P G6 Salt Hydrolysis Name______________________________Per___

$$HA \leftrightharpoons H^+ + A^-$$

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

Really useful information

$$B + H_2O \leftrightharpoons OH^- + HB^+$$

$$K_b = \frac{[OH^-][HB^+]}{[B]}$$

Strong Acids

HCl	HNO_3
HBr	H_2SO_4
HI	$HClO_4$
	$HClO_3$

$$K_w = [H^+][OH^-]$$

$$K_a \times K_b = K_w$$

$$M \times V = M \times V$$

Equilibrium Konstants

K_a or K_b as appropriate for the listed substance.

HCN	$K_a = 4.9 \times 10^{-10}$
HF	$K_a = 3.5 \times 10^{-4}$
$HC_2H_3O_2$	$K_a = 1.8 \times 10^{-5}$
Al^{3+}	$K_a = 1.5 \times 10^{-5}$
NH_3	$K_b = 1.8 \times 10^{-5}$
$(C_2H_5)_2NH$	$K_b = 1.3 \times 10^{-3}$

Strong Bases

LiOH	CsOH
NaOH	$Ca(OH)_2$
KOH	$Sr(OH)_2$
RbOH	$Ba(OH)_2$

1. Which of the following salts, when dissolved in water, at 25ºC, cause a change in pH? If there is a pH change, will the pH be above or below 7? Write a hydrolysis reaction that illustrates the cause of the pH change. Calculate the pH if 2.0 g of the salt is dissolved to make 100 ml of solution.

   a. barium chloride, $BaCl_2$ (208.2 g/mol) Acidic, Basic or Neutral?

   b. ammonium perchlorate, NH_4ClO_4(117.492 g/mol) Acidic, Basic or Neutral?

   c. sodium cyanide, NaCN (49.01 g/mol) Acidic, Basic or Neutral?

   d. ammonium nitrate, NH_4NO_3 (80.052 g/mol) Acidic, Basic or Neutral?

   e. potassium acetate, $KC_2H_3O_2$ (98.144 g/mol) Acidic, Basic or Neutral?

   f. diethylamide bromide, $(C_2H_5)_2NH_2Br$ (154.046 g/mol) Acidic, Basic or Neutral?

   g. aluminum perchlorate, $Al(ClO_4)_3$ (325.33 g/mol) Acidic, Basic or Neutral?

P G6 Salt Hydrolysis *ANSWERS*

1. Which of the following salts, when dissolved in water, at 25ºC, cause a change in pH? If there is a pH change, will the pH be above or below 7? Write a hydrolysis reaction that illustrates the cause of the pH change. Calculate the pH if 2.0 g of the salt is dissolved in 100 ml of water.

   a. barium chloride, $BaCl_2$ (208.2 g/mol)

pH will remain at 7. $BaCl_2 \rightarrow Ba^{2+} + 2\,Cl^-$ (note the single arrow since $BaCl_2$ is a soluble ionic compound). The Ba^{2+} ions are "pathetic" meaning they do not hydrolyze in water and thus do not produce any extra H^+ or OH^- ions. The Cl^- ions are also "pathetic" meaning they do not hydrolyze in water and thus do not produce any extra H^+ or OH^- ions.

   b. ammonium perchlorate, NH_4ClO_4 (117.492 g/mol)

pH will change to below 7, acidic. $NH_4ClO_3 \rightarrow NH_4^+ + ClO_3^-$ (note the single arrow since NH_4ClO_3 is a soluble ionic compound) The ClO_3^- ions are are "pathetic" meaning they do not hydrolyze in water and thus do not produce any extra H^+ or OH^- ions. But the NH_4^+ ions are a conjugate WA and partially dissociate in water and produce H^+ ions. $NH_4^+ \leftrightharpoons H^+ + NH_3$

$$2g\times\frac{1mol}{117.492\text{ g}} = 0.017\text{ mol} \qquad \frac{0.017\text{ mol}}{0.1L} = 0.17\text{ M} \qquad K_a\times K_b = K_w \qquad \frac{1\times10^{-14}}{1.8\times10^{-5}} = 5.56\times10^{-10} \qquad K_b = \frac{\left[H^+\right]\left[NH_3\right]}{\left[NH_4^+\right]}$$

$$5.56\times10^{-10} = \frac{x^2}{[0.17\text{ M}]} \qquad x = \left[H^+\right] = 9.7\times10^{-6} \qquad pH = 5.01$$

   c. sodium cyanide, NaCN (49.01 g/mol)

pH will change to above 7, basic. $NaCN \rightarrow Na^+ + CN^-$ (note the single arrow since NaCN is a soluble ionic compound) The Na^+ ions are "pathetic" meaning they do not hydrolyze in water and thus do not produce any extra H^+ or OH^- ions. But the CN^- ions are a conjugate WB which hydrolyzes in water and produces extra OH^- ions. $CN^- + H_2O \leftrightharpoons OH^- + HCN$

$$2g\times\frac{1mol}{49.01g} = 0.0408mol \qquad \frac{0.0408mol}{0.1L} = 0.408M \qquad K_a\times K_b = K_w \qquad \frac{1\times10^{-14}}{3.5\times10^{-4}} = 2.9\times10^{-11} \qquad K_b = \frac{\left[OH^-\right]\left[HCN\right]}{\left[CN^-\right]}$$

$$2.9\times10^{-11} = \frac{x^2}{\left[0.408\right]} \qquad x = \left[OH^-\right] = 3.4\times10^{-6} \qquad pOH = 5.47 \qquad pH = 8.53$$

   d. ammonium nitrate, NH_4NO_3 (80.052 g/mol)

pH will change to below 7, acidic. $NH_4NO_3 \rightarrow NH_4^+ + NO_3^-$ (note the single arrow since NH_4NO_3 is a soluble ionic compound) The NO_3^- ions are are "pathetic" meaning they do not hydrolyze in water and thus do not produce any extra H^+ or OH^- ions. But the NH_4^+ ions are a conjugate WA and partially dissociate in water and produce H^+ ions. $NH_4^+ \leftrightharpoons H^+ + NH_3$

$$2g\times\frac{1mol}{80.052g} = 0.025mol \qquad \frac{0.025mol}{0.1L} = 0.250M \qquad K_a\times K_b = K_w \qquad \frac{1\times10^{-14}}{1.8\times10^{-5}} = 5.56\times10^{-10} \qquad K_b = \frac{\left[H^+\right]\left[NH_3\right]}{\left[NH_4^+\right]}$$

$$5.56\times10^{-10} = \frac{x^2}{\left[0.25\right]} \qquad x = \left[H^+\right] = 1.2\times10^{-5} \qquad pH = 4.93$$

e. potassium acetate, $KC_2H_3O_2$ (98.144 g/mol)

pH will change to above 7, basic. $KC_2H_3O_2 \rightarrow K^+ + C_2H_3O_2^-$ (note the single arrow since $KC_2H_3O_2$ is a soluble ionic compound) The K^+ ions are "pathetic" meaning they do not hydrolyze in water and thus do not produce any extra H^+ or OH^- ions. But the $C_2H_3O_2^-$ ions are a conjugate WB which hydrolyzes in water and produces extra OH^- ions.

$C_2H_3O_2^- + H_2O \leftrightharpoons OH^- + HC_2H_3O_2$

$$2g \times \frac{1 mol}{98.144 g} = 0.0204 mol \quad \frac{0.0204 mol}{0.1 L} = 0.204 M \quad K_a \times K_b = K_w \quad \frac{1\times10^{-14}}{1.8\times10^{-5}} = 5.56\times10^{-10} \quad K_b = \frac{\left[OH^-\right]\left[HC_2H_3O_2\right]}{\left[C_2H_3O_2^-\right]}$$

$$5.56\times10^{-10} = \frac{x^2}{[0.204]} \quad x = \left[OH^-\right] = 1.1\times10^{-5} \quad pOH = 4.97 \quad pH = 9.03$$

f. diethylamide bromide, $(C_2H_5)_2NH_2Br$ (154.046 g/mol)

pH will change to below 7, acidic. $(C_2H_5)_2NH_2Br \rightarrow (C_2H_5)_2NH_2^+ + Br^-$ (note the single arrow since $(C_2H_5)_2NH_2Br$ is a soluble ionic compound, you should be able to recognize this because of the Br^- at the end of the molecule and the acid/base context of the question) The Br^- ions are are "pathetic" meaning they do not hydrolyze in water and thus do not produce any extra H^+ or OH^- ions. But the $(C_2H_5)_2NH_2^+$ ions partially dissociate in water and produce H^+ ions.

$(C_2H_5)_2NH_2^+ \leftrightharpoons H^+ + (C_2H_5)_2NH$

$$2g \times \frac{1 mol}{154.046 g} = 0.013 mol \quad \frac{0.013 mol}{0.1 L} = 0.130 M \quad K_a \times K_b = K_w \quad \frac{1\times10^{-14}}{1.3\times10^{-3}} = 7.69\times10^{-12} \quad K_a = \frac{\left[H^+\right]\left[(C_2H_5)_2NH\right]}{\left[(C_2H_5)_2NH_2^+\right]}$$

$$7.69\times10^{-12} = \frac{x^2}{[0.130]} \quad x = \left[H^+\right] = 9.99\times10^{-7} \quad pH = 6.00$$

g. aluminum perchlorate, $Al(ClO_4)_3$ (325.33 g/mol)

pH will change to below 7, acidic. $Al(ClO_4)_3 \rightarrow Al^{3+} + ClO_4^-$ (note the single arrow since ClO_4 is a soluble ionic compound, you should be able to recognize this because of the ClO_4^- at the end and the acid/base context) The Al^{3+} ions interact with water and produce H^+ ions. But the ClO_4^- ions are are "pathetic" meaning they do not hydrolyze in water and thus do not produce any extra H^+ or OH^- ions. ($Al(H_2O)_6^{3+} \leftrightharpoons Al(H_2O)_5(OH)^{2+} + H^+$ *(Note: You would never have to write this equation.)*)

$$2g \times \frac{1 mol}{325.33 g} = 0.00615 mol \quad \frac{0.00615 mol}{0.1 L} = 0.0615 M$$

$$K_a = \frac{\left[H^+\right]\left[Al(OH)^{2+}\right]}{\left[Al^{3+}\right]} 1.5\times10^{-5} = \frac{x^2}{[0.0615]} \quad x = \left[H^+\right] = 9.6\times10^{-4} \quad pH = 3.02$$