ChemQuest 47

The Reaction Quotient

Name: ______________________________

Date: ________________

Hour: _____

Critical Thinking Questions

1. If K_c for a given reaction is very large would there be a large amount of products or reactants in the mixture?
   Large amounts of products.
2. If K_c for a given reaction is very small would there be a large amount of products or reactants in the mixture?
   Large amounts of reactants.
3. Offer a mathematical explanation for your answers to questions 1 and 2.
   Since K_c equals the concentration of products divided by reactants, a large K_c means a large numerator (products) whereas a small K_c indicates a small numerator.

Information: The Reaction Quotient

The reaction quotient, Q_c, is calculated in the same way as you would calculate the equilibrium constant. For the reaction aA + bB ←→ cC + dD, the reaction quotient is:

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

It is important to keep in mind that the reaction quotient does not involve equilibrium concentrations. The concentrations used to calculate Q_c are at <u>any time</u>, not just at equilibrium.

Critical Thinking Questions

4. Consider the following reaction: $CO + 3H_2 \leftrightarrow CH_4 + H_2O$. While carrying out a reaction between carbon monoxide and hydrogen, a scientist analyzed the mixture and found that in the 3.5 L container there were 0.35 moles of CO, 0.42 moles of H_2, 0.29 moles of CH_4, and 0.38 moles of H_2O. What is the reaction quotient for this mixture?
   $[CO] = 0.35 \div 3.5 = 0.10$ M; $[H_2] = 0.42 \div 3.5 = 0.12$ M; $[CH_4] = 0.29 \div 3.5 = 0.0829$ M; $[H_2O] = 0.38 \div 3.5 = 0.109$ M

$$Q_c = \frac{[CH_4][H_2O]}{[CO][H_2]^3} = \frac{(0.0829)(0.109)}{(0.10)(0.12)^3} = 52.3$$

Information: What Q_c Tells Us

As a reaction proceeds it will always tend to go toward equilibrium. For example, the equilibrium constant for the reaction described in question 4 is 3.92. The concentration of products and reactants will adjust themselves so that as the reaction progresses until the products divided by reactants (raised to the appropriate power) will equal 3.92.

Critical Thinking Questions

5. Given your answer to question 4 and the fact that K_c equals 3.92 for the reaction, what must happen for the reaction to reach equilibrium?

   A) more products must form B) more reactants must form

   Q_c is 0.75 and it must increase to 3.92 as the reaction proceeds. To increase the value of Q, the concentration of the products must increase.

6. At a certain time during a reaction whose equilibrium constant was 12.5, it was found that the reaction quotient was 4.2. Predict what will happen to the concentration of reactants and products as the reaction progresses.
   4.2 must increase to 12.5 by increasing the concentration of products and decreasing the concentration of reactants.

7. At a certain time during a reaction whose equilibrium constant was 0.45, it was found that the reaction quotient was 2.1. Predict what will happen to the concentration of products and reactants as the reaction progresses.
   2.1 must decrease to 0.45 by decreasing the concentration of products and increasing the concentration of reactants.

8. Given your answers to questions 6 and 7, complete the following sentences.

   If Q_c is greater than K_c, then the concentration of products needs to __decrease______.

   If Q_c is less than K_c, then the concentration of products needs to ____increase________.

9. Consider the equilibrium reaction of hydrogen gas reacting with nitrogen gas to produce ammonia, NH_3. K_c for the reaction is 0.500. A 50.0 L reaction vessel contains 1.00 mol N_2, 3.00 mol H_2, and 0.500 mol of NH_3. Will more NH_3 be formed or will more N_2 and H_2 form as the reaction proceeds?

$$3\ H_2 + N_2 \leftrightarrow 2\ NH_3$$

$[H_2] = 3.00 \div 50.0 = 0.0600$ M; $[N_2] = 1.00$ mol$\div 50.0 = 0.0200$ M; $[NH_3] = 0.500 \div 50.0 = 0.0100$ M

$$Q = \frac{[NH_3]^2}{[H_2]^3[N_2]} = \frac{(0.0100)^2}{(0.0600)^3(0.0200)} = 23.1$$

Since Q is greater than K_c, the amount of product (NH_3) needs to decrease and more reactants (H_2 and N_2) will form.