Victorian Certificate of Education

CHEMISTRY 2026 Unit 3

SAC 2 AOS 2 Outcome 2

Reading time: 5 minutes

Writing time: 60 minutes

Directions to students

Student's Name: _____

Teacher: _____

Structure of booklet

Section	Question to be answered	Total marks
Short answer	5	50
	Total	50

Materials

- Students are permitted to bring into the examination room: pencils, highlighters, erasers, sharpeners, rulers, and an approved scientific calculator.

- Students are NOT permitted to bring into the examination room:
white out liquid/tape, phones or electronic devices, including smart watches.

- Students are provided with the following: Question and answer book of 13 pages and VCAA Data booklet.

The task

- Please ensure that you write your name and teacher's name on this booklet. This paper consists of short answer questions.

- There are a total of 50 marks available.

- Be sure to include states with all chemical equations.

- All numerical answers need to be quoted to the correct number of significant figures.

- All working out must be shown in the space provided.

1. A given amount of compound X was placed in a sealed vessel and allowed to reach equilibrium, at constant temperature, according to the reaction below.

$$2X\,(g) \rightleftharpoons 2A\,(g) + Y(g)\ \Delta H>0$$

a. Draw the changes to [A] and [Y] on the graph below. *1 mark*

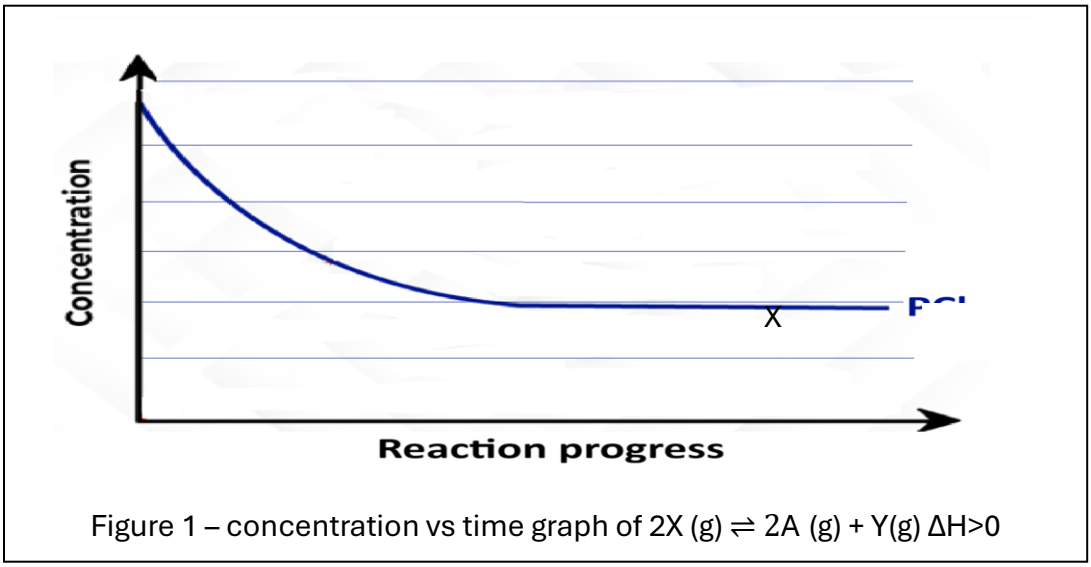

Figure 1 – concentration vs time graph of $2X\,(g) \rightleftharpoons 2A\,(g) + Y(g)\ \Delta H>0$

b. The partial pressure of X is shown on the graph, in fig. 2, below. Draw the graph for the total pressure of the system over time. *2 marks*

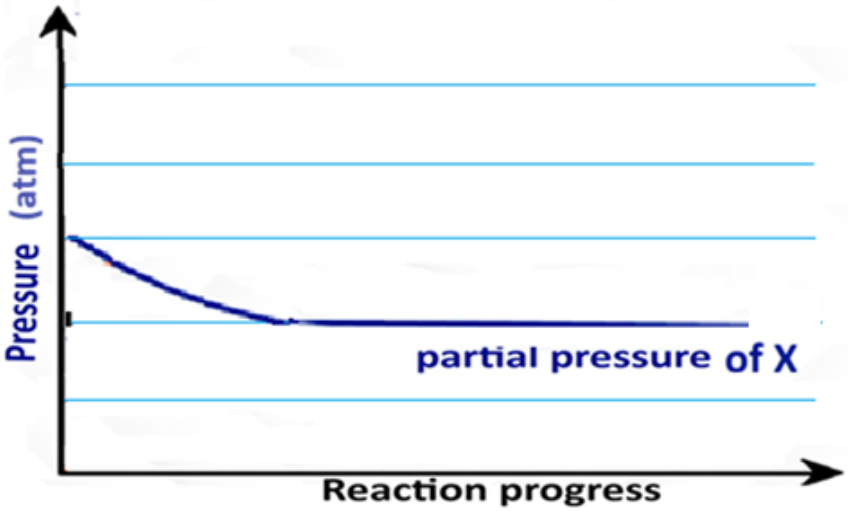

Figure 2 – pressure vs time graph of $2X\,(g) \rightleftharpoons 2A\,(g) + Y(g)\ \Delta H>0$

c. The rate of the forward reaction is shown below. Draw how the rate of the reverse reaction changes with time on the graph below. *1 mark*

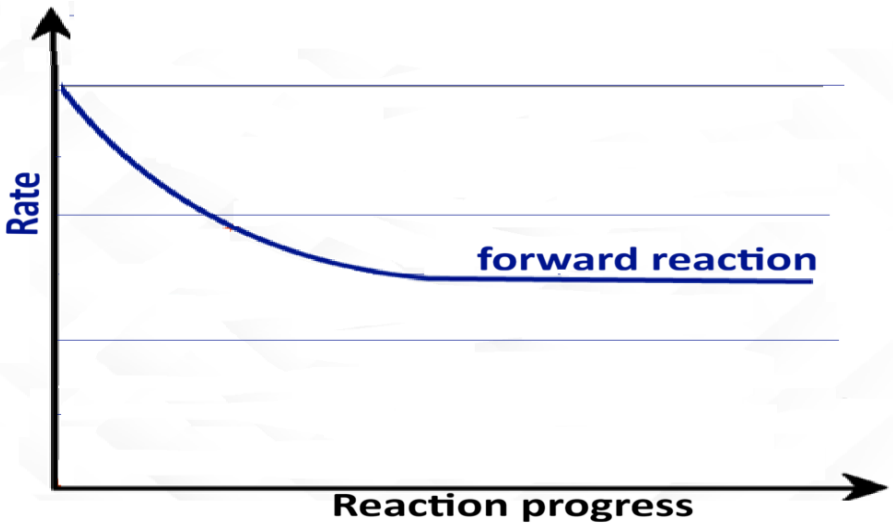

Figure 3 – rate vs time graph of 2X (g) ⇌ 2A (g) + Y(g) ΔH>0

d. Justify your answer to c above with reference to collision theory.

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_____ *2 marks*

e. In another sealed vessel A and Y were mixed and allowed to reach equilibrium according to the reaction shown in fig 4, below.

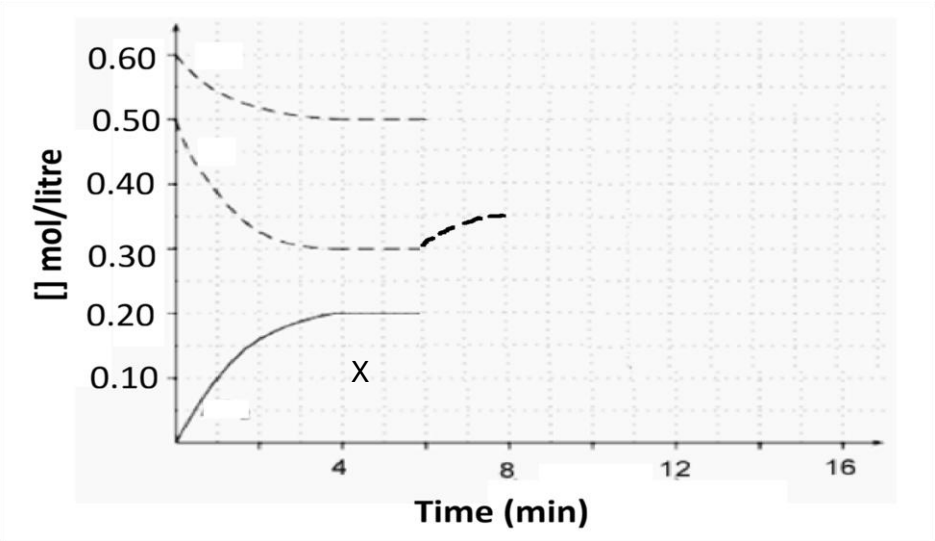

Figure 4 - A concentration vs time graph of the reactants and products of the **synthesis** of compound X

$(2A(g) + Y(g)) \rightleftharpoons 2X(g))$

The following stresses were applied to the system. Draw on the graph above how the system responds. Clearly label all graphs.

i. At the 6 minute mark the temperature of the reaction vessel was changed, equilibrium was reestablished by the 8 minute mark. The graph indicates how the concentration of one of the species changed. Graph the concentrations of the other two species. *1 mark*

ii. At the 8 minute mark, an amount of X was removed which decreased [X] to 0.1 M. Equilibrium was reestablished by the 12 minute mark. *1 mark*

iii. At the 12 minute mark the volume of the reaction vessel increased by 50% and equilibrium was reestablished by the 14 minute mark. *1 mark*

iv. A catalyst was added to the mixture at the 16 minute mark. *1 mark*

v. With reference to the graph in fig 4, describe how the temperature may have changed at the 6 minute mark. Justify you answer.

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_____ *2 marks*

f. At 88 °C a given amount of gas X is placed in a sealed vessel and allowed to come to equilibrium according to the reaction below.

$$2X\,(g) \rightleftharpoons 2A\,(g) + Y(g)\ \Delta H>0$$

The K_c at this temperature has a magnitude of 10.0.

The concentrations of each gas present at equilibrium, at 88°C, are given below.

- [X] = 2.000 M
- [Y] = 1.000 M
- [A] = 0.500 M

i. Give the Q_c expression for this equilibrium system. *1 mark*

ii. Calculate Q_c at this temperature with the appropriate units *2 marks*

iii. Using the value of K_c given in the stem of the question and your calculation of Q_c, determine whether the system is favouring the forward or reverse reaction at the time of sampling. Justify your answer.

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_____ *2 marks*

g. A student suggested that the reaction quotient (Q_c) is constant at a given temperature and its value is called the equilibrium constant (K_c). Define both Q_c and K_c and justify whether this statement is true or false.

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_____*2 marks*

2. In industry, high yields and fast rates of reaction are essential for a viable economy. Conditions for optimal yield and optimal rate can be conflicting.

   a. Using the two reactions below, suggest how optimal yield and optimal rate are achieved in the industrial production of products using endothermic and exothermic reactions. In your explanations suggest how optimal yield and optimal rate are achieved.

      i. --------- $N_2(g)+3H_2(g) \rightleftharpoons 2NH_3(g) \Delta H=-92 \text{ kJ mol}^{-1}$

      ii. --------- $CO_2(g)+3H_2(g) \rightleftharpoons CH_3OH(g)+H_2O(g) \Delta H=+49 \text{ kJ mol}^{-1}$

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_____ *3 marks*

   b. Using Item 24, Part II, page 24 of the 2026 data booklet:

      i. give two Green Chemistry Principles that are addressed by the industrial production of ammonia

- Green Chemistry Principle (1) _____*1 mark*

- Green Chemistry Principle (2)_____*1 mark*

      ii. Give a brief explanation of how these principles are relevant.

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_____*1 mark*

3. Consider the energy profile shown in fig. 5

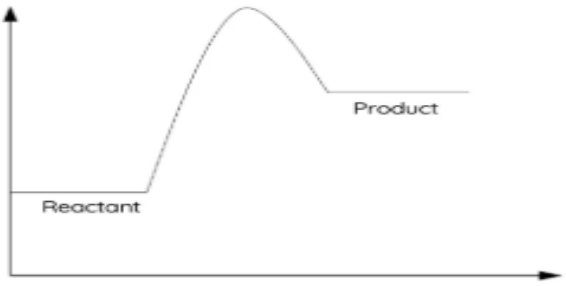

Figure 5 – An energy profile of an endothermic reaction

a. Indicate how the energy profile will change by the addition of a catalyst. *1 mark*

b. Give a clear explanation as to how the catalyst impacts the reaction.

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_____1 *mark*

c. Suggest a reason why, at constant temperature and without a catalyst, the reverse reaction of an endothermic reaction generally occurs at a faster rate.

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_____ *2 marks*

d. Consider the equilibrium system represented by the reactions below.

$$3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H<0$$

i. Indicate on the diagram in fig. 6 how the forward and reverse rates will change as a result of a temperature increase at t_2. *1 mark*

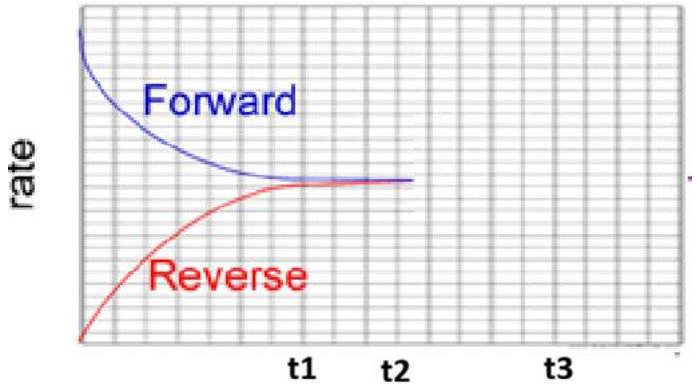

Figure 6 – rate time diagram of the reaction

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

ii. Indicate on the diagram in fig 7 how the forward and reverse rates will change as a result of the addition of a catalyst at t_2. *1 mark*

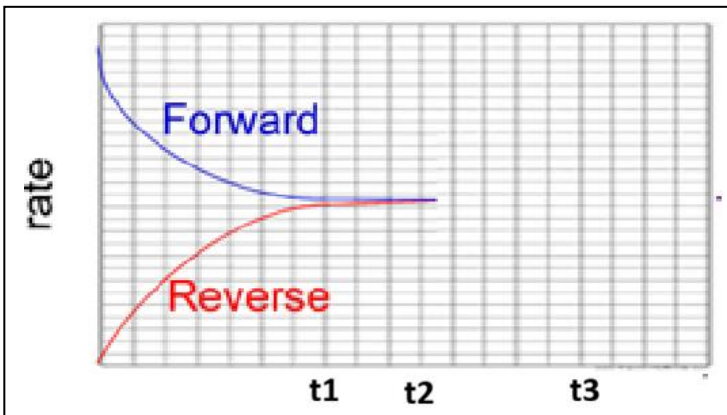

Figure 7– rate time diagram of the reaction

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

4. Complete the table shown below by circling the correct response in the right hand column that best identifies the response of the system to the stress. *7 marks*

System already at equilibrium	Stress	Response (circle correct response)	
$NH_3(aq) + HCl(aq) \rightleftharpoons NH_4^+(aq) + Cl^-(aq)$ This system exists in 100 mL volume of water	0.1 gram of $AgNO_3$ is added. *Assume no change to volume of the system.*	Q_c	increases, no change, decreases
		K_c	increases, no change, decreases
		$[NH_4^+]$	increases, no change, decreases
		Mol of Cl^-	increases, no change, decreases
$NH_3(aq) + HCl(aq) \rightleftharpoons NH_4^+(aq) + Cl^-(aq)$ This system exists in 100 mL volume of water	20 mL of distilled water is added	Q_c	increases, no change, decreases
		K_c	increases, no change, decreases
		$[NH_4^+]$	increases, no change, decreases
		Mol of Cl^-	increases, no change, decreases
$2\ H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$ This system exists in a sealed 100 mL vessel	Volume of the vessel is doubled.	Q_c	increases, no change, decreases
		K_c	increases, no change, decreases
		[CO]	increases, no change, decreases
		Mol of CO	increases, no change, decreases
$2\ H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$	N_2 gas was added	Reaction proceeds to the Left right no response	
$2\ H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$	Catalyst added	Reaction proceeds to the Left right no response	

5. Consider the electrolytic cell shown below in fig. 8. A piece of copper metal is to be plated with a layer of nickel metal.

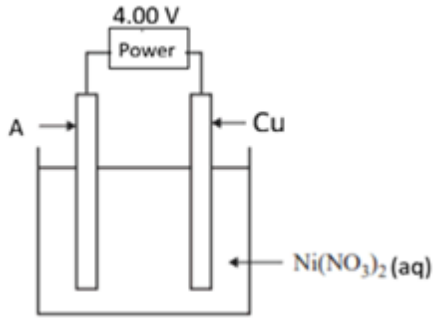

Figure 8 – Electrolysis with $Ni(NO_3)_2(aq)$

a. What is the polarity of electrode A?

_____ *1 mark*

b. Which electrode represents the cathode? Justify your response using a relevant, balanced half-equation.

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_____ *2 marks*

c. What material is the anode composed of?

_____ *1 mark*

d. Write the balanced equation, states included, for the reaction taking place at the anode.

_____ *1 mark*

e. A current of 4.00 amps is applied for a fixed time period to deposit a total mass of 1.174 grams of nickel on the copper metal.

i. Using the answer to question d, above and given that the cell operates at 80% efficiency, calculate the total charge, in coulombs (C), needed to deposit the amount of nickel metal stated in the stem of the question. *3 marks*

f. Calculate the time, in seconds, the cell was allowed to operate for. *1 mark*

g. An electrolyser operating at 80 °C uses a proton exchange membrane (PEM) to produce hydrogen gas, as shown in Fig. 9.

i. In the boxes provided in the diagram, identify the particles that travel through the membrane. Indicate the direction of movement with arrows. *1 mark*

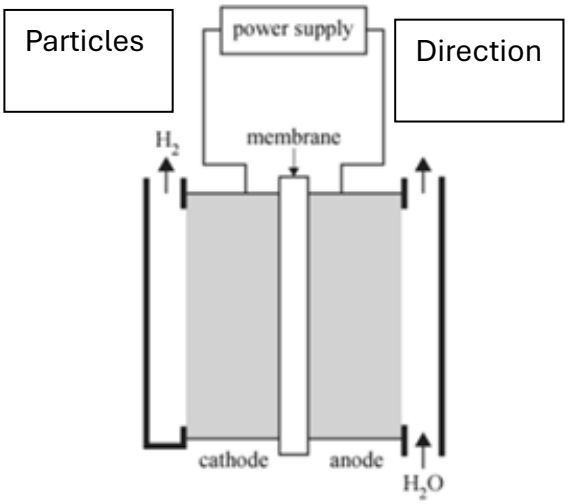

Figure 9 -An PEM electrolyser producing hydrogen gas

ii. Write the half-equation for the reaction occurring at the anode.

_____ *2 marks*

End of assessment task