

Problem Set #14
CHEM101A: General College Chemistry

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November 21, 2025

12 Topic G Problem 12

1.00 g of N_2O_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 NO_2 in the equilibrium mixture is found to be equal to 6.68×10^{-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	N_2O_4	\rightleftharpoons	2NO_2
I	0.00217344		0
C	-3.34×10^{-4}		6.68×10^{-4}
E	18.3944×10^{-4}		6.68×10^{-4}

Now we calculate K_c .

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

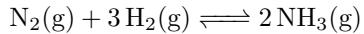
Next we use that to find K_p .

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

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

13 Topic G Problem 13

When 0.100 mol of gaseous N₂ and 0.100 mol of gaseous H₂ 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_p and K_c for this reaction at 300°C.

13.1 Solution

I'll use an ICE table.

M	N ₂ (g)	+	3 H ₂ (g)	\rightleftharpoons	2 NH ₃ (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 NH₃.

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

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

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

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

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

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

M	N ₂ (g)	+	3 H ₂ (g)	\rightleftharpoons	2 NH ₃ (g)
E	0.01947		0.018397		0.010688

This can be used to find K_c.

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

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°C :



- a) A flask contains 0.100 mol/L of 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 PCl_5 , 0.200 mol/L of PCl_3 , and 0.300 mol/L of Cl_2 . What will be the concentrations of all three gases when the above reaction reaches equilibrium?

14.1 Solution (a)

Use an ICE table.

M	$\text{PCl}_5(\text{g})$	\rightleftharpoons	$\text{PCl}_3(\text{g})$	+	$\text{Cl}_2(\text{g})$
I	0.100		0		0
C	$-x$		$+x$		$+x$
E	$0.100 - x$		x		x

Use K_c to find x .

$$K_c = 0.0168 = \frac{[\text{PCl}_3][\text{Cl}_2]}{[\text{PCl}_5]} = \frac{x^2}{0.100 - x} \quad (15)$$

$$x^2 = 0.00168 - 0.0168x \quad (16)$$

$$0 = x^2 + 0.0168x - 0.00168 \quad (17)$$

$$x = 0.0334397 \text{ or } -0.0502397 \quad (18)$$

We use the positive one to complete the ICE table. That contains our answers.

M	$\text{PCl}_5(\text{g})$	\rightleftharpoons	$\text{PCl}_3(\text{g})$	+	$\text{Cl}_2(\text{g})$
E	0.0666		0.0334		0.0334

14.2 Solution (b)

First find Q. That tells us where it will skew.

$$Q = \frac{[\text{PCl}_3][\text{Cl}_2]}{[\text{PCl}_5]} = \frac{0.200 * 0.300}{0.100} = 0.6 \quad (19)$$

This is way bigger than K_c . This means it skews way towards PCl_5 (left). From here, use an ICE table.

M	$\text{PCl}_5(\text{g})$	\rightleftharpoons	$\text{PCl}_3(\text{g})$	+	$\text{Cl}_2(\text{g})$
I	0.100		0.200		0.300
C	$+x$		$-x$		$-x$
E	$0.100 + x$		$0.200 - x$		$0.300 - x$

Find x using K_c .

$$K_c = 0.0168 = \frac{(0.200 - x)(0.300 - x)}{0.100 + x} \quad (20)$$

$$0.00168 + 0.0168x = x^2 - 0.500x + 0.0600 \quad (21)$$

$$0 = x^2 - 0.5168x + 0.05832 \quad (22)$$

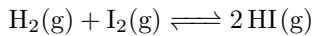
$$x = 0.350327 \text{ or } 0.166473 \quad (23)$$

The former is too big, so we use the latter.

M	$\text{PCl}_5(\text{g})$	\rightleftharpoons	$\text{PCl}_3(\text{g})$	+	$\text{Cl}_2(\text{g})$
E	0.266		0.0335		0.134

15 Topic G Problem 15

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

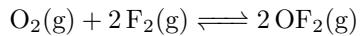


- a) A flask holds some gaseous HI at this temperature and a pressure of 3.00 atm. What will be the partial pressures of all three gases when the above reaction reaches equilibrium?
- b) A second flask contains a mixture of the three gases with the following partial pressures: $H_2 = 0.433$ atm, $I_2 = 0.0471$ 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 F_2 to an equilibrium mixture of these three chemicals, which way will the reaction proceed?
- b) If you add some gaseous O_2 to an equilibrium mixture of these three chemicals, what will happen to the partial pressure of 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 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:

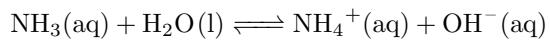


- a) If you add a little solid NH_4Cl to the mixture, what will happen to the mass of NH_3 ?
- b) If you add a little gaseous NH_3 to the mixture, what will happen to the mass of HCl ?
- c) If you add a little gaseous HCl to the mixture, what will happen to the mass of NH_4Cl ?

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 MgCl₂ 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 NH₄NO₃ 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

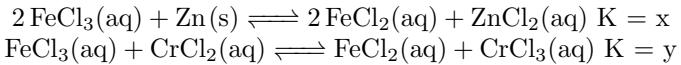
For the reaction $4 \text{HBr}(\text{aq}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{Br}_2(\text{aq}) + 2 \text{H}_2\text{O}(\text{l})$, $K_c = 6.7 \times 10^{10}$. Use this information to calculate the equilibrium constant for each of the following reactions.

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

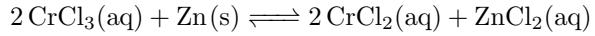
20.1 Solution

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.



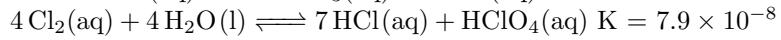
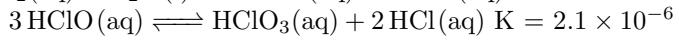
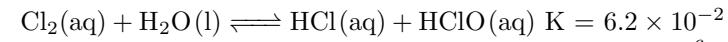
21.1 Solution

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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