



TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE
NAME

CIVICS GROUP

H1 CHEMISTRY

8873/02

Paper 2 Structured Questions

12 September 2024

2 hours

Candidates answer on the Question Paper.

Additional materials: *Data Booklet*

READ THESE INSTRUCTIONS FIRST

Write your name and civics group in the spaces provided at the top of this page.

Write in dark blue or black pen on both sides of the paper.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

Section A

Answer **all** the 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.

Examiner's Use		
Paper 1	MCQ	/ 30
Paper 2	Section A	
	Q1	/ 9
	Q2	/ 6
	Q3	/ 14
	Q4	/ 8
	Q5	/ 10
	Q6	/ 13
	Section B	
	Q7	/ 20
	Q8	/ 20
	/ 80	
Total		/ 100
Grade		

Section A

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

- 1 (a) Aluminium and boron are two elements of Group 13.

- (i) Complete the electronic configuration for Al and Al^{3+} .

Al : $1s^2$

Al^{3+} : $1s^2$ [1]

- (ii) Atoms of elements are made up of the three subatomic particles: protons, electrons and neutrons, in varying numbers.

Complete Table 1.1 for each subatomic particle of an atom of ${}^{26}_{13}\text{Al}$.

Table 1.1

atom	number of protons	number of neutrons	number of unpaired electrons
${}^{26}_{13}\text{Al}$			

[1]

- (b) The compounds of aluminium and boron have many uses. Aluminium oxide, Al_2O_3 , is commonly used as a refractory material for lining furnaces while aluminium chloride, AlCl_3 , is an antiperspirant agent. Boron trichloride, BCl_3 , is used in the refining process of aluminium.

- (i) Draw the dot-and-cross diagrams for Al_2O_3 and AlCl_3 .

[2]

- (ii) Briefly describe the bonding in AlCl_3 in terms of the overlap of orbitals.

.....
 [1]



- (iii) With reference to the Valence Shell Electron Pair Repulsion Theory, explain the shape and bond angle with respect to the B atom in BCl_3 .

.....

.....

.....

..... [2]

- (c) Table 1.2 shows the melting points of two different boron compounds, BCl_3 and NaBH_4 .

Table 1.2

compound	melting point / °C
BCl_3	– 107
NaBH_4	400

With reference to structure and bonding, explain the difference in melting points of the two compounds.

.....

.....

.....

.....

..... [2]

[Total: 9]



2 This question is about ionisation energies of elements.

(a) (i) Define the term *first ionisation energy*.

.....

 [1]

(ii) Explain the general trend in first ionisation energy of elements down a Group in the Periodic Table.

.....

 [2]

(b) The first six ionisation energies for an unknown element **X** is given in Table 2.1.

Table 2.1

	1st	2nd	3rd	4th	5th	6th
ionisation energy of X / kJ mol ⁻¹	1050	1900	2910	4960	6270	21300

(i) Deduce the Group number of element **X**, giving your reasoning.

.....

 [2]



- (ii) The graph in Fig. 2.1 shows a sketch of the first ionisation energies of six consecutive elements within Periods 2 and Period 3.

The letters do not represent the symbols of elements.

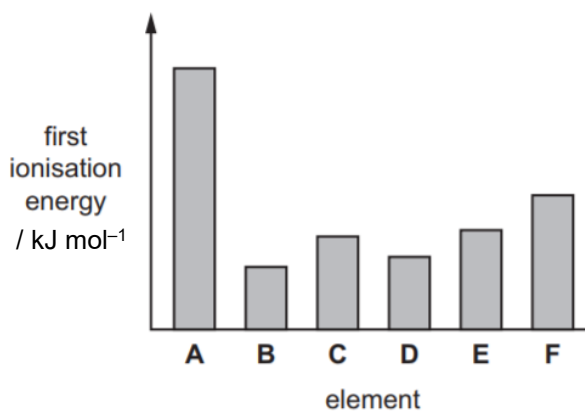


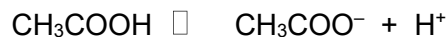
Fig. 2.1

Identify the alphabet letter in Fig. 2.1 that belongs to element X.

..... [1]

[Total: 6]

- 3 (a) Ethanoic acid is a weak acid.



A sample of ethanoic acid can be mixed with aqueous sodium ethanoate to make a buffer solution.

- (i) Define the term *pH*.

.....
 [1]

- (ii) Explain with aid of equations, how the sample mixture of ethanoic acid and sodium ethanoate behaves as a buffer.

.....

 [3]

- (iii) The sample of ethanoic acid with a pH value of 3.0 has a molar concentration of $0.0750 \text{ mol dm}^{-3}$.

The degree of dissociation, α , is the percentage of acid molecules that dissociate into ions:

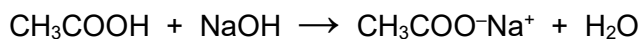
$$\alpha = \frac{[\text{acid}]_{\text{dissociated}}}{[\text{acid}]_{\text{initial}}} \times 100\%$$

Using this information, determine α for the sample of ethanoic acid.

$\alpha = \dots\dots\dots\%$
 [2]



- (b) A student determines the concentration of ethanoic acid in a sample of vinegar by titrating it with aqueous sodium hydroxide.



A 10.0 cm³ portion of the sample of vinegar is transferred into a 250 cm³ volumetric flask.

The solution is made up to 250 cm³ with deionised water.

Several 25.0 cm³ portions of this diluted vinegar are titrated against 0.0220 mol dm⁻³ sodium hydroxide, using thymolphthalein indicator. The mean volume of aqueous sodium hydroxide added is 21.10 cm³.

- (i) Calculate the concentration, in mol dm⁻³, of ethanoic acid in the original sample of vinegar.

[2]



- (ii) The minimum legal acidity level of vinegar in most countries is 4% by mass. Below this level, it cannot be sold as vinegar.

Calculate the percentage by mass of ethanoic acid in the original sample of vinegar and state whether the vinegar meets the minimum legal acidity level.

Assume the density of vinegar to be 1 g cm^{-3} .

[2]

- (c) Ethanoic acid can be reduced to form ethanol, $\text{C}_2\text{H}_5\text{OH}$, which is useful as fuel. A direct-ethanol fuel cell (DEFC) is a type of fuel cell that uses ethanol as a fuel source.

The redox reaction in DEFC involves the oxidation of ethanol to carbon dioxide and the reduction of oxygen to water.

- (i) Determine the average oxidation number of carbon in ethanol and the oxidation number of carbon in carbon dioxide.

[1]

- (ii) Construct the half-equations for the redox reaction in the DEFC.

.....
 [2]

- (iii) Hence, or otherwise, write the overall equation for the redox reaction in the DEFC.

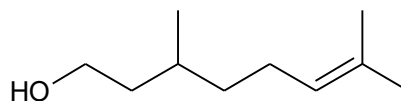
..... [1]

[Total: 14]



4 Organic compounds can have a vast variety of uses and can be found naturally or man-made.

(a) Citronellol has a distinct smell found in perfumes and in some natural insect repellents.



citronellol

Deduce the molecular formula of citronellol.

..... [1]

(b) Fig. 4.1 shows reactions of citronellol.

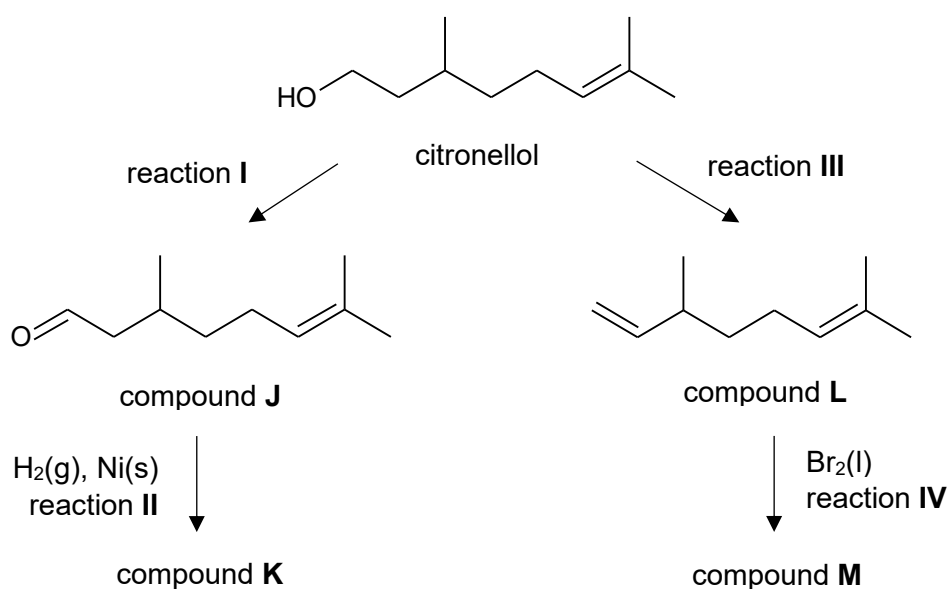
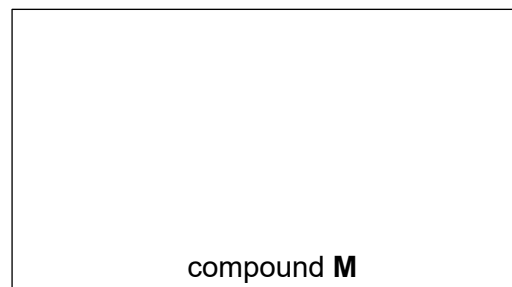
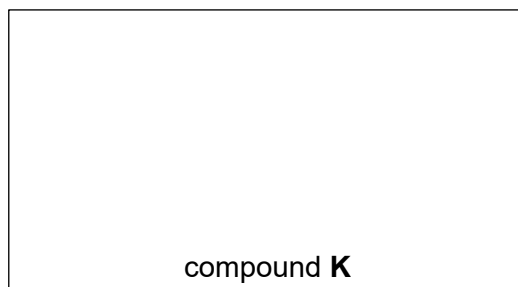


Fig. 4.1

(i) Give the **skeletal** formulae for compounds **K** and **M**.



[2]

(ii) Suggest the reagents and conditions for reactions **I** and **III**.

for reaction **I**

for reaction **III**

[2]

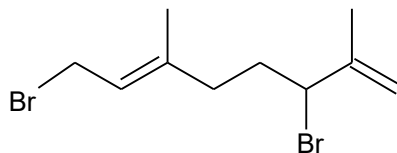
(iii) State the type of reaction occurring in reaction III.

type of reaction [1]

(iv) Suggest the IUPAC name for compound L.

..... [1]

(v) Compound **M** can be converted into compound **N** which displays cis-trans isomerism.



compound **N**

Explain why compound **N** can exhibit cis-trans isomerism while citronellol cannot.

.....

..... [1]

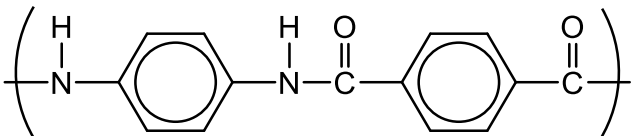
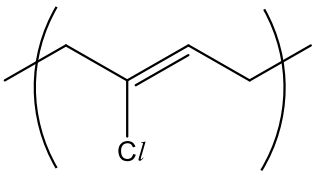
[Total: 8]

5 Many organic molecules are widely used in creating polymers.

(a) *Kevlar*, polylactic acid (PLA) and neoprene are some examples.

(i) Complete the boxes in Table 5.1.

Table 5.1

polymer	structure of repeat unit of polymer	structural formula of monomer(s)
<i>Kevlar</i>		
PLA		$\text{HOCH}(\text{CH}_3)\text{CO}_2\text{H}$ lactic acid
neoprene		

[4]

(ii) Suggest **two** properties why *Kevlar* is suitable to be used in the manufacture of bulletproof vests, racing tires and racing sails.

.....
 [1]



- (b) PLA is a thermoplastic and used as medical implants in biomedical applications, food packaging and single-use cups.

- (i) State the type of polymerisation used to form PLA.

type for polymerisation [1]

- (ii) PLA can be used as biomedical implants are intended to be absorbed into the body within two years as they form lactic acid which is non-toxic to the body. Explain why PLA can be broken down in the body.

.....
..... [1]

- (iii) Explain, in terms of structure and bonding, the difference in how a thermoplastic polymer behaves when heated compared to a thermosetting polymer.

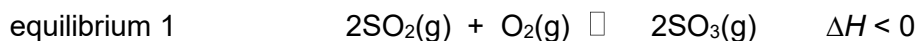
.....
.....
.....
.....
.....
.....
.....
.....
.....
..... [3]

[Total: 10]



- 6 Sulfur trioxide and ammonia are manufactured industrially in processes that involve adjusting conditions to their respective reaction equilibria to optimise production yields.

- (a) The Contact process is used to prepare sulfur trioxide from sulfur dioxide and oxygen. The process is a reversible reaction and is performed in a closed system to achieve dynamic equilibrium.



- (i) Define what is meant by *dynamic equilibrium*.

.....

 [1]

- (ii) Write the expression for the equilibrium constant, K_c , of the reaction, stating its units.

$K_c =$

units

[2]

- (iii) At a certain temperature, 3.00 mol of SO_2 and 2.00 mol of O_2 were added into a reaction chamber of 2.00 dm^3 . At equilibrium, the O_2 concentration was found to be 0.30 mol dm^{-3} .

Calculate a value for the equilibrium constant K_c at this temperature.

[2]



(iv) Explain how the following changes would affect the position of equilibrium 1 in the Contact process:

- compression of the container volume,

.....

 [2]

- increase in temperature.

.....

 [2]

(b) The Haber process is used to produce ammonia as shown:

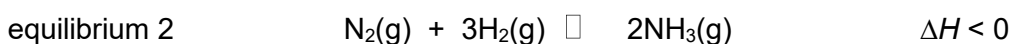


Fig. 6.1 shows the relationship between temperature, pressure (p) and the percentage of gases converted. A conversion of 100% means the limiting reagent is fully depleted.

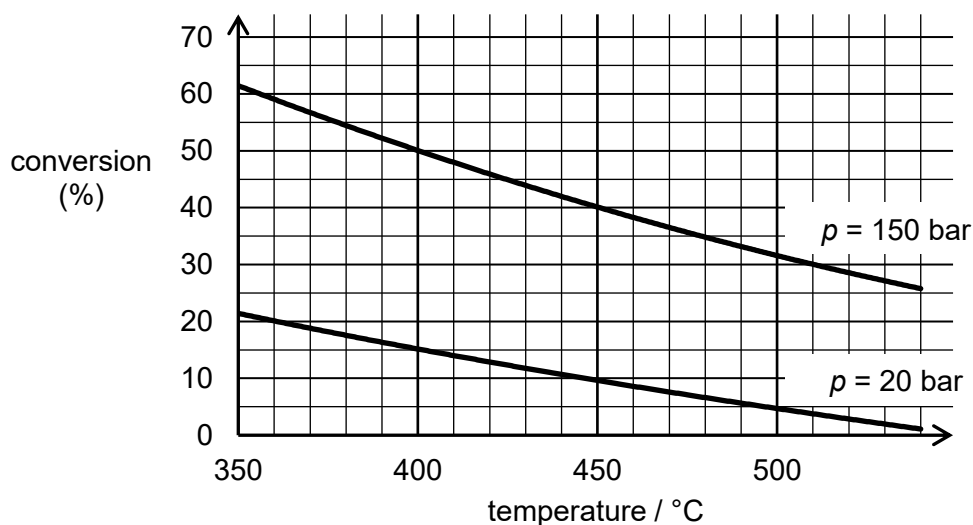


Fig. 6.1

(i) Using Fig. 6.1, estimate the expected percentage conversion of reactants into products at a temperature of 400 °C and pressure of 20 bar. Give your answer to two significant figures.

..... [1]

- (ii) Hence, calculate the amount of ammonia gas that will be present at equilibrium when excess nitrogen gas is mixed with 2.00 mol of hydrogen gas at 400 °C and 20 bar.

[2]

- (iii) Estimate the pressure needed to achieve 30% conversion at a temperature of 450 °C. State any assumption made.

.....

..... [1]

[Total: 13]

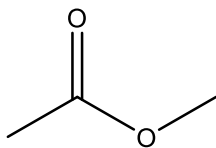




Section B

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

- 7 (a) The skeletal structure of the ester methyl ethanoate, $\text{C}_3\text{H}_6\text{O}_2$, is shown below.



- (i) Define the *standard enthalpy change of formation* of methyl ethanoate.

.....
 [1]

- (ii) Use data from Table 7.1 and the energy cycle to calculate the standard enthalpy change of formation of methyl ethanoate, $\Delta H_f^\ominus$.

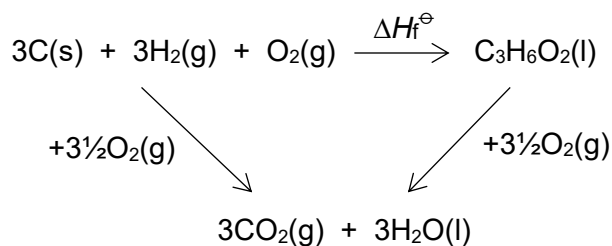


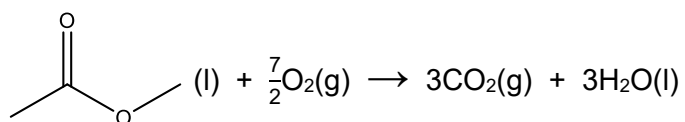
Table 7.1

substance	standard enthalpy change of combustion, $\Delta H_c^\ominus$ / kJ mol^{-1}
C(s)	−394
H ₂ (g)	−286
C ₃ H ₆ O ₂ (l)	−1592

[2]



- (iii) The complete combustion of methyl ethanoate is shown below.



With the aid of appropriate bond energies from the *Data Booklet*, calculate another value for the standard enthalpy change of combustion of methyl ethanoate.

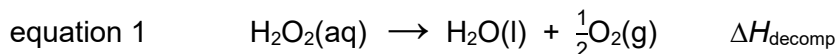
[3]

- (iv) The enthalpy change of combustion of methyl ethanoate determined in (a)(iii) differs from that listed in Table 7.1. Suggest a reason why this is so.

.....

..... [1]

- (b) Hydrogen peroxide decomposes very slowly to form water and oxygen gas as shown in the equation below.



The enthalpy change of decomposition, ΔH_{decomp} , is exothermic. Iron(III) nitrate, $\text{Fe}(\text{NO}_3)_3$, is an effective catalyst in this reaction. A student used the apparatus shown in Fig. 7.1 to carry out an experiment to determine ΔH_{decomp} .

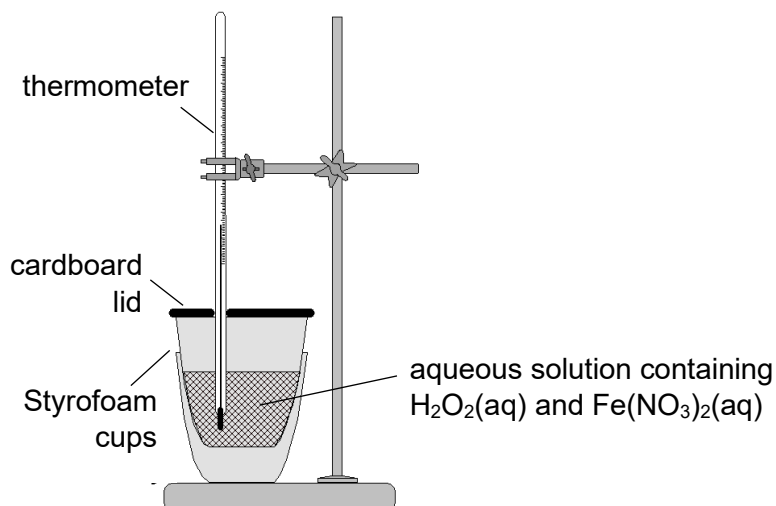


Fig. 7.1

- 50.0 cm^3 of $0.850 \text{ mol dm}^{-3}$ aqueous H_2O_2 was placed in Styrofoam cup, which was in turn placed into another cup.
- At fixed time intervals, the temperature of the solution was measured.
- At time $t = 4.0 \text{ min}$, 50.0 cm^3 of aqueous $\text{Fe}(\text{NO}_3)_3$ was added to the H_2O_2 .
- The reaction was monitored with temperature taken at fixed time intervals.
- A consistent fall in temperature indicated that the reaction had finished.
- The results are shown in Fig. 7.2.

temperature / °C

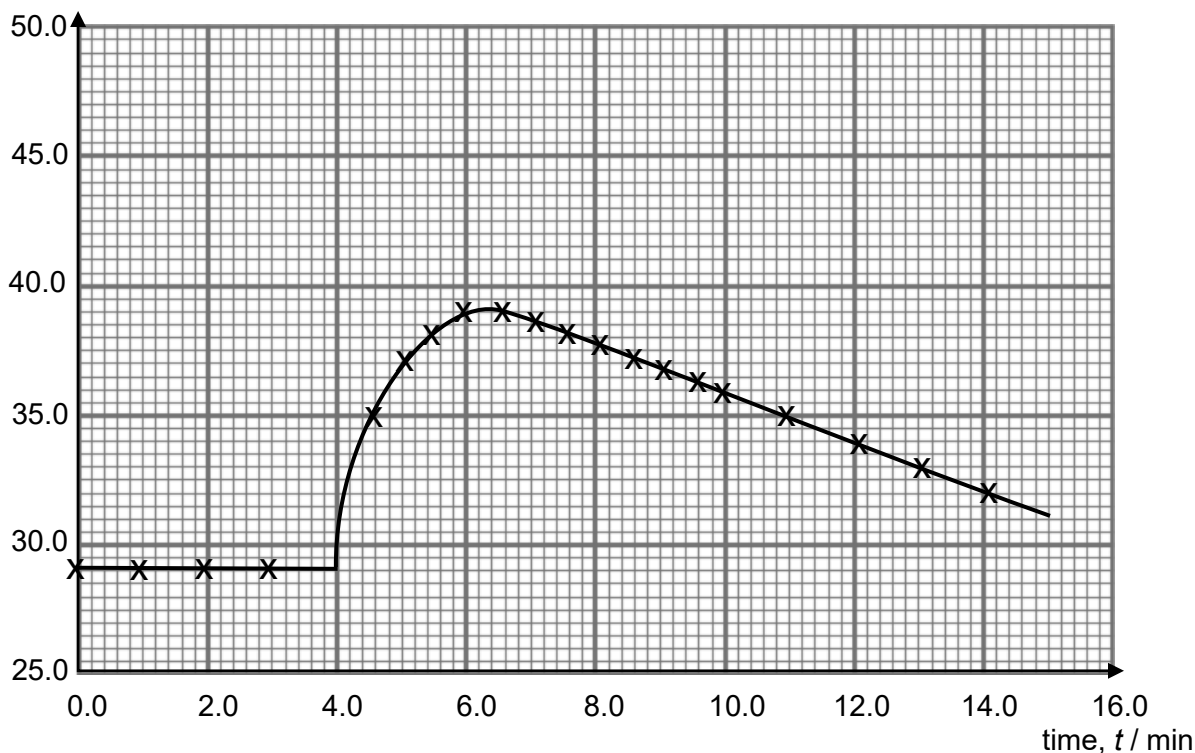


Fig. 7.2

- (i) On the grid in Fig. 7.2, taking into account the portion of the graph after the reaction had finished, extrapolate (extend) the line back to $t = 4.0$ min.

Determine a value for the maximum theoretical temperature, $T_{\max}$, and the temperature change for the experiment, ΔT , at $t = 4.0$ min.

$T_{\max} = \dots\dots\dots$

$\Delta T = \dots\dots\dots$

[2]

- (ii) Hence, calculate the enthalpy change for the decomposition, ΔH_{decomp} , for the reaction shown in equation 1.

The specific heat capacity of the aqueous solution is $4.18 \text{ J g}^{-1} \text{ K}^{-1}$.

Assume the density of the aqueous solution to be 1 g cm^{-3} .

[3]



- (iii) Suggest **one** feature of the experimental set-up in Fig. 7.1 that minimises heat loss.

.....
 [1]

- (c) The chlorides of elements in the third period of the Periodic Table show variations in different properties.

- (i) Sketch the general trend of melting point of the chlorides in Fig. 7.3.

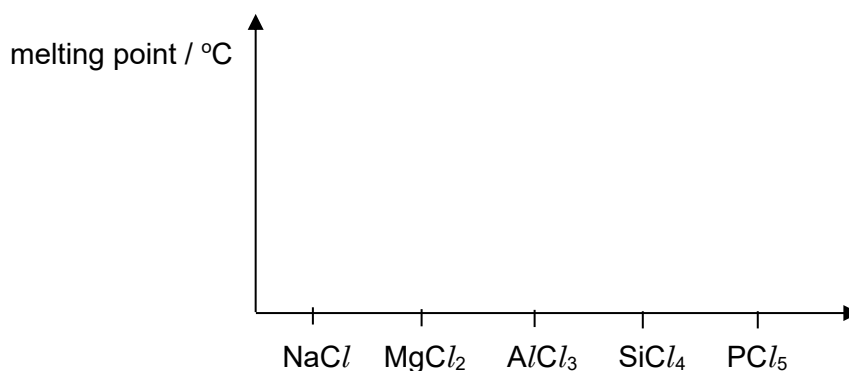


Fig. 7.3

[1]

- (ii) With the aid of chemical equations, describe and explain what happens when samples of NaCl , AlCl_3 and PCl_5 are each added separately to water. In each case, state the likely pH of the resulting solution.

.....

 [4]

- (iii) Describe the thermal decomposition of the hydrogen halides HBr and HI, and explain the difference in their thermal stabilities.

.....

.....

.....

.....

.....

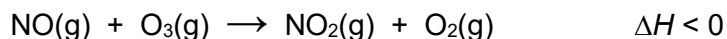
..... [2]

[Total: 20]



8 Nitric oxide, NO, and ozone, O₃, are pollutants commonly associated with car engine exhaust.

(a) NO and O₃ react according to the following equation.



An experiment was conducted in a container with constant volume to monitor the concentration of NO over time. O₃ was used in excess. Fig. 8.1 shows the graph obtained.

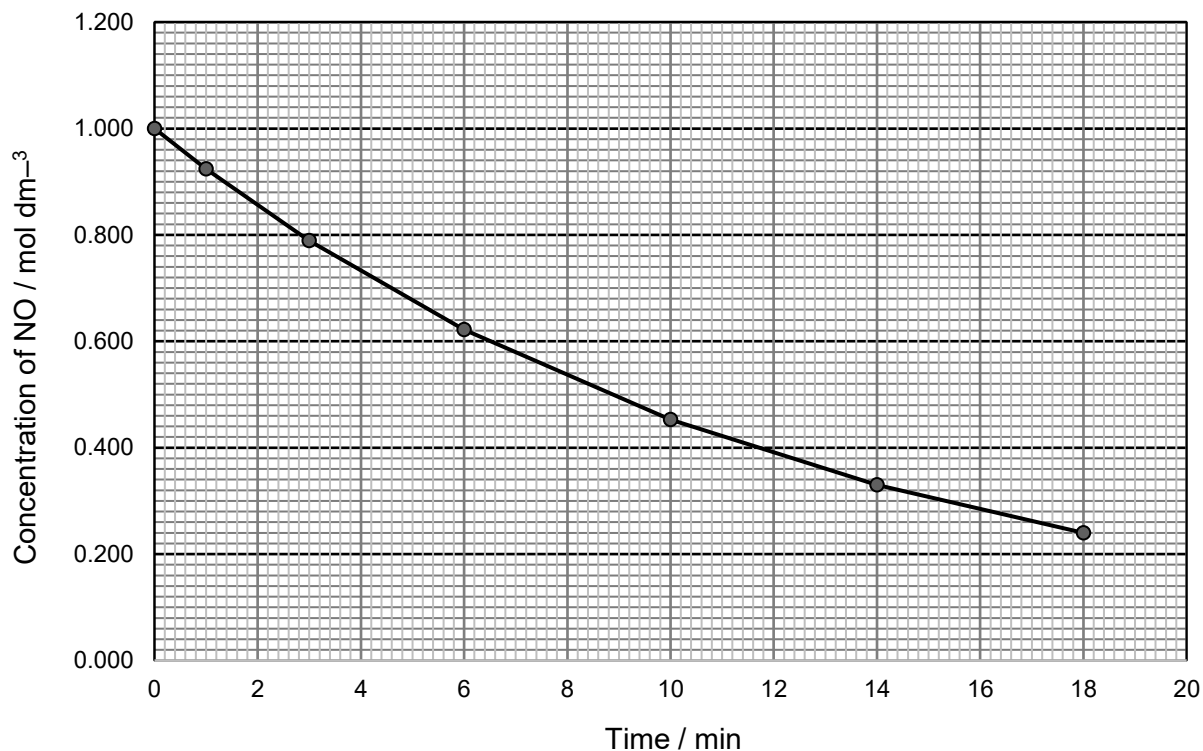


Fig. 8.1

(i) Using the data in Fig. 8.1, show that the order of reaction with respect to NO is one.

[1]

(ii) Sketch a graph of the rate of reaction versus [NO] using the axes given below.



[1]

- (iii) Another set of experiments were conducted to determine the order of reaction with respect to O_3 .

Using the data in Table 8.1, determine the order of reaction with respect to O_3 .

Table 8.1

expt	$[NO] / \text{mol dm}^{-3}$	$[O_3] / \text{mol dm}^{-3}$	relative rate
1	0.5	0.6	0.5
2	1.0	0.6	1.0
3	2.0	1.8	6.0

[1]

- (iv) Hence, write a rate equation for the reaction between NO and O_3 .

..... [1]

- (v) Suggest how the half-life of the graph in Fig. 8.1 will change when

- $[NO]$ is doubled,

..... [1]

- $[O_3]$ is doubled.

..... [1]

- (vi) Assuming a one-step reaction, complete the reaction pathway diagram for the reaction between NO with O_3 . Label clearly the activation energy, E_a , the enthalpy change of reaction, ΔH , the reactants, and the products.



[2]

- (vii) When a catalyst is used, the reaction rate increases. With the aid of a labelled diagram, explain this in terms of the Boltzmann distribution.

.....
.....
.....
.....
..... [3]

- (b) In recent years, rhodium nanoparticles have replaced the finely divided metals that were used as heterogeneous catalysts in catalytic converters to remove NO and CO from car exhaust gases.

- (i) Define the term *nanoparticles*.

.....
..... [1]

- (ii) Suggest a health reason why the exhaust gases must be removed before releasing into the environment.

.....
..... [1]

- (iii) Write a balanced equation for the reaction between NO and CO, producing two harmless gases.

..... [1]



- (iv) Describe the mechanism for heterogenous catalysis.

.....

.....

.....

.....

.....

.....

.....

.....

..... [3]

- (v) State a feature of rhodium nanoparticles which could explain why it can replace finely divided metals as a more efficient catalyst.

.....

..... [1]

- (vi) The use of nanoparticle catalytic convertors has also made them more cost efficient. Suggest a reason why this is so.

.....

..... [1]

- (vii) Disposal of a catalytic convertor releases nanoparticles into the air. Give an example of how this can cause a potential health hazard to the human body.

.....

..... [1]

[Total: 20]

