AP CHEMISTRY

TOPIC 6: EQUILIBRIUM, PART A

Day 64:

- Chemical Equilibrium
- Equilibrium position
- Equilibrium expression
- Reaction Quotient

---

1) Characterize a system at chemical equilibrium with respect to each of the following:
   a) The rates of the forward and reverse reactions.

Answer:
The RATES of the forward reaction and reverse reactions are the SAME at equilibrium.

   b) The overall composition of the reaction mixture.

Answer:
There is no net change in the composition (as long as the temperature is constant). In other words, the "ratio" of the products over the reactants remains the same – we will discuss the mechanisms to this shortly.

2) Write the reaction quotient expression (Q) for each of the following gas-phase reactions, which occur in the atmosphere:
   a) $NO_{(g)} + O_{3\,(g)} \rightleftharpoons NO_{2\,(g)} + O_{2\,(g)}$

$$Q = \frac{[NO_2]\,[O_2]}{[NO]\,[O_3]}$$

   b) $2\,O_{3\,(g)} \rightleftharpoons 3\,O_{2\,(g)}$

$$Q = \frac{[O_2]^3}{[O_3]^2}$$

3) Calculate the reaction quotient for:

$$O_{2\,(g)} + 2\,SO_{2\,(g)} \rightleftharpoons 2\,SO_{3\,(g)}$$

$[O_2]$ = 3.70 M
$[SO_2]$ = 4.50 M
$[SO_3]$ = 2.50 M

$$Q = \frac{[SO_3]^2}{[O_2]\,[SO_2]^2} = \frac{(2.50\ M)^2}{(3.70\ M)\,(4.50\ M)^2} = 0.0834\ \frac{1}{M}$$

4) Calculate the reaction quotient for:

$$2\,SO_{3\,(g)} \rightleftharpoons O_{2\,(g)} + 2\,SO_{2\,(g)}$$

$[O_2]$ = 3.70 M
$[SO_2]$ = 4.50 M
$[SO_3]$ = 2.50 M

$$Q = \frac{[O_2]\,[SO_2]^2}{[SO_3]^2} = \frac{(3.70\ M)\,(4.50\ M)^2}{(2.50\ M)^2} = 11.99\ M$$

4) For the synthesis of ammonia at 500^{0}C, the equilibrium constant is 6.0 x 10^{-2} (K = 6.0 x 10^{-2}). Predict the direction in which the system will shift to reach equilibrium in each of the following cases:

a) $[NH_3]_0 = 1.0 \times 10^{-3}\ M$; $[N_2]_0 = 1.0 \times 10^{-5}\ M$; $[H_2]_0 = 2.0 \times 10^{-3}\ M$ (note: the "0" at the bottom right of the [ ] = "initial")

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

$$Q = \frac{[NH_3]^2}{[N_2]\,[H_2]^3} = \frac{\left(1.0\times10^{-3}\ M\right)^2}{\left(1.0\times10^{-5}\ M\right)\left(2.0\times10^{-3}\ M\right)^3} = 1.25\times10^{7}\ \frac{1}{M^2}$$

Since K = 6.0 x 10^{-2}, $Q > K$, The reaction will shift to the left (form more reactants)

b) $[NH_3]_0 = 2.00 \times 10^{-4}\ M$; $[N_2]_0 = 1.50 \times 10^{-5}\ M$; $[H_2]_0 = 3.54 \times 10^{-1}\ M$

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

$$Q = \frac{[NH_3]^2}{[N_2]\,[H_2]^3} = \frac{\left(2.00\times10^{-4}\ M\right)^2}{\left(1.50\times10^{-5}\ M\right)\left(3.54\times10^{-1}\ M\right)^3} = 6.01\times10^{-2}\ \frac{1}{M^2}$$

Since K = 6.0 x 10^{-2}, $Q = K$, The reaction will NOT shift (the reaction is at equilibrium)

c) $[NH_3]_0 = 1.00 \times 10^{-4}\ M$; $[N_2]_0 = 5.0\ M$; $[H_2]_0 = 1.0 \times 10^{-2}\ M$

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

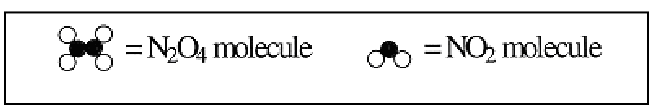
$$Q = \frac{[NH_3]^2}{[N_2]\,[H_2]^3} = \frac{\left(1.00\times10^{-4}\ M\right)^2}{\left(5.0\ M\right)\left(1.0\times10^{-2}\ M\right)^3} = 2.00\times10^{-3}\ \frac{1}{M^2}$$

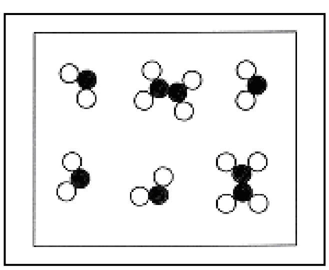
Since K = 6.0 x 10^{-2}, $Q < K$, The reaction will shift to the right (form more products)

5. Consider the following gas-phase reaction, at equilibrium, under conditions where the value of the equilibrium constant equals 8.00:

$$N_2O_{4\,(g)} \rightleftharpoons 2\,NO_{2\,(g)}\,,\quad K_{eq} = 8.00$$

a) Draw a picture (diagram) that represents a snapshot of a very small portion of the system at equilibrium. Below is representative of $N_2O_{4\,(g)}$ and $NO_{2\,(g)}$, use this information to assist you in drawing the picture.





$$Q = \frac{[NO_2]^2}{[N_2O_4]} = \frac{(4.0\ M)^2}{(2.0\ M)} = 8.00\ M = K$$

b) Calculate the reaction quotient, and determine the direction of shift (if any):
$[N_2O_4] = 3.75 \times 10^{-2}\ M$, $[NO_2] = 5.88 \times 10^{-1}\ M$

$$Q = \frac{[NO_2]^2}{[N_2O_4]} = \frac{\left(5.88\times10^{-1}\ M\right)^2}{\left(3.75\times10^{-2}\ M\right)} = 9.22\ M$$

$Q > K$, The reaction will shift to the left (form more reactants)