CH40S **Calculations Involving K_{eq}** Name:_______

Part A: Finding Keq with all Concentrations at Equilibrium

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 Keq **expression**, and Find the **value** of the equilibrium constant, K_{eq} at the temperature that the experiment was done.

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

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

c) Is this equilibrium product or reactant favoured? How do you know?

↳ $K_{eq} < 1$ (more Reactants)

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,** and calculate the **value** of K_{eq} at 50°C.

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

$$= \frac{(0.09)^2}{[(0.37)(0.53)^3]} = \boxed{0.147}$$

c) Is this equilibrium product or reactant favoured? How do you know?

↳ $K_{eq} < 1$

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

a) If in an equilibrium mixture the [A] = 0.45M, [B] = 0.63M and [C] = 0.30M. Calculate the value of the equilibrium constant for this reaction.

$$K_{eq} = \frac{[C]}{[A][B]} = \frac{(0.3)}{(0.45)(0.63)} = \boxed{1.06}$$

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]*.

$$1.06 = \frac{(0.7)}{[A](0.21)} \qquad [A] = \frac{0.7}{[(1.06)(0.21)]} = \boxed{3.14 \frac{mol}{L}}$$

Part B: Finding Keq – NOT all Concentrations at Equilibrium (Using ICE Tables)

4. For the following reaction, 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.*)

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

	A_2	B	$2C$
I	0	0	1.5M
C	+0.3	+0.3	−0.6
E	0.3M	0.3M	0.9M

a) What is [A] at equilibrium? Answer 0.3M

b) What is [B] at equilibrium? Answer 0.3M

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

d) Write the keq **expression** for the equilibrium constant and calculate the **value** of Keq at the temperature at the experiment was done.

$$K_{eq} = \frac{[C]^2}{[A_2][B]}$$

$$= \frac{(0.9)^2}{(0.3)(0.3)} = \boxed{9}$$

5. 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.*)

$\frac{0.87 \text{ mol}}{5 L} = 0.174 \frac{mol}{L} = [AB_3]$

	$2AB_3$	A_2	$3B_2$
I	0.174 M	0	0
C	−0.14	+0.07	+0.21
E	0.034 M	0.07 M	0.21 M

a) Calculate the equilibrium concentration of AB_3. Answer 0.034 M

b) Calculate the equilibrium $[A_2]$. Answer 0.07 M

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

d) Write the equilibrium expression and solve for the value of Keq.

$$K_{eq} = \frac{[B_2]^3[A_2]}{[AB_3]^2} = \frac{(0.07)(0.21)^3}{(0.034)^2} = \boxed{0.56}$$

6. Two moles 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:*)

	$2NH_3$	N_2	$3H_2$
I	2 M	0	0
C	−1.0	+0.5	+1.5
E	1.0 M	0.5 M	1.5 M

a) What is the equilibrium $[N_2]$? Answer 0.5 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.

$$K_{eq} = \frac{[N_2][H_2]^3}{[NH_3]^2} = \frac{(0.5)(1.5)^3}{(1.0)^2} = \boxed{1.69}$$

7. Calculate the **value** of the equilibrium constant 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 equilibrium it is found that 0.78 mol of NH_3 is present. The reaction is:

$[NH_3]_i = \frac{1 mol}{5 L} = 0.2 M$

$[N_2]_i = \frac{0.4 mol}{5 L} = 0.08 M$

$[NH_3]_{eq} = \frac{0.78 mol}{5 L} = 0.156 M$

	$2NH_{3(g)}$ ⇄	$3H_{2(g)}$ +	$N_{2(g)}$
I	0.2M	0	0.08M
C	−0.044	+0.066	+0.022
E	0.156M	0.066M	0.102M

$$K_{eq} = \frac{[N_2][H_2]^3}{[NH_3]^2} = \frac{(0.102)(0.066)^3}{(0.156)^2} = 1.2 \times 10^{-3}$$

8. 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.

a) Calculate the **value** of the equilibrium constant, K_{eq}, given the reaction:

$[PCl_5]_i = \frac{0.4 mol}{10 L} = 0.04 M$

$[Cl_2]_{eq} = \frac{0.25 mol}{10 L} = 0.025 M$

	$PCl_{5(g)}$ ⇄	$PCl_{3(g)}$ +	$Cl_{2(g)}$
I	0.04M	0	0
C	−0.025	+0.025	+0.025
E	0.015M	0.025M	0.025M

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

b) Is this equilibrium reactant or ~~product~~ favoured? How do you know?

→ $K_{eq} < 1$

Part 3: Finding Equilibrium Concentrations (everything at equilibrium)

9. The K_{eq} for the reaction below 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 ?

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

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

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

$$[PCl_3] = \frac{(0.42)(0.012)}{(0.049)}$$

$$[PCl_3] = 0.01 \frac{mol}{L}$$

10. At a certain temperature the reaction below 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* $[CH_3OH]$?

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

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

$$0.5 = \frac{[CH_3OH]}{(0.21)(0.1)^2}$$

$$[CH_3OH] = (0.5)(0.21)(0.1)^2$$

$$[CH_3OH] = 1.05 \times 10^{-3} \frac{mol}{L}$$

Part 4: Finding Equilibrium Concentrations (NOT everything at equilibrium)

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

$$\frac{1 mol}{100 L} = 0.01 \frac{mol}{L} = [CO] + [H_2O]$$

	$CO_{(g)}$ +	$H_2O_{(g)}$ ⇄	$CO_{2(g)}$ +	$H_{2(g)}$
I	0.01 M	0.01 M	0	0
C	−x	−x	+x	+x
E	(0.01−x)	(0.01−x)	x	x

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

$$\sqrt{0.4} = \sqrt{\frac{x^2}{(0.01-x)^2}}$$

$$0.632 = \frac{x}{0.01-x}$$

$$x = 0.0039$$

$$\therefore [CO_2] = [H_2] = 0.0039 \frac{mol}{L}$$

$$[CO] = [H_2O] = 0.01 - 0.0039 = 0.0061 \frac{mol}{L}$$

12. The reaction below 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 $[Y_2]$.

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

	$2XY$	X_2	Y_2
I	3.0M	0	0
C	−2x	+x	+x
E	(3.0−2x)	x	x

(1)

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

(1)

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

$$5.92 = \frac{x}{(3.0-2x)}$$

$$17.76 - 11.84x = x$$

$$17.76 = 12.84x$$

$$x = 1.38 \frac{mol}{L}$$

(1)

$$\therefore [X_2] = [Y_2] = 1.38 \frac{mol}{L}$$

13. At 448°C the reaction below has a **Keq value of 50**. 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]?

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$

$$[H_2]_i = \frac{1.0 mol}{0.5 L} = 2 \frac{mol}{L}$$

$$[I_2]_i = 2 \frac{mol}{L}$$

H_2	I_2	$2HI$
2M	2M	∅
−x	−x	+2x
(2−x)	(2−x)	2x

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

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

$$7.07 = \frac{2x}{2-x}$$

$$14.14 - 7.07x = 2x$$

$$14.14 = 9.07x$$

$$x = 1.56$$

$$\therefore [HI]_{eq} = 2x = 2(1.56) = 3.12 \frac{mol}{L}$$