Chemistry 2, HW11

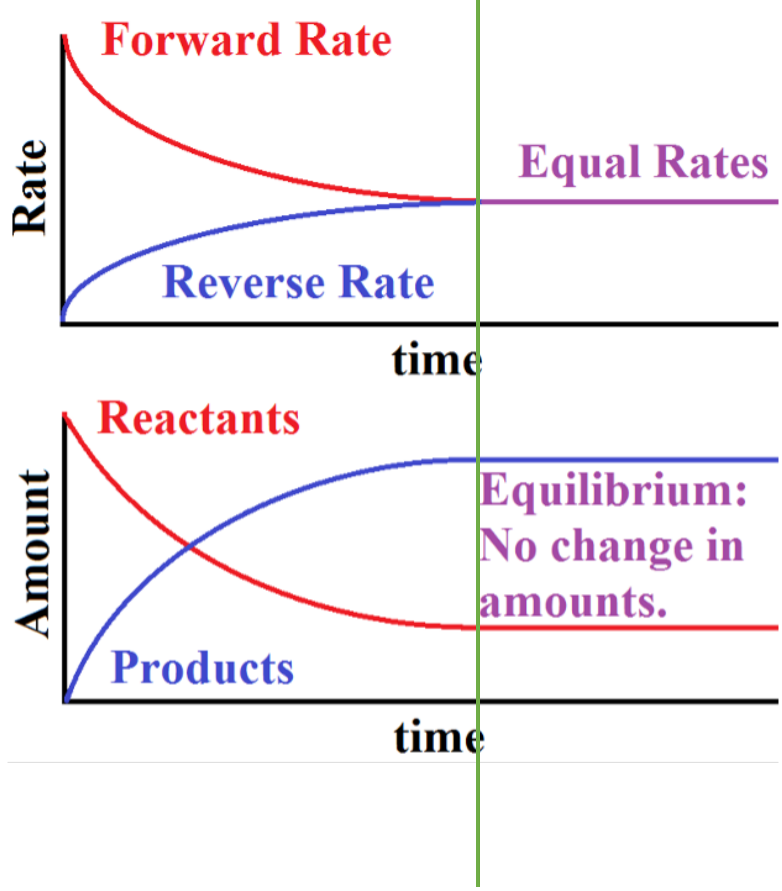
EQUILIBRIUM

$CaCO_3(s) \rightleftharpoons CaO\ (s) + CO_2\ (g)$

We have forward and reverse reactions (we use double arrows to demonstrate this).The rate of decomposition of calcium carbonate is exactly the same as the rate of CaCO3 synthesis from CaO
and carbon dioxide. This type of equilibrium is a dynamic equilibrium.
Dynamic equilibrium: concentrations of all reactants and products remain constant and the rate of the forward
reaction is equal to the rate of the reverse reaction.
Equilibrium can be attained only in a closed system.
All substances in the chemical equation are present in the equilibrium reaction mixture.

A → B + C
←

Equilibrium can be reached from either direction. The left side from the green line – system is in chemical equilibrium.



The position of equilibrium can be shifted. If a system at equilibrium is subjected to a change, the position of equilibrium will shift in order to minimize the effect of the change – Le Chatelier's principle. Change in concentrations of the reactants or products, change in temperature of the reaction can shift the equilibrium to the left or to the right.

If the concentration of one of the species in an equilibrium mixture is increased, the position of equilibrium shifts to opposite side to reduce the concentration of this substances.

If we change the temperature:

If we increase the temperature, in order to minimize the effect, the equilibrium has to shift in the endothermic direction.

If we cool reaction mixture: position of equilibrium is shifted in the exothermic direction.

$A \rightleftharpoons B + C$ let's pretend the forward reaction is exothermic. If the temperature is increased the equilibrium will shift to the left, now in the reaction mixture we will have bigger % of A if we compare this % with previous equilibrium state. For example, at the beginning we had 70 % of A in the mixture, after temperature increase we will have 85% of A in the mixture.

Another scenario, we increased concentration of A in the reaction mixture, equilibrium will shift to the right, we will get more B and C in the reaction mixture.

Equilibrium constant, K_c:

The equilibrium constant is the constant for a particular reaction at a particular conditions.

$aA + bB \rightleftharpoons cC + dD$ a,b,c,d, - number of moles, [C], [D], [A],[B] - concentarions

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

If $K_c \ll 1$ reaction hardly proceeds toward products

$K_c \gg 1$ reaction proceeds almost totally towards products.

Temperature change will effect the eq. constant. If we increase temperature in exothermic reaction,

the value of equilibrium constant decreases.

Summary of the effects on the position of equilibrium and K_c.

	Effect on position of equilibrium	Effect on value of equilibrium constant
concentration	The position will shift in order to use up added substance	No effect
Catalyst	No effect	No effect, catalyst increases the rates of forward and reverse reactions equally
Temperature	If the T is up the position of equilibrium shifts in the endothermic direction. If the T is down the position of equilibrium shifts in the exothermic direction.	If the T is increased, K_c decreases for exothermic reaction. If the T is decreased, K_c increases for endothermic reaction.

Questions:

1. Explain effect of the following on the position of equilibrium (will it shift to the left or right) and the value of the equilibrium constant (will it increase or decrease):
   a. Increasing temperature in $CH_4 + H_2O \leftrightarrow CO + 3H_2$ $\Delta H = 206$ kJ/mol
   b. Decreasing temperature in $H_2O + CO \leftrightarrow H_2 + CO_2$ $\Delta H = -40$ kJ/mol
   c. Increasing concentration of H_2 in $N_2 + 3H_2 \leftrightarrow 2NH_3$
   d. Introducing a catalyst into the reaction: $2SO_2 + O_2 \leftrightarrow 2SO_3$

2. Which of the following is true for a system at equilibrium?
   a. The rate of the reverse reaction is zero.
   b. The concentration of reactants and products are equal.
   c. The rate of the forward reaction is equal to the rate of the reverse reaction
   d. The rate of the forward reaction is maximum
3. Look at the following reaction $CO_2 + 4H_2 \leftrightarrow CH_4 + 2HO_2$, write the expression for equilibrium constant.