09 Chemical Equilibria

Set A Foundations

Name	Time 1 hour	Total 34 marks	Score ____ / 34

A Data Booklet may be used.

A From the lesson

13 MARKS

1 COMMON Write K_c and K_p, with units, for $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$.

[2]

/2

Source: Learners' Alley, Chemical Equilibria slides

2 CHALLENGE Write K_c for $Fe^{3+}(aq) + 3H_2O(l) \rightleftharpoons Fe(OH)_3(s) + 3H^+(aq)$.

[1]

/1

Source: Learners' Alley, Chemical Equilibria slides

3 COMMON 1.00 mol of H_2 and 1.00 mol of I_2 are heated in a 1.00 dm^3 flask: $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$. At equilibrium there is 1.56 mol of HI. Find K_c.

[2]

/2

Source: Learners' Alley, Chemical Equilibria slides

4 COMMON Predict the effect of increasing pressure on the position of equilibrium in each of the following. All species are gases.

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

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[1]

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

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[1]

(c) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

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[1]

/3

Source: Learners' Alley, Chemical Equilibria slides

5 Define dynamic equilibrium.

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[1]

/1

Source: Learners' Alley, Chemical Equilibria slides

6 Write K_c for $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, with units.

[1]

/1

Source: Learners' Alley, Chemical Equilibria slides

7 Why does a catalyst not change the yield?

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[1]

/1

Source: Learners' Alley, Chemical Equilibria slides

8 Why is 450 °C used in the Haber process, not a lower temperature?

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[2]

/2

Source: Learners' Alley, Chemical Equilibria slides

B Practice

21 MARKS

9 COMMON The equation describes the equilibrium between some gases. $2NO(g) + 2H_2(g) \rightleftharpoons N_2(g) + 2H_2O(g)$ $\Delta H < 0$

Which of the changes increase the K_p of the reaction?

1 Decreasing the volume of the reaction vessel
2 Decreasing the temperature of the system
3 Injecting more hydrogen gas into the reaction vessel

A 2 only **B** 1 and 3 only **C** 2 and 3 only **D** 1, 2 and 3

Answer [ ] [1]

/1

Source: IJC 2017 Promo, via Chemical Equilibria Topical Revision Booklet, Q4

10 In the industrial production of nitric acid, the first step involves the oxidation of ammonia to nitrogen oxide. $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$ $\Delta H < 0$

Which of the following would favour the oxidation of ammonia?

A removal of H_2O
B addition of catalyst
C increase in temperature
D reduction in the volume of the system

Answer [ ] [1]

/1

Source: IJC 2017 Promo, via Chemical Equilibria Topical Revision Booklet, Q6

11 For the reaction $2X_2(g) + Y_2(g) \rightleftharpoons 2X_2Y(g)$, the value of the equilibrium constant K_c is 5.00. Determine the value of K_c for each of the following equilibria, including its units.

(a) $4X_2(g) + 2Y_2(g) \rightleftharpoons 4X_2Y(g)$

[1]

(b) $X_2Y(g) \rightleftharpoons X_2(g) + \frac{1}{2}Y_2(g)$

[1]

/2

Source: EJC 2022 JC1 Chemical Equilibria Tutorial, A6

12 A mixture contained 1.00 mol of ethanoic acid and 5.00 mol of ethanol. After the system had come to equilibrium, a portion of the mixture was titrated against 0.200 mol dm^{-3} sodium hydroxide solution. The titration showed that the whole of the equilibrium mixture would require 289 cm^3 of the standard alkali for neutralisation. Find the value of K_c for the esterification reaction, $CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$.

[3]

/3

Source: EJC 2022 JC1 Chemical Equilibria Tutorial, A7

13 COMMON Industrially, coal can be converted into a combustible gas by passing steam over white hot coke. $H_2O(g) + C(s) \rightleftharpoons H_2(g) + CO(g) \quad \Delta H = +131 \text{ kJ mol}^{-1}$

(a) Write an expression for the equilibrium constant, K_p, including its units.

[1]

(b) How would the composition of the equilibrium mixture change if there were an increase in pressure and in temperature respectively? Explain your answer.

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..... **[2]**

(c) Steam was passed over coke at 730 °C. At equilibrium, p_{H_2O} is 90 kPa and p_{H_2} is 183 kPa. Calculate the equilibrium partial pressure of carbon monoxide and hence K_p. If the steam is now brought to a new equilibrium partial pressure of 150 kPa by compression of the whole vessel, what will be the new equilibrium partial pressure of hydrogen?

[3]

/6

Source: EJC 2022 JC1 Chemical Equilibria Tutorial, A9(a) to (c)

14 Zinc oxide can be produced from zinc and steam. $Zn(s) + H_2O(g) \rightleftharpoons ZnO(s) + H_2(g)$ $\Delta H < 0$. 2.60 mol of zinc and 2.60 mol of steam are placed in a sealed vessel and heated. At equilibrium, 2.58 mol of zinc oxide is produced. The total pressure at equilibrium is 10 atm.

(a) Calculate the partial pressure of H_2 at equilibrium.

[1]

(b) Write the expression for the equilibrium constant, K_p, of this reaction. Use your expression to calculate the value of K_p.

[2]

(c) Explain how a decrease in temperature affects the yield of zinc oxide.

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[1]

/4

Source: 2023 RI J2 Prelim P2 Q5(e)

15 **CHALLENGE** The Fischer–Tropsch process is one method of manufacturing methane. $CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$. A mixture of CO and H_2 in the molar ratio 1 : 3 is added into a sealed vessel and heated to 800 °C. At equilibrium, the total pressure is 32 atm and 40% of CO has reacted. Write the expression for the equilibrium constant, K_p, for this reaction. Use your expression to calculate the value of K_p for this reaction. Include its units.

[4]

/4

Source: 2024 CJC J2 Prelim P3 Q2(b)(ii)