Catholic Junior College

JC1 Continual Assessment 2

Higher 2

CANDIDATE NAME	
CLASS	1T

CHEMISTRY **9476**

Structured Questions **July 2025**

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class in the boxes above.
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.

Answer **all** questions in the spaces provided on the Question Paper.
The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

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

For Examiner's Use	
Q1	15
Q2	7
Q3	13
Q4	10
TOTAL	45
OVERALL (100%)	
GRADE	

This document consists of **11** printed pages and **1** blank page.

Answer all questions in the spaces provided.

1 Many physical properties in substances around us can be explained by the type of structure and bonding present within these substances.

(a) Silicon carbide, SiC, is a shiny, hard, chemically inert material with a very high melting point. It can be used to sharpen knives and make crucibles.

Using structure and bonding, account for why silicon carbide has a very high melting point.

[2]

(b) Boron trifluoride, BF_3 (m.p. −144 °C) and aluminium fluoride, AlF_3 (m.p. 1291 °C) differ markedly in many of their physical properties.

(i) Draw the dot-and-cross diagrams for these two compounds to illustrate the bonding in each of these compounds.

	BF_3	AlF_3
Dot-and-cross diagram		

[2]

(ii) Aluminium chloride, $AlCl_3$ has a very much lower melting point (192 °C) as compared to aluminium fluoride, AlF_3 (1291 °C) due to differences in their bonding.

With reference to ionic size, state and explain the nature of the bonding in $AlCl_3$ and in AlF_3.

[2]

(c) Two layers of liquids are observed to be formed when equal volumes of hexane, $CH_3CH_2CH_2CH_2CH_2CH_3$, and water are mixed, shaken and allowed to stand, whereas propanol, $CH_3CH_2CH_2OH$, is miscible with water.

By considering the type of intermolecular forces present, explain why:

- Hexane and water are immiscible.

- Propanol and water are miscible.

[4]

(d) The following table shows the boiling points of fluorine and chlorine as well as the bond energies of the F–F and Cl–Cl bonds.

	F_2	Cl_2
Boiling point / °C	–188	–34
Bond Energy / kJ mol^{-1}	158	244

A student argued that the higher boiling point of chlorine compared to fluorine is due to the stronger Cl–Cl bond. In terms of structure and bonding, explain why the student's argument is incorrect, and account for the difference in boiling points.

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.....[3]

(e) State the number of bond pairs and lone pairs of electrons around P and hence, predict the shape and bond angle of PCl_3 molecule. Draw an appropriate diagram to illustrate the shape.

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.....[2]

[Total: 15]

2 (a) As part of safety regulations, it is mandatory for all aircrafts to provide an inflatable life vest for every passenger. One particular model of life vest uses a rapid inflation system of compressed CO_2 in a canister.

A canister typically contains 11.0 g of CO_2, which will inflate a life vest fully at room temperature and pressure.

(i) Calculate the capacity of the life vest at room temperature and pressure.

[1]

(ii) State two main assumptions of the ideal gas law.

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.....[2]

(iii) The canister of compressed CO_2 has a volume of 14.0 cm^3 and can withstand a maximum pressure of 500 bar. Calculate the maximum temperature that the canister can be exposed to before it explodes. Give your answer to three significant figures.

[2]

(b) Ammonia is currently under research and testing as an environmentally-friendly alternative to traditional jet fuel, as it does not contribute to CO_2 emissions.

The two graphs below in Fig. 2.1 show deviation from ideal gas behaviour for 1 mole each of CO_2 and NH_3 gas at 25 °C.

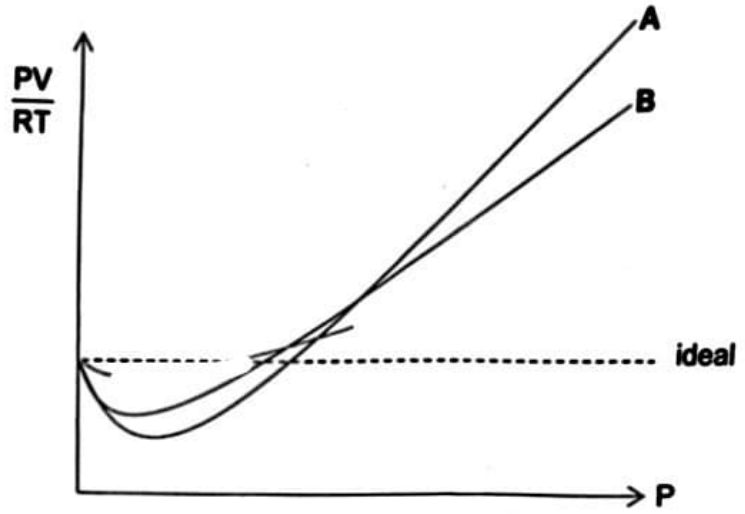

Fig. 2.1

(i) Identify the graph for NH_3 and explain your choice.

NH_3 .....

Explanation:

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.....[1]

(ii) On Fig. 2.1 above, draw a graph to show how 1 mole of CO_2 would behave at a temperature of 70 °C. [1]

[Total: 7]

2

3 (a) Methanol, CH_3OH, is a volatile and flammable liquid.

An experiment was conducted to determine the enthalpy change of combustion of liquid methanol. The energy obtained from burning 2.12 g of methanol was used to heat 150 g of water. This process was 80% efficient, and the temperature of the water rose from 25 °C to 89 °C. The specific heat capacity of water is 4.18 J K^{-1} g^{-1}.

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

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.....[1]

(ii) Use the data above to determine the heat released from combustion of methanol and hence deduce the enthalpy change of combustion of liquid methanol.

[2]

(b) Methanol, CH_3OH, can be synthesised from methane and steam by a process with the reaction for the final stage as shown below.

$$CO(g) + 2H_2(g) \rightarrow CH_3OH(g) \qquad \Delta H = -91 \text{ kJ mol}^{-1}$$

The standard enthalpy changes of combustion of carbon monoxide and hydrogen are −283 kJ mol^{-1} and −286 kJ mol^{-1}, respectively.

(i) Using the data above, calculate a value for the enthalpy change of the following reaction.

$$CH_3OH(g) + \tfrac{3}{2} O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \qquad \Delta H_1$$

[2]

(ii) Hence, calculate the enthalpy change of vaporisation of methanol, using your answers in (a)(ii) and (b)(i).

If you were unable to calculate a value for (b)(i), you should use –800 kJ mol^{-1}. This is not the correct answer.

[1]

(iii) The entropy change, ΔS, of the final stage, as shown below, is –219 J K^{-1} mol^{-1}.

$$CO(g) + 2H_2(g) \rightarrow CH_3OH(g) \qquad \Delta H = -91 \text{ kJ mol}^{-1}$$

I Explain why the above reaction has a negative entropy change.

II Calculate the standard Gibbs free energy change, $\Delta G^{\ominus}$ and predict whether the reaction is spontaneous under standard conditions.

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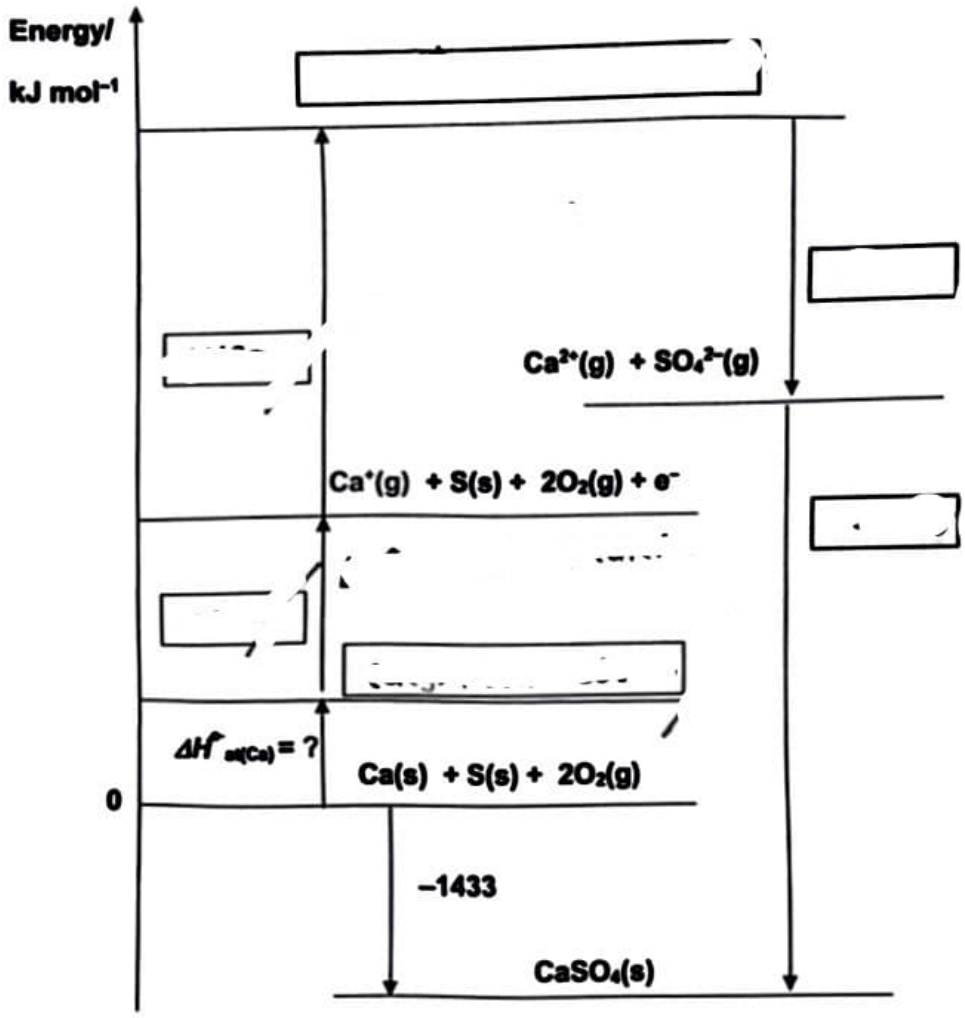
(c) (i) Using the following data, as well as relevant data from the *Data Booklet*, complete the energy level diagram below. Fill in all the boxes with the values of the enthalpy changes and the chemical species, including state symbols, at each stage.

	$\Delta H^{\ominus}$ / kJ mol^{-1}
Standard enthalpy change of formation of $CaSO_4(s)$	–1433
Lattice energy of $CaSO_4(s)$	–2489
$S(s) + 2O_2(g) + 2e^- \rightarrow SO_4^{2-}(g)$	–839



[3]

(ii) Hence, calculate the standard enthalpy change of atomisation, $\Delta H^{\ominus}_{at}$ of Ca(s).

[1]

[Total: 13]

4 Carbon monoxide and hydrogen react to form methanol, CH_3OH, under suitable conditions.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -91 \text{ kJ mol}^{-1}$$

A mixture of CO and H_2 in the molar ratio of 1:2 is placed in a sealed vessel and heated to 500 K with a copper catalyst. At equilibrium, 25% of carbon monoxide has reacted. The total pressure in the vessel is 60.0 atm at equilibrium.

(a) Explain what is meant by *dynamic equilibrium*.

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(b) Write the K_p expression for the equilibrium.
Use your expression to calculate the value of K_p for this equilibrium.
Include its units in your answer.

K_p =

[4]

(c) To reduce production costs of methanol, a chemical engineer suggests to either lower the pressure or lower the temperature for this reaction.

(i) Explain how the equilibrium amount of CH_3OH would change based on the shift in the position of equilibrium, if the reaction is carried out at a lower pressure while keeping the temperature at 500 K.

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.....[2]

(ii) Explain how the composition of the reaction mixture would change based on the shift in the position of equilibrium, if the reaction is carried out at a lower temperature of 400 K and predict how the K_p will change.

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.....[2]

[Total: 10]