

JURONG PIONEER JUNIOR COLLEGE 2022 JC1 YEAR END EXAMINATION

Higher 2

CANDIDATE NAME							
CLASS	2	2	S		EXAM INDEX		

CHEMISTRY

Paper 2 Structured and Free Response Questions

9729/02

2 hours

28 September 2022

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and exam index number on all the work you hand in. Write in dark blue or black pen on both sides of the paper. You may use a HB pencil for any diagrams, graphs. Do not use staples, paper clips, glue or correction fluid.

Answer <u>all</u> questions in <u>Section A</u> (55 marks) and in <u>Section B</u> (20 marks) in the spaces provided on the Question paper. For Section B, if additional space is required, you should use the pages at the end of this booklet. The question number must be clearly shown.

At the end of the examination, fasten all your work securely together. The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use					
	1	7			
Section A	2	13			
Section A	3	8			
	4	14			
	5	13			
Section B	6	20			
Penalty	(delete accor	dingly)			
Lack 3sf in fina	al answer	–1 / NA			
Missing/wror in final an	–1 / NA				
Tota	75				

This document consists of 19 printed pages and 3 blank pages.

Section A (55 marks)

Answer **<u>ALL</u>** the questions in the spaces provided.

1 Atoms contain the subatomic particles – electrons, protons and neutrons. Protons and electrons were discovered by observations of their behaviours in electric field.

charge on plate negative protons source charge on plate positive Fig. 1.1 electrons • deflects more in the opposite direction relative to proton • parabolic <u>only within</u> electric field (width of plate)

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[1]

[1]

Fig. 1.1 shows the behaviour of separate beams of protons and neutrons in an electric field.

- (i) Complete the diagram in Fig. 1.1 with the relative charge of each of the electrically charged plates.
- (ii) In Fig. 1.1, show how a separate beam of electrons from the same source behaves in the same electric field.
- (iii) If the particles are all travelling at the same speed, through an electric field of constant strength, the angle of deflection is proportional to their charge/mass ratio.

In this particular experimental set-up, protons are deflected through an angle of $+15^{\circ}$. Assuming an identical set of experimental conditions, calculate the angle of deflection for ${}^{4}\text{He}^{2+}$.

	charge mass	angle of deflection
proton	<u>1+</u> 1	+15°
⁴ He ²⁺	$\frac{2+}{4} = \frac{1+}{2}$	¹ ⁄₂ × (+15°) = <u>+7.50°</u> (sign + 3sf + units)
	· · ·	

(a)

Under identical conditions, a beam of particles, **A**, each having 12 times the mass of a proton, was deflected by an angle of $+5^{\circ}$.



	charge mass	angle of deflection
proton	<u>1+</u> 1	+15°
Α	$\frac{q_{+}}{12}$	$\frac{q_{\scriptscriptstyle +}}{12} \times (+15^{\circ}) = +5^{\circ} \implies q_{\scriptscriptstyle +} = 4+$

<u>4+</u> (sign after number for charge)

(v) Given that a particle of **A** contains 6 protons, deduce the number of neutrons and electrons in a particle of **A**.

Recall:

- mass of a proton = mass of a neutron
- electron is very light (mass of an electron << mass of a proton or a neutron) so mass of cation A = mass of protons and neutrons

Since cation **A** contains 6 protons and has an ionic charge of 4+, number of neutrons = 12 - 6 = 6 and number of electrons = 6 - 4 = 2.

(b) *Hydron* is a general term used to represent the ions ${}^{1}_{1}H^{+}$, ${}^{2}_{1}H^{+}$ and ${}^{3}_{1}H^{+}$.

State, in terms of subatomic particles in the nucleus, what is the same about each of these ions and what is different.

same <u>number of protons</u>	
different <u>number of neutrons</u>	[1]

[Total: 7]

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[1]

[2]

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- 4
- 2 (a) Group 1 chlorides are white crystalline solids.

so ionic radius decreases.

Fig 2.1 shows the structure of the simplest repeat unit in a crystal of lithium chloride and in a crystal of caesium chloride.

In LiC*l*, each Li⁺ ion is surrounded by six Cl^- ions. In CsC*l*, each Cs⁺ ion is surrounded by eight Cl^- ions.



(i) Explain why the ionic radius of the Group 1 cations increases down the group. <u>Consider the effect of each factor</u>

011	Taulus	-	
1.	no. of p.q.s. ↑	\Rightarrow radius \uparrow	Since the trend shows increasing radius,
2.	shielding ↑	\Rightarrow radius \uparrow	combined effects of factor 1 and 2
3.	nuclear charge 1	`⇒ radius ↓	outweigh effect of factor 3.

The effects of increasing number of principal quantum shells AND

increasing shielding outweigh the effect of increasing nuclear charge. Hence, nuclear attraction on outermost electrons decreases

[1]

[1]

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(ii) NaCl and KCl have the same crystal structure as LiCl. Suggest why CsCl has a different crystal structure.

Surrounded by & CITions <u>Cs</u>⁺, having a much larger radius than Na⁺ and K⁺ so more CI⁻ ions can

fit/pack around (or surround) each Cs⁺ ion

<u>Concept check</u>: CsC*l* is ionic (Read info given in qn stem!) so it is incorrect to mention Cs can form more bond pairs or can expand octet which involves formation of covalent bonds.

(b) The distance between the centres of two adjacent ions in a crystal structure can be calculated by using the equation shown.

interionic distance = cation radius + anion radius

Table 2.2 shows some information about 3 different ionic solids.

ionic solid	lattice energy / kJ mol⁻¹	cation radius / nm	anion radius / nm	cation charge	anion charge	crystal structure
LiC <i>l</i>	-853	0.076	0.181	+1	-1	see Fig 2.1
NaC <i>l</i>	-771	0.095	0.181	+1	-1	same as LiC <i>l</i>
MgO	-3899	0.065	0.140	+2	-2	same as LiC <i>l</i>

_			_	_
Та	b	e	2.	2

Use the information in Table 2.2 to state the two factors that determine the numerical magnitude of lattice energy and deduce which factor has the greater effect. Explain your answer.



- (c) The solubility of ionic solids varies according to the solvent used. Both water and hexane are solvents.
 - (i) Draw a labelled diagram to show the significant force of attraction between **two** water molecules. Include the name of attraction in your diagram.



(ii) Suggest why LiC*l* is soluble in water but insoluble in hexane. Refer to the forces of attraction between particles in your answer.

 Hydration energy released from formation of ion-dipole attracts

 between ions of LiC/ and polar H₂O molecules is sufficient to

 overcome the strong ionic bonds between Li⁺ and Cl⁻ ions in LiC/ and

 the hydrogen bonds between H₂O molecules.

 However, ions of LiC/ is not able to form effective interactions with

 non-polar hexane molecules. Thus LiC/ is insoluble in hexane.

(d) Potassium chloride is a water-soluble salt. When a sample of potassium chloride is added to a beaker of water, the solution cools down.

Table 2.3 shows the standard enthalpy and entropy changes of solution for this process at 298 K.

Table 2.3

ΔS^{\ominus}_{sol}	+94.4 J K ⁻¹ mol ⁻¹
ΔH^{\ominus}_{sol}	+17.2 kJ mol⁻¹

(i) Write an equation to represent the *standard enthalpy change of solution* of KC*l*(s).

 $\mathbf{KC}(\mathbf{s}) \rightarrow \mathbf{K}^{+}(\mathbf{aq}) + \mathbf{C}^{-}(\mathbf{aq}) \quad \text{OR} \quad \mathbf{KC}(\mathbf{s}) \rightarrow \mathbf{KC}(\mathbf{aq})$ ^[1]

(ii) Explain the significance of the positive sign for ΔS^{\ominus} with respect to the process that is occurring.

 $\Delta S^{\oplus}_{sol} > 0$ as there is an **increase in the disorderliness** since the **ions**

in fixed position <u>in solid becomes</u> free-moving/mobile <u>aqueous ions</u> (OR there is an <u>increase in number/amount of aqueous ions after</u> <u>solid is dissolved</u>). [1]

(iii) State the sign of ΔG^{\ominus} for this reaction at 298 K. Explain your reasoning without reference to any calculation.

Since the solution cools down when KC/ is added to water, KC/ can dissolve in water at 298 K. So the reaction is spontaneous and thus ΔG^{\oplus} is negative. [1] (iv) Calculate the theoretical minimum temperature at which potassium chloride would dissolve in water. Suggest why this value is only theoretical.
 Reaction is spontaneous when ∆G ≤ 0.

 $\Delta H - T\Delta S \le 0$ $(+17.2) - T\left(\frac{+94.4}{1000}\right) \le 0$ $T \ge 182.2 \text{ K}$ minimum temperature = <u>183 K</u>
At <u>183 K (-90°C)</u>, ice would be present instead of liquid water (or water is the solid state) and will not be able to dissolve KC/. [2]

[Total: 13]

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- **3** (a) The Winkler Method is often used to determine the oxygen concentration in water samples. The method involves the following steps:
 - Manganese(II) hydroxide is prepared and added in excess to 100 cm³ of the water sample containing dissolved oxygen.

 $\frac{1}{2}O_2(g) + 2Mn(OH)_2(s) + H_2O(l) \rightarrow 2Mn(OH)_3(s)$

• An excess of acidified potassium iodide is then added.

 $2Mn(OH)_3(s) + 2I^{-}(aq) + 6H^{+}(aq) \rightarrow 2Mn^{2+}(aq) + I_2(aq) + 6H_2O(l)$

• The mixture is then transferred to a conical flask and titrated with a standard solution of sodium thiosulfate using starch as an indicator.

 $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^{-}(aq) + S_4O_6^{2-}(aq)$

(i) State the electronic configuration of the manganese ion in Mn(OH)₃. [1]

Mn atom: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$ (To form cation, remove e⁻ from 4s)

1s² 2s² 2p⁶ 3s² 3p⁶ 3d⁴

(ii) A 100 cm³ sample of water containing dissolved oxygen required 11.20 cm^3 of 0.0100 mol dm⁻³ sodium thiosulfate solution to reach the end point. Calculate the concentration of O₂ in this water sample in mol dm⁻³.

 $n(S_2O_3^{2^-}) \text{ used } = 0.0100 \times \frac{11.20}{1000} = \underline{0.000112 \text{ mol}}$ Since $\frac{1}{2}O_2 = 2Mn(OH)_3 = I_2 = 2S_2O_3^{2^-}$ (*i.e.* $1O_2 = 4S_2O_3^{2^-}$), $n(O_2) \text{ present } = \frac{1}{4} \times 0.000112 = \underline{2.80 \times 10^{-5} \text{ mol}}$ $[O_2] \text{ in sample } = \frac{2.80 \times 10^{-5}}{100/1000}$ $= \underline{2.80 \times 10^{-4} \text{ mol dm}^{-3}}$

[3]

The concentration of oxygen gas in a 1 dm³ sample of distilled water saturated (b) with oxygen was measured at different temperatures and the results are shown in Table 3.1.

Sample temperature / °C concentration of oxygen at saturation / mg dm⁻³ 9.07 1 20 2 25 8.24 3 30 7.54 4 35 6.93 (i) The temperature of a 1 dm³ sample of distilled water saturated with oxygen is raised from 25 °C to 35 °C and allowed to reach equilibrium. 8.24 mg O₂ at 25 °C Calculate the amount of O₂ gas, in moles, which will have escaped from the sample. 1.31 mg O₂ escaped $(4.0938 \times 10^{-5} \text{ mol})$ mass of O₂ escaped in 1 dm³ sample = 8.24 - 6.93 = 1.31 mg ٨ $n(O_2)$ escaped = $\frac{1.31 \times 10^{-3}}{(2 \times 16.0)}$ 6.93 mg O₂ = 4.0938 × 10⁻⁵ = 4.09 × 10⁻⁵ mol at 35 °C [2] A sealed vessel, **B**, contains 1 dm³ of oxygen gas and 1 dm³ of distilled water saturated with oxygen at 25 °C and 100 kPa. Assuming O_2 is an ideal gas, calculate the amount of O_2 , in moles, in (ii) 1 dm³ of oxygen gas at 25 °C and 100 kPa. Express your answer in five significant figures. $n(O_2) = \frac{PV}{RT} = \frac{(100 \times 10^3)(1 \times 10^{-3})}{(8.31)(25 + 273)} = \underline{0.040382} \text{ mol}$ 8.24 mg O₂ at 25 °C [1] The temperature of vessel B is increased to 35 °C and a new equilibrium is (iii) established. 382 mol O₂ Using your answers in (b)(i) and (b)(ii), calculate the pressure of oxygen 9<mark>38 × 10⁻⁵ mol</mark> gas in vessel B at 35 °C. O₂ escaped ᠕ $O_2(aq)$ $O_2(g)$ \rightleftharpoons 6.93 mg O₂ initial / mol 0.040382 at 35 °C change -4.0938×10^{-5} $+4.0938 \times 10^{-5}$ eqm / mol 0.040423 pressure of O₂ gas at 35 °C = $\frac{nRT}{V} = \frac{(0.040423)(8.31)(35 + 273)}{(1 \times 10^{-3})}$ = 103 kPa OR Since PV = nRT and for constant volume, $P \propto nT$ $\frac{P_{O_2}}{O_2} - \frac{(0.040423)(35+273)}{(0.040423)(35+273)}$ $\overline{100}^{-}$ $\overline{(0.040382)(25+273)}$

Table 3.1





pressure of O₂ gas at 35 °C = 103 kPa [1]



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Examiner's

9 For 4 Ammonia, NH_3 , is manufactured from nitrogen and hydrogen by the Haber process. Examiner's Use $\Delta H = -92 \text{ kJ mol}^{-1}$ $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ (a) (i) Explain the meaning of the term bond energy. Enthalpy change / heat change / energy absorbed when one mole of covalent bonds between 2 atoms in gaseous phase is broken [1] (ii) Using the given ΔH and relevant bond energies from *Data Booklet*, calculate a value for the N–H bond energy in NH₃. $\Delta H = \Sigma E$ (all bonds in rxts) – ΣE (all bonds in pdts) N=N(4) + 3H-H(4)-3=(+++) 2 × 3E(N-H) $\Delta H = E(N \equiv N) + 3 \times E(H - H) - 6 \times E(N - H)$ gaseous atoms 3 N-Hlord per NHS $-92 = (+944) + 3 \times (+436) - 6 \times E(N-H)$ moleciale $E(N-H) = \frac{1}{6} [(+944) + 3 \times (+436) - (-92)] = +\frac{391}{6} \text{ kJ mol}^{-1}$ [2] (b) The Haber process is usually carried out at a temperature of approximately 400 °C in the presence of an iron catalyst. With the aid of Boltzmann distribution graph, state and explain the effect of the iron catalyst on the reaction rate. No. of molecules with kinetic energy $\geq E_a$ of uncatalyed reaction No. of molecules with kinetic energy $\geq E_a$ of catalysed reaction Correct diagram should include labelled axes correct shape of curve which number of starts at origin molecules shading of areas under curve

 Catalyst provides an alternative reaction pathway with lower activation

 energy, E_a '. So the number of molecules with kinetic energy \geq lowered

 activation energy E_a ' increases.

 \therefore frequency of effective/successful collisions between molecules

 increases and hence rate increases.

 [3]

Ea

Ea

beyond E_a and E_a'

legend to explain shaded areas

kinetic energy / kJ mol⁻¹

0

- (c) 1.00 mol of nitrogen, $N_2(g)$, was mixed with 3.00 mol of hydrogen, $H_2(g)$ and allowed to reach equilibrium at a pressure of 2.00×10^7 Pa. The final equilibrium mixture formed contained 0.300 mol of ammonia, $NH_3(g)$.
 - (i) Calculate the amounts of $N_2(g)$ and $H_2(g)$ in the equilibrium mixture.

Initial amount /mol	N ₂ (g) 1.00	+	3H ₂ (g) 3.00	⇒	2NH₃(g) 0	
change	-½(0.300) = -0.150		$-\frac{3}{2}(0.300)$ = -0.450		+0.300	
eqm amount / <u>mol</u>	<u>0.850</u> (3st	f + ur	<u>2.55</u> nits)		0.300	

(ii) Calculate the partial pressure of NH₃(g) in the equilibrium mixture.

$$p(NH_3) = \frac{0.300}{(0.850 + 2.55 + 0.300)} \times 2.00 \times 10^7$$
$$= \underline{1.62 \times 10^6 \text{ Pa}} \text{ (3sf + units)}$$

(d) In another equilibrium mixture, the partial pressures are as shown in Table 4.1.

substance	partial pressure / Pa
N ₂ (g)	$2.20 imes 10^{6}$
H ₂ (g)	$9.62 imes 10^5$
NH₃(g)	$1.40 imes 10^4$

Table 4.1

Write the expression for the equilibrium constant, K_p, for the production of NH₃(g) from N₂(g) and H₂(g).



[1]

[1]

(ii) Calculate the value of K_p for this reaction. State the units.

$$K_{p} = \frac{(1.40 \times 10^{4})^{2}}{(2.20 \times 10^{6}) \times (9.62 \times 10^{5})^{3}}$$
$$= \underline{1.00 \times 10^{-16}} \,\underline{Pa^{-2}} \,(3sf + units)$$

[2]

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(iii)	$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ This reaction is repeated with the same starting amounts of nitrogen and hydrogen. The same temperature is used but the container has a smaller volume. State and explain the effects, if any, of this change on the yield of ammonia and on the value of K_p .	For Examiner's Use
	effect on yield of ammonia … <mark>increases</mark>	
	explanation Smaller volume results in an increase in pressure (or increase	
	in partial pressure of each gas). So the position of equilibrium shifts to	
	the right to reduce number/amount of gas molecules.	
	effect on value of <i>K</i> _p … <u>no change</u>	
	explanation .Temperature remains unchanged	
	[3]	

[Total: 14]

- For Examiner's Use
- Two unknown organic compounds **X** and **Y** were found to contain carbon, hydrogen 5 and chlorine only.
 - (a) Compound X, M_r = 147, contains 49.0% carbon, 2.7% hydrogen and 48.3% chlorine by mass.

Determine the molecular formula of **X**, showing all your working.

element	С	н	Cl
mass /g	49.0	2.7	48.3
amount /mol	$\frac{49.0}{12.0} = 4.08$	$\frac{2.7}{1.0}$ = 2.70	$\frac{48.3}{35.5}$ = 1.36
simplest ratio	$\frac{4.08}{1.36} = 3$	$\frac{4.08}{1.36} = 1.99 \approx 2$	$\frac{1.36}{1.36} = 1$

Empirical formula of X is C_3H_2CI . (with clear working as shown above)

Let the molecular formula of **X** be $C_{3n}H_{2n}Cl_n$.

 $M_r = n[3(12.0) + 2(1.0) + 35.5] = 147 \implies n = 2$

 \therefore Molecular formula of X is <u>C₆H₄Cl₂</u>. (with clear working as shown above)

[2]

[1]

of c= c with

C 2 different groups of atoms

> same molecular formula but different structural formulae

C with 4 different groups of atoms

Η

(b) Compound **Y** has a molecular formula of C_4H_7Cl .

The molecule of Y has the following features:

- The carbon chain is unbranched and the molecule is non-cyclic. •
- The chlorine atom is not attached to any carbon atom involved in double bond.

There are **three** possible constitutional isomers, **Y1**, **Y2** and **Y3**, which fit these data. Y1 and Y2 exhibit stereoisomerism and Y3 does not.

Y3 has the formula of $CH_2=CHCH_2CH_2Cl$.

(i) Give the IUPAC name for Y3.

Cland (2)

4-chlorobut-1-ene [1m]

longest chain contains 4 C atoms 1 Clatomat C4. H 1 C=C bond at c1 (between

(ii) Y1 and Y2 show different types of stereoisomerism.

Use the above information and that given in (b), draw structural formulae to illustrate the type of stereoisomerism shown by **Y1** and **Y2** respectively.

State the type of stereoisomerism.





For Examiner's

Use

- 14
- (c) Y3 can be converted to other compounds as shown in Fig. 5.1.



Fig. 5.1

(i) Classify the type of organic reaction that **Y3** has undergone in each reaction.

reaction	1	addition
reaction	2	substitution

[2]

For

Examiner's Use

(ii) Compound Z, an isomer of Y3, has the structure below.



Explain why Z has a lower boiling point than that of Y1.

Due to **<u>branching</u>** of carbon chain, there is **<u>less surface area of contact</u>**

between molecules of Z.

Thus, <u>less energy is required to overcome the less extensive</u> instantaneous dipole-induced dipole attractions between molecules of Z than that between molecules of Y1.

[Total: 13]

15 Section B (20 marks)

Answer the question in the spaces provided.

6 In heavily polluted air, a brown haze is often seen due to the formation of nitrogen dioxide, NO₂, from nitrogen monoxide, NO, that passes into the atmosphere.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$
 $\Delta H = y$

(a) Explain the meaning of order of reaction.

<u>Order of reaction</u> with respect to a <u>reactant</u> is the <u>power to which the</u> <u>concentration of that reactant is raised to in an experimentally determined</u> <u>rate equation</u>.

OR In an <u>experimentally determined rate equation</u> whereby <u>rate = k [NO]^a</u> [O₂]^b, <u>a and b are order of reaction with respect to [NO] and [O₂] respectively</u>.

(b) In a series of experiments carried out to investigate the reaction between NO and O_2 , the results are shown in Table 6.1.

	concentration / mol dm ⁻³		initial rate
experiment	NO(g)	O ₂ (g)	/ mol dm⁻³ s⁻¹
1	0.001	0.1	$0.70 imes 10^{-3}$
2	0.002	0.1	2.80×10^{-3}
3	0.003	0.2	12.60 × 10 ⁻³

Table 6.1

(i) Deduce the order of reaction with respect to each reactant, and hence write the rate equation for the reaction.

Compare expt 1 & 2 whereby $[O_2]$ remains the same, rate $\propto [NO]^a$ $\frac{2.80 \times 10^{-3}}{0.70 \times 10^{-3}} = \frac{(0.002)^a}{(0.001)^a} \Rightarrow a = 2$ $\therefore \text{ order with respect to NO is } \underline{2}.$ Compare expt 2 & 3, rate $\propto [NO]^2 [O_2]^b$ $\frac{2.80 \times 10^{-3}}{12.60 \times 10^{-3}} = \frac{(0.002)^2(0.1)^b}{(0.003)^2(0.2)^b} \Rightarrow b = 1$ $\therefore \text{ order with respect to } O_2 \text{ is } \underline{1}.$ Hence, rate equation is rate = k [NO]^2 [O_2]
Calculate a value for the rate constant k, giving its units.
[2]
Substitute data from expt 1 (or expt 2 or expt 3) into the rate equation $k = \frac{0.7 \times 10^{-3}}{(0.001)^2(0.1)} \text{ or } \frac{2.80 \times 10^{-3}}{(0.002)^2(0.1)} \text{ or } \frac{12.60 \times 10^{-3}}{(0.003)^2(0.2)}$

= 7000 mol⁻² dm⁶ s⁻¹

(ii)

[1]

[3]

The first step of a 2-step mechanism for the reaction between NO and O_2 is shown below.

step 1
$$2NO(g) \rightarrow N_2O_2(g)$$
 fast

(iii) Draw dot-and-cross diagrams to show the electronic structures of the two molecules, NO and N₂O₂.

Hence, identify a feature in the electronic structure of NO that would suggest this is a fast step in the reaction.

NO is **<u>reactive</u>** since it has <u>an unpaired electron / single electron</u> (**OR** is a <u>radical</u>).

(v) By considering the overall equation, suggest an equation for step 2.

[1]

[3]

step 1 step 2	$2NO \rightarrow N_2O_2$ $\underline{N_2O_2 + O_2} \rightarrow 2NO_2$	fast slow
overall	$2NO + O_2 \rightarrow 2NO_2$	

(c) In the above experiment in (b), the initial rates of the reaction with varying concentrations of NO and O_2 were studied to obtain the rate equation for the reaction.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

(i) The rate equation of the reaction can also be investigated by monitoring a change in the product. Suggest briefly how this method is carried out to determine the order of reaction with respect to O₂.

[2]

Conduct the experiment with a <u>large excess of NO</u>. Since NO₂ is a brown gas, <u>use a colorimeter</u> to <u>measure the colour intensity</u> of the mixture <u>at</u> <u>various time intervals</u> until no further change.

A light of a certain wavelength is passed through the reaction mixture whereby absorbance of the light ∞ colour intensity of the mixture. The higher the concentration of NO₂, the more intense the colour and so the higher the absorbance.

(ii) The order of reaction with respect to O₂ is one.

Sketch the graph you would obtain for the method you suggested in (c)(i) and show clearly, on the graph, how the order can be confirmed.





(d) Use the data in Table 6.2, draw an energy cycle to calculate the value of y.

Table	6.2
-------	-----

	ΔH / kJ mol ⁻¹
$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$	У
$4NO_2(g) + O_2(g) \rightarrow 2N_2O_5(g)$	-123
$2N_2(g) + 5O_2(g) \rightarrow 2N_2O_5(g)$	+10.0
$2NO(g) \rightarrow N_2(g) + O_2(g)$	-180



- (e) The removal of NO₂ is important because it has significant environmental consequences if emitted into the atmosphere by internal combustion engines.
 - (i) State one unwanted environmental consequence of atmospheric NO₂. [1]

It can result in the <u>formation of acid rain</u> that damage buildings or ecosystems **OR** the <u>formation of photochemical smog</u>

(ii) One way to remove atmospheric NO₂ is to fit these engines with a catalytic converter, which uses ammonia as a reducing agent. One possible reaction is shown by the following **unbalanced** equation.

$$\mathsf{NH}_3 + \mathsf{NO}_2 \rightarrow \mathsf{N}_2 + \mathsf{H}_2\mathsf{O}$$

Deduce the changes in oxidation number, stating which element is involved in each change. Hence, balance the equation.

The O.N. of <u>N increases from -3 in NH₃ to 0 in N₂</u> while O.N. of <u>N</u> decreases from +4 in NO₂ to 0 in N₂.

 $\begin{array}{ll} [O] & 2NH_3 \rightarrow N_2 + 6H^+ + 6e^- & eqn (1) \\ [R] & 2NO_2 + 8H^+ + 8e^- \rightarrow N_2 + 4H_2O & eqn (2) \\ 4 \times eqn (1) + 3 \times eqn (2) \\ \end{array}$

[Total: 20]

[2]

[3]