Chemistry 12
Worksheet 2-3
Calculations Involving the Equilibrium Constant K_{eq})

1. Given the equilibrium equation below:

$$A_{2(g)} + B_{2(g)} \rightleftarrows 2AB_{(g)}$$

If, *at equilibrium*, the concentrations are as follows:

$[A_2] = 3.45$ M, $[B_2] = 5.67$ M and $[AB] = 0.67$ M

a) Write the **expression** for the equilibrium constant, K_{eq}

b) Find the **value** of the equilibrium constant, K_{eq} at the temperature that the experiment was done.

Answer _____

2. Given the equilibrium equation:

$$X_{2(g)} + 3Y_{2(g)} \rightleftarrows 2XY_{3(g)}$$

at a temperature of 50°C, it is found that when equilibrium is reached that:

$[X_2] = 0.37$ M, $[Y_2] = 0.53$ M and $[XY_3] = 0.090$ M

a) Write the **equilibrium constant expression** (K_{eq})

b) Calculate the **value** of K_{eq} at 50°C.

Answer _____

3. For the reaction: $A_{2(g)} + B_{(g)} \rightleftarrows 2C_{(g)}$

it is found that by adding 1.5 moles of C to a 1.0 L container, an equilibrium is established in which 0.30 moles of B are found. (*Hint: Make a table and use it to answer the questions below.*)

a) What is [A] at equilibrium? Answer _____

b) What is [B] at equilibrium? Answer _____

c) What is [C] at equilibrium? Answer _____

d) Write the **expression** for the equilibrium constant, K_{eq} .

e) Calculate the **value** for the equilibrium constant at the temperature at the experiment was done.

Answer _____

4. Considering the following equilibrium:

$$2AB_{3(g)} \rightleftarrows A_{2(g)} + 3B_{2(g)}$$

If 0.87 moles of AB_3 are injected into a 5.0 L container at 25°C , at equilibrium the final $[A_2]$ is found to be 0.070 M.(*Hint: Make a table and use it to answer the questions below.*)

a) Calculate the equilibrium concentration of AB_3. Answer _____

b) Calculate the equilibrium $[A_2]$. Answer _____

c) Calculate the equilibrium $[B_2]$. Answer _____

5. Consider the reaction:

$$A_{(g)} + B_{(g)} \rightleftarrows C_{(g)}$$

a) In an equilibrium mixture the following concentrations were found:

[A] = 0.45M, [B] = 0.63M and [C] = 0.30M. Calculate the value of the equilibrium constant for this reaction.

Answer _____

b) At the same temperature, another equilibrium mixture is analyzed and it is found that [B] = 0.21 M and [C] = 0.70 M. From this and the information above, calculate the *equilibrium [A]*.

Answer _____

c) In another equilibrium mixture at the same temperature, it is found that [A] = 0.35 M and the [C] = 0.86 M. From this and the information above, calculate the *equilibrium [B]*.

$$A_{(g)} + B_{(g)} \rightleftarrows C_{(g)}$$

Answer _____

6. Two mole of gaseous NH_3 are introduced into a 1.0 L vessel and allowed to undergo partial decomposition at high temperature according to the reaction:

$$2NH_{3(g)} \rightleftarrows N_{2(g)} + 3H_{2(g)}$$

At equilibrium, 1.0 mole of $NH_{3(g)}$ remains.
(*Make a table and use it to answer the questions below:*)

a) What is the equilibrium $[N_2]$? Answer _____

b) What is the equilibrium $[H_2]$? Answer _____

c) Calculate the **value** of the equilibrium constant at the temperature of the experiment.

Answer _____

7. At a high temperature, 0.50 mol of HBr was placed in a 1.0 L container and allowed to decompose according to the reaction:

$$2HBr_{(g)} \rightleftarrows H_{2(g)} + Br_{2(g)}$$

At equilibrium the $[Br_2]$ was measured to be 0.13 M. What is K_{eq} for this reaction at this temperature?

Answer _____

8. When 1.0 mol of $NH_{3(g)}$ and 0.40 mol of $N_{2(g)}$ are placed in a 5.0 L vessel and allowed to reach equilibrium at a certain temperature, it is found that 0.78 mol of NH_3 is present. The reaction is:

$$2NH_{3(g)} \rightleftarrows 3H_{2(g)} + N_{2(g)}$$

a) Calculate the **equilibrium concentrations** of all three species.

$[NH_3]$ = _____ $[H_2]$ = _____ $[N_2]$ = _____

b) Calculate the **value** of the equilibrium constant at this temperature.

Answer _____

c) How many **moles** of H_2 are present at equilibrium?

Answer _____

d) How many **moles** of N_2 are present at equilibrium?

Answer _____

9. When 0.40 mol of PCl_5 is heated in a 10.0 L container, an equilibrium is established in which 0.25 mol of Cl_2 is present. (*Make a table and answer the questions below. Be sure to read all questions a-d before making your table!:*)

$$PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$$

a) Calculate the **equilibrium concentration** of each species.

$[PCl_5]$ = _____ $[PCl_3]$ = _____ $[Cl_2]$ = _____

b) Calculate the **value** of the equilibrium constant, K_{eq} at the temperature of the experiment.

Answer _____

c) What **amount** (moles) of PCl_3 is present at equilibrium?

Answer _____

d) What **amount** (moles) of PCl_5 is present at equilibrium?

Answer _____

10. A mixture of H_2 and I_2 is allowed to react at 448°C. When *equilibrium* is established, the concentrations of the participants are found to be:

$[H_2]$ = 0.46 M, $[I_2]$ = 0.39 M and [HI] = 3.0 M.

The equation is: $H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$

a) Calculate the **value** of K_{eq} at 448°C.

Answer _____

b) In another equilibrium mixture of the *same* participants at 448°C , the concentrations of I_2 and H_2 are both 0.050 M. What is the *equilibrium concentration* of HI?

Answer _____

11. The K_{eq} for the reaction:

$$PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$$

at 250°C is found to be ***0.042***. In an *equilibrium mixture* of these species, it is found that $[PCl_5]$ = 0.012 M, and $[Cl_2]$ = 0.049 M. What is the equilibrium $[PCl_3]$ at 250°C ?

Answer _____

12. At a certain temperature the reaction:

$$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)}$$

has a Keq = ***0.500***. If a reaction mixture at equilibrium contains 0.210 M CO and 0.100 M H_2 , what is the *equilibrium* $[CH_3OH]$?

Answer_____

13. At a certain temperature the reaction: $CO_{(g)} + H_2O_{(g)} \rightleftarrows CO_{2(g)} + H_{2(g)}$

has a K_{eq} = ***0.400***. Exactly *1.00 mol* of each gas was placed in a 100.0 L vessel and the mixture was allowed to react. Find the **equilibrium concentration** of each gas.

Answer _____

14. The reaction: $2XY_{(g)} \rightleftarrows X_{2(g)} + Y_{2(g)}$

has a K_{eq} = ***35*** at 25°C. If 3.0 moles of XY are injected into a 1.0 L container at 25°C , find the equilibrium $[X_2]$ and $[Y_2]$.

Answer $[X_2]$ =_____ $[Y_2]$ = _____

15. The equilibrium constant for the reaction:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)} \qquad \text{at } 448°C \text{ is } \boldsymbol{50}.$$

a) If 1.0 mol of H_2 is mixed with 1.0 mol of I_2 in a 0.50 L container and allowed to react at 448°C , what is the **equilibrium** [HI]?

Answer _____

b) How many **moles** of HI are formed at equilibrium? (Actual yield)

Answer _____

16. Given K_{eq} for the reaction:

$$PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$$

is ***0.042*** at 250°C , what will happen if 2.50 mol of PCl_5, 0.600 mol of Cl_2 and 0.600 mol of PCl_3 are placed in a 1.00 flask at 250°C ? (*Will the reaction shift left, right, or not occur at all?*)

Answer _____

17. Given the equilibrium equation: $H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$

at 448°C, K_{eq} = ***50.*** If 3.0 mol of HI, 2.0 mol of H_2, and 1.5 mol of I_2 are placed in a 1.0 L container at 448°C, will a reaction occur?

Answer _____

If so, which way does the reaction shift? _____

18. Given the equilibrium equation: $H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$

at 448°C, K_{eq} = ***50.*** If 5.0 mol of HI, 0.7071 mol of H_2, and 0.7071 mol of I_2 are placed in a 1.0 L container at 448°C, will a reaction occur? (*Round any answers off to 3 significant digits!*)

Answer _____

If so, which way does the reaction shift? _____

19. Determine the equilibrium constant for the reaction: $H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$ given that an equilibrium mixture is analyzed and found to contain the following concentrations: $[H_2]$ = 0.0075 M, $[I_2]$ = 0.000043 M and [HI] = 0.0040 M

Answer _____

20. Given the equilibrium equation: $3A_{(g)} + B_{(g)} \rightleftarrows 2C_{(g)}$

If 2.50 moles of A and 0.500 moles of B are added to a 2.00 L container, an equilibrium is established in which the [C] is found to be 0.250 M.

a) Find [A] and [B] at equilibrium.

Answer _____

b) Calculate the value of the equilibrium constant K_{eq} .

Answer _____

21. At 800°C, the equilibrium constant K_{eq} , for the reaction:

$$CO_{2(g)} + H_{2(g)} \rightleftarrows CO_{(g)} + H_2O_{(g)} \quad \text{is } 0.279$$

If 1.50 moles of CO_2 and 1.50 moles of H_2 are added to a 1.00 L container, what would the [CO] be at equilibrium?

Answer _____

22. Given that the equilibrium constant K_{eq} for the reaction:

$$A_{(g)} + B_{(g)} \rightleftarrows C_{(g)} + D_{(g)}$$ is ***0.015*** at 25^oC,

if 1.0 mole of each gas is added to a 1.0 L container at 25^oC, which way will the equation shift in order to reach equilibrium?

Answer _____

23. Calculate the **equilibrium constant** K_{eq} for the following reaction:

$$2A_{2(g)} + 3B_{2(g)} \rightleftarrows 2A_2B_{3(g)}$$

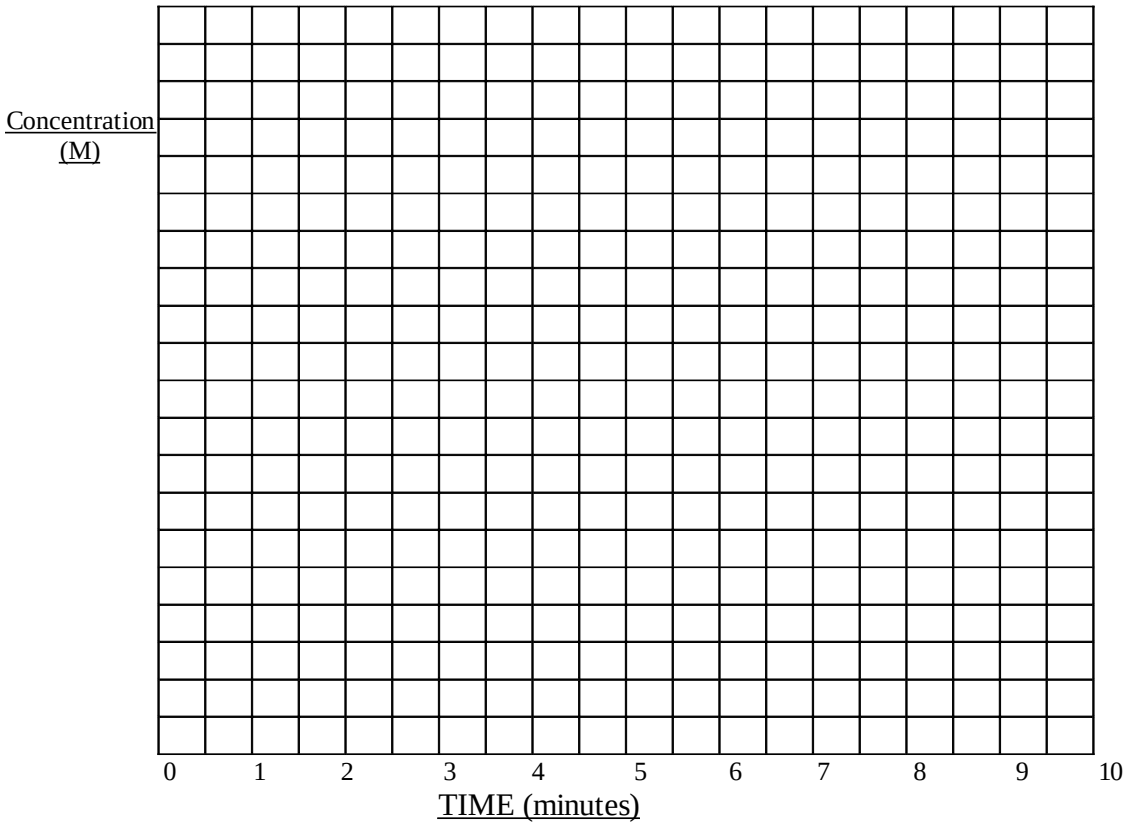
given that the *partial pressure* of each substance at equilibrium is as follows:

Partial Pressure of A_2 = 20.0 kPa, Partial Pressure of B_2 = 30.0 kPa, Partial Pressure of A_2B_3 = 5.00 kPa.

Answer _____

24. Consider the following equilibrium system: $A_{(g)} + B_{(g)} \rightleftarrows C_{(g)}$

1.0 mole of A and 2.0 moles of B are simultaneously injected into an empty 1.0 L container. At equilibrium (after 5.0 minutes), [C] is found to be 0.20 M. Make calculations and draw graphs to show how each of [A], [B] and [C] change with time over a period of 10.0 minutes. (*HINT: You have to make a table first.*)



25. Given the reaction:

$$4HCl_{(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(g)} + 2Cl_{2(g)} \qquad \Delta H = -113 \text{ kJ}$$

How will the value of the equilibrium constant K_{eq} at 550^oC compare with it's value at 450^oC? _____

Explain your answer. _____

_____

26. The following system is at equilibrium, in a closed container:

$$4NH_{3(g)} + 3O_{2(g)} \rightleftarrows 6H_2O_{(g)} + 2N_{2(g)} + \text{Heat}$$

a) How is the *amount of* N_2 in the container affected if the ***volume*** of the container is ***doubled***? _____

b) How is the rate of the **forward reaction** affected if more water vapor is introduced into the container? _____

c) How is the amount of O_2 in the container affected if a *catalyst* is added?

_____

27. At a certain temperature, K_{eq} for the reaction:

$$3C_2H_2 \rightleftarrows C_6H_6 \quad \text{is} \quad \mathbf{5.0}\,.$$

If the *equilibrium concentration* of C_2H_2 is 0.40 moles/L, what is the *equilibrium concentration* of C_6H_6?

Answer _____

Chemistry 12
Worksheet 2-3
KEY

Calculations Involving the Equilibrium Constant K_{eq})

1. Given the equilibrium equation below:

$$A_{2(g)} + B_{2(g)} \rightleftarrows 2AB_{(g)}$$

If, *at equilibrium*, the concentrations are as follows: (2 SD)

$[A_2] = 3.45$ M, $[B_2] = 5.67$ M and $[AB] = 0.67$ M

a) Write the **expression** for the equilibrium constant, K_{eq}

$$K_{eq} = \frac{[AB]^2}{[A_2][B_2]}$$

b) Find the **value** of the equilibrium constant, K_{eq} at the temperature that the experiment was done.

$$K_{eq} = \frac{(0.67)^2}{(3.45)(5.67)} = 0.023$$

Answer $K_{eq} = 0.023$

2. Given the equilibrium equation:

$$X_{2(g)} + 3Y_{2(g)} \rightleftarrows 2XY_{3(g)}$$

at a temperature of 50°C, it is found that when equilibrium is reached that:

$[X_2] = 0.37$ M, $[Y_2] = 0.53$ M and $[XY_3] = 0.090$ M (All 2 SD)

a) Write the **equilibrium constant expression** (K_{eq})

$$K_{eq} = \frac{[XY_3]^2}{[X_2][Y_2]^3}$$

b) Calculate the **value** of K_{eq} at 50°C.

$$K_{eq} = \frac{(0.090)^2}{(0.37)(0.53)^3} = 0.15$$

Answer $K_{eq} = 0.15$

3. For the reaction: $A_{2(g)} + B_{(g)} \rightleftarrows 2C_{(g)}$

KEY

it is found that by adding 1.5 moles of C to a 1.0 L container, an equilibrium is established in which 0.30 moles of B are found. (*Hint: Make a table and use it to answer the questions below.*)

4/1 2/1

	A_2	+ B	$\rightleftarrows$ 2 C
[I]	0	0	1.5
[C]	+0.30	+0.30	-0.60
[E]	0.30	0.30	0.9

1 dec place

a) What is [A] at equilibrium? Answer 0.30M

b) What is [B] at equilibrium? Answer 0.30 M

c) What is [C] at equilibrium? Answer 0.9 M

d) Write the **expression** for the equilibrium constant, K_{eq}.

$$K_{eq} = \frac{[C]^2}{[A][B]}$$

e) Calculate the **value** for the equilibrium constant at the temperature at the experiment was done.

1 SD

$$K_{eq} = \frac{(0.9)^2}{(0.30)(0.30)} = 9$$

Answer $K_{eq} = 9$

KEY

4. Considering the following equilibrium:

$$2AB_{3(g)} \rightleftarrows A_{2(g)} + 3B_{2(g)}$$

If 0.87 moles of AB_3 are injected into a 5.0 L container at 25°C , at equilibrium the final $[A_2]$ is found to be 0.070 M.(*Hint: Make a table and use it to answer the questions below.*)

Initial $[AB_3] = \frac{0.87\ mol}{5.0\ L} = 0.174\ M$ (limited to 2 SD's) (= 2 dp's)

2/1 3/1

	$2AB_3$	$\rightleftarrows A_2 +$	$3B_2$
[I]	0.174 (2dp)	0	0
[C]	-0.14	+0.070	+0.21
[E]	0.034 (2dp = 1SD)	0.070	0.21

a) Calculate the equilibrium concentration of AB_3. Answer 0.03 M

b) Calculate the equilibrium $[A_2]$. Answer 0.070 M

c) Calculate the equilibrium $[B_2]$. Answer 0.21 M

5. Consider the reaction:

$$A_{(g)} + B_{(g)} \rightleftarrows C_{(g)}$$

a) In an equilibrium mixture the following concentrations were found: (2 SD)

[A] = 0.45M, [B] = 0.63M and [C] = 0.30M. Calculate the value of the equilibrium constant for this reaction.

$K_{eq} = \frac{[C]}{[A][B]} = \frac{(0.30)}{(0.45)(0.63)} = 1.0582$

Answer $K_{eq} = 1.1$

b) At the same temperature, another equilibrium mixture is analyzed and it is found that [B] = 0.21 M and [C] = 0.70 M. From this and the information above, calculate the *equilibrium [A]*. (use unrounded value for K_{eq})

$1.0582 = \frac{(0.70)}{[A](0.21)}$ so $[A] = \frac{(0.70)}{(1.0582)(0.21)} = 3.2M$

Answer $[A] = 3.2M$

c) In another equilibrium mixture at the same temperature, it is found that [A] = 0.35 M and the [C] = 0.86 M. From this and the information above, calculate the *equilibrium [B]*.

$K_{eq} = \frac{[C]}{[A][B]}$ $\quad A_{(g)} + B_{(g)} \rightleftharpoons C_{(g)}$

$1.0582 = \frac{(0.86)}{(0.35)[B]} \rightarrow [B] = \frac{(0.86)}{1.0582(0.35)} = 2.3M$

Answer [B] = 2.3 M

6. Two mole of gaseous NH_3 are introduced into a 1.0 L vessel and allowed to undergo partial decomposition at high temperature according to the reaction:

$$2NH_{3(g)} \rightleftharpoons N_{2(g)} + 3H_{2(g)}$$

At equilibrium, 1.0 mole of $NH_{3(g)}$ remains.
(*Make a table and use it to answer the questions below:*)

$2\,NH_3 \rightleftharpoons N_2 + 3\,H_2$ (1/2 for N_2, 3/2 for H_2)

	$2\,NH_3$	N_2	$3\,H_2$
[I]	2.0	0	0
[C]	-1.0	+0.50	+1.5
[E]	1.0	0.50	1.5

a) What is the equilibrium $[N_2]$? Answer 0.50 M

b) What is the equilibrium $[H_2]$? Answer 1.5 M

c) Calculate the **value** of the equilibrium constant at the temperature of the experiment.

$K_{eq} = \frac{[N_2][H_2]^3}{[NH_3]^2} = \frac{(0.50)(1.5)^3}{(1.0)^2} = 1.7$

Answer $K_{eq} = 1.7$

7. At a high temperature, 0.50 mol of HBr was placed in a 1.0 L container and allowed to decompose according to the reaction:

$$2HBr_{(g)} \rightleftharpoons H_{2(g)} + Br_{2(g)}$$

At equilibrium the $[Br_2]$ was measured to be 0.13 M. What is K_{eq} for this reaction at this temperature?

	$2HBr$	$\rightleftharpoons H_2$	$+ Br_2$
[I]	0.50	0	0
[C]	−0.26	+0.13	+0.13
[E]	0.24	0.13	0.13

$$K_{eq} = \frac{[H_2][Br_2]}{[HBr]^2} = \frac{(0.13)^2}{(0.24)^2} = 0.29$$

Answer $K_{eq} = 0.29$

8. When 1.0 mol of $NH_{3(g)}$ and 0.40 mol of $N_{2(g)}$ are placed in a 5.0 L vessel and allowed to reach equilibrium at a certain temperature, it is found that 0.78 mol of NH_3 is present. The reaction is:

$$2NH_{3(g)} \rightleftharpoons 3H_{2(g)} + N_{2(g)}$$

Initial $[NH_3] = \frac{1.0\ mol}{5.0\ L} = 0.20\ M$ Initial $[N_2] = \frac{0.40\ mol}{5.0\ L} = 0.080\ M$

Equil^m $[NH_3] = \frac{0.78\ mol}{5.0\ L} = 0.156\ M$

	$2NH_3$	$\rightleftharpoons 3H_2$	$+ N_2$
[I]	0.20	0	0.080
[C]	−0.044	+0.066	+0.022
[E]	0.156	0.066	0.102

a) Calculate the **equilibrium concentrations** of all three species.

$[NH_3] =$ 0.16 M $[H_2] =$ 0.066 M $[N_2] =$ 0.10 M

b) Calculate the **value** of the equilibrium constant at this temperature.
(use unrounded concs, then round to 2 SD's)

$$K_{eq} = \frac{[H_2]^3[N_2]}{[NH_3]^2} = \frac{(0.066)^3(0.102)}{(0.156)^2} = 0.0012$$

Answer 1.2×10^{-3}

c) How many **moles** of H_2 are present at equilibrium?

$0.066\ M \times 5.0\ L = 0.33\ mol$

Answer 0.33 mol

d) How many **moles** of N_2 are present at equilibrium?

$0.102\ M \times 5.0\ L = 0.51\ mol$

Answer 0.51 mol

9. When 0.40 mol of PCl_5 is heated in a 10.0 L container, an equilibrium is established in which 0.25 mol of Cl_2 is present. (*Make a table and answer the questions below. Be sure to read all questions a-d before making your table!:*)

initial $[PCl_5] = \frac{0.40\ mol}{10.0\ L} = 0.040M$

equilm $[Cl_2] = \frac{0.25 mol}{10.0 L} = 0.025M$

	$PCl_{5(g)}$ ⇄	$PCl_{3(g)}$ +	$Cl_{2(g)}$
[I]	0.040	0	0
[C]	-0.025	+0.025	+0.025
[E]	0.015	0.025	0.025

a) Calculate the **equilibrium concentration** of each species.

$[PCl_5] =$ 0.015 M $[PCl_3] =$ 0.025 M $[Cl_2] =$ 0.025 M

b) Calculate the **value** of the equilibrium constant, K_{eq} at the temperature of the experiment.

$K_{eq} = \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{(0.025)^2}{(0.015)} = 0.042$

Answer $K_{eq} = 0.042$

c) What **amount** (moles) of PCl_3 is present at equilibrium?

$0.025 M \times 10.0 L = 0.25 mol$

Answer 0.25 mol

d) What **amount** (moles) of PCl_5 is present at equilibrium?

$0.015 M \times 10.0 L = 0.15 mol$

Answer 0.15 mol

10. A mixture of H_2 and I_2 is allowed to react at 448°C. When *equilibrium* is established, the concentrations of the participants are found to be:

$[H_2] = 0.46$ M, $[I_2] = 0.39$ M and $[HI] = 3.0$ M.

The equation is: $H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$

a) Calculate the **value** of K_{eq} at 448°C.

$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = \frac{(3.0)^2}{(0.46)(0.39)} = 50.167$

Answer 50. or 5.0×10^1

b) In another equilibrium mixture of the *same* participants at 448°C , the concentrations of I_2 and H_2 are both 0.050 M. What is the *equilibrium concentration* of HI?

$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} \rightarrow 50.167 = \frac{[HI]^2}{(0.050)^2}$

$[HI]^2 = 50.167 \times (0.050)^2 \rightarrow [HI] = 0.35\,M$

$[HI]^2 = 0.1254$

Answer 0.35 M

11. The K_{eq} for the reaction:

$$PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$$

at 250°C is found to be ***0.042***. In an *equilibrium mixture* of these species, it is found that $[PCl_5] = 0.012$ M, and $[Cl_2] = 0.049$ M. What is the equilibrium $[PCl_3]$ at 250°C ?

$K_{eq} = \frac{[PCl_3][Cl_2]}{[PCl_5]} \rightarrow [PCl_3] = \frac{(0.042)(0.012)}{(0.049)} = 0.010\,M$

$0.042 = \frac{[PCl_3](0.049)}{(0.012)}$

Answer 0.010 M

12. At a certain temperature the reaction:

$$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)}$$

has a Keq = ***0.500***. If a reaction mixture at equilibrium contains 0.210 M CO and 0.100 M H_2 , what is the *equilibrium* $[CH_3OH]$?

$K_{eq} = \frac{[CH_3OH]}{[CO][H_2]^2}$

$[CH_3OH] = (0.500)(0.210)(0.100)^2$

$= 0.00105\,M$

$0.500 = \frac{[CH_3OH]}{(0.210)(0.100)^2}$

Answer 0.00105 M
or 1.05×10^{-3} M

13. At a certain temperature the reaction: $CO_{(g)} + H_2O_{(g)} \rightleftarrows CO_{2(g)} + H_{2(g)}$

has a $K_{eq} = 0.400$. Exactly *1.00 mol* of each gas was placed in a 100.0 L vessel and the mixture was allowed to react. Find the **equilibrium concentration** of each gas.

initial $[CO]$, $[H_2O]$, $[CO_2]$ & $[H_2] = \frac{1.00\ mol}{100.0\ L} = 0.0100M$

Trial $K_{eq} = 1.00$
$K_{eq} = 0.400$, so rx. will shift LEFT as it approaches equilm

$CO + H_2O \rightleftarrows CO_2 + H_2$

[I]	0.0100	0.0100	0.0100	0.0100
[C]	+x	+x	−x	−x
[E]	0.0100+x	0.0100+x	0.0100−x	0.0100−x
[E]	0.0100 +0.002251	0.0100 +0.002251	0.0100 −0.002251	0.0100 −0.002251
[E]	0.0123	0.0123	0.0078	0.0078

$K_{eq} = \frac{[CO_2][H_2]}{[CO][H_2O]}$

$0.400 = \frac{(0.0100-x)^2}{(0.0100+x)^2}$

$\sqrt{0.400} = \frac{(0.0100-x)}{0.0100+x}$

$0.63246(0.0100+x) = 0.0100-x$

$0.0063246 + 0.63246x = 0.0100 - x$

$1.63246x = 0.0100 - 0.0063246$

$1.63246x = 0.0036754$

$x = \frac{0.0036754}{1.63246}$

$x = 0.00225145$ (3 SDs = 5 dps)

Answer $[CO] = [H_2O] = 0.0123\ M$, $[CO_2] = [H_2] = 0.0078\ M$

14. The reaction: $2XY_{(g)} \rightleftarrows X_{2(g)} + Y_{2(g)}$

has a $K_{eq} = 35$ at 25°C. If 3.0 moles of XY are injected into a 1.0 L container at 25°C, find the equilibrium $[X_2]$ and $[Y_2]$.

Trial $K_{eq} = \frac{[X_2][Y_2]}{[XY]^2} = \frac{0}{(3.0)^2} = 0$ ($K_{eq} = 35$)
so rx. will shift RIGHT as it approaches equilm

$2XY \rightleftarrows X_2 + Y_2$

[I]	3.0	0	0
[C]	−2x	+x	+x
[E]	3.0−2x	x	x
[E]	3.0−2(1.383)	1.383	1.383
[E]	0.2338	1.383	1.383

$K_{eq} = \frac{[X_2][Y_2]}{[XY]^2}$

$35 = \frac{x^2}{(3.0-2x)^2}$

$\sqrt{35} = \frac{x}{3.0-2x}$

$5.916(3.0-2x) = x$

$17.7482 - 11.832x = x$

$12.832x = 17.7482$

$x = \frac{17.7482}{12.832}$

$x = 1.383$

Answer $[X_2] = 1.4M$ $[Y_2] = 1.4M$

15. The equilibrium constant for the reaction:

$$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)} \qquad \text{at } 448^\circ C \text{ is } \mathbf{50.}$$

a) If 1.0 mol of H_2 is mixed with 1.0 mol of I_2 in a 0.50 L container and allowed to react at 448°C, what is the **equilibrium** [HI]?

Initial $[H_2] = \frac{1.0\,mol}{0.50\,L} = 2.0\,M$, $[I_2] = 2.0M$, $[HI] = 0$

$H_2 + I_2 \rightleftharpoons 2\,HI$

[I]	2.0	2.0	0
[C]	−x	−x	+2x
[E]	2.0−x	2.0−x	2x
[E]	2.0−1.559	2.0−1.559	2(1.559)
[E]	0.44	0.44	3.1

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]}$$

$$50. = \frac{(2x)^2}{(2.0-x)^2}$$

$$\sqrt{50.} = \frac{2x}{2-x}$$

$$7.071(2-x) = 2x$$
$$14.142 - 7.071x = 2x$$
$$14.142 = 9.071x$$
$$x = \frac{14.142}{9.071} = 1.559$$

Answer $[HI] = 3.1\,M$

b) How many **moles** of HI are formed at equilibrium? (Actual yield)

$3.118\,M \times 0.50\,L = 1.6\,mol$

Answer 1.6 moles of HI

16. Given K_{eq} for the reaction:

$$PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$$

is ***0.042*** at 250°C, what will happen if 2.50 mol of PCl_5, 0.600 mol of Cl_2 and 0.600 mol of PCl_3 are placed in a 1.00 flask at 250°C ? (*Will the reaction shift left, right, or not occur at all?*)

$$K_{eq} = \frac{[PCl_3][Cl_2]}{[PCl_5]}$$

$$\text{Trial } K_{eq} = \frac{(0.600)(0.600)}{(2.50)}$$

Trial $K_{eq} = 0.144$

Actual $K_{eq} = 0.042$

Since Trial K_{eq} > K_{eq} The reaction will shift to the LEFT as it approaches equilm. So $[PCl_5]$ will increase while $[PCl_3]$ and $[Cl_2]$ decrease.

Answer shift LEFT

17. Given the equilibrium equation: $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$

at 448°C, $K_{eq} = 50.$ If 3.0 mol of HI, 2.0 mol of H_2, and 1.5 mol of I_2 are placed in a 1.0 L container at 448°C, will a reaction occur?

$K_{eq} = \frac{[HI]^2}{[H_2][I_2]}$

$\text{Trial } K_{eq} = \frac{(3.0)^2}{(2.0)(1.5)} = 3.0$

→ Trial K_{eq} (3.0) < K_{eq} (50.) so the reaction will proceed to the RIGHT in order to reach equilibrium.

Answer Yes, it will

If so, which way does the reaction shift? to the RIGHT

18. Given the equilibrium equation: $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$

at 448°C, $K_{eq} = 50.$ If 5.0 mol of HI, 0.7071 mol of H_2, and 0.7071 mol of I_2 are placed in a 1.0 L container at 448°C, will a reaction occur? (*Round any answers off to 3 significant digits!*)

$K_{eq} = \frac{[HI]^2}{[H_2][I_2]}$

$\text{Trial } K_{eq} = \frac{(5.0)^2}{(0.7071)^2} = 50.$ since Trial K_{eq} = K_{eq}

Answer Rx. will NOT occur

If so, which way does the reaction shift? neither way.

19. Determine the equilibrium constant for the reaction: $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$ given that an equilibrium mixture is analyzed and found to contain the following concentrations: $[H_2] = 0.0075$ M, $[I_2] = 0.000043$ M and $[HI] = 0.0040$ M

$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = \frac{(0.0040)^2}{(0.0075)(0.000043)} = 50.$

Answer $K_{eq} = 50.$

20. Given the equilibrium equation: $3A_{(g)} + B_{(g)} \rightleftarrows 2C_{(g)}$

If 2.50 moles of A and 0.500 moles of B are added to a 2.00 L container, an equilibrium is established in which the [C] is found to be 0.250 M.

a) Find [A] and [B] at equilibrium.

initial $[A] = \frac{2.50\,mol}{2.00\,L} = 1.25\,M$, $[B] = \frac{0.500\,mol}{2.00\,L} = 0.250\,M$

3/2 1/2

$3A + B \rightleftarrows 2C$

	A	B	C
[I]	1.25	0.250	0
[C]	-0.375	-0.125	+0.250
[E]	0.875	0.125	0.250

2 dec. places

Answer $[A] = 0.88\,M$ $[B] = 0.125\,M$

b) Calculate the value of the equilibrium constant K_{eq}.

$$K_{eq} = \frac{[C]^2}{[A]^3[B]} = \frac{(0.250)^2}{(0.875)^3(0.125)} = 0.746$$

Answer $K_{eq} = 0.75$

21. At 800°C, the equilibrium constant K_{eq}, for the reaction:

$$CO_{2(g)} + H_{2(g)} \rightleftarrows CO_{(g)} + H_2O_{(g)} \quad \text{is } 0.279$$

If 1.50 moles of CO_2 and 1.50 moles of H_2 are added to a 1.00 L container, what would the [CO] be at equilibrium?

$CO_2 + H_2 \rightleftarrows CO + H_2O$

	CO_2	H_2	CO	H_2O
[I]	1.50	1.50	0	0
[C]	-x	-x	+x	+x
[E]	1.50-x	1.50-x	x	x
[E]	1.50-0.5185	1.50-0.5185	0.5185	0.5185
[E]	0.982	0.982	0.518	0.518

$$K_{eq} = \frac{[CO][H_2O]}{[CO_2][H_2]}$$

$$0.279 = \frac{x^2}{(1.50-x)^2}$$

$$\sqrt{0.279} = \frac{x}{1.50-x}$$

$$0.5282(1.50-x) = x$$

$0.7923 - 0.5282x = x$

$0.7923 = 1.5282x$

$x = \frac{0.7923}{1.5282}$

$x = 0.5185$

Answer equilm $[CO] = 0.518\,M$

22. Given that the equilibrium constant K_{eq} for the reaction:

$$A_{(g)} + B_{(g)} \rightleftarrows C_{(g)} + D_{(g)} \quad \text{is } \textbf{0.015} \text{ at } 25^oC,$$

if 1.0 mole of each gas is added to a 1.0 L container at 25°C, which way will the equation shift in order to reach equilibrium?

$K_{eq} = \frac{[C][D]}{[A][B]}$

Trial $K_{eq} = \frac{(1.0)(1.0)}{(1.0)(1.0)} = 1.0$

Trial K_{eq} (1.0) > K_{eq} (0.015) so reaction will shift LEFT to reach equilm.

Answer LEFT

23. Calculate the **equilibrium constant** K_{eq} for the following reaction:

$$2A_{2(g)} + 3B_{2(g)} \rightleftarrows 2A_2B_{3(g)}$$

given that the *partial pressure* of each substance at equilibrium is as follows:

Partial Pressure of A_2 = 20.0 kPa, Partial Pressure of B_2 = 30.0 kPa, Partial Pressure of A_2B_3 = 5.00 kPa.

$K_{eq} = \frac{P_{A_2B_3}^2}{P_{A_2}^2 \cdot P_{B_2}^3} = \frac{(5.00)^2}{(20.0)^2 (30.0)^3} = 2.31 \times 10^{-6}$

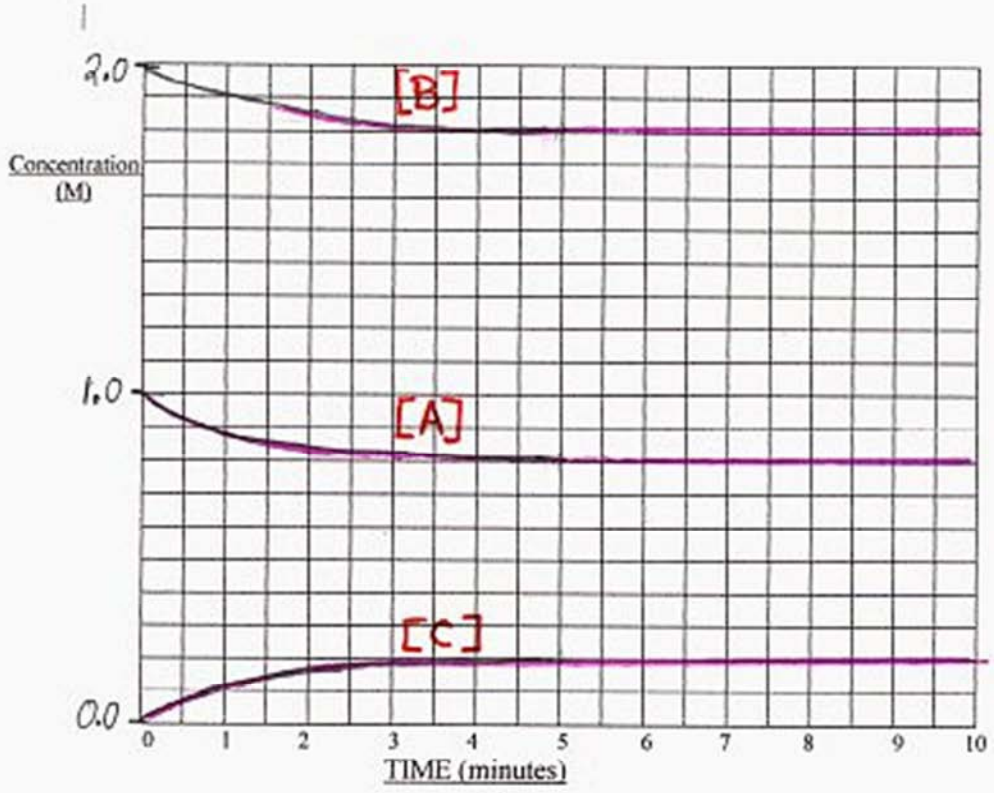
Answer $K_{eq} = 2.31 \times 10^{-6}$

24. Consider the following equilibrium system: $A_{(g)} + B_{(g)} \rightleftarrows C_{(g)}$

1.0 mole of A and 2.0 moles of B are simultaneously injected into an empty 1.0 L container. At equilibrium (after 5.0 minutes), [C] is found to be 0.20 M. Make calculations and draw graphs to show how each of [A], [B] and [C] change with time over a period of 10.0 minutes. (*HINT: You have to make a table first.*)

$A_{(g)} + B_{(g)} \rightleftarrows C_{(g)}$

[I]	1.0	2.0	0
[C]	-0.20	-0.20	+0.20
[E]	0.80	1.80	0.20



25. Given the reaction:

$$4HCl_{(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(g)} + 2Cl_{2(g)} \quad \Delta H = -113 \text{ kJ}$$

How will the value of the equilibrium constant K_{eq} at 550°C compare with it's value at 450°C? Keq at 550°c will have a lower value.

Explain your answer. Since the rx. is exothermic, adding heat will cause the reaction to shift LEFT. This will decrease the value of Keq.

26. The following system is at equilibrium, in a closed container:

$$4NH_{3(g)} + 3O_{2(g)} \rightleftarrows 6H_2O_{(g)} + 2N_{2(g)} + \text{Heat}$$

(7 mog. 8 mog)

a) How is the *amount of N_2* in the container affected if the ***volume*** of the container is ***doubled***? Increased (decreasing P will cause a shift RIGHT producing more N_2)

b) How is the rate of the **forward reaction** affected if more water vapor is introduced into the container? Increase (First inc. $[H_2O]$ will speed up rev. rx, forming more reactants. Then forward rx. will speed up.)

c) How is the amount of O_2 in the container affected if a *catalyst* is added?

No change (A catalyst speeds up forward & rev. rx. equally)

27. At a certain temperature, K_{eq} for the reaction:

$$3C_2H_2 \rightleftarrows C_6H_6 \quad \text{is } \mathbf{5.0}.$$

If the *equilibrium concentration* of C_2H_2 is 0.40 moles/L, what is the *equilibrium concentration* of C_6H_6?

$$K_{eq} = \frac{[C_6H_6]}{[C_2H_2]^3} \rightarrow 5.0 = \frac{[C_6H_6]}{(0.40)^3} \rightarrow [C_6H_6] = (5.0)(0.40)^3 = 0.32\text{M}$$

Answer 0.32 M