} = -\frac{1840}{0.01241} = -\underline{148}\text{ kJ mol}^{-1}$$

(b) Magnesium bromide, $MgBr_2$, is often used as a mild sedative and as an anticonvulsant for treatment of nervous disorders.

(i) Write an equation to represent the lattice energy of magnesium bromide.

[1]

$$Mg^{2+}(g) + 2Br^{-}(g) \longrightarrow MgBr_2(s)$$

(ii) How would you expect the lattice energy of barium bromide to compare with that of magnesium bromide? Explain your answer, using relevant data from the *Data Booklet*.

[3]

Lattice energy of $BaBr_2$ is less exothermic than that of $MgBr_2$.

Ionic radius of Ba^{2+} (0.135 nm) is larger than that of Mg^{2+} (0.065 nm), the inter–ionic distance between Ba^{2+} and Br^{-} will be larger. This results in weaker electrostatic forces of attraction between the Ba^{2+} and Br^{-}. Hence lattice energy of $BaBr_2$ is less exothermic.

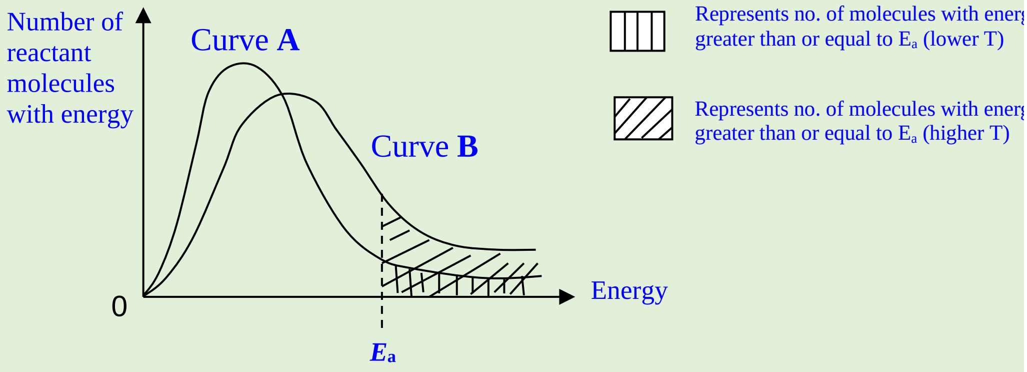
(c) The Contact Process is used in the manufacture of sulfuric acid. There are several stages to the reaction. At the heart of the process is the reversible reaction of converting sulfur dioxide to sulfur trioxide shown below.

$$SO_2(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons SO_3(g)$$

(i) Draw a Boltzmann distribution curve for the molecular energies of the gaseous reaction mixture.

Label the curve **A** and label the activation energy ***E*$_a$**.

[2]



(ii) On the axes that you have drawn, draw a second Boltzmann distribution curve for the molecular energies of the same gaseous reaction mixture at a higher temperature. Label this curve **B**.

Use curves **A** and **B** to describe and explain the effect of an increase in temperature on the rate of reaction.

[3]

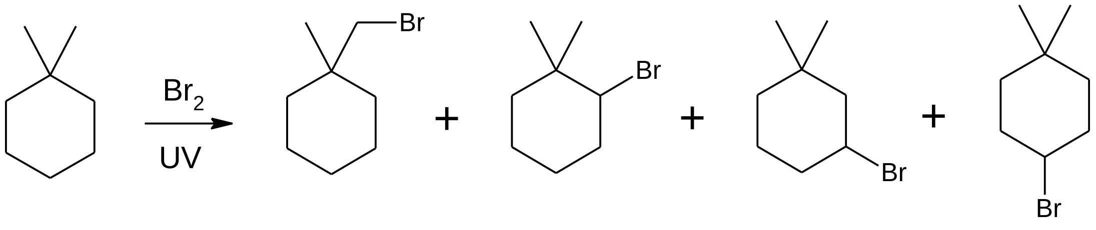
When temperature increases from curve A to curve B,

- the **average kinetic energy of the molecules increases**.

With reference to the shaded areas under curve **A** and curve **B**, the **number of reactant molecules with energy greater than or equal to the activation energy, *E*$_a$, will increase**.

- This results in an **increase in the frequency of effective collision**
- **The rate constant, k, increases** and hence **rate of reaction increases**.

(d) Hydrocarbon **T** reacts with limited bromine in the presence of ultraviolet light to form a mixture of four mono-brominated products, **W** to **Z**.



T **W** **X** **Y** **Z**

(i) Give the IUPAC name for hydrocarbon **T**.

[1]

1,1–dimethylcyclohexane

(ii) Assuming all the hydrogen atoms present in **T** are equally reactive, what is the expected ratio of **W** : **X** : **Y** : **Z** formed?

[1]

3 : 2 : 2 : 1

(iii) Compound **Z** forms different products when heated separately with aqueous NaOH and NaOH in ethanol.

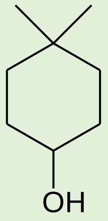
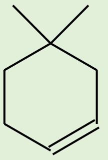
In Table 8.1 below, draw the products formed and state the type of reaction.

Table 8.1

Regents and conditions	Product	Type of reaction
Aqueous NaOH, heat		
NaOH in ethanol, heat		

[3]

Regents and conditions	Product	Type of reaction

Aqueous NaOH, heat		Substitution
NaOH in ethanol, heat		Elimination

[Total: 20]