Part D: Equilibrium Expressions and Constants- *Answer the following and show all work.*

1) Write the following equilibrium expression in each box:

a. $O_3(g) + NO(g) \leftrightarrow O_2(g) + NO_2(g)$

b. $2CO(g) + O_2(g) \leftrightarrow 2CO_2(g)$

c. ~~$NH_4NO_3(s)$~~ $\leftrightarrow N_2O(g) + 2H_2O(l)$

d. $2H_2O(g) + \leftrightarrow 2H_2(g) + O_2(g)$

e. $2NO(g) + O_2(g) \leftrightarrow 2NO_2(g)$

f. ~~$2Li(s)$~~ $+ 2HCl(aq) \leftrightarrow H_2(g) + 2LiCl(aq)$

a. $K = \frac{[O_2][NO_2]}{[O_3][NO]}$

b. $K = \frac{[CO_2]^2}{[CO]^2[O_2]}$

c. $K = [N_2O]$

d. $K = \frac{[H_2]^2[O_2]}{[H_2O]^2}$

e. $K = \frac{[NO_2]^2}{[NO]^2[O_2]}$

f. $K = \frac{[H_2][LiCl]^2}{[HCl]^2}$

2) Equilibrium is established in the reversible reaction: $2A(aq) + B(aq) \leftrightarrow A_2B(aq)$. The equilibrium concentrations are [A]= 0.55M, [B]= 0.33M, and $[A_2B]$= 0.43 M. What is the equilibrium expression and value of the equilibrium constant, K_c for this reaction?

$K = \frac{[A_2B]}{[A]^2[B]}$ $\quad K = \frac{[0.43]}{[0.55]^2[0.33]} = 4.31$

3) What is the equilibrium expression and equilibrium constant if the equilibrium concentrations are as follows: PCl_5 is 0.0096 M, PCl_3 is 0.0247 M, and Cl_2 is 0.0247M? $PCl_5(g) \leftrightarrow PCl_3(g) + Cl_2(g)$

$K = \frac{[PCl_3][Cl_2]}{[PCl_5]}$ $\quad K = \frac{[0.0247][0.0247]}{[0.0096]} = 0.064$

4) At a certain temperature, a container has an equilibrium mixture consisting of 0.102 M of NH_3, 1.03 M N_2, and 1.62 M of H_2. Calculate the K_c for the equilibrium system. $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$

$K = \frac{[NH_3]^2}{[N_2][H_2]^3}$ $\quad K = \frac{[0.102]^2}{[1.03][1.62]^3} = 0.0024$

5) What is the equilibrium expression and equilibrium constant if the equilibrium consists of ~~10.0g of NaOH~~, 0.50M HCl, ~~1.0L H_2O~~, and 0.88M NaCl. ~~$NaOH(s)$~~ $+ HCl(aq) \leftrightarrow$ ~~$H_2O(l)$~~ $+ NaCl(aq)$

$K = \frac{[NaCl]}{[HCl]}$ $\quad K = \frac{[0.88]}{[0.50]} = 1.76$

6) At a given temperature, the K_c for the reaction below is 1.40×10^{-2}. If the concentrations of H_2 and I_2 at equilibrium are 2.00×10^{-4} M, find the concentration of HI. $2HI(g) \leftrightarrow H_2(g) + I_2(g)$

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

~~$\frac{(2\times10^{-4})(2\times10^{-4})}{(1.4\times10^{-2})^2} = 0.00020$~~

$1.4\times10^{-2} = \frac{(2\times10^{-4})(2\times10^{-4})}{[HI]}$ $\quad [HI] = 2.0\times10^{-6}\,M$

Part E: Le Chatelier's Principle

1) State Le Chatelier's Principle: When a stress is applied to a system @ equilibrium, the system will shift to relieve the stress

2) Predict which way the following equilibrium systems will shift when the total pressure is increased. (Note: some may have no shift)

a. $N_2(g) + O_2(g) \leftrightarrow 2NO(g)$ — No shift

b. $2SO_2(g) + O_2(g) \leftrightarrow 2SO_3(g)$ — right / products

c. $4NH_3(g) + 5O_2(g) \leftrightarrow 4NO(g) + 6H_2O(g)$ — left / reactants

3) $N_2O_4(g)$ is a colorless gas and $NO_2(g)$ is a dark brown gas. Use Le Chatelier's principle to explain why a flask filled with $NO_2(g)$ and $N_2O_4(g)$ will get darker when heated. Use the equation: $N_2O_4(g) + \text{heat} \leftrightarrow 2NO_2(g)$

When heated the reaction shifts to the right, making more NO_2, which is a dark brown gas

4) List at least 3 ways to increase amount of oxygen gas in the following reaction.

$H_2O_2(aq) \leftrightarrow H_2(g) + O_2(g) \quad \Delta H = +187.00\ kJ$

a. increase $[H_2O_2]$

b. decrease $[H_2]$

c. heat the reaction

d. decrease pressure

5) Complete the following chart by writing left, right, or none for the equilibrium shift. Write decrease, increases, or remains the same for the concentrations of reactants and products.

12.6 kcal + 2HCl (aq) ↔ $H_2(g)$ + $Cl_2(g)$

Stress	Equilibrium Shift	$[H_2]$	$[Cl_2]$	[HCl]
1.Add H_2	Left	~~↑~~	decreases	increases
2.Add Cl_2	← L	↓	~~↑~~	↑
3.Add HCl	→ R	↑	↑	~~↓~~
4.Remove H_2	→ R	~~↓~~	↑	↓
5.Remove Cl_2	→ R	↑	~~↓~~	↓
6.Remove HCl	← L	↓	↓	~~↑~~
7.Increase Temperature	→ R	↑	↑	↓
8.Decrease Temperature	← L	↓	↓	↑
9.Increase Pressure	← L	↓	↓	↑
10.Decrease Pressure	→ R	↑	↑	↓

Keep going Part E continues on the next page!

$Ca^{+2}(aq) + SO_4^{-2}(aq) + 10.6\ kcal \leftrightarrow CaSO_4(s)$

(Remember that pure solids and liquids do not affect equilibrium values.)

Stress	Equilibrium Shift	Amount of $CaSO_4(s)$	$[Ca^{+2}]$	$[SO_4^{-2}]$
1.Add $CaSO_4(s)$	NO	Shift		
2.Add $CaCl_2$ (adds Ca^{+2})	→ R	↑	~~↓~~	↓
3.Add $MgSO_4$ (adds SO_4^{-2})	→ R	↑	↓	~~↓~~
4.Remove SO_4^{-2}	← L	↓	↑	~~↓~~
5.Increase temperature	→ R	↑	↓	↓
6. Decrease temperature	← L	↓	↑	↑
7. Increase Pressure	NO	SHIFT		
8. Decrease Pressure				

Part F: Vocabulary and Concepts

1) Provide an example of a heterogeneous reaction and an example of a homogeneous reaction. Support your answer. heterogeneous = rxn w/ different states of matter $2HCl_{(aq)} \rightarrow 2H_{2(g)} + 2I_{2(s)}$

homogeneous = rxn w/ all same states of matter $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$

2) List 5 factors the affect the rate of a reaction:
   a. nature of reactants
   b. catalysts and inhibitors
   c. pressure
   d. concentration
   e. temperature

3) Using the collision theory explain why the rate of a reaction increases when pressure is increased.

Increase in pressure = less space = more collisions
more collision → faster reaction

4) The process of milk spoiling is a chemical reaction. Using your knowledge of rates of chemical reactions and collision theory, explain why we keep milk in the refrigerator.

Cooling the rxn down, slows the particles and lowers their energy so the reaction slows down

5) It has been observed that more gas station fires occur on hot days than on cold days. Explain this phenomenon using your knowledge of collision theory.

- hot = faster molecules = more collisions = faster reaction

Keep going Part F continues
on the next page!

6) What is chemical equilibrium?
Condition when rate of forward reaction is same as rate of reverse reaction

7) What is equal at chemical equilibrium?

rate forward = rate reverse

8) What is constant at chemical equilibrium?

Concentration

9) At the macroscopic level a system at equilibrium appears to be unchanging. Is it also unchanging at the molecular level? Explain.
no - macroscopic appears to be unchanging b/c reaction rate forward = reaction rate reverse and [ ] remains constant, but equilibrium is dynamic & constantly chang...

10) True or False: At equilibrium the amount of reactants is equal to the amount of products. FALSE

11) What is the formula for writing an equilibrium expression? $aA + bB \leftrightarrow cC + dD$

$$K = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

12) What do brackets [ ] indicate? Concentration

13) List 2 examples of enzymes and explain their function.
① lactase - breakdown lactose
② Sucrase - break down sugar + starch

14) Model a reaction at equilibrium. Be sure to consider concentration, the fact the equilibrium is dynamic, and rates of forward and reverse reactions. Be sure to include a key. $3A + 3B \leftrightarrow A_3B$