

Problem Set #14  
CHEM101A: General College Chemistry

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November 21, 2025

## 12 Topic G Problem 12

1.00 g of  $\text{N}_2\text{O}_4$  is put into a 5.00 L container and heated to 50°C. At this temperature, the following reaction occurs and reaches equilibrium:



The concentration of  $\text{NO}_2$  in the equilibrium mixture is found to be equal to  $6.68 \times 10^{-4}$  M. Calculate  $K_c$  and  $K_p$  for this reaction at 50°C.

### 12.1 Solution

First convert grams to moles.

$$MM(\text{N}_2\text{O}_4) = 92.02 \text{ g/mol} \quad (1)$$

$$n(\text{N}_2\text{O}_4) = \frac{m}{MM} = \frac{1.00 \text{ g}}{92.02 \text{ g/mol}} = 0.0108672 \text{ mol} \quad (2)$$

$$M(\text{N}_2\text{O}_4) = \frac{n}{V} = \frac{0.0108672 \text{ mol}}{5.00 \text{ L}} = 0.00217344 \text{ M} \quad (3)$$

Now, I'll use an ICE table.

| M | $\text{N}_2\text{O}_4$   | $\rightleftharpoons$ | $2\text{NO}_2$        |
|---|--------------------------|----------------------|-----------------------|
| I | 0.00217344               |                      | 0                     |
| C | $-3.34 \times 10^{-4}$   |                      | $6.68 \times 10^{-4}$ |
| E | $18.3944 \times 10^{-4}$ |                      | $6.68 \times 10^{-4}$ |

Now we calculate  $K_c$ .

$$K_c = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} = \frac{(6.68 \times 10^{-4})^2}{18.3944 \times 10^{-4}} = 242.5868 \times 10^{-6} \text{ M} = \boxed{243 \times 10^{-6} \text{ M}} \quad (4)$$

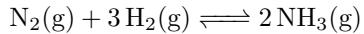
Next we use that to find  $K_p$ .

$$K_p = K_c(RT)^{\Delta n} = (243 \times 10^{-6} \text{ M})(0.08206 \times 323.15)^1 \quad (5)$$

$$= 6.43284 \times 10^{-3} \text{ atm} = \boxed{6.43 \times 10^{-3} \text{ atm}} \quad (6)$$

## 13 Topic G Problem 13

When 0.100 mol of gaseous N<sub>2</sub> and 0.100 mol of gaseous H<sub>2</sub> are put into a 5.00 L container at 300°C, the following reaction occurs and reaches equilibrium.



The partial pressure of ammonia in the equilibrium mixture is 0.0506 atm. Calculate K<sub>p</sub> and K<sub>c</sub> for this reaction at 300°C.

### 13.1 Solution

I'll use an ICE table.

| M | N <sub>2</sub> (g) | + | 3 H <sub>2</sub> (g) | $\rightleftharpoons$ | 2 NH <sub>3</sub> (g) |
|---|--------------------|---|----------------------|----------------------|-----------------------|
| I | 0.0200             |   | 0.0200               |                      | 0                     |
| C | $-x$               |   | $-3x$                |                      | $2x$                  |
| E | $0.0200 - x$       |   | $0.0200 - 3x$        |                      | $2x$                  |

Now we solve for  $x$ , using the partial pressure of NH<sub>3</sub>.

$$PV = nRT \quad (7)$$

$$[\text{NH}_3] = \frac{n}{V} = \frac{P}{RT} = \frac{0.0506 \text{ atm}}{(0.08206 \frac{\text{atm}\cdot\text{L}}{\text{mol}\cdot\text{K}})(573.15 \text{ K})} \quad (8)$$

$$= 0.010688 \text{ M} \quad (9)$$

$$2x = [\text{NH}_3] \quad (10)$$

$$x = \frac{[\text{NH}_3]}{2} = \frac{0.010688 \text{ M}}{2} = 0.005344 \text{ M} \quad (11)$$

This gives us the value of  $x$ , which we can use.

| M | N <sub>2</sub> (g) | + | 3 H <sub>2</sub> (g) | $\rightleftharpoons$ | 2 NH <sub>3</sub> (g) |
|---|--------------------|---|----------------------|----------------------|-----------------------|
| E | 0.01947            |   | 0.018397             |                      | 0.010688              |

This can be used to find K<sub>c</sub>.

$$K_c = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^2} = \frac{0.010688^2}{0.01947 \times 0.018397^2} = 9.42565 = \boxed{9.43} \quad (12)$$

Next convert it to pressure.

$$K_p = K_c(RT)^{\Delta n} = 9.42565 \left( 0.08206 \frac{\text{atm}\cdot\text{L}}{\text{mol}\cdot\text{K}} (573.15 \text{ K}) \right)^{-2} \quad (13)$$

$$= 0.004261 = \boxed{0.00426} \quad (14)$$

## 14 Topic G Problem 14

For the reaction below,  $K_c = 0.0168$  at  $250^\circ\text{C}$ :

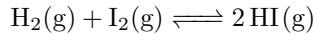


- a) A flask contains 0.100 mol/L of  $\text{PCl}_5$ . What will be the concentrations of all three gases when the above reaction reaches equilibrium?
- b) A different flask contains 0.100 mol/L of  $\text{PCl}_5$ , 0.200 mol/L of  $\text{PCl}_3$ , and 0.300 mol/L of  $\text{Cl}_2$ . What will be the concentrations of all three gases when the above reaction reaches equilibrium?

### 14.1 Solution

## 15 Topic G Problem 15

For the reaction below,  $K_p = 0.513$  at a certain temperature.

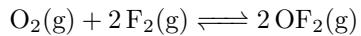


- a) A flask holds some gaseous HI at this temperature and a pressure of 3.00 atm. What will be the partial pressures of all three gases when the above reaction reaches equilibrium?
- b) A second flask contains a mixture of the three gases with the following partial pressures:  $H_2 = 0.433$  atm,  $I_2 = 0.0471$  atm,  $HI = 0.0310$  atm. What will be the partial pressures of all three gases when the above reaction reaches equilibrium?

### 15.1 Solution

## **16 Topic G Problem 16**

Parts a through d of this problem relate to the reaction below:



- a) If you add some gaseous  $\text{F}_2$  to an equilibrium mixture of these three chemicals, which way will the reaction proceed?
- b) If you add some gaseous  $\text{O}_2$  to an equilibrium mixture of these three chemicals, what will happen to the partial pressure of  $\text{F}_2$  in the mixture (i.e. will it go up, go down, or remain the same)?
- c) If you increase the volume of the container, which way will the reaction proceed?
- d) If you decrease the volume of the container, what will happen to the mass of  $\text{OF}_2$  in the mixture?
- e) If you increase the temperature, which way will the reaction proceed? You will need to look up the bond energy values to answer this question.

### **16.1 Solution**

## **17 Topic G Problem 17**

Will the value of the equilibrium constant K change in any of the parts of problem 16? If so, which parts?

### **17.1 Solution**

## 18 Topic G Problem 18

Consider an equilibrium mixture of ammonium chloride, ammonia, and hydrogen chloride:

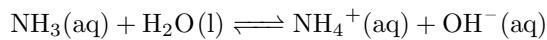


- a) If you add a little solid  $\text{NH}_4\text{Cl}$  to the mixture, what will happen to the mass of  $\text{NH}_3$ ?
- b) If you add a little gaseous  $\text{NH}_3$  to the mixture, what will happen to the mass of  $\text{HCl}$ ?
- c) If you add a little gaseous  $\text{HCl}$  to the mixture, what will happen to the mass of  $\text{NH}_4\text{Cl}$ ?

### 18.1 Solution

## 19 Topic G Problem 19

The reaction below is allowed to reach equilibrium:



- a) If you add a little 1 M HCl to the mixture, which way will the reaction proceed? Or will it be unaffected? Explain your answer.
- b) If you add a little 1 M MgCl<sub>2</sub> to the mixture, which way will the reaction proceed? Or will it be unaffected? Explain your answer.
- c) If you add a little 1 M NH<sub>4</sub>NO<sub>3</sub> to the mixture, which way will the reaction proceed? Or will it be unaffected? Explain your answer.

### 19.1 Solution

## 20 Topic G Problem 20

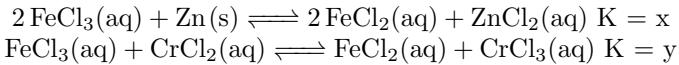
For the reaction  $4 \text{HBr}(\text{aq}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{Br}_2(\text{aq}) + 2 \text{H}_2\text{O}(\text{l})$ ,  $K_c = 6.7 \times 10^{10}$ . Use this information to calculate the equilibrium constant for each of the following reactions.

- a)  $2 \text{HBr}(\text{aq}) + \frac{1}{2} \text{O}_2(\text{g}) \rightleftharpoons \text{Br}_2(\text{aq}) + \text{H}_2\text{O}(\text{l})$
- b)  $4 \text{Br}_2(\text{aq}) + 4 \text{H}_2\text{O}(\text{l}) \rightleftharpoons 8 \text{HBr}(\text{aq}) + 2 \text{O}_2(\text{g})$

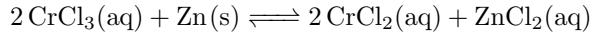
### 20.1 Solution

## 21 Topic G Problem 21

Consider the following reactions, where the equilibrium constants are represented by the variables x and y:



Write an expression for the equilibrium constant for the reaction below, in terms of x and y.



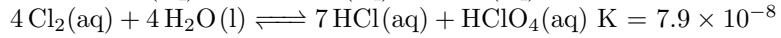
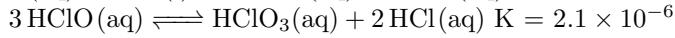
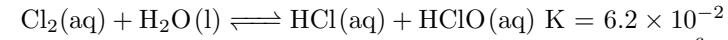
### 21.1 Solution

## 22 Topic G Problem 22

Calculate the equilibrium constant for the following reaction:



Use the following equilibrium constants.



### 22.1 Solution

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