LESSON MAKER PRO

Equilibrium in Action

Use equilibrium concentrations to calculate K_c.

HIGH SCHOOL · CHE.11

CHE.11 "Enrichment: Students will understand that chemical equilibrium is a dynamic process at the molecular level. Enrichment: Construct explanations to explain how to use Le Chatelier's principle to predict the effect of changes in..."

NAME _____ DATE _____

THE EQUILIBRIUM RULE

At equilibrium, the forward and reverse reactions continue at equal rates, so concentrations stay constant. To find K_c, multiply the equilibrium concentrations of the products, each raised to its coefficient, and divide by the same kind of product for the reactants. Include gases and dissolved substances, but leave out pure solids and liquids.

WORKED EXAMPLE

For $SO_2Cl_2(g) \rightleftharpoons SO_2(g) + Cl_2(g)$, the equilibrium concentrations are $[SO_2Cl_2] = 0.8$ mol/L, $[SO_2] = 0.4$ mol/L, and $[Cl_2] = 0.2$ mol/L. Find K_c.

1. Write $K_c = [SO_2][Cl_2]/[SO_2Cl_2]$.
2. Substitute: $K_c = (0.4)(0.2)/0.8$.
3. Calculate: $K_c = 0.08/0.8$.

Answer: $K_c = 0.1$

PRACTICE 6 problems

1 For $H_2(g) + Br_2(g) \rightleftharpoons 2HBr(g)$, $[H_2] = 2$ mol/L, $[Br_2] = 3$ mol/L, and $[HBr] = 6$ mol/L at equilibrium. Write the K_c expression and find its value.

ANSWER _____

2 For $N_2O_4(g) \rightleftharpoons 2NO_2(g)$, $[N_2O_4] = 4$ mol/L and $[NO_2] = 2$ mol/L at equilibrium. Write the K_c expression and find its value.

ANSWER _____

3 For $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$, $[SO_3] = 2$ mol/L, $[SO_2] = 4$ mol/L, and $[O_2] = 3$ mol/L at equilibrium. Write the K_c expression and find its value.

ANSWER _____

4 For $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$, $[CO] = 3$ mol/L, $[Cl_2] = 4$ mol/L, and $[COCl_2] = 6$ mol/L at equilibrium. Find K_c.

ANSWER _____

5 For $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$, $[NO] = 2$ mol/L, $[O_2] = 3$ mol/L, and $[NO_2] = 6$ mol/L at equilibrium. A classmate writes $K_c = [NO_2]/([NO][O_2])$. Correct the expression and find K_c.

ANSWER _____

6 For $2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$, $[NH_3] = 2$ mol/L, $[N_2] = 4$ mol/L, and $[H_2] = 2$ mol/L at equilibrium. Find K_c.

ANSWER _____

APPLY IT Show your work

1 Fertilizer production helps grow food. A plant studies $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$. At equilibrium, $[N_2] = 1/2$ mol/L, $[H_2] = 1/2$ mol/L, and $[NH_3] = 1/4$ mol/L. Find K_c for these conditions.

WORK SPACE

ANSWER _____

2 Researchers study a gas found in car exhaust using a sealed lab chamber. For $2NO_2(g) \rightleftharpoons N_2O_4(g)$, $K_c = 2$ at the test temperature. When the chamber reaches equilibrium, $[NO_2] = 1/2$ mol/L. Find $[N_2O_4]$.

WORK SPACE

ANSWER _____

CHALLENGE One step up

For $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$, the equilibrium concentrations are $[PCl_5] = 2$ mol/L, $[PCl_3] = 4$ mol/L, and $[Cl_2] = 4$ mol/L. Find K_c for the reaction as written and for $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$. Explain why the two values differ.

WORK SPACE AND ANSWER

Equilibrium in Action

PART 1 · PRACTICE

#	PROBLEM	ANSWER
1	For $H_2(g) + Br_2(g) \rightleftharpoons 2HBr(g)$, $[H_2] = 2$ mol/L, $[Br_2] = 3$ mol/L, and $[HBr] = 6$ mol/L at equilibrium. Write the K_c expression and find its value.	**$K_c = [HBr]^2/([H_2][Br_2]) = 6$**
2	For $N_2O_4(g) \rightleftharpoons 2NO_2(g)$, $[N_2O_4] = 4$ mol/L and $[NO_2] = 2$ mol/L at equilibrium. Write the K_c expression and find its value.	**$K_c = [NO_2]^2/[N_2O_4] = 1$**
3	For $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$, $[SO_3] = 2$ mol/L, $[SO_2] = 4$ mol/L, and $[O_2] = 3$ mol/L at equilibrium. Write the K_c expression and find its value.	**$K_c = [SO_2]^2[O_2]/[SO_3]^2 = 12$**
4	For $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$, $[CO] = 3$ mol/L, $[Cl_2] = 4$ mol/L, and $[COCl_2] = 6$ mol/L at equilibrium. Find K_c.	**$K_c = 1/2$**
5	For $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$, $[NO] = 2$ mol/L, $[O_2] = 3$ mol/L, and $[NO_2] = 6$ mol/L at equilibrium. A classmate writes $K_c = [NO_2]/([NO][O_2])$. Correct the expression and find K_c.	**$K_c = [NO_2]^2/([NO]^2[O_2]) = 3$**
6	For $2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$, $[NH_3] = 2$ mol/L, $[N_2] = 4$ mol/L, and $[H_2] = 2$ mol/L at equilibrium. Find K_c.	**$K_c = 8$**

PART 2 · APPLY IT

1. **$K_c = 1$** $K_c = [NH_3]^2/([N_2][H_2]^3) = (1/4)^2/((1/2)(1/2)^3) = (1/16)/(1/16) = 1$.
2. **$[N_2O_4] = 1/2$ mol/L** $K_c = [N_2O_4]/[NO_2]^2$, so $[N_2O_4] = 2(1/2)^2 = 1/2$ mol/L.

CHALLENGE

$K_c = (4)(4)/2 = 8$ for the first reaction. $K_c = 2/((4)(4)) = 1/8$ for the reverse reaction. Reversing the reaction swaps the numerator and denominator, so the constants are reciprocals.

Accept equivalent unsimplified expressions when the powers match the reaction coefficients. All concentrations supplied in the problems are equilibrium concentrations.