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**Equilibrium    Le Châtelier's Principle**

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**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:  $\text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g)$

a. Concentration:	$\uparrow\text{N}_2$ : will increase the reaction with $\text{H}_2$ , thereby $\downarrow\text{H}_2$ and $\uparrow\text{NH}_3$
b. Pressure:	affects only gases; the reaction will shift to the side with the fewer number of particles: $1 + 3 \rightleftharpoons 4$ , so the reaction will shift to the right ( $\downarrow\text{N}_2$ $\downarrow\text{H}_2$ and $\uparrow\text{NH}_3$ )
c. Temperature:	$\uparrow\text{T}$ will shift to favor the endothermic reaction. This reaction is exothermic: $\text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g)$ $\Delta\text{H} = -46.2$ kJ/mol. Treating enthalpy as a substance: $46.2$ kJ + $\text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g)$ . $\uparrow\text{T}$ 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.

- $\text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g)$ 
  - Remove  $\text{NH}_3$  gas.
  - Reduce pressure.
- $2\text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{SO}_3(g) + \text{energy}$ 
  - Increase  $\text{SO}_2$  concentration.
  - Increase temperature.
- $\text{CO}_2(g) + \text{H}_2(g) \rightleftharpoons \text{CO}(g) + \text{H}_2\text{O}(g)$   $\Delta\text{H} = -41.16$  kJ
  - Decrease temperature.
  - Add a catalyst.
- $\text{CH}_4(g) + 2\text{H}_2\text{S}(g) \rightleftharpoons \text{CS}_2(g) + 4\text{H}_2(g)$ 
  - Decrease the concentration of dihydrogen sulfide.
  - Increase the pressure on the system.
  - Increase the concentration of carbon disulfide.
  - Decrease the concentration of methane.
- $\text{CO}_2(g) + \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_2\text{CO}_3(aq) \rightleftharpoons \text{H}^+(aq) + \text{HCO}_3^-(aq)$ 

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  $\text{CO}_2$  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.

b. During extended diarrhea (e.g., cholera), when hydrogen carbonate is excessively excreted by the kidneys.

\* Climbing high altitude mountain without supplemental oxygen.