AP CHEMISTRY

TOPIC 6: EQUILIBRIUM, PART D

Day 67:

- Le Chatelier's Principle

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1. Suppose the reaction system

$$UO_{2\,(s)} + 4\,HF_{(g)} \leftrightarrow UF_{4\,(g)} + 2\,H_2O_{(g)}$$

has already reached equilibrium. Predict the effect that each of the following changes has on the equilibrium position. Indicate whether the equilibrium will shift to the right, will shift to the left, or will not be affected.

a) Additional $UO_{2\,(s)}$ is added to the system.

Answer:

No Effect, Adding more of a pure solid or pure liquid has no effect on the equilibrium position.

b) The reaction is performed in a glass reaction vessel; $HF_{(g)}$ attacks and reacts with the glass.

Answer:

Shifts Left, $HF_{(g)}$ will be removed by the reaction with glass. As $HF_{(g)}$ is removed, the reaction will shift left to produce more $HF_{(g)}$.

c) Water vapor is removed.

Answer:

Shifts Right, As $H_2O_{(g)}$ is removed, the reaction will shift to the right to produce more $H_2O_{(g)}$.

2. Predict the shift in the equilibrium position that will occur for each of the following reactions when the volume of the reaction container is increased.

Answer:

When the volume of a reaction container is increased, the reaction itself will want to increase its own volume by shifting to the side of the reaction that contains the most molecules of gas. When the molecules of gas are equal on both sides of the reaction, then the reaction will remain at equilibrium no matter what happens to the volume of the container.

a) $N_{2\,(g)} + 3\,H_{2\,(g)} \leftrightarrow 2\,NH_{3\,(g)}$	Shifts to left, toward reactants
b) $PCl_{5\,(g)} \leftrightarrow PCl_{3\,(g)} + Cl_{2\,(g)}$	Shifts to right, toward products
c) $H_{2\,(g)} + F_{2\,(g)} \leftrightarrow 2\,HF_{(g)}$	No Shift, equal number of reactants and products
d) $COCl_{2\,(g)} \leftrightarrow CO_{(g)} + Cl_{2\,(g)}$	Shifts to right, toward products
e) $CaCO_{3\,(s)} \leftrightarrow CaO_{(s)} + CO_{2\,(g)}$	Shifts to right, toward products (ignore solids and pure liquids)

3. An important reaction in the commercial production of hydrogen is

$$CO_{(g)} + H_2O_{(g)} \leftrightarrow H_{2\,(g)} + CO_{2\,(g)}$$

How will this system at equilibrium shift in each of the of the following cases?

a) Gaseous carbon dioxide is removed.	Shifts to right
b) Water vapor is added.	Shifts to right
c) The pressure is increased by adding helium gas.	No Shift, helium gas is neither a reactant or product (inert gas)
d) The temperature is increased (the reaction is exothermic).	Shifts to left, Since the reaction is exothermic, heat is a product.
e) The pressure is increased by decreasing the volume of the reaction container.	No Shift, since there are the same number molecules on both sides of the reaction.

4. What will happen to the number of moles of SO_3 in equilibrium with SO_2 and O_2 in the reaction

$$2\ SO_{3\,(g)} \leftrightarrow 2\ SO_{2\,(g)} + O_{2\,(g)} \qquad \Delta H^0 = +197\ \text{kJ}$$

in each of the following cases

a) Oxygen gas is added	Number of moles of SO_3 will increase, Shift to the left
b) The pressure is increased by decreasing the volume of the reaction container.	Number of moles of SO_3 will increase, Since there are fewer molecules on the reactant side will shift the reaction left
c) The pressure is increased by adding argon gas.	Number of moles of SO_3 will remain the same, Argon is not a reactant nor a product (inert gas)
d) The temperature is decreased.	Number of moles of SO_3 will increase, Decreasing the temperature will remove heat, shifting an endothermic reaction to the left
e) Gaseous sulfur dioxide is removed.	Number of moles of SO_3 will decrease, Shift to the right

5. Ammonia is produced by the Haber process, in which nitrogen gas and hydrogen gas are reacted directly using an iron mesh impregnated with oxides as a catalyst. For the reaction

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

equilibrium constants (K_p values) as a function of temperature are

300 ^{0}C,	4.34×10^{-3}
500 ^{0}C,	1.45×10^{-5}
600 ^{0}C,	2.25×10^{-6}

Is the reaction exothermic or endothermic?

Answer:

*As temperature increases, the value of K decreases. This is consistent with an **exothermic reaction**. In an exothermic reaction, heat is a product and an increase in temperature shifts the equilibrium to the reactant side (as well as lowering the value of K).*
See the graphic below…

One **adds energy** to the system, as a result the equilibrium constant, K, decreases.

$$4\ X_{(g)} + 3\ Y_{2\,(g)} \leftrightarrow 2\ X_2Y_{3\,(g)} + \textbf{Heat}$$ (*type of reaction*: ***Exothermic***)

$$\longleftarrow$$

$$K = \frac{[X_2Y_3]^2}{[X]^4[Y_2]^3} = \frac{[prod.]\downarrow}{[react.]\uparrow} = lower$$