KEY

Practice – Equilibrium Constants

1.) What are the concentrations of hydronium and hydroxide in pure water?

Answer - $K_w = [H_3O^+][OH^-]$ $K_w = [x][x]$ $1.00 \times 10^{-14} = x^2$

$x = 1.00 \times 10^{-7}\ M$ $[OH^-] = 1.00 \times 10^{-7} M$ $[H_3O^+] = 1.00 \times 10^{-7} M$

2.) When water is heated;

a.) What happens to the $[H_3O^+]$?

Answer – increases (remember Le Chatelier). $H^+_{(aq)} + OH^-_{(aq)} \rightleftharpoons H_2O_{(l)} + 59\ J$

b.) Is this hot water acidic, basic, or neutral?

Answer – neutral. Both the $[H_3O^+]$ and $[OH^-]$ increase equally keeping water neutral.

c.) What happens o the K_w when the water is heated?

Answer – increases.

3.) Determine what the $[H_3O^+]$ and $[OH^-]$ in the following solutions.

a.) $4.0\ M$ HCl

$K_w = [H_3O^+][OH^-]$ $1.00 \times 10^{-14} = [4.0][x]$

$x = 2.5 \times 10^{-15}\ M$

$[OH^-] = 2.5 \times 10^{-15}\ M$ $[H_3O^+] = 4.0\ M$

b.) $8.0\ M$ $Mg(OH)_2$

$K_w = [H_3O^+][OH^-]$ $1.00 \times 10^{-14} = [x][8.0]$

$x = 1.25 \times 10^{-15}\ M$

$[OH^-] = 8.0\ M$ $[H_3O^+] = 1.25 \times 10^{-15}\ M$

c.) $0.0050\ M$ H_2SO_4

$K_w = [H_3O^+][OH^-]$ $1.00 \times 10^{-14} = [0.0050][x]$

$x = 2.0 \times 10^{-12}\ M$

$[OH^-] = 2.0 \times 10^{-12}\ M$ $[H_3O^+] = 5.0 \times 10^{-3}\ M$

d.) $0.15\ M$ NaOH

$K_w = [H_3O^+][OH^-]$ $1.00 \times 10^{-14} = [x][0.15]$

$x = 2.5 \times 10^{-15}\ M$

$[OH^-] = 0.15\ M$ $[H_3O^+] = 6.7 \times 10^{-14}\ M$

4.) Write the acid ionization constant expression for the below reactions when the chemical is acting as an acid with water.

a.) HF Answer - $K_a = \frac{[F^-][H_3O^+]}{[HF]}$

b.) HPO_4^{-2} Answer - $K_a = \frac{[PO_4^{-3}][H_3O^+]}{[HPO_4^{-2}]}$

c.) HIO_3 Answer - $K_a = \frac{[IO_3^-][H_3O^+]}{[HIO_3]}$

5.) Write the base ionization constant expression for the below reactions when the chemical is acting as a base with water.

a.) CN^- Answer - $K_b = \frac{[HCN][OH^-]}{[CN^-]}$

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b.) $HC_2O_4^-$ Answer – $K_b = \frac{[H_2C_2O_4][OH^-]}{[HC_2O_4^-]}$

c.) CH_3NH_2 Answer – $K_b = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]}$

6.) Calculate the K_b for the following bases.

a.) SO_4^{-2} $K_a \times K_b = K_w$ $2.0 \times 10^{-2} \times K_b = 1.00 \times 10^{-14}$ $K_b = 5.0 \times 10^{-13}$

b.) HS^- $K_a \times K_b = K_w$ $9.1 \times 10^{-8} \times K_b = 1.00 \times 10^{-14}$ $K_b = 1.1 \times 10^{-7}$

c.) HCO_3^- $K_a \times K_b = K_w$ $4.3 \times 10^{-7} \times K_b = 1.00 \times 10^{-14}$ $K_b = 2.3 \times 10^{-8}$

d.) HO_2^- $K_a \times K_b = K_w$ $2.4 \times 10^{-12} \times K_b = 1.00 \times 10^{-14}$ $K_b = 4.2 \times 10^{-3}$

e.) $C_6H_5COO^-$ $K_a \times K_b = K_w$ $6.5 \times 10^{-5} \times K_b = 1.00 \times 10^{-14}$ $K_b = 1.5 \times 10^{-10}$

f.) $C_2O_4^{-2}$ $K_a \times K_b = K_w$ $6.4 \times 10^{-5} \times K_b = 1.00 \times 10^{-14}$ $K_b = 1.6 \times 10^{-10}$

7.) If $K_b = 1.7 \times 10^{-6}$ for N_2H_4, what is the K_a for $N_2H_5^+$?

Answer – $K_a \times K_b = K_w$ $K_a \times 1.7 \times 10^{-6} = 1.00 \times 10^{-14}$ $K_b = 5.9 \times 10^{-9}$

8.) If a substance has a $K_b = 2.0 \times 10^{-10}$, is the substance a weak acid, weak base, strong acid, or a strong base? Explain.

Answer – Weak base. Strong acids and bases completely ionize and have no K_a/K_b value and since the k_b is given it must act as a base.

9.) Write the acid/base equilibrium that would occur for the following pairs, including labels for the acid/base conjugate pairs.

a.) CO_3^{-2} and HF Answer – $CO_3^{-2} + HF \leftrightarrow HCO_3^- + F^-$

b.) H_3PO_4 or HS^- Answer – $H_3PO_4 + HS^- \leftrightarrow H_2PO_4^- + H_2S$

c.) HSO_3^- or OH^- Answer – $HSO_3^- + OH^- \leftrightarrow SO_3^{-2} + H_2O$

d.) HCOOH or CN^- Answer – $HCOOH + CN^- \leftrightarrow HCOO^- + HCN$

10.) Are reactants or products favoured in the following equilibrium equations?

a.) $H_2S + NH_3 \rightleftharpoons HS^- + NH_4^+$ products

b.) $H_2PO_4^- + HS^- \rightleftharpoons HPO_4^{-2} + H_2S$ reactants

c.) $H_2O_2 + SO_3^{-2} \rightleftharpoons HO_2^- + HSO_3^-$ reactants

d.) $CH_3COOH + PO_4^{-3} \rightleftharpoons CH_3COO^- + HPO_4^{-2}$ products

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11.) Write the equilibrium reactions when the following are put into water, and predict if reactants or products are favoured.

a.) HSO_4^- and NO_2^- Answer – $HSO_4^- + NO_2^- \leftrightarrow SO_4^{-2} + HNO_2$ products

b.) H_3PO_4 and HPO_4^{-2} Answer – $H_3PO_4 + HPO_4^{-2} \leftrightarrow H_2PO_4^- + H_2PO_4^-$ products

c.) HCO_3^- and HSO_3^- Answer – $HCO_3^- + HSO_3^- \leftrightarrow SO_3^{-2} + H_2CO_3$ reactants

d.) HSO_3^- and $HC_2O_4^-$ Answer – $HSO_3^- + HC_2O_4^- \leftrightarrow C_2O_4^{-2} + H_2SO_3$ reactants

e.) $(NH_4)_2CO_3$ Answer – $(NH_4)_2CO_3 \rightarrow 2\ NH_4^+ + CO_3^{-2}$ (salts)

$NH_4^+ + CO_3^{-2} \leftrightarrow NH_3 + HCO_3^-$ products

12.) $K_{eq} = 14$ at equilibrium. $H_2Te + HSe^- \rightleftharpoons HTe^- + H_2Se$

a.) Which acid is stronger? Answer – H_2Te

b.) Which base is stronger? Answer – HSe^-

c.) From your previous answers, fill in the blanks below with the following terms: Stronger acid, weaker acid, Stronger base, weaker base.

__Stronger acid__ + __Stronger base__ ⇌ __weaker base__ + __weaker acid__

13.) $HOI + H_2GeO_4^- \rightleftharpoons OI^- + H_3GeO_4$; $K_{eq} = 8.8 \times 10^{-3}$ $HOI < H_3GeO_4$

$HOCl + OBr^- \rightleftharpoons OCl^- + HOBr$; $K_{eq} = 14$ $HOCl > HOBr$

$HOBr + H_2GeO_4^- \rightleftharpoons OBr^- + H_3GeO_4$; $K_{eq} = 7.9 \times 10^2$ $HOBr > H_3GeO_4$

Arrange the four acids from strongest to weakest.

__HOCl__, __HOBr__, __H_3GeO_4__, __HOI__

14.) Three different acids are: H_2SO_3, H_3PO_4, and HCOOH. Which would form an equilibrium with F^- in which the reactants are favoured? Explain.

Answer – $H_2SO_3 + F^- \leftrightarrow HSO_3^- + HF$

$H_3PO_4 + F^- \leftrightarrow H_2PO_4^- + HF$

$HCOOH + F^- \leftrightarrow HCOO^- + HF$ HF is a stronger acid than HCOOH ∴ so favours reactants!