Le Chatelier's Principle Exercises

"If a stress is applied to a system at chemical equilibrium, the equilibrium will shift in such a manner as to counteract the effects of that stress."

This only applies to systems at equilibrium. Other reactions can go to completion:

Many other chemical reactions can only run in one direction, going only from the reactants on the left side of the arrow to the products on the right side of the arrow. These reactions are called "not reversible."

A good example of this might be burning some paper:

Cellulose(s) + O_2(g) → CO_2(g) + H_2O(g)

The reaction proceeds until all of either one of the reactants is used up and then it stops. You cannot make the reaction run in reverse. This is usually because of the complexity of one or more of the reactants. For example, imagine putting some carbon dioxide and water together in a beaker and trying to get starch or sugar or any number of other CHO (complex carbohydrate) compounds. It just does not happen!! Typically, reversible reactions are simple one-step reactions in both directions. The making of cellulose by a plant requires many steps, some with different requirements of temperature or time, whereas to break cellulose down to CO_2 and H_2O takes only one step.

1. Assume that the following reaction is in chemical equilibrium:

4n gas 2n gas

N_2(g) + 3 H_2(g) ⇄ 2 NH_3(g) + heat

Explain the effect of each of the following changes upon the system in terms of Le Chatelier's Principle and a shift toward either the product or reactant side.

S W S

1. More hydrogen is added to the system. ↑[H_2] = ↓[H_2] = right
2. Ammonia is removed from the system. ↓[NH_3] = ↑[NH_3] = right
3. Nitrogen is removed from the system. ↓[N_2] = ↑[N_2] = left
4. The temperature is raised. ↑T = ↓T = left
5. The pressure of the system is decreased by doubling the total volume. ↓P = ↑P = left

2. Which way will the equilibrium shift if the system temperature goes up (heat is added)? Why?

stress ↑T
want ↓T
shift left

$$2\ SO_2(g) + O_2(g) \leftrightarrow 2\ SO_3(g) + \text{heat}$$

3. The container holding the following reaction (already at equilibrium) has its volume suddenly reduced by half. Which way will the equilibrium shift to compensate? Why?

stress ↑P
want ↓P
shift right

$$PCl_3(g) + Cl_2(g) \leftrightarrow PCl_5(g)$$

2 n gas 1 n gas

4. The container holding the following reaction (already at equilibrium) has its volume suddenly increased. Which way will the equilibrium shift to compensate? Why?

stress ↓P
want ↑P
shift N/A

$$H_2(g) + Cl_2(g) \leftrightarrow 2\ HCl(g)$$

2 n gas 2 n gas
no shift bec no benefit

✱ 5. The system below is already at equilibrium when some neon is added to the system. What happens to the position of the equilibrium? Does it shift right, left, or no change?

∅

$$H_2(g) + Cl_2(g) \leftrightarrow 2\ HCl(g)$$

non-reacting gas!
so even though the P ↑ it does not change the concentrations of the reacting gases

No change in [gases] that are reacting

6. The system below is already at equilibrium when a catalyst is added to the system. What happens to the position of the equilibrium? Does it shift right, left, or no change? Why?

$$PCl_3(g) + Cl_2(g) \leftrightarrow PCl_5(g)$$

- no shift
- no stress
- a catalyst only gets you to the ⇋ position faster
- it is not a stress
- ∴ no shift

stress ↑T
want ↓T
shift left

The Effect of Temperature on Equilibrium Position

$$H_2(g) + Cl_2(g) \rightarrow 2\,HCl(g) + \text{heat energy}$$

a) What effect would increasing the temperature have on the equilibrium position? Explain.

b) What effect would increasing the temperature have on the equilibrium constant? Explain.

Practice writing Keq (equilibrium constants)

$$K_{eq} = \frac{[P]^x}{[R]^y}$$ With products and reactants raised to their coefficients.

n.b. solids and liquids are NOT included as you cannot change the concentration of a solid or a liquid

Write an equilibrium expression for each of the following reactions.

1) $3\,O_2(g) \leftrightarrow 2\,O_3(g)$

2) $N_2(g) + 3\,H_2(g) \leftrightarrow 2\,NH_3(g)$

3) $NaCl(s) \leftrightarrow Na^+(aq) + Cl^-(aq)$

4) $Cu(s) + 2\,AgNO_3(aq) \leftrightarrow 2\,Ag(s) + Cu(NO_3)_2(aq)$

5) $2\,NaBr(aq) + I_2(s) \leftrightarrow Br_2(l) + 2\,NaI(aq)$