Le Châtelier's Principle

Chem Worksheet 18-6

Name _____

A stress that is applied to a reaction that is at equilibrium conditions will shift the equilibrium position in a direction that tends to reduce this stress. This concept was first described by Le Châtelier. A reaction can be 'stressed' by changing the concentration of a reactant or product, changing the volume, and changing the temperature. Each stress tends to either favor the forward or reverse reaction until a new equilibrium position is established. If the forward reaction is increased we say equilibrium shifts to the right, and if the reverse reaction is increased equilibrium shifts to the left.

When the **concentration** of a gaseous or aqueous reactant or product is increased the equilibrium reaction shifts in the direction that decreases the concentration of that substance. If more product is added to a system at equilibrium, the reverse reaction increases in order to use the extra product, shifting equilibrium to the left. When the **volume** is reduced the equilibrium reaction shifts toward the side that contains the fewest gas particles. An increase in volume shifts to the side with the most gas particles. An increase in **temperature** will favor a reaction that is endothermic. A decrease in temperature will favor the reaction that is exothermic.

Concentration Changed	
$2A\,(g) + 3B\,(g) \leftrightarrows 2C\,(g) + D\,(g)$	
Action	**Effect**
Increase [A]	Shift to the right
Increase [C]	Shift to the left
Decrease [B]	Shift to the left
Decrease [C]	Shift to the right

Temp. Changed for Endothermic Rxn.	
$A\,(g) + B\,(g) + \text{heat} \leftrightarrows C\,(g) + D\,(g)$	
Action	**Effect**
Increase Temp.	Shifts to right (endothermic rxn.)
Decrease Temp.	Shifts to left (exothermic rxn.)

Volume Changed	
$2A\,(g) + 3B\,(g) \leftrightarrows 2C\,(g) + D\,(g)$	
Action	**Effect**
Volume decreased	Shifts to right (side with fewest gases)
Volume increased	Shifts to left (side with most gases)

Temp. Changed for Exothermic Rxn.	
$A\,(g) + B\,(g) \leftrightarrows C\,(g) + D\,(g) + \text{heat}$	
Action	**Effect**
Increase Temp.	Shifts to left (endothermic rxn.)
Decrease Temp	Shifts to right (exothermic rxn.)

Predict the direction equilibrium will shift when the following stresses occur. Explain your prediction. Assume each reaction occurs in a sealed container and has reached equilibrium.

$$2NO_2\,(g) \leftrightarrows N_2\,(g) + 2O_2\,(g) \quad \Delta H = +33 \text{ kJ/mol (endothermic)}$$

1. NO_2 is added to the system.
2. N_2 is added to the system.
3. O_2 is removed from the system.
4. The temperature of the container is increased.
5. The volume of the container is increased.
6. N_2 is added and NO_2 is removed.

$$CaCO_3\,(s) \leftrightarrows CaO\,(s) + CO_2\,(g) \quad \Delta H = +179 \text{ kJ/mol (endothermic)}$$

7. CO_2 is added to the system.
8. The volume of the container is decreased.
9. CaO is removed from the system.
10. The temperature of the container is decreased.
11. The volume of the container is increased.
12. $CaCO_3$ is added to the system.

$$H_2\,(g) + Cl_2\,(g) \leftrightarrows 2HCl\,(g) \quad \Delta H = -185 \text{ kJ/mol (exothermic)}$$

13. H_2 is removed from the system.
14. HCl is removed from the system.
15. The volume of the container is increased.
16. The temperature of the container is increased.
17. The concentration is Cl_2 is decreased.
18. The volume of the container is decreased.

$2NO_{2(g)} \rightleftharpoons N_{2(g)} + 2O_{2(g)} \quad \Delta H = +33 kJ/mol$

1) stress: NO_2 is added.
response: shift right
reason: Rate of forward reaction increases due to increase in collisions.

2) stress: N_2 is added
response: shift left
reason: more collisions occur between $N_2 + O_2$ which makes reverse reaction rate faster.

3) stress: O_2 is removed
response: shift right
reason: less O_2 results in fewer $N_2 + O_2$ collisions this makes reverse reaction slow down.

4) stress: temp. inc.
response: shift right
reason: increased temp. increases the rate of the endothermic reaction greater than the exothermic. The forward reaction is endothermic.

5) stress: volume inc. (same as dec. pressure)
response: shift right
reason: shift in direction with greater moles of gas.

6) stress: add N_2 and remove NO_2
response: shift left.
The equilibrium wants to use N_2 and replenish NO_2.

$CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)} \quad \Delta H = +179\ kJ/mol$

7) stress: CO_2 added.
response: shift left
reason: reverse reaction will use the added $CO_{2(g)}$

8) stress: volume decreased (same as pressure ↑)
response: shift left
reason: shift towards fewer moles of gas (fewer collisions)

9) stress: CaO removed
response: no shift
reason: solids do not influence systems @ equilibrium

10) stress: temp decreased
response: shift left.
reason: Lower temp favors exothermic reaction
this results in a shift left because the reverse reaction is exothermic.

11) stress: volume of container increased (same as P ↓)
response: shift right.
reason: shift towards greater moles.

12) stress: $CaCO_3$ added
response: no shift
reason: $CaCO_3$ is a solid and its concetration does not influence equilibrium

$H_{2(g)} + Cl_{2(g)} \rightleftharpoons 2HCl_{(g)} \quad \Delta H = -185\ kJ/mol$

13) stress: H_2 is removed.
response: shift left
reason: system will shift in the direction which replenishes the H_2.

14) stress: HCl is removed.
response: shift right
reason: system will shift to replenish HCl which is the forward reaction.

15) stress: volume container increased. ($P \downarrow$)
response: no shift
reason: equal moles of gases on both sides.

16) stress: temp increased
response: shift left
reason: an increase in temp favors the endothermic reaction. In this reaction the reverse is endothermic.

17) stress: conc. of Cl_2 decreased
response: shift left
reason: the reverse reaction will replenish Cl_2.

18) stress: volume container decreased
response: no shift
reason: equal moles of gas.