Chemistry

Name: Date:

Equilibrium **Le Châtelier's Principle**

Introduction

A chemical reaction at equilibrium is sometimes subjected to an outside stress or influence.

Le Châtelier's Principle: *If a system in equilibrium is subjected to a stress, the equilibrium in an attempt to reduce the stress.*

Example: $N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$

a. Concentration:	↑N_2: will increase the reaction with H_2, thereby ↓H_2 and ↑NH_3
b. Pressure:	affects only gases; the reaction will shift to the side with the fewer number of particles: 1 + 3 $\rightleftarrows$ 4, so the reaction will shift to the right (↓N_2 ↓H_2 and ↑NH_3)
c. Temperature:	↑T will shift to favor the endothermic reaction. This reaction is exothermic: $N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$ ΔH –46.2 kJ/mol. Treating enthalpy as a substance: 46.2 kJ + $N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$. ↑T will drive reaction to the right.

Problems

For the following gaseous equilibrium reactions, indicate what happens to the equilibrium position (shifts left or right) with the indicated stress. Justify your answer.

1. $N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$

   a. Remove NH_3 gas.

	$N_2(g)$	$3H_2(g)$	$2NH_3(g)$	direction of rxn	Reducing product concentration drives reaction to right, trying to replenish removed product and thereby decreasing reactant concentrations.
Stress			↓	→	
Result	↓	↓	↑		

   b. Reduce pressure.

	$N_2(g)$	$3H_2(g)$	$2NH_3(g)$	direction of rxn	Reducing pressure will drive reaction to increase the total number of particles. (1+3) >2
Stress				←	
Result	↑	↑	↓		

2. $2SO_2(g) + O_2(g) \rightleftarrows 2SO_3(g)$ + energy

   a. Increase SO_2 concentration.

	$2SO_2(g)$	$O_2(g)$	$2SO_3(g)$	energy	direction of rxn	Increasing reactant concentration drives reaction right. More SO2 reacts, reducing concentration of the other reactant, and increasing product and energy released.
Stress	↑				→	
Result	↓	↓	↑	↑		

   b. Increase temperature.

	$2SO_2(g)$	$O_2(g)$	$2SO_3(g)$	energy	direction of rxn	The reaction is exothermic. Increasing the temperature will put more energy into the system to create bonds with more potential energy, i.e., reactants.
Stress				↑	←	
Result	↑	↑	↓			

3. $CO_2(g) + H_2(g) \rightleftarrows CO(g) + H_2O(g)$ $\Delta H = -41.16$ kJ

a. Decrease temperature.

Rearranged equation: $CO_2(g) + H_2(g) \rightleftarrows CO(g) + H_2O(g) + 41.16$ kJ

	$CO_2(g)$	$H_2(g)$	$CO(g)$	$H_2O(g)$	direction of rxn	The reaction is exothermic. Treating energy as a chemical, reducing temperature will drive reaction to the right.
Stress					→	
Result	↓	↓	↑	↑		

b. Add a catalyst.

	$CO_2(g)$	$H_2(g)$	$CO(g)$	$H_2O(g)$	direction of rxn	Catalysts only affect the rate of a reaction, not the shift in equilibrium.
Stress					n/c	
Result	-	-	-	-		

4. $CH_4(g) + 2H_2S(g) \rightleftarrows CS_2(g) + 4H_2(g)$

a. Decrease the concentration of dihydrogen sulfide.

	$CH_4(g)$	$2H_2S(g)$	$CS_2(g)$	$4H_2(g)$	direction of rxn	Removal of reactant would drive reaction to the left to reestablish the equilibrium.
Stress		↓			←	
Result	↑	↑	↓	↓		

b. Increase the pressure on the system.

	$CH_4(g)$	$2H_2S(g)$	$CS_2(g)$	$4H_2(g)$	direction of rxn	Increase pressure will drive reaction to reduce the number of molecules. $(3 < 5)$
Stress					←	
Result	↑	↑	↓	↓		

c. Increase the concentration of carbon disulfide.

	$CH_4(g)$	$2H_2S(g)$	$CS_2(g)$	$4H_2(g)$	direction of rxn	Addition of product will drive reaction to the left to reestablish the equilibrium.
Stress			↑		←	
Result	↑	↑	↓	↓		

d. Decrease the concentration of methane.

	$CH_4(g)$	$2H_2S(g)$	$CS_2(g)$	$4H_2(g)$	direction of rxn	Removal of reactant would drive reaction to the left to reestablish the equilibrium.
Stress	↓				←	
Result	↑	↑	↓	↓		

5. $CO_2(g) + H_2O(l) \rightleftarrows H_2CO_3(aq) \rightleftarrows H^+(aq) + HCO_3^-(aq)$
Carbon dioxide is released from cells in the body during cellular respiration. It is carried away in the veins by combining with water in the blood and forming carbonic acid. When it reaches the lungs, carbonic acid decomposes and allows CO_2 to be exhaled and removed from the body. However, in the blood, carbonic acid is a major factor in maintaining the proper pH (approximately 6.35-7.45) of the body. The most common acid-base abnormality is when the blood is too basic (respiratory alkalosis). The normal compensatory mechanism of acid-base imbalance is to shift the above equation: creating more H^+ will decrease pH making it more acidic; removing H^+ will make it more basic.

a. Hyperventilation.

Hyperventilation, an increase in the rate of breathing, which causes a decrease in CO_2. This will shift the entire reaction to the right. This includes of a decrease H^+ (alkalosis).
Because CO_2 is carried in the blood as H_2CO_3, decreased CO2 caused decreased of H_2CO_3. This, in turn, lowers the $[H^+]$.

$CO_2(g)$	$H_2O(g)$	$H_2CO_3(aq)$	$H^+(aq)$	$HCO_3^-(aq)$	direction of rxn
↓					←
↑	↑	↓	↓	↓	

b. During extended diarrhea (e.g., cholera), when hydrogen carbonate is excessively excreted by the kidneys.
Decreasing $HCO^-_{(aq)}$ will drive the reaction to the right in order to compensate for its loss and reestablish the equilibrium.

$CO_2(g)$	$H_2O(g)$	$H_2CO_3(aq)$	$H^+(aq)$	$HCO_3^-(aq)$	direction of rxn
					→
↓	↓	↓	↓	↓	

* Climbing high altitude mountain without supplemental oxygen.
The oxygen concentration at high elevations is less than what most people are accustomed to. The person will hyperventilate in order to take in more oxygen. Thus, the results are the same as above hyperventilation.