Equilibrium worksheet

1. Once a system has reached equilibrium, are the following true or false?
   1. The reaction is finished, no more products are forming. \_\_**\_\_\_\_\_\_**\_\_
   2. The concentrations of the reactants and the products are equal. **\_\_\_\_\_\_\_\_\_\_\_\_**\_\_
   3. The concentrations are no longer changing. \_**\_\_\_\_\_\_\_\_\_**\_
   4. The reaction is not over, but will continue forever if isolated. \_**\_\_\_\_\_\_\_\_\_\_\_**\_
   5. The speed at which products are made equals the speed at which reactants form. **\_\_\_\_\_\_\_\_\_\_**
2. What is equal at equilibrium? \_\_\_\_**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
3. What general information can be gathered by observing the magnitude of the equilibrium constant?
4. Write Kc expressions for the following reactions:
5. 3 O2 (g)  2 O3 (g)

b) N2 (g) + 3 H2 (g)  2 NH3 (g)

c) H2 (g) + I2 (g)  2 HI (g)

d) PCl5 (g)  PCl3 (g) + Cl2 (g)

e) SO2 (g) + ½ O2 (g)  SO3 (g)

1. 2 K3PO4(aq) + 3 Ca(NO3)2(aq)  6 KNO3(aq) + Ca3(PO4)2(s)
2. Arrange the reactions in order of their increasing tendency to proceed toward completion: \_\_ \_\_ \_\_ \_\_

(a) 4NH3(g) + 3O2(g)  2N2(g) + 6H2O(g) Kc = 1 x 10228

(b) N2(g) + O2(g)  2NO(g) Kc = 5 x 10-31

(c) 2HF(g)  H2(g) + F2(g) Kc = 1 x 10-13

(d) 2NOCl(g)  2NO(g) + Cl2(g) Kc = 4.7 x 10-4

1. Which way will the equilibrium of the following reversible reaction be shifted under each of the following conditions:

N2 + O2 + heat ⮀ 2NO

a) Heat is added to the reaction Towards Reactants Towards Products

b) NO is added to the reaction Towards Reactants Towards Products

c) O2 is added to the reaction Towards Reactants Towards Products

1. According to LeChâtelier’s principle, which way will the equilibrium of the reaction shown below be shifted under the following conditions?

N2 (*g*) + 3H2 (*g*) ⮀ 2NH3 (*g*) + 22 kcal

a) NH3 is added b) heat is removed c) H2 is added

1. Using the Ka or pKa values, rank the acids in order from strongest (1) to weakest (2) acid.

|  |  |  |  |
| --- | --- | --- | --- |
| **Acid** | **Ka** | **pKa** | **Rank** |
| Benzoic acid | 6.3 x 10-5 | 4.2 |  |
| Trichloroacetic acid | 2.3 x 10-1 | 0.64 |  |
| Acetic acid | 1.8 x 10-5 | 4.8 |  |
| Citric acid | 8.7 x 10-4 | 3.1 |  |
| Phenol | 1.0 x 10-10 | 10 |  |

1. For the following reaction: CH3CO2H + H2O ⮀ CH3CO2- + H3O+

a) Identify which reactant is the acid and which is the base.

b) Identify the conjugate acid and conjugate base.

c) Write the equilibrium expression for the reaction.

d) Ka = 1.8 x 10-5 for CH3CO2H. Does the equilibrium favor reactants or products ?

e) Could you make a buffer with CH3CO2H? If so, what would you add besides CH3CO2H and H2O?

Equilibrium worksheet Key

1. Once a system has reached equilibrium, are the following true or false?
   1. The reaction is finished, no more products are forming. \_\_ **false** \_\_
   2. The concentrations of the reactants and the products are equal. **false** \_\_
   3. The concentrations are no longer changing. \_ **true** \_
   4. The reaction is not over, but will continue forever if isolated. \_ **true** \_
   5. The speed at which products are made equals the speed at which reactants form. **true**
2. What is equal at equilibrium? \_\_\_\_**forward and reverse rates**\_\_\_\_\_
3. What general information can be gathered by observing the magnitude of the equilibrium constant?

**Whether a reaction is reactant- or product-favored.**

1. Write Kc expressions for the following reactions:

a) 3 O2 (g)  2 O3 (g) Kc = [(O3)2] / [(O2)3]

b) N2 (g) + 3 H2 (g)  2 NH3 (g) Kc = [(NH3)2] / [N2][(H2)3]

c) H2 (g) + I2 (g)  2 HI (g) Kc = [(HI)2] / [H2][I2]

d) PCl5 (g)  PCl3 (g) + Cl2 (g) Kc = [PCl3][Cl2] / [PCl5]

e) SO2 (g) + ½ O2 (g)  SO3 (g) Kc = [SO3] / [SO2][(O2)1/2]

1. 2 K3PO4(aq) + 3 Ca(NO3)2(aq)  6 KNO3(aq) + Ca3(PO4)2(s) Kc = 
2. Arrange the reactions in order of their increasing tendency to proceed toward completion: \_B\_ \_C\_ \_D\_ \_A\_

(a) 4NH3(g) + 3O2(g)  2N2(g) + 6H2O(g) Kc = 1 x 10228

(b) N2(g) + O2(g)  2NO(g) Kc = 5 x 10-31

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c) O2 is added to the reaction Towards Reactants Towards Products

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N2 (*g*) + 3H2 (*g*) ⮀ 2NH3 (*g*) + 22 kcal

a) NH3 is added b) heat is removed c) H2 is added

Towards reactants Towards products Towards products

1. Using the Ka or pKa values, rank the acids in order from strongest (1) to weakest (2) acid.

|  |  |  |  |
| --- | --- | --- | --- |
| **Acid** | **Ka** | **pKa** | **Rank** |
| Benzoic acid | 6.3 x 10-5 | 4.2 | 3 |
| Trichloroacetic acid | 2.3 x 10-1 | 0.64 | 1 |
| Acetic acid | 1.8 x 10-5 | 4.8 | 4 |
| Citric acid | 8.7 x 10-4 | 3.1 | 2 |
| Phenol | 1.0 x 10-10 | 10 | 5 |

1. For the following reaction: CH3CO2H + H2O ⮀ CH3CO2- + H3O+

a) Identify which reactant is the acid and which is the base.

Acid = CH3CO2H, Base = H2O

b) Identify the conjugate acid and conjugate base.

Conjugate acid = H3O+, Conjugate base = CH3CO2-

c) Write the equilibrium expression for the reaction.

Ka = [CH3CO2-][H3O+]/[CH3CO2H]

d) Ka = 1.8 x 10-5 for CH3CO2H. Does the equilibrium favor reactants or products ?

e) Could you make a buffer with CH3CO2H? If so, what would you add besides CH3CO2H and H2O?

Yes, CH3CO2H is a weak acid, so can be used to make a buffer. You would need to add a salt that contains its conjugate base, such as NaCH3CO2.