Name _____

No calculators are permitted in answering the following:

1. (10 pts) Label the following compounds as soluble (S) or insoluble (I) in water:

   a) $Mg_3(PO_4)_2$ I

   b) $Zn(ClO_3)_2$ S

   c) Hg_2I_2 I

   d) $Cu(OH)_2$ I

   e) $Ca(CH_3CO_2)_2$ S

2. (6 pts) Write the chemical formulas of the six strong acids:

   i) HCl

   ii) HBr

   iii) HI

   iv) HNO_3

   v) H_2SO_4

   vi) $HClO_4$

Turn in this portion of the exam.

Name _____

You are now permitted to use calculators.

3. (21 pts) Complete and balance the following reactions, then give the net ionic equation and indicate the spectator ions.

a) _____ $Pb(NO_3)_2(aq)$ + __2__ $NH_4I(aq)$ → $PbI_2(s) + 2\ NH_4NO_3(aq)$

Net Ionic: $Pb^{2+}_{(aq)} + 2\ I^-_{(aq)} \longrightarrow PbI_2(s)$

Spectator Ions: $NH_4^+\ NO_3^-$

b) _____ $CuCO_3(s)$ + __2__ $HNO_3(aq)$ → $H_2CO_3(aq) + Cu(NO_3)_2(aq)$
↳ $H_2O(l) + CO_2(g)$

$CuCO_3(s) + 2\ HNO_3(aq) \longrightarrow H_2O(l) + CO_2(g) + Cu(NO_3)_2(aq)$

Net Ionic:

$CuCO_3(s) + 2\ H^+_{(aq)} \rightarrow H_2O(l) + CO_2(g) + Cu^{2+}_{(aq)}$

Spectator Ions:

NO_3^-

c) _____ $HClO_4(aq)$ + _____ $NH_4OH(aq)$ → $H_2O(l) + NH_4ClO_4(aq)$

Net Ionic: $H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O(l)$

Spectator Ions:

$NH_4^+\ ClO_4^-$

4. (10 pts) Terephthalic acid is an important chemical used in the manufacture of polyesters and plasticizers. It contains only carbon, hydrogen, and oxygen. Combustion of 19.81 mg of terephthalic acid produced 41.98 mg CO_2 and 6.45 mg H_2O. What is the empirical formula of terephthalic acid?

$$(41.98\text{ mg } CO_2)\left(\frac{1\text{ g}}{1000\text{ mg}}\right)\left(\frac{\text{mol } CO_2}{44\text{ g}}\right)\left(\frac{\text{mol C}}{\text{mol } CO_2}\right)\left(\frac{12.011\text{ g}}{\text{mol C}}\right) = .0115\text{ g C}$$

$$= .000954\text{ mol C}$$

$$(6.45\text{ mg } H_2O)\left(\frac{1\text{ g}}{1000\text{ mg}}\right)\left(\frac{\text{mol } H_2O}{18\text{ g}}\right)\left(\frac{2\text{ mol H}}{\text{mol } H_2O}\right)\left(\frac{1.0079\text{ g H}}{\text{mol H}}\right) = .000773\text{ g H}$$

$$= .000717\text{ mol H}$$

$$.01981\text{ g C+H+O}$$
$$-.0115\text{ g C}$$
$$-.000773\text{ g H}$$
$$.007537\text{ g O}\quad\left(\frac{\text{mol O}}{16\text{ g}}\right) = .000471\text{ mol O}$$

$$C_{\frac{.000954}{.000471}}\ H_{\frac{.000717}{.000471}}\ O_{\frac{.000471}{.000471}}$$

$$C_2H_{1.5}O_1 \Longrightarrow \boxed{C_4H_3O_2}$$

5. (18 pts) Zinc is found in nature in the form of the mineral sphalerite (ZnS). A step in the smelting of zinc is the roasting of sphalerite with oxygen to produce zinc oxide:

$$2\ ZnS(s) + 3\ O_2(g) \rightarrow 2\ ZnO(s) + 2\ SO_2(g)$$

a) Use the following table to determine $\Delta H°$ for this reaction.

compound	ΔH_f° (kJ/mol)
ZnS(s)	–205.98
ZnO(s)	–348.28
$SO_2(g)$	–296.83

$$\left[2(-348.28) + 2(-296.83)\right] - 2\left[-205.98 + 3(0)\right]$$

$$= -878.26\ kJ$$

b) Imagine all the heat from this reaction could be used to heat a beaker of water. How many grams of sphalerite would be required to raise the temperature of 100.0 mL of water from 25.0°C to 75.0°C?

$$\text{heat needed} = c \cdot m \cdot \Delta T$$

$$= \left(4.184\ J/g \cdot K\right)(100.0\ g)(50.0\ K)$$

$$= 20920\ J = 20.9_2\ kJ$$

$$(20.9_2\ kJ)\left(\frac{2\ mol}{878.26\ kJ}\right)\left(\frac{97.46\ g}{1\ mol}\right) = \boxed{4.64\ g}$$

6. (12 pts) An 11.31-g sample of ethanol, C_2H_5OH, is reacted with 13.48 g of phosphorus trichloride, PCl_3. The products of the reaction are chloroethane, C_2H_5Cl, and phosphorous acid, H_3PO_3.

a) Write a balanced equation for this reaction.

$$3\,C_2H_5OH + PCl_3 \rightarrow 3\,C_2H_5Cl + H_3PO_3$$

C_2H_5OH: 46.07 g/mol; PCl_3: 137.3 g/mol; C_2H_5Cl: 64.514 g/mol

b) What is the percent yield if 12.4 g of chloroethane are produced?

$$(11.31\text{ g } C_2H_5OH)\left(\frac{1\text{ mol } C_2H_5OH}{46.07\text{ g}}\right)\left(\frac{3\text{ mol } C_2H_5Cl}{3\text{ mol } C_2H_5OH}\right)\left(\frac{64.514\text{ g}}{\text{mol}}\right)$$

$$= 15.84\text{ g}$$

$$(13.48\text{ g } PCl_3)\left(\frac{1\text{ mol } PCl_3}{137.3\text{ g}}\right)\left(\frac{3\text{ mol } C_2H_5Cl}{1\text{ mol } PCl_3}\right)\left(\frac{64.514\text{ g}}{\text{mol}}\right)$$

$$= 19.00\text{ g}$$

$\Rightarrow C_2H_5OH$ is limiting

$$\frac{12.4}{15.84} \times 100 = \boxed{78.3\%}$$

7. (8 pts) A 1.00-g sample of an unknown acid is dissolved to make 100.0 mL of solution and titrated with 0.250 M NaOH. It required 86.9 mL of NaOH to reach the endpoint of the titration. Assuming that the acid has only one acidic hydrogen per molecule, compute the formula mass of the acid.

acid = HA

$$HA + NaOH \rightarrow H_2O + NaA$$

$$\text{mol } HA = \text{mol } NaOH = M \cdot V = (.250\,M)(.0869\,L)$$

$$= .0217\text{ mol } HA$$

$$\frac{1.00\text{ g } HA}{.0217\text{ mol } HA} = \boxed{46.0\text{ g/mol}}$$

8. ~~(11~~ 12 pts) Calculate the enthalpy change for the reaction:

$$BrCl(g) \rightarrow Br(g) + Cl(g) \qquad \Delta H = ?$$

by using the following data:

1	$Br_2(\ell) \rightarrow Br_2(g)$	$\Delta H_1 = +30.91$ kJ
2	$Br_2(g) \rightarrow 2\ Br(g)$	$\Delta H_2 = +192.9$ kJ
3	$Cl_2(g) \rightarrow 2\ Cl(g)$	$\Delta H_3 = +243.4$ kJ
4	$Br_2(\ell) + Cl_2(g) \rightarrow 2\ BrCl(g)$	$\Delta H_4 = +29.2$ kJ

$-\frac{1}{2}$ Rxn 4: $BrCl(g) \longrightarrow \frac{1}{2}Br_2(\ell) + \frac{1}{2}Cl_2(g)$

$+\frac{1}{2}$ Rxn 3: $\frac{1}{2}Cl_2(g) \longrightarrow Cl(g)$

$+\frac{1}{2}$ Rxn 2: $\frac{1}{2}Br_2(g) \longrightarrow Br(g)$

$+\frac{1}{2}$ Rxn 1: $\frac{1}{2}Br_2(\ell) \rightarrow \frac{1}{2}Br_2(g)$

$$BrCl(g) \longrightarrow Br(g) + Cl(g)$$

$$\Delta H = -\tfrac{1}{2}\Delta H_4 + \tfrac{1}{2}\Delta H_3 + \tfrac{1}{2}\Delta H_2 + \tfrac{1}{2}\Delta H_1$$

$$= -\tfrac{1}{2}(29.2) + \tfrac{1}{2}(243.4) + \tfrac{1}{2}(192.9) + \tfrac{1}{2}(30.91)$$

$$= \boxed{+219.0 \text{ kJ}}$$

Would you expect this reaction to be product-favored or reactant-favored? Why?

reactant-favored.

Most reactant-favored reactions are endothermic.

9. (20 pts) A 1.00-g sample of NaCl and a 0.500-g sample of $MgCl_2$ are mixed together, dissolved in water, and diluted to a final volume of 100.0 mL.

a) What is the concentration of sodium ion, in mol/L, in the final solution?

$$(1.00\text{ g NaCl})\left(\frac{1\text{ mol NaCl}}{58.44\text{ g}}\right) = .01711\text{ mol NaCl}$$

$$= .01711\text{ mol Na}^+$$

$$[Na^+] = \frac{.01711\text{ mol}}{.1000\text{ L}} = \boxed{0.171\text{ M Na}^+}$$

b) What is the concentration of chloride ion, in mol/L, in the final solution?

From NaCl: .01711 mol Cl^-

From $MgCl_2$:

$$(0.500\text{ g } MgCl_2)\left(\frac{1\text{ mol } MgCl_2}{95.21\text{ g}}\right)\left(\frac{2\text{ mol } Cl^-}{\text{mol } MgCl_2}\right)$$

$$= .0105\text{ mol } Cl^-$$

$$\Rightarrow [Cl^-] = \frac{.01711 + .0105}{.1000\text{ L}} = \boxed{0.276\text{ M } Cl^-}$$

c) Imagine that 20.00 mL of the solution are pipetted into a separate flask and diluted to a final volume of 50.00 mL. What is the concentration of sodium ion, in mol/L, in this new solution?

$$M_1V_1 = M_2V_2$$

$$(.171\text{ M})(.02000\text{ L}) = M_2(.05000\text{ L})$$

$$M_2 = \boxed{0.0684\text{ M}}$$

10. (10 pts) In lab you determined that the heat of neutralization of HCl(aq) and NaOH(aq) is around –55.9 kJ per mole of H_2O produced. If 50.00 mL of 2.00 M HCl at 30.6°C is added to 51.00 mL of 2.00 M NaOH at 30.6°C in a coffee-cup calorimeter, what will the highest temperature of the resulting mixture be after the reaction has occurred? (Assume the mixture has a heat capacity of 3.89 J/g·K a density of 1.04 g/mL.)

$$HCl + NaOH \rightarrow NaCl + H_2O$$

mol HCl = M·V = (2.00 M)(.05000 L) = .100 mol HCl

mol NaOH = M·V = (2.00 M)(.05100 L) = .102 mol NaOH

$$(.100 \text{ mol HCl})\left(\frac{55.9 \text{ kJ}}{\text{mol}}\right) = 5.59 \text{ kJ}$$

$$\times 1000 = 5.59 \times 10^3 \text{ J}$$

heat = c · m · ΔT

$$5.59 \times 10^3 \text{ J} = \left(3.89 \frac{\text{J}}{\text{g}\cdot\text{°C}}\right)(101 \text{ mL})\left(\frac{1.04 \text{ g}}{\text{mL}}\right)\Delta T$$

$$\Delta T = 13.7$$

$$\Rightarrow T_f = 30.6 + 13.7 = \boxed{44.3\text{°C}}$$

Remember to consider the pledge!!