Neap

Diagnostic Topic Test 2024

VCE Chemistry Units 3&4

Question and Answer Booklet

Test time: 45 minutes
Total marks: 35 marks

Test 3: How can the rate and yield of chemical reactions be optimised?

- Rates of chemical reactions
- Extent of chemical reactions

Student's Name: _____

Teacher's Name: _____

Instructions

Write your **name** and your **teacher's name** in the space provided above on this page.

A data booklet is provided.

Unless otherwise indicated, the diagrams in this booklet are **not** drawn to scale.

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

SECTION A – MULTIPLE-CHOICE QUESTIONS

Instructions for Section A

Circle the response that is **correct** or that **best answers** the question.
A correct answer scores 1; an incorrect answer scores 0.
Marks will **not** be deducted for incorrect answers.
No marks will be given if more than one answer is completed for any question.
Unless otherwise indicated, the diagrams in this booklet are **not** drawn to scale.

Question 1

Many industrial processes use a catalyst.

Catalysts

A. increase the value of the equilibrium constant, K.

B. provide alternate reaction pathways.

C. change the sign of ΔH for a reaction.

D. shift the position of equilibrium towards the products.

Question 2

According to Le Chatelier's principle: 'If a chemical system at equilibrium is subjected to a change in conditions, the system will respond

A. in such a way that the equilibrium constant for the reaction is always unchanged'.

B. in order to return all concentrations to their original values'.

C. by altering the temperature and volume of the reaction vessel to achieve a new equilibrium'.

D. to re-establish equilibrium in such a way as to partially overcome the imposed change'.

Question 3

Compound X decomposes according to the following equation.

$$\mathrm{X(g)} \rightleftharpoons \mathrm{Y(g)} + \mathrm{Z(g)} \qquad \Delta H > 0 \qquad K = 1.70 \text{ M at } T\,^{\circ}\mathrm{C}$$

If 1.0 mol of the reactant and 1.0 mol of each product were introduced and allowed to mix in a 1.0 L thermally insulated vessel, the temperature of the reaction mixture would

A. increase, and the mass of X would increase.

B. increase, and the mass of X would decrease.

C. decrease, and the mass of X would increase.

D. decrease, and the mass of X would decrease.

Question 4

Consider the equilibrium shown in the following equation.

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

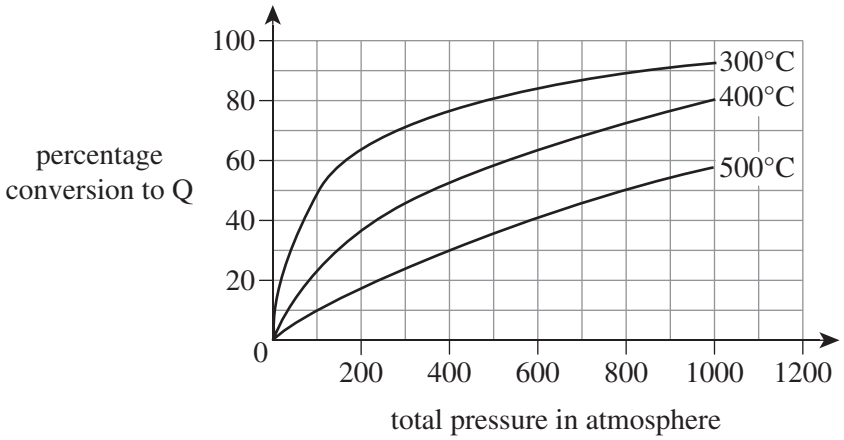
A reaction mixture at equilibrium is heated.

Which of the following rows in the table shows the possible changes occurring as a result of the heating?

	Amount of H_2	Amount of NH_3
A.	increases by 0.189 mol	decreases by 0.284 mol
B.	increases by 0.243 mol	decreases by 0.162 mol
C.	decreases by 0.143 mol	increases by 0.095 mol
D.	decreases by 0.155 mol	increases by 0.155 mol

Question 5

The production of chemical Q from chemicals L and M proceeds in the presence of a catalyst. The graph below shows the variation in the equilibrium yield of Q with pressure over a range of temperatures.



Which of the following equations could represent the production process?

A. $2L(g) + 2M(g) \rightleftharpoons Q(g) \qquad \Delta H < 0$

B. $2L(g) + M(g) \rightleftharpoons 4Q(g) \qquad \Delta H < 0$

C. $L(g) + M(g) \rightleftharpoons 3Q(g) \qquad \Delta H > 0$

D. $L(g) + 2M(g) \rightleftharpoons 2Q(g) \qquad \Delta H > 0$

Question 6

A dilemma for many industrial chemists is the conflict between the operating temperature required for maximum yield and the temperature required for maximum rate of reaction. Consider the two reactions below.

I $X(g) + 2Y(g) \rightleftharpoons 4Z(g)$ $\Delta H = +243 \text{ kJ mol}^{-1}$

II $2X(g) + 2Y(g) \rightleftharpoons 3Z(g)$ $\Delta H = -193 \text{ kJ mol}^{-1}$

For which of the two reactions listed above would this dilemma occur?

A. I only

B. II only

C. I and II

D. neither I nor II

Use the following information to answer Questions 7 and 8.

The industrial production of chemical R proceeds via the reaction represented by the following equation.

$$2P(g) + 4Q(g) \rightleftharpoons R(g) + 2S(g)$$

Question 7

Which of the following statements concerning the rate of this reaction is correct?

A. The rate of formation of R is one quarter the rate of the disappearance of Q.

B. The rate of disappearance of Q is one half of the rate of the disappearance of P.

C. The rate of formation of S is double the rate of the disappearance of Q.

D. The rate of disappearance of P is unrelated to the rate of the appearance of S.

Question 8

A catalyst is used in the production of R.

Which of the following rows in the table shows the effect of the catalyst on the rate of formation of R, and on the amount of R produced?

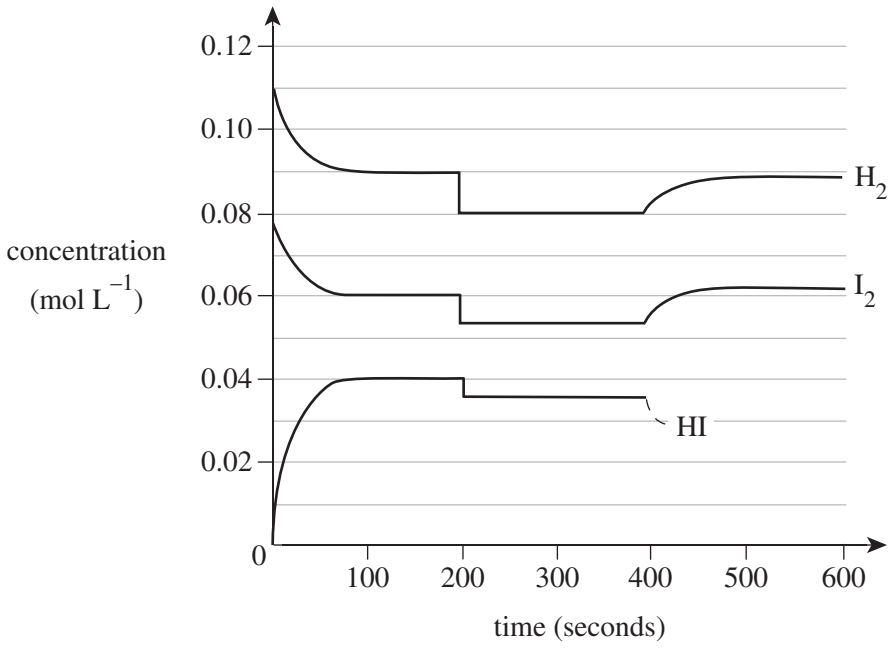
	Rate of formation of R	Amount of R formed
A.	increases	decreases
B.	increases	increases
C.	increases	no change
D.	no change	increases

Use the following information to answer Questions 9 and 10.

When $H_2(g)$ and $I_2(g)$ are placed in a sealed container, equilibrium will establish according to the following equation.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

The results of an experiment using this equilibrium system are shown in the graph below.



During the time interval 0 to 200 seconds, the temperature of the system was kept constant by removing heat from the container.

Question 9

Which of the following changes was made to the system at $t = 200$ s?

A. The volume of the vessel was increased by a factor of approximately 10%.

B. The volume of the vessel was increased by a factor of approximately 20%.

C. The volume of the vessel was decreased by a factor of approximately 10%.

D. The volume of the vessel was decreased by a factor of approximately 20%.

Question 10

Which of the following describes the change made to the system at $t = 400$ s, and the concentration of hydrogen iodide when the system returns to equilibrium following the change?

A. The temperature was decreased and the new equilibrium hydrogen iodide concentration will be 0.018 M.

B. The temperature was decreased and the new equilibrium hydrogen iodide concentration will be 0.027 M.

C. The temperature was increased and the new equilibrium hydrogen iodide concentration will be 0.018 M.

D. The temperature was increased and the new equilibrium hydrogen iodide concentration will be 0.027 M.

END OF SECTION A

SECTION B

Instructions for Section B

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

Give simplified answers to all numerical questions, with an appropriate number of significant figures; unsimplified answers will not be given full marks.

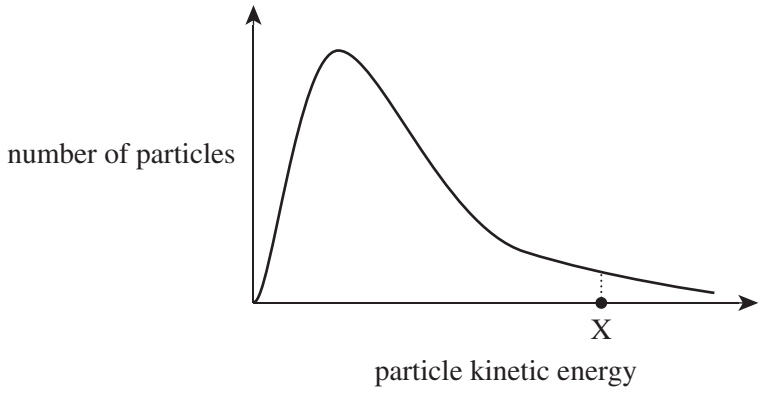
Show all working in your answers to numerical questions; no marks will be given for an incorrect answer unless it is accompanied by details of the working.

Ensure chemical equations are balanced and that the formulas for individual substances include an indication of state, for example, $H_2(g)$, NaCl(s).

Unless otherwise indicated, the diagrams in this booklet are **not** drawn to scale.

Question 1 (9 marks)

In order for a chemical reaction to proceed, particles must collide with sufficient energy and in the correct orientation. The graph below shows the range of kinetic energies held by particles in a reaction mixture at a particular temperature.



a. **i.** Point X represents the activation energy of the reaction.
What is meant by the term 'activation energy'? 1 mark

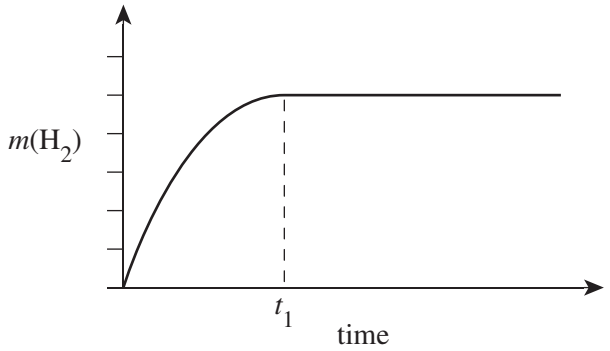
ii. On the axes above, draw a new graph to represent the range of particle energies at a higher temperature. 1 mark

iii. By referring to the graph in **part a.ii.**, explain why even a small increase in temperature can result in a significant increase in reaction rate. 2 marks

b. A series of experiments were conducted in which the rate of reaction of magnesium with dilute hydrochloric acid was investigated. The equation that represents this reaction is as follows.

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

In the first experiment, 2.0 g of magnesium ribbon was added to a beaker containing 150 mL of 2.0 M hydrochloric acid. The hydrochloric acid was in excess. The mass of hydrogen gas produced was measured at regular intervals and the results are shown on the graph below.



i. Explain why the graph plateaus at time t_1. 1 mark

ii. The experiment was repeated using 1.0 g of powdered magnesium and the results were recorded.

On the axes above, sketch the results expected for the second experiment. 2 marks

iii. In terms of collision theory, explain why the rate of reaction between the magnesium and hydrochloric acid would increase if 3.0 M HCl replaced the 2.0 M solution used in the experiment. 2 marks

Question 2 (5 marks)

Chlorine trifluoride, ClF_3, is used in the electronics industry to clean electronic circuit boards during their manufacture. It is produced by reacting chlorine and fluorine gases according to the following equation.

$$Cl_2(g) + 3F_2(g) \rightleftharpoons 2ClF_3(g) \qquad \Delta H = -160 \text{ kJ mol}^{-1}$$

The activation energy for the forward reaction is 40 kJ mol^{-1}.

a. **i.** Write an equilibrium law expression (K) for this reaction. 1 mark

ii. A reaction mixture is allowed to reach equilibrium at 400°C. It is determined that the equilibrium concentrations are $[Cl_2] = 0.173$ M, $[F_2] = 0.419$ M and $[ClF_3] = 1.059$ M.

Calculate the value of the equilibrium constant at 400°C. 1 mark

b. **i.** Determine the activation energy for the reaction $2ClF_3(g) \rightleftharpoons Cl_2(g) + 3F_2(g)$. 1 mark

ii. Determine ΔH for the reaction $2ClF_3(g) \rightleftharpoons Cl_2(g) + 3F_2(g)$. 1 mark

iii. Determine the value of the equilibrium constant, at 400°C, for the reaction $ClF_3(g) \rightleftharpoons \frac{1}{2}Cl_2(g) + \frac{3}{2}F_2(g)$. 1 mark

Question 3 (7 marks)
Phosphorus trichloride reacts with chlorine gas to produce phosphorus pentachloride according to the following equation.

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) \qquad \Delta H = -125 \text{ kJ mol}^{-1}$$

At 250°C it has been determined that the equilibrium constant, K, is 0.041 M^{-1}.

a. At a certain temperature, 0.533 mol of PCl_3 and 0.291 mol of Cl_2 were introduced into an evacuated 4.00 L vessel. Once equilibrium was established, 60% of the PCl_3 remained.

i. Calculate the concentrations of all three gases in the container once equilibrium has been established. 3 marks

ii. Show that the value of the equilibrium constant for the reaction at this temperature is greater than 0.041 M^{-1}, the value at 250°C. 2 marks

b. Was the experiment carried out at a temperature higher or lower than 250°C? Explain your answer. 2 marks

Question 4 (4 marks)

Methanol, CH_3OH, is produced in large quantities industrially for use as a fuel and as a raw material for the production of other chemicals. One of the main reactions that occurs in methanol synthesis is as follows.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206 \text{ kJ mol}^{-1}$$

Reaction is carried out at high temperature and low pressure.

Complete the table below by stating **one** advantage and **one** disadvantage of each of the conditions listed for the reaction.

Reaction condition	Advantage	Disadvantage
high temperature		
low pressure		

END OF TEST