SCH4U - Equilibrium Assignment Total = Name: ANSWER

1. Solid copper (II) sulfate reacts with water vapour to produce solid copper (II) sulfate pentahydrate. Write the chemical equation that represents the reversible reaction.

/2 $CuSO_{4(s)} + 5H_2O_{(g)} \rightarrow CuSO_4 \cdot 5H_2O$

2. Predict whether the following equilibria favour reactant formation, product formation, or neither.

Reaction		What is favoured?
$PCl_{5(g)} \leftrightarrow PCl_{3(g)} + Cl_{2(g)}$	K = 0.45	Reactants
$H_{2(g)} + Cl_{2(g)} \leftrightarrow 2HCl_{(g)}$	K = 1.0	Neither
$I_{2(g)} + Cl_{2(g)} \leftrightarrow 2ICl_{(g)}$	K = 2.0×10^6	Products

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3. Write chemical equation for the following:

a. Methane gas reacts with hydrogen sulfide gas to produce carbon disulfide gas and hydrogen gas.

/2 $CH_{4(g)} + 2H_2S_{(g)} \rightleftharpoons CS_{2(g)} + 4H_{2(g)}$

b. Hydrogen sulfide gas combusts in air to produce solid sulfur and water vapour.

/2 $8H_2S_{(g)} + 4O_{2(g)} \rightleftharpoons S_{8(s)} + 8H_2O_{(g)}$

c. Solid silicon dioxide reacts with hydrogen fluoride gas to produce silicon tetraflouride and water vapour.

/2 $SiO_{2(s)} + 4HF_{(g)} \rightleftharpoons SiF_{4(s)} + 2H_2O_{(g)}$

4. For each of 3 a), b), and c) above, write the equilibrium expression. (/6)

a. $K = \dfrac{[CS_2][H_2]^4}{[CH_4][H_2S]^2}$

b. $K = \dfrac{[H_2O]^8}{[H_2S]^8 + [O_2]^4}$

c. $K = \dfrac{[H_2O]^2}{[HF]^4}$

2. Rank the acids below in terms of their strength. Justify your choices.

Chemical formula	Name	K_a	
$HNO_2(aq)$	nitrous acid	4.8×10^{-4}	2
$HNO_3(aq)$	nitric acid	very high	1
$HC_2H_3O_2(aq)$	acetic acid	1.8×10^{-5}	3

12.

13. Rank: (3 marks K)

#1	$HNO_3(aq)$	#2	$HNO_2(aq)$	#3	$HC_2H_3O_2(aq)$.

Why? (2 marks T)

4. Determine the concentration of H_3O^+ and OH^- ions, pH, and pOH for a 0.15 mol/L NaOH solution. (4 marks T)

$[OH^-] = 0.15\,M$.

$NaOH \longrightarrow Na^+ + OH^-$

0.15M 0.15M

$pOH = 0.82$

$pH = 13.17$

$[H_3O^+] = 6.67 \times 10^{-14}$.

$[H^+][OH^-] = 1.0 \times 10^{-14}$.

$pH + pOH = 14$.

5. Determine the pH, pOH, [H+] and [OH-] of a 15.0 mol/L solution of NH_3. (4 marks T)

$[OH^-] = 0.01643M$

$[H^+] = 6.09 \times 10^{-13}\,M$

$pOH = 1.78$

$pH = 12.21$

$NH_{3(g)} + H_2O_{(l)} \rightleftharpoons NH_4^+ + OH^-$

	15.0M	0	0
I			
C	$-x$	$+x$	$+x$
E	$15-x$.	x	x

$15 - x \approx 15$ 100 rule.

$K_b = \frac{[x^2]}{[NH_3]}$ $1.8 \times 10^{-5} = \frac{x^2}{[15]}$

$x = 0.01643M$

6. Calculate the pH, pOH, [H+] and [OH-] of a 0.25 mol/L solution of HF. (4 marks T)

$[H^+] = 0.01285\,M$

$[OH^-] = 7.78 \times 10^{-13}$

$pH = 1.89$

$pOH = 12.11$

$HF_{(aq)} \rightleftharpoons H^+_{(aq)} + F^-_{(aq)}$

	0.25	0	0
I			
C	$-x$	$+x$	$+x$
E	$0.25-x$	x	x

$K_a = \frac{[H^+][F^-]}{[HF]}$

$6.6 \times 10^{-4} = \frac{x^2}{[0.25]}$ 100 rule.

$0.000165 = x^2$

$x = 0.01285\,M$.

3. Hydrogen sulfide gas decomposes into its elements. If K = 1.67 x 10-7, at a constant temperature and 0.035 mol of hydrogen sulfide gas is placed in a 0.75 L flask, what will be the concentrations of hydrogen and sulfur gas once equilibrium has been reached?

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$8H_2S_{(g)} \rightleftharpoons 8H_{2(g)} + S_{8(s)}$ $[H_2S] = 0.04M$.

	$8H_2S_{(g)}$	$8H_{2(g)}$	$S_{8(s)}$
I	0.04667	0	X
C	$-8x$	$8x$	
E	$0.04667-8x$	$8x$	

IDK 100 Rule

$1.67\times10^{-7} = \frac{[8x]^8}{[0.04667-8x]^8}$ $1.67\times10^{-7} = \frac{[8x]^8}{[0.04667]^8}$

$x = 8.294\times10^{-4}$ M

9. Given that K = 2.0 x 10^{-6} for the following reaction, what is the equilibrium concentration of $CO_{(g)}$ if 2.3 mol of carbon dioxide gas is placed into a 2.5 L reaction vessel?

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$2.0\times10^{-6} = \frac{[2x]^2[x]}{[0.92-2x]^2}$ ← IDK 100 Rule

$2.0\times10^{-6} = \frac{4x^3}{[0.92]^2}$

$2CO_{2(g)} \rightleftharpoons 2CO_{(g)} + O_{2(g)}$

	$2CO_{2(g)}$	$2CO_{(g)}$	$O_{2(g)}$
I	0.92 M	0	0
C	$-2x$	$+2x$	$+x$
E	$0.92-2x$	$2x$	x

$x = 0.0075M$

$[CO] = 0.015M$.

10. A student determines that the solubility of magnesium carbonate solid in water at a certain temperature is 2.63 x 10^{-3} mol/L.
    a. What is K_{sp} for magnesium carbonate?

$MgCO_{3(s)} \rightleftharpoons Mg^{2+}_{(aq)} + CO_3^{-2}{}_{(aq)}$

	$MgCO_{3(s)}$	$Mg^{2+}_{(aq)}$	$CO_3^{-2}{}_{(aq)}$
I	X	0	0
C		$+2.63\times10^{-3}$	$+2.63\times10^{-3}$
E		2.63×10^{-3}	2.63×10^{-3}

$K_{sp} = [Mg^{2+}][CO_3^{2-}]$

$K_{sp} = [2.63\times10^{-3}]^2$

$= 6.92\times10^{-6}$

5. The Haber process generates ammonia, which is used to make a number of important products, including fertilizer. Using the following chemical equation representing the Haber process, complete the chart below:

$$N_{2(g)} + 3H_{2(g)} \leftrightarrow 2NH_{3(g)} + 92KJ$$

Change	System Shift	Effect on K
$[NH_3]$ decreased	Right →	↑
$[H_2]$ decreased	Left ←	↓
Pressure decreased	Left ←	↓
Volume decreased	Right →	↑
Temperature increased	Left ←	↓
Addition of argon gas	No shift	none.

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6. At equilibrium in a reaction vessel, the concentrations of $O_{2(g)}$ and $N_{2(g)}$ are 4.3 mol/L. Given the following equation, determine the concentration of $NO_{(g)}$.

$$O_{2(g)} + N_{2(g)} \leftrightarrow 2NO_{(g)} \qquad K_{eq} = 6.3 \times 10^{-4}$$

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$$K = \frac{[NO]^2}{[O_2][N_2]}$$

$$6.3 \times 10^{-4} = \frac{[NO]^2}{[4.3][4.3]}$$

$$[NO] = 0.108\ M$$

7. Into a 2.00 L vessel is placed 0.600 mol of methane gas. The following reaction proceeds:

$$2CH_{4(g)} \leftrightarrow C_2H_{4(g)} + 3H_{2(g)}$$

At equilibrium, the vessel is found to contain 0.0900 mol C_2H_4. Calculate the equilibrium constant for this reaction.

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	$2CH_4$	$\leftrightarrow C_2H_4$	$+ 3H_2$
I	0.3	0	0
C	$-2x$	$+x$	$+3x$
E	$0.3-2x$	x	$3x$
	0.21	0.045 M	0.135

$$K = \frac{[C_2H_4][H_2]^3}{[CH_4]^2}$$

$$K = \frac{[0.045][0.135]^3}{[0.21]^2}$$

$$K = 2.51 \times 10^{-3}$$