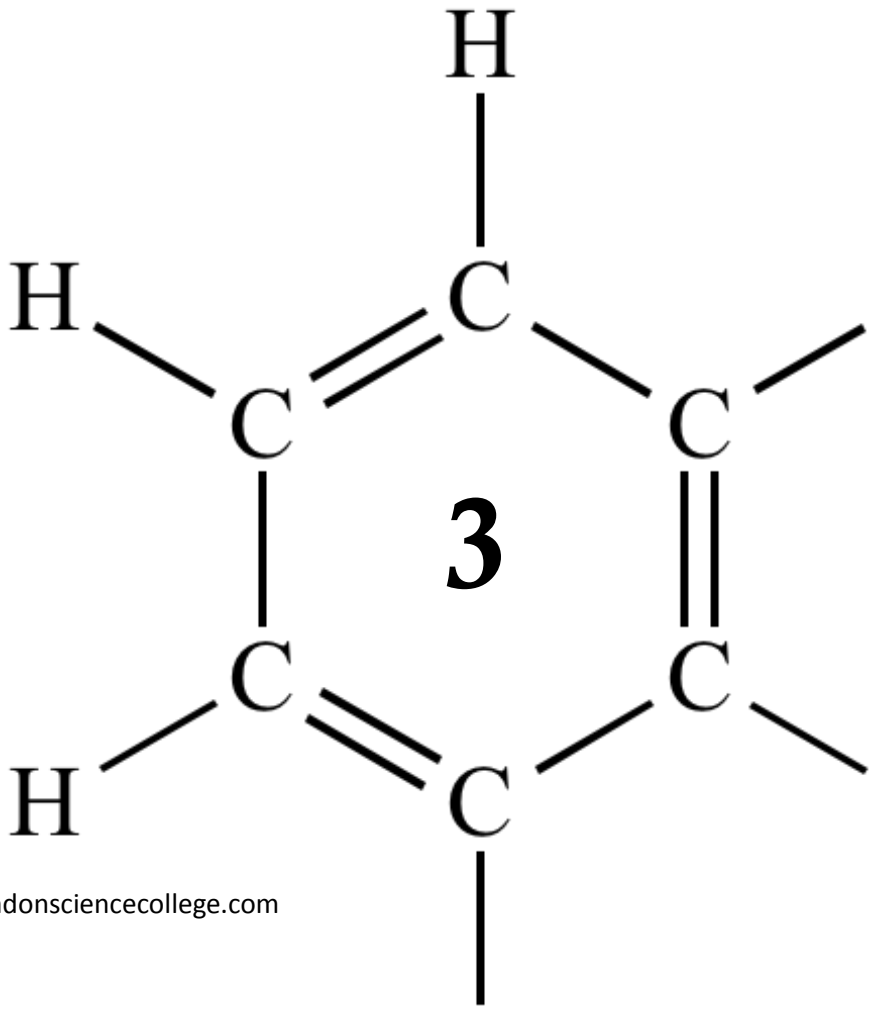
LONDON SCIENCE COLLEGE

AQA AS CHEMISTRY

EQUILIBRIA



3

1 A study of equilibrium is important for understanding chemical reactions.

(a) State le Chatelier's principle.

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(1)

(b) Catalysts play an important role in many reactions.

(i) State the meaning of the term *catalyst*.
Explain, in general terms, how catalysts work.

Meaning of the term *catalyst* .....

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How catalysts work .....

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(3)

(Extra space) .....

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(ii) State the effect, if any, of a catalyst on the time taken to reach equilibrium.

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(1)

(iii) State the effect, if any, of a catalyst on the position of an equilibrium.

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(1)

(c) Consider the following equilibrium reactions.

				$\Delta H^{\ominus}$ / kJ mol^{-1}
P	$H_2(g) + I_2(g)$	$\rightleftharpoons$	$2HI(g)$	−10
Q	$CO_2(g) + 3H_2(g)$	$\rightleftharpoons$	$CH_3OH(g) + H_2O(g)$	−49
R	$N_2O_4(g)$	$\rightleftharpoons$	$2NO_2(g)$	+58
S	$N_2(g) + 3H_2(g)$	$\rightleftharpoons$	$2NH_3(g)$	−92
T	$C_2H_4(g) + H_2O(g)$	$\rightleftharpoons$	$CH_3CH_2OH(g)$	−42

In each of parts (c)(i) to (c)(v), you should record in the box one of the letters, **P, Q, R, S** or **T**, that corresponds to the equilibrium that best fits the information provided.
You may use each letter once, more than once or not at all.

(i) A decrease in temperature at constant pressure shifts the position of this equilibrium from right to left.

(1)

(ii) This equilibrium uses concentrated phosphoric acid as a catalyst in a hydration reaction.

(1)

(iii) A decrease in pressure at constant temperature shifts the position of this equilibrium from left to right.

(1)

(iv) There is no change in the position of this equilibrium when the pressure is increased at constant temperature.

(1)

(v) An increase in the concentration of steam at constant temperature and constant pressure shifts the position of this equilibrium from right to left.

☐

(1)

(Total 11 marks)

2 Methanol (CH_3OH) is an important fuel that can be synthesised from carbon dioxide.

(a) The table shows some standard enthalpies of formation.

	$CO_2(g)$	$H_2(g)$	$CH_3OH(g)$	$H_2O(g)$
$\Delta H_f^{\ominus}$/kJ mol^{-1}	– 394	0	– 201	– 242

(i) Use these standard enthalpies of formation to calculate a value for the standard enthalpy change of this synthesis.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

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(Extra space) .....

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(3)

(ii) State why the standard enthalpy of formation for hydrogen gas is zero.

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(1)

(b) State and explain what happens to the yield of methanol when the total pressure is increased in this synthesis.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

Effect on yield .....

Explanation .....

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(Extra space) .....

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(3)

(c) The hydrogen required for this synthesis is formed from methane and steam in a reversible reaction. The equation for this reaction is shown below.

$$CH_4(g) + H_2O(g) \rightleftharpoons C0(g) + 3H_2(g) \qquad \Delta H = +206 \text{ kJ mol}^{-1}$$

State and explain what happens to the yield of hydrogen in this reaction when the temperature is increased.

Effect on yield .....

Explanation .....

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(Extra space) .....

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(3)

(d) The methanol produced by this synthesis has been described as a carbon-neutral fuel.

(i) State the meaning of the term *carbon-neutral*.

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(Extra space) .....

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(1)

(ii) Write an equation for the complete combustion of methanol.

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(1)

(iii) The equation for the synthesis of methanol is shown below.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

Use this equation and your answer to part (d)(ii) to deduce an equation to represent the overall chemical change that occurs when methanol behaves as a carbon-neutral fuel.

Equation .....

(1)

(e) A student carried out an experiment to determine the enthalpy change when a sample of methanol was burned.

The student found that the temperature of 140 g of water increased by 7.5 °C when 0.011 mol of methanol was burned in air and the heat produced was used to warm the water.

Use the student's results to calculate a value, in kJ mol $^{-1}$, for the enthalpy change when one mole of methanol was burned.

(The specific heat capacity of water is 4.18 J K^{-1} g^{-1}).

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(Extra space) .....

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(3)

(Total 16 marks)

3 A student investigated the chemistry of the halogens and the halide ions.

(a) In the first two tests, the student made the following observations.

Test	Observation
1. Add chlorine water to aqueous potassium iodide solution.	The colourless solution turned a brown colour.
2. Add silver nitrate solution to aqueous potassium chloride solution.	The colourless solution produced a white precipitate.

(i) Identify the species responsible for the brown colour in Test **1**.

Write the **simplest ionic** equation for the reaction that has taken place in Test **1**.

State the type of reaction that has taken place in Test **1**.

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(Extra space) .....

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(3)

(ii) Name the species responsible for the white precipitate in Test **2**.

Write the **simplest ionic** equation for the reaction that has taken place in Test **2**.

State what would be observed when an excess of dilute ammonia solution is added to the white precipitate obtained in Test **2**.

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(Extra space) .....

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(3)

(b) In two further tests, the student made the following observations.

Test	Observation
3. Add concentrated sulfuric acid to solid potassium chloride.	The white solid produced misty white fumes which turned blue litmus paper to red.
4. Add concentrated sulfuric acid to solid potassium iodide.	The white solid turned black. A gas was released that smelled of rotten eggs. A yellow solid was formed.

(i) Write the **simplest ionic** equation for the reaction that has taken place in Test **3**.

Identify the species responsible for the misty white fumes produced in Test **3**.

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(Extra space) .....

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(2)

(ii) The student had read in a textbook that the equation for one of the reactions in Test **4** is as follows.

$$8H^+ + 8I^- + H_2SO_4 \longrightarrow 4I_2 + H_2S + 4H_2O$$

Write the **two** half-equations for this reaction.

State the role of the sulfuric acid and identify the yellow solid that is also observed in Test **4**.

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(Extra space) .....

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(4)

(iii) The student knew that bromine can be used for killing microorganisms in swimming pool water.
The following equilibrium is established when bromine is added to cold water.

$$Br_2(l) + H_2O(l) \rightleftharpoons HBrO(aq) + H^+(aq) + Br^-(aq)$$

Use Le Chatelier's principle to explain why this equilibrium moves to the right when sodium hydroxide solution is added to a solution containing dissolved bromine.

Deduce why bromine can be used for killing microorganisms in swimming pool water, even though bromine is toxic.

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(Extra space) .....

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(3)
(Total 15 marks)

4 (a) A mixture of 1.50 mol of hydrogen and 1.20 mol of gaseous iodine was sealed in a container of volume V dm^3. 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.

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

Moles of hydrogen .....

Moles of iodine .....

(2)

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

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(1)

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

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(1)

(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.

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(Extra space) .....

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(2)

(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

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

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ $\quad \Delta H^{\ominus} = +52 \text{ kJ mol}^{-1}$ [ ]

(1)

(ii) Change: increase the total pressure of the equilibrium mixture at constant temperature.

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

(1)

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

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

(1)

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

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

(1)
(Total 10 marks)

5 Ammonia is manufactured by the Haber process in which the following equilibrium is established.

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

(a) Give **two** features of a reaction at equilibrium.

Feature 1 .....

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Feature 2 .....

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(2)

(b) Explain why a catalyst has no effect on the position of an equilibrium.

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(Extra space) .....

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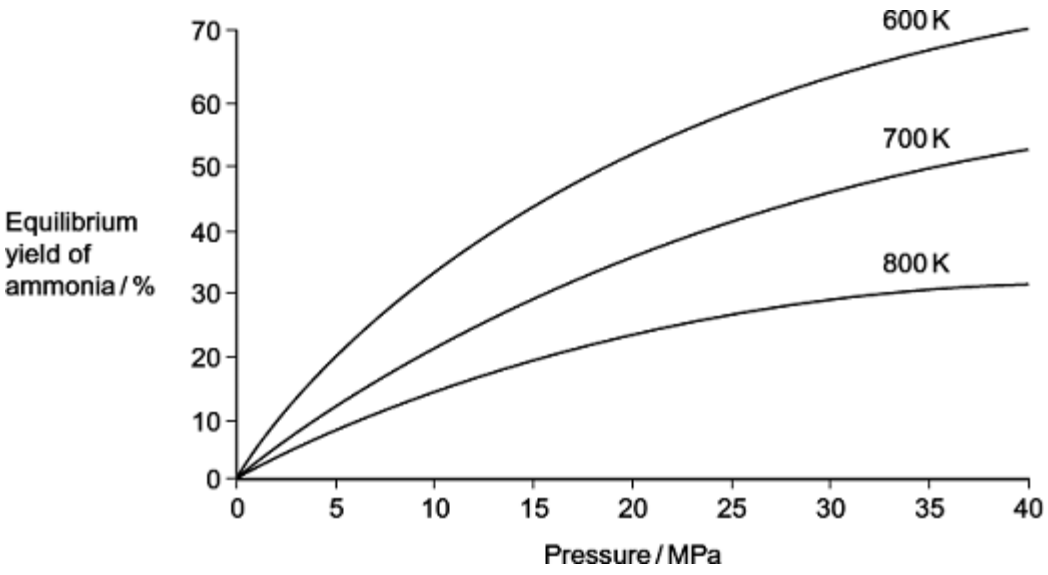
(2)

(c) The diagram shows how the equilibrium yield of ammonia varies with changes in pressure and temperature.



(i) Use the diagram to state the effect of an **increase** in pressure at constant temperature on the yield of ammonia. Use Le Chatelier's principle to explain this effect.

Effect on yield .....

Explanation .....

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(Extra space) .....

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(3)

(ii) Use the diagram to state the effect of an **increase** in temperature at constant pressure on the yield of ammonia. Use Le Chatelier's principle to explain this effect.

Effect on yield .....

Explanation .....

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(Extra space) .....

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(3)

(d) At equilibrium, with a pressure of 35 MPa and a temperature of 600 K, the yield of ammonia is 65%.

(i) State why industry uses a temperature higher than 600 K.

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(1)

(ii) State why industry uses a pressure lower than 35 MPa.
Do **not** include references to safety.

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(1)
(Total 12 marks)

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

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

(a) In an experiment, 8.0mol 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.

(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)

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

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(1)

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

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(1)

(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.)

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(Extra space) .....

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(3)

(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:

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

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(1)

(ii) the value of K_c

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(1)

(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 .....

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(Extra space) .....

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(3)
(Total 12 marks)

7 A sample of nitrogen dioxide gas (NO_2) was prepared by the reaction of copper with concentrated nitric acid.

(a) (i) Balance the equation for the reaction of copper with concentrated nitric acid.

$$Cu + ... HNO_3 \rightarrow Cu(NO_3)_2 + ... NO_2 + ... H_2O$$

(1)

(ii) Give the oxidation state of nitrogen in each of the following compounds.

HNO_3 .....

NO_2 .....

(2)

(iii) Deduce the half-equation for the conversion of HNO_3 into NO_2 in this reaction.

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(1)

(b) The following equilibrium is established between colourless dinitrogen tetraoxide gas (N_2O_4) and dark brown nitrogen dioxide gas.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = 58 \text{ kJ mol}^{-1}$$

(i) Give two features of a reaction at equilibrium.

Feature 1 .....

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Feature 2 .....

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(2)

(ii) Use Le Chatelier's principle to explain why the mixture of gases becomes darker in colour when the mixture is heated at constant pressure.

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(2)

(iii) Use Le Chatelier's principle to explain why the amount of NO_2 decreases when the pressure is increased at constant temperature.

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(2)
(Total 10 marks)