RAFFLES INSTITUTION
2024 YEAR 6 PRELIMINARY EXAMINATION

Higher 1

CANDIDATE NAME

CLASS INDEX NUMBER

CHEMISTRY 8873/02

Paper 2 Structured Questions **10 September 2024**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not open this question booklet until you are told to do so.

Write your name, class and index number in the spaces provided at the top of this page.
Write in dark blue or black pen.
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.
A Data Booklet is provided. Do not write anything in it.

For Examiner's Use		
Section A	1	/ 11
	2	/ 8
	3	/ 11
	4	/ 10
	5	/ 11
	6	/ 9
Section B (Please circle the question you have attempted)	7	/ 20
	8	/ 20
Total		/ 80

You are reminded of the need for good English and clear presentation in your answers.

The number of marks is given in brackets [ ] at the end of each question or part question.

Section A

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

1 (a) Complete Table 1.1 for each species.

Table 1.1

species	number of protons	number of neutrons	number of electrons	electronic configuration
$^{40}_{19}K$				$1s^2$……..
	24	28	21	$1s^2$……..

[3]

(b) The strength of interaction between particles determines whether the substance is a solid, liquid or gas at room temperature.

Magnesium oxide, MgO, is a solid while sulfur trioxide, SO_3, is a liquid at room temperature.

(i) Explain in terms of structure and bonding, why MgO is a solid while SO_3 is a liquid at room temperature.

……..…….

……..…….

……..……

……..……

……..……[2]

(ii) Suggest one other difference in the physical properties of MgO and SO_3.

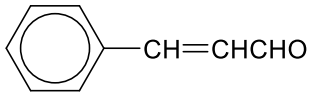
……..……..

……..……[1]

(iii) Draw a 'dot-and-cross' diagram to show the arrangement of outer electrons in MgO.

[2]

(c) 3-phenylpropenal is the compound which gives cinnamon its characteristic flavour and odour.



3-phenylpropenal

(i) Draw the two *cis-trans* isomers of 3-phenylpropenal and label each structure. Explain how this isomerism arises.

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……[3]

[Total: 11]

2 (a) An ideal gas consists of particles of negligible volume and the gas particles exert negligible attractive forces on one another. Most gases are non-ideal but under certain conditions, some gases behave like ideal gases. One gas that behaves like this is oxygen.

The volume of oxygen occupied by a fixed amount of oxygen at different temperatures is shown in Fig. 2.1.

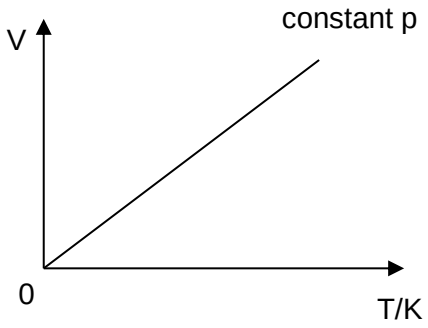

Fig. 2.1

(i) Describe the relationship between the volume of oxygen and temperature.

……..….....

…….[1]

(ii) State the conditions which would result in the greatest intermolecular forces between gaseous oxygen molecules.

…….[1]

(iii) Liquefaction of gases is the process by which substances in their gaseous state are converted to the liquid state.

It is difficult to liquefy oxygen but easy to liquefy ammonia, NH_3. With the aid of a labelled diagram, explain why it is easier to liquefy ammonia. Your diagram should include two ammonia molecules.

……

……[3]

(b) Draw a diagram to illustrate the structure of graphene and explain why graphene

- is a good electrical conductor.
- has high tensile strength.

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…… [3]

[Total: 8]

3 At high temperatures, steam and methane react to produce hydrogen gas.

$$2H_2O(g) + CH_4(g) \rightleftharpoons CO_2(g) + 4H_2(g)$$

(a) Given that the percentage yield of hydrogen increases with increasing temperature, deduce whether the forward reaction is exothermic or endothermic.

Explain your answer using references to the equilibrium position.

……...……...

……...……...

……...……..[1]

(b) State and explain how the percentage yield of hydrogen might alter when the pressure is decreased.

……...……...

……...……...

……...……...

……...……...

……...……...

……...……..[2]

(c) State and explain the effect that each of the following has on the value of the equilibrium constant for the above equilibrium.

increase in temperature

……...……..…....

……...……..[1]

introduction of a catalyst

……..……..…....

……...……..[1]

(d) When the temperature of the reaction mixture is increased, the reaction rate increases.

Explain this in terms of the Boltzmann distribution.

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……

……

……

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……[2]

(e) The reaction of steam with methane occurs in two stages.

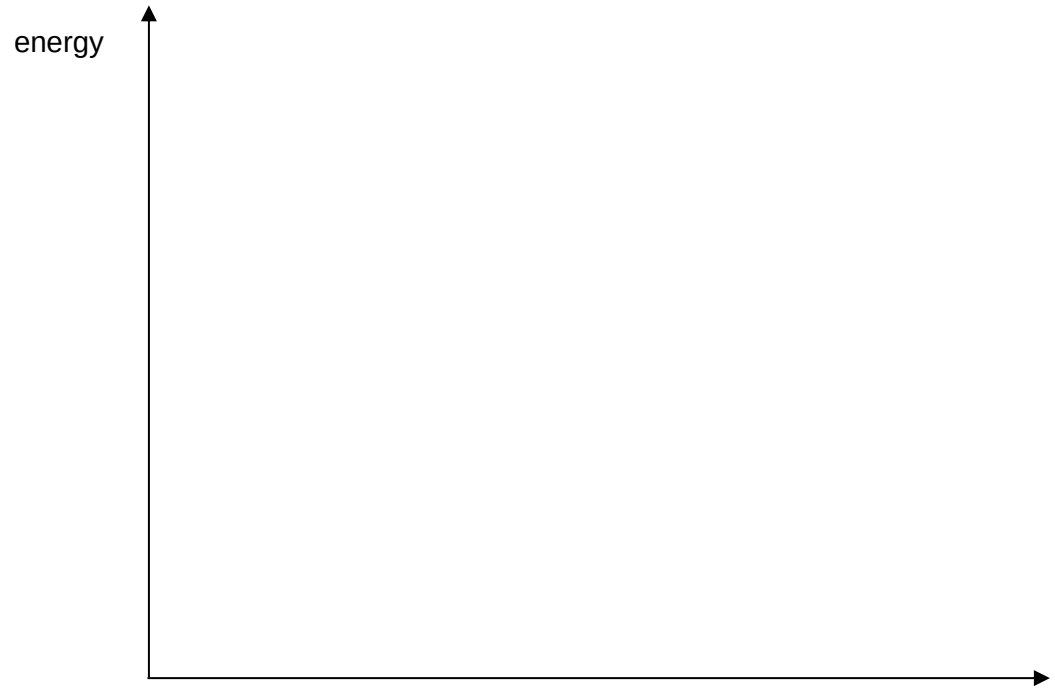
Stage 1

$$H_2O(g) + CH_4(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +210 \text{ kJ mol}^{-1}$$

Stage 2

$$H_2O(g) + CO(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad \Delta H = -42 \text{ kJ mol}^{-1}$$

Complete and label the reaction pathway diagram for the overall reaction between steam and methane showing both of these stages.



[4]

[Total: 11]

4 Fermented milk has a sour taste due to the presence of lactic acid, $CH_3CH(OH)CO_2H$.

Lactic acid is a weak monobasic acid.

$$CH_3CH(OH)CO_2H(aq) \rightleftharpoons CH_3CH(OH)CO_2^-(aq) + H^+(aq)$$

If the concentration of lactic acid is greater than 1% by mass, then the fermented milk has an unpleasant taste.

An experiment is conducted to determine the concentration of lactic acid in a sample of fermented milk by titrating it with aqueous sodium hydroxide. Assume that the rest of the contents in fermented milk do not react with aqueous sodium hydroxide.

A 10.0 cm^3 portion of the sample of fermented milk is transferred into a 100 cm^3 volumetric flask. The solution is made up to 100 cm^3 with deionised water.

Two 10.0 cm^3 portions of the diluted milk are titrated against 0.00500 mol dm^{-3} sodium hydroxide. The mean volume of aqueous sodium hydroxide added is 16.00 cm^3.

(a) State the IUPAC name for lactic acid.

……..……..[1]

(b) Write an equation for the reaction between lactic acid and sodium hydroxide.

……..……..[1]

(c) Calculate the concentration, in mol dm^{-3}, of lactic acid in the original sample of fermented milk.

[3]

(d) Calculate the percentage by mass of lactic acid in the original sample of fermented milk.

Hence, state whether the fermented milk would taste pleasant or unpleasant.

The density of milk is 1.04 g cm^{-3}. (1000 cm^3 = 1 dm^3)

[3]

(e) Table 4.1 shows some data on four indicators.

Table 4.1

indicator	colour in acid	colour in alkali	pH range of colour change
methyl orange	red	yellow	3.2 – 4.4
methyl red	red	yellow	4.8 – 6.0
bromothymol blue	yellow	blue	6.0 – 7.6
thymolphthalein	colourless	blue	8.8 – 10.5

State and explain which indicator is the most suitable for the neutralisation of lactic acid by aqueous sodium hydroxide.

……..……..……

……..……...

……..……..[2]

[Total: 10]

5 Tofu has gained popularity as a plant-based protein alternative to animal protein.

The process of making tofu is shown below.

Stage 1 The soybeans are soaked in water, grinded and filtered to obtain soymilk.

Stage 2 The soymilk is boiled.

Stage 3 A coagulant is mixed with water and added to the soymilk. This allows the protein molecules to come together i.e. coagulate and the soymilk is converted to solid or semi-solid state (curds). A simple representation of a protein molecule before the addition of coagulant is shown in Fig. 5.1.

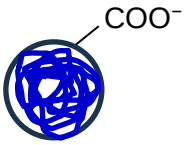


Fig. 5.1

Stage 4 The soymilk curds are transferred into a mould with a cotton cloth.

Stage 5 The cotton cloth is wrapped tightly around the soymilk curds and the curds are pressed with weights. Solid white blocks of varying level of hardness are formed when water is squeezed out.

Salt coagulants are added to make hard tofu for stir-fried dishes. Two common salt coagulants are nigari and gypsum. Nigari is mainly magnesium chloride, $MgCl_2$, obtained from the evaporation of seawater while gypsum is calcium sulfate, $CaSO_4$.

Tofu's inexpensive price and high nutrition may help to mitigate problems of protein deficiency in some countries. Table 5.1 shows the protein content of 100 g of tofu when different concentrations of $CaSO_4$ or $MgCl_2$ are added as the coagulant.

Table 5.1

	protein content of tofu (%)	
concentration of coagulant (w/v %)	$CaSO_4$	$MgCl_2$
0.3	12.9	1.5
0.5	13.1	1.5
1.0	12.6	1.2

(a) Identify two variables which must be controlled during Stage 5 to make tofu of varying hardness.

variable 1 ……..

variable 2 ……..

[2]

[Turn Over

(b) Explain why the soymilk does not form curds before the addition of the salt coagulants.

……..……...

……..……..[1]

(c) Suggest an advantage of using nigari as the salt coagulant.

……..……

……[1]

(d) When salt coagulants are added, coagulation occurs due to the cross-linking of protein molecules in soymilk with the salt's cation.

Complete Fig. 5.2 when Ca^{2+} ions from $CaSO_4$ are added as the coagulant, resulting in a three-dimensional network.

State the forces of attraction that exist between the Ca^{2+} ions with the protein molecules.

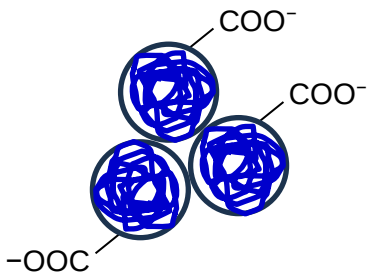


Fig. 5.2

forces of attraction ……
[2]

(e) State and suggest a reason for the differences in protein content in Table 5.1 when $CaSO_4$ or $MgCl_2$ is added as the coagulant.

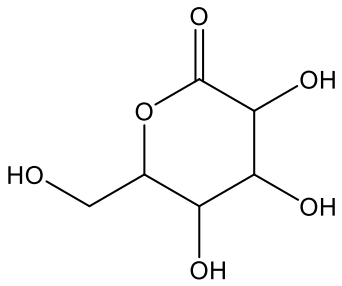
……..……...

……..……...

……..……...

……..……..[2]

Acid coagulants are added to make soft tofu for desserts. Glucono delta lactone (GDL) is a common acid coagulant.



GDL

Soymilk can be converted to curds when the pH of the soy protein is between 4.5 to 5.5.

(f) GDL can only act as an acid coagulant when it is mixed with water.

Name the *type of reaction* GDL undergoes and draw the structural formula of the product formed.

type of reaction ……

structural formula of product

[2]

(g) Suggest a suitable acid coagulating agent you can find in your household to make tofu.

……..……..[1]

[Total: 11]

6 **(a)** Compound **W**, $CH_2{=}CHCN$, is used to make a polymer **Y**, which is present in carbon fibres.

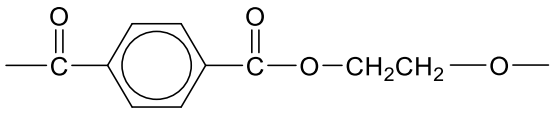
Draw **one** repeat unit of polymer **Y** and state the type of polymerisation that produces **Y**.

type of polymerisation …….

[2]

(b) Many apparel companies have started making shirts from recycled poly(ethylene terephthalate) (PET) bottles, which is a *thermoplastic* polymer.

A repeat unit of PET is shown.



(i) Give the structural formulae of the two monomers used to make PET.

[2]

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

…….[1]

(iii) Explain the meaning of the term *thermoplastic*.

……..……...

……..…….[1]

[Turn Over

(c) Laundry pods which are advertised to reduce wastage of detergent, are typically encased in a poly(vinyl alcohol)(PVA) film.

PVA is a polymer which is soluble in water.
Explain how PVA dissolves in water. Include a diagram in your answer.

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……..……..[3]

[Total: 9]

Section B

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

7 (a) A major explosion occurred in the Port of Beirut in 2020. One of the reactions contributing to the explosion is shown in equation 1.

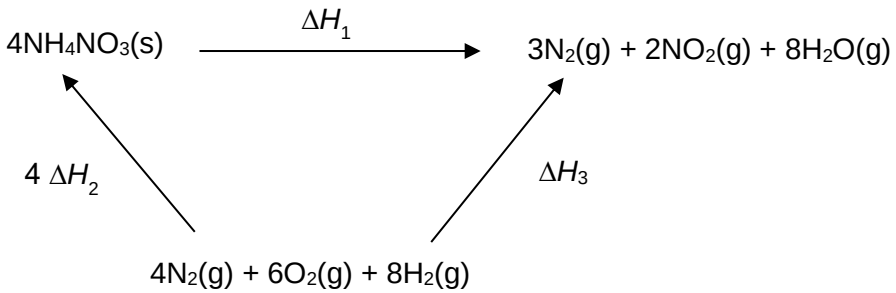
equation 1 $4NH_4NO_3(s) \longrightarrow 3N_2(g) + 2NO_2(g) + 8H_2O(g)$

(i) Define the term *standard enthalpy change of formation*.

……

……[1]

(ii) An energy cycle involving equation 1 is shown in the diagram.



Write an equation to show the relationship between ΔH_1, ΔH_2 and ΔH_3 shown in the diagram.

……[1]

(iii) Use the following data and your answer from **(a)(ii)** to calculate a value in kJ mol^{-1}, for ΔH_1.

$\Delta H_f^{\ominus}$ $NH_4NO_3(s)$ = −365.6 kJ mol^{-1}

$\Delta H_f^{\ominus}$ $NO_2(g)$ = +33.2 kJ mol^{-1}

$\Delta H_f^{\ominus}$ $H_2O(g)$ = −241.8 kJ mol^{-1}

Show your working.

[3]

(b) The melting point of magnesium chloride is 714 °C and of silicon tetrachloride is −69 °C.

(i) Explain how the electronegativity of these elements influences the bonding in each chloride.

……

……

……[1]

(ii) Write equations to show what happens when samples of magnesium chloride, $MgCl_2$, and silicon tetrachloride, $SiCl_4$, are added separately to water. Suggest the expected pH of the resulting solutions.

……

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……

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……

……

……[3]

(iii) Table 7.1 shows the pH of two solutions.

Table 7.1

compound	cation	cationic radii / nm	pH of a 1.0 mol dm^{-3} solution
$AlCl_3$	Al^{3+}	0.050	3.0
$FeCl_3$	Fe^{3+}	0.055	4.0

Explain why $FeCl_3$ has a higher pH than that of $AlCl_3$.

……

……

……

……

……[1]

(c) When chlorine reacts with iron(II) nitrate, chloride is formed as one of the products.

When iodine reacts with iron(II) nitrate, iodide is **not** formed as one of the products.

Explain the above observations.

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……

……[1]

(d) 1-Bromobutane is a good cleaning agent and can dissolve oil and grease.

Fig. 7.1 shows the various reactions that 1-bromobutane undergoes.

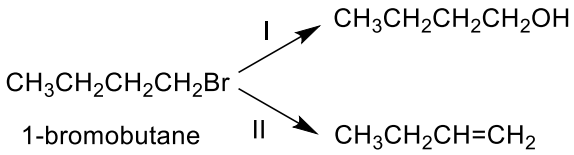

Fig. 7.1

For each reaction, state the type of reaction and the reagents and conditions needed.

reaction I

……...

……[2]

reaction II

……

……[2]

(e) Hydrochloric acid is a strong Brønsted-Lowry acid.

(i) Define the term *strong Brønsted-Lowry acid.*

……

……[2]

(ii) Equation 2 shows the neutralisation reaction between HC*l* and NaOH.

equation 2 $HCl + NaOH \longrightarrow NaCl + H_2O$

Identify the acid, the base, the conjugate acid and the conjugate base in equation 2.

……

……[1]

(iii) A solution is formed by mixing 14.00 cm^3 of 0.200 mol dm^{-3} of HC*l*(aq) and 20 cm^3 of 0.100 mol dm^{-3} of NaOH(aq).

Calculate the pH of the resultant solution.

[2]

[Total: 20]

8 **(a)** A sample of calcium contains three isotopes.

Data for two of the isotopes present in this sample are shown in Table 8.1.

Table 8.1

mass number	abundance (%)
40	95.00
43	1.00

The sample has a relative atomic mass, A_r, of 40.11.

Calculate the mass number of the third isotope.

[2]

Chlorine is often found in compounds that have bleaching and disinfecting properties.

(b) Bleaching powder **Q**, $Ca_xO_yCl_z$, contains 31.5% by mass of calcium and 12.6% by mass of oxygen.

The relative molecular mass, M_r, of **Q** is 127.1.

(i) Calculate the empirical formula of **Q**.

[2]

(ii) Calculate the molecular formula of **Q**.

[1]

(c) Chlorine, Cl_2, is used to disinfect water, forming hypochlorous acid, HC*l*O.

HC*l*O ionises partially to form hydrogen ions, H^+, and hypochloride, ClO^-.

$$HClO\ (aq) \rightleftharpoons H^+\ (aq) + ClO^-\ (aq) \qquad K_a = 3.0 \times 10^{-8}\ \text{mol dm}^{-3}$$

The concentration of '*chlorine*' in the system is given by [HC*l*O] + [ClO^-].

At 25°C, the total concentration of '*chlorine*' in the solution at equilibrium is 1.0×10^{-4} mol dm^{-3}.

(i) Write the expression for the acid dissociation constant, K_a.

[1]

(ii) At equilibrium, $[H^+] = 1.0 \times 10^{-6}$ mol dm^{-3} and [ClO^-] = **x** mol dm^{-3}.

Express the equilibrium concentration of HC*l*O in terms of **x**.

[1]

(iii) Calculate the equilibrium concentration of HC*l*O at 25 °C.

[2]

(d) Explain why the first ionisation energy of chlorine is greater than the first ionisation energy of sodium.

……

……

……

……

……[2]

(e) Explain why the ionic radii of a Cl^- ion is larger than a Na^+ ion.

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……

……

……

……[2]

(f) **(i)** State the **two** factors that affect the magnitude of a lattice energy.

factor 1 ……

factor 2 ……

[2]

(ii) Using one of the factors identified in **(f)(i)**, answer why the lattice energy of strontium sulfide, SrS, is more exothermic than that of sodium chloride, NaCl.

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……

……

……[1]

(g) **H**, **I** and **J** are constitutional isomers with a molecular formula of $C_4H_{10}O$. When heated with excess conc. H_2SO_4, **H**, **I** and **J** formed alkenes.

Table 8.2 shows the observations when **H**, **I** and **J** are heated under reflux with excess acidified $K_2Cr_2O_7$.

Table 8.2

	H	**I**	**J**
heated under reflux with excess acidified $K_2Cr_2O_7$	remains orange	orange to green organic product formed turned moist blue litmus paper red	orange to green organic product formed did not turn moist blue litmus paper red

(i) What type of reaction occurred between **I** and excess acidified $K_2Cr_2O_7$?

…….[1]

(ii) Suggest the structures of **H**, **I** and **J**.

H	**I**	**J**

[3]

[Total: 20]

– END OF PAPER –

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