Section A

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

1 (a) A mixture of 1.50 mol of hydrogen and 1.20 mol of gaseous iodine was sealed in a container of volume V dm³. The mixture was left to reach equilibrium as shown by the following equation.

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

At a given temperature, the equilibrium mixture contained 2.06 mol of hydrogen iodide.

1 (a) (i) Calculate the amounts, in moles, of hydrogen and of iodine in the equilibrium mixture.

Moles of hydrogen ....

Moles of iodine ....
(2 marks)

1 (a) (ii) Write an expression for the equilibrium constant (K_c) for this equilibrium.

....

....
(1 mark)

1 (a) (iii) K_c for this equilibrium has no units.
State why the units cancel in the expression for K_c

....

....
(1 mark)

1 (a) (iv) A different mixture of hydrogen, iodine and hydrogen iodide was left to reach equilibrium at the same temperature in a container of the same volume.
This second equilibrium mixture contained 0.38 mol of hydrogen, 0.19 mol of iodine and 1.94 mol of hydrogen iodide.

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

....

....

....

....
(2 marks)

(Extra space) ....

....

1 (b)   This question concerns changes made to the four equilibria shown in parts **(b)(i)** to **(b)(iv)**.
In each case, use the information in the table to help you choose from the letters **A** to **E** the best description of what happens as a result of the change described. Write your answer in the box.

Each letter may be used once, more than once or not at all.

	Position of equilibrium	**Value of equilibrium constant, K_c**
A	remains the same	same
B	moves to the right	same
C	moves to the left	same
D	moves to the right	different
E	moves to the left	different

1 (b)(i)   Change: increase the temperature of the equilibrium mixture at constant pressure.

$$H_2(g) \; + \; I_2(g) \; \rightleftharpoons \; 2HI(g) \qquad\qquad \Delta H^\ominus = +52 \, kJ \, mol^{-1}$$

(1 mark)

1 (b)(ii)   Change: increase the total pressure of the equilibrium mixture at constant temperature.
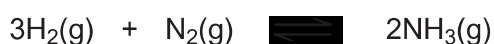
$$3H_2(g) \; + \; N_2(g) \; \rightleftharpoons \; 2NH_3(g) \qquad\qquad \Delta H^\ominus = -92 \, kJ \, mol^{-1}$$

(1 mark)

1 (b)(iii)   Change: add a catalyst to the equilibrium mixture at constant temperature.

$$CO(g) \; + \; H_2O(g) \; \rightleftharpoons \; CO_2(g) \; + \; H_2(g) \qquad \Delta H^\ominus = -41 \, kJ \, mol^{-1}$$

(1 mark)

1 (b)(iv)   Change: add chlorine to the equilibrium mixture at constant temperature.

$$PCl_5(g) \; \rightleftharpoons \; PCl_3(g) \; + \; Cl_2(g) \qquad\qquad \Delta H^\ominus = +93 \, kJ \, mol^{-1}$$
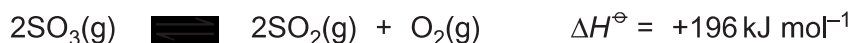
(1 mark)

10

Turn over ▶

2 At high temperatures and in the presence of a catalyst, sulfur trioxide decomposes according to the following equation.

$$2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g) \qquad \Delta H^\ominus = +196 \, kJ \, mol^{-1}$$

2 (a) In an experiment, 8.0 mol of sulfur trioxide were placed in a container of volume 12.0 dm^3 and allowed to come to equilibrium.
At temperature T_1 there were 1.4 mol of oxygen in the equilibrium mixture.

2 (a) (i) Calculate the amount, in moles, of sulfur trioxide and of sulfur dioxide in the equilibrium mixture.

Amount of sulfur trioxide ....

Amount of sulfur dioxide ....

(2 marks)

2 (a) (ii) Write an expression for the equilibrium constant, K_c, for this equilibrium.

....

....

(1 mark)

2 (a) (iii) Deduce the units of K_c for this equilibrium.

....

....

(1 mark)

2 (a) (iv) Calculate a value of K_c for this equilibrium at temperature T_1

(If you were unable to complete the calculations in part **(a)(i)** you should assume that the amount of sulfur trioxide in the equilibrium mixture was 5.8 mol and the amount of sulfur dioxide was 2.1 mol. These are **not** the correct values.)

....

....

....

....

....

(3 marks)

(Extra space) ....

....

2 (b) The experiment was repeated at the same temperature using the same amount of sulfur trioxide but in a larger container.
State the effect, if any, of this change on:

2 (b) (i) the amount, in moles, of oxygen in the new equilibrium mixture

....
(1 mark)

2 (b) (ii) the value of K_c

....
(1 mark)

2 (c) The experiment was repeated in the original container but at temperature T_2
The value of K_c was smaller than the value at temperature T_1
State which is the higher temperature, T_1 or T_2
Explain your answer.

Higher temperature ....

Explanation ....

....

....

....

....
(3 marks)

(Extra space) ....

....

12

3 The following dynamic equilibrium was established at temperature T in a closed container.

$$P(g) + 2Q(g) \rightleftharpoons 2R(g) \qquad \Delta H^{\ominus} = -50 \, kJ \, mol^{-1}$$

The value of K_c for the reaction was $68.0 \, mol^{-1} \, dm^3$ when the equilibrium mixture contained $3.82 \, mol$ of **P** and $5.24 \, mol$ of **R**.

3 (a) Give the meaning of the term *dynamic equilibrium*.

....

....

....

....

(2 marks)

(Extra space) ....

....

3 (b) Write an expression for K_c for this reaction.

....

....

(1 mark)

3 (c) The volume of the container was $10.0 \, dm^3$.

Calculate the concentration, in $mol \, dm^{-3}$, of **Q** in the equilibrium mixture.

....

....

....

....

....

(4 marks)

(Extra space) ....

....

3 (d)   State the effect, if any, on the equilibrium amount of **P** of increasing the temperature.
All other factors are unchanged.

....
(1 mark)

3 (e)   State the effect, if any, on the equilibrium amount of **P** of using a container of larger
volume. All other factors are unchanged.

....
(1 mark)

3 (f)   State the effect, if any, on the value of K_c of increasing the temperature.
All other factors are unchanged.

....
(1 mark)

3 (g)   State the effect, if any, on the value of K_c of using a container of larger volume.
All other factors are unchanged.

....
(1 mark)

3 (h)   Deduce the value of the equilibrium constant, at temperature T, for the reaction

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

....

....
(1 mark)

12

Turn over for the next question

Turn over ▶