

Equilibrium Review

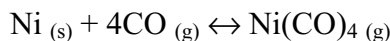
Quantitative Review:

1) The following reactions occur at 500 K. Arrange them in order of increasing tendency to proceed to completion (i.e. least to greatest tendency):

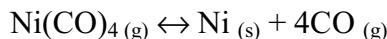
- a. $2 \text{NOCl} \leftrightarrow 2 \text{NO} + \text{Cl}_2$ $K_c = 1.7 * 10^{-2}$
b. $2 \text{SO}_3 \leftrightarrow 2 \text{SO}_2 + \text{O}_2$ $K_c = 1.3 * 10^{-5}$
c. $2 \text{NO}_2 \leftrightarrow 2 \text{NO} + \text{O}_2$ $K_c = 5.9 * 10^{-5}$

(Answer: $b < c < a$)

2) The equilibrium constant for the reaction:



is $5.0 * 10^4$ at 25°C . What is the value of the equilibrium constant for the following reaction:



(Answer: $K_c = \frac{1}{K_c} = \frac{1}{5 * 10^4} = 2 * 10^{-5}$)

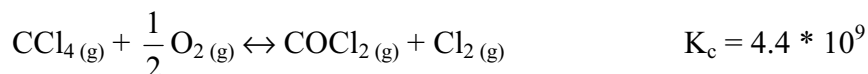
3) For the following reactions the equilibrium constants are defined:

- a. $\text{A} + 2 \text{B} \leftrightarrow \text{C}$ K_1
b. $\text{C} \leftrightarrow \text{D} + \text{E}$ K_2
c. $\text{A} + 2 \text{B} \leftrightarrow \text{D} + \text{E}$ K_c

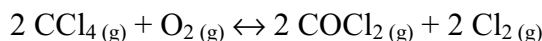
The final equilibrium constant is given by what expression?

(Answer: $K_c = K_1 * K_2$)

4) Carbon tetrachloride reacts at high temperatures with oxygen to produce two toxic gases: phosgene, COCl_2 and chlorine, Cl_2 :

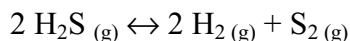


Calculate the equilibrium constant for the following reaction:



(Answer: $K_c = (4.4 * 10^9)^2 = 1.9 * 10^{19}$)

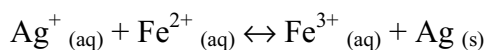
5) An equilibrium mixture for the reaction:



On analysis was found to contain 1.0 mol of H_2S , 4.0 mol of H_2 , and 0.80 mol of S_2 in a 4.0 dm^3 vessel. Calculate the equilibrium constant for this reaction.

(Answer: 3.2 mol dm^{-3})

6) An aqueous solution is made by dissolving 1.00 mol of AgNO_3 and 1.00 mol of FeSO_4 in water and making up to 1.00 dm^3 :



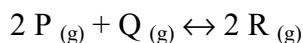
When the equilibrium was established the following concentrations were obtained:

$$\begin{aligned} [\text{Ag}^+] &= [\text{Fe}^{2+}] = 0.44 \text{ mol dm}^{-3} \\ [\text{Fe}^{3+}] &= 0.56 \text{ mol dm}^{-3} \end{aligned}$$

Find the equilibrium constant.

(Answer: $2.89 \text{ mol}^{-1} \text{ dm}^3$)

7) For the equilibrium:

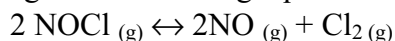


K_c is numerically equal to 6.0. Into a 1.00 dm^3 flask are introduced 3.0 mol of P, 3.0 mol of Q, and 3.0 mol of R.

- State the units in which K_c is expressed.
- Is the mixture at equilibrium?
- If not, what must the volume of the flask be in order for such a mixture to exist in equilibrium at the temperature for which K_c was given?

(Answer: a) M^{-1} ; b) 0.33; c) $K_c = 6 = \frac{(\frac{3}{V})^2}{(\frac{3}{V})^2 (\frac{3}{V})} \rightarrow V = 18.0 \text{ dm}^3$)

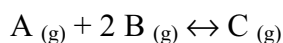
- 8) 2.50 mol of NOCl was placed in a 2.50 dm³ reaction vessel at 400°C. After equilibrium was established, it was found that 28% of NOCl has dissociated according to the following equation:



Calculate the equilibrium constant for the reaction.

(Answer: 0.021 mol dm⁻³)

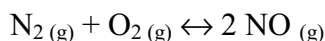
- 9) The following reaction was allowed to come to equilibrium:



The initial amounts of reactants placed into a 5.00 dm³ container were 1.0 mol of A and 1.8 mol of B. After the reaction reached equilibrium, 1.0 mol of B was found. Calculate the value of K_c for this reaction.

(Answer: 17 mol⁻² dm⁶)

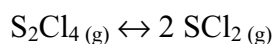
- 10) Consider the reaction:



Here the equilibrium constant is 0.10 at 2000°C. Starting with initial concentrations of 0.040 mol dm⁻³ of N₂ and 0.040 mol dm⁻³ of O₂, calculate the equilibrium constant concentration of NO.

(Answer: 0.011 mol dm⁻³)

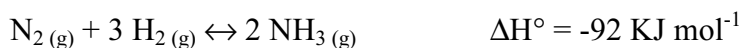
- 11) 4.21 moles of S₂Cl₄ are introduced into a 2.0 dm³ vessel where the following reaction occurs:



It is allowed to come to equilibrium, and 1.25 moles of S₂Cl₄ are found in the container. Calculate the equilibrium constant for the reaction.

(Answer: 14 mol dm⁻³)

- 12) The following question refers to the Haber process for the synthesis of ammonia. The equation which represents the reaction is given below:



- a) Give one source each of nitrogen and hydrogen for this process.

(Answer: Air, water or natural gas)

b) Write the expression for the equilibrium constant.

(Answer: $K_p = \frac{P_{\text{NH}_3}^2}{P_{\text{N}_2} * P_{\text{H}_2}^3}$)

c) What is the relationship between K_c and K_p for this reaction?

(Answer: $K_p = K_c(RT)^{-2}$)

d) If the pressure is measured in kPa, what will be the units of K_p ?

(Answer: kPa^{-2})

e) State and explain the effect on the equilibrium constant, and its numerical value, if:

1. Pressure is increased? (Answer: Shift to the right but K_c is constant)

2. Temperature is increased? (Answer: Shift to the left and K_c will decrease)

f) The numerical value of the equilibrium constant, K_c , is $6.0 * 10^{-2} \text{ mol}^{-2} \text{ dm}^6$ at 500°C . The following concentrations were determined in a mixture:

$$[\text{NH}_3] = 1.0 * 10^{-3} \text{ mol dm}^{-3}$$

$$[\text{N}_2] = 1.0 * 10^{-5} \text{ mol dm}^{-3}$$

$$[\text{H}_2] = 2.0 * 10^{-2} \text{ mol dm}^{-3}$$

1. Is the reaction at equilibrium? (Answer: No)

2. Predict the direction that the system will shift to reach equilibrium. (Answer: Left)