2018 / 2019

5 The equation of a simulated photosynthesis is represented by

$$6\,CO_2\,(g) + 6\,H_2O\,(g) \rightleftharpoons C_6H_{12}O_6\,(s) + 6\,O_2\,(g) \qquad \Delta H^o = +ve$$

At 31°C, the following equilibrium concentrations were found

$[H_2O] = 7.91 \times 10^{-2}$ M , $[CO_2] = 9.30 \times 10^{-1}$ M , $[O_2] = 2.40 \times 10^{-3}$ M.

(b) Calculate the equilibrium constant, K_p for the reaction.

(c) Determine the initial mass of CO_2 involved in the above reaction.

(d) Explain how the equilibrium position would be affected for each of the following changes:

i) water is added.

ii) temperature is increased. [12 marks]

2019 / 2020

5 (a) Sulphur trioxide, SO_3 gas decomposes sulphur dioxide and oxygen gas according to the following equation:

$$2SO_3\,(g) \rightleftharpoons 2SO_2\,(g) + O_2\,(g)$$

When 1.0 mol of SO_3 is placed into a 2 L vessel and heated to 344 K, the system achieves equilibrium and 0.6 mol of SO_3 gas is remained.

i) Calculate the concentration of each gas at equilibrium.

ii) Calculate the equilibrium constant, K_c at 344 K.

[7 marks]

(b) Phosphorus pentachloride, PCl_5 is left in a sealed container to establish equilibrium

$$PCl_5\,(g) \rightleftharpoons PCl_3(g) + Cl_2\,(g) \qquad \Delta H = -ve$$

i) Explain the effect of lowering temperature on the equilibrium constant, K_p of the system.

ii) Explain the effect of adding argon gas at constant volume on the equilibrium position.

[4 marks]

2020 / 2021

5 (a) Ammonia, NH_3, is produced at 500 °C and 200 atm in the presence of Fe_2O_3 catalyst according to the following equation:

$$3H_2\,(g) + N_2\,(g) \rightleftharpoons 2NH_3\,(g) \qquad \Delta H = \text{-}92.22\ \text{kJ}$$

Suggest **two (2) changes** that can be made to increase yield of NH_3. Explain your suggestions.

[4 marks]

(b) Consider the following reaction:

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3(g) \qquad K_c = 4.62$$

Determine the direction of the reaction if the concentrations of $SO_2(g)$, $SO_3(g)$ and $O_2(g)$ are 0.2 M, 0.15 M and 8.55×10^{-3} M, respectively.

[5 marks]

2021 / 2022

23. The following equilibrium is set up in a solution by dissolving cobalt (II) chloride crystal in water to form the pink coloration and followed by addition of concentrated hydrochloric acid until the solution becomes blue. Select the statement(s) that explain(s) the colour change observed upon cooling the reacted mixture.

$$\underset{\text{Pink}}{Co(H_2O)_6} + 4Cl^- \rightleftharpoons \underset{\text{Blue}}{CoCl_4^{2-}} + 6H_2O \qquad \Delta H_{rxn} = +\text{ve kJ}$$

I Solution becomes blue

II Solution becomes pink

III Position of equilibrium shifts to the left to produce heat

A. I only

B. I and II

C. II and III

D. I, II and III

24. A mixture of gas containing 0.174 mol N_2 and 0.441 mol H_2 is added to a 1.000L container, allowed to reach equilibrium as in the followingequation:

$$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3(g) \quad K_c = 4.62$$

At equilibrium, it is found that the concentration of NH_3 is 0.128 M. Calculate the value of K_c for the reaction.

A. 1.1
B. 1.7
C. 2.8
D. 9.6

25. The equilibrium constant for the reaction below is 1.0×10^{-5} at 1500K

$$N_2\,(g) + O_2\,(g) \rightleftharpoons 2NO(g)$$

In an experiment, the concentrations of N_2 , O_2 and NO are 0.05 M, 0.02 M and 0.30 M respectively. Predict the direction of the reaction.

A. Net reaction is to the right
B. Net reaction is to the left
C. Reaction lies in the middle
D. Reaction is at equilibrium

2022 / 2023

5 The equilibrium constant, K_p, for the reaction below is 8.3×10^{-3} at 400 °C.

$$2Cl_2\,(g) + 2H_2O\,(g) \rightleftharpoons 4HCl\,(g) + O_2\,(g) \qquad \Delta H^o = 115\ kJ\ mol^{-1}$$

(b) Calculate K_c for the reaction at 400°C. [4 *marks*]

(c) Explain how the mass of HCl is affected by increasing the temperature. [2 *marks*]

(d) Predict the direction of the net reaction if at one instant, the concentrations of Cl_2, H_2O, HCl and O_2 measured are 0.70 M, 0.35 M, 0.25 M and 0.05 M respectively. [3 *marks*]

2023 / 2024

5 The second step in the contact process for producing sulphuric acid, H_2SO_4, involves the oxidation of sulphur dioxide gas, SO_2 to generate sulphur trioxide gas, SO_3, as indicated by the reversible equation below.

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g)$$

a) Sketch and label the graph to illustrate the change in concentration over time for SO_2 gas and SO_3 gas until equilibrium is achieved. [3 *marks*]

b) Equilibrium is achieved when the partial pressure of SO_3 gas is 0.364 atm and the total pressure is 0.658 atm at a temperature of 500°C. Determine the initial pressure of SO_2 gas if the initial pressure of O_2 gas is 0.250 atm. [5 *marks*]

c) Predict the position of the equilibrium if 50% of SO_3 gas is removed from the system. [1 *mark*]

2024 / 2025

5 (a) The water-gas shift reaction is important in several chemical processes, such as the production of H_2 for fuel cells. The reaction can be written as follows:

$$H_2\,(g) + CO_2\,(g) \rightleftharpoons H_2O\,(g) + CO\,(g) \qquad K_c = 0.106$$

A mixture of gases initially contains 0.025 M H_2 and 0.015 M CO_2 and is allowed to attain equilibrium at 700 K.

Determine the equilibrium concentrations of H_2 and CO_2.

[4 *marks*]

(b) A mixture consisting of 0.42 M of N_2, 0.20 M of H_2 and 0.10 M of NH_3 is placed in a vessel at certain temperature and pressure, and allowed to react based on the following equation:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad K_c = 0.0584$$

(i) Determine the direction of the net reaction under these conditions.

(ii) Explain the effect on the equilibrium position when the volume of the vessel is decreased.

[5 *marks*]