PLI #8 Worksheet
Monday, 14 June 2021

1. **Suppose a piece of iron (specific heat capacity = 0.449 J/g*K) with a mass of 21.5 g at a temperature of 100.0°C is dropped into an insulated container of water. The mass of the water is 132.0 g and its temperature before adding the iron is 20.0°C. What will be the final temperature of the system once thermal equilibrium is reached? (specific heat capacity of water = 4.184 J/g*K)**

$$q_{Fe} + q_{H_2O} = 0$$

$$q_{Fe} = -q_{H_2O}$$

$$(21.5\ g)\left(0.449 \frac{J}{g\ ^\circ\mathrm{C}}\right)(\Delta T) = -\left[(132.0\ g)\left(4.184 \frac{J}{g\ ^\circ\mathrm{C}}\right)(\Delta T)\right]$$

$$(21.5\ g)\left(0.449 \frac{J}{g\ ^\circ\mathrm{C}}\right)(T_f - 100.0^\circ\mathrm{C}) = -\left[(132.0\ g)\left(4.184 \frac{J}{g\ ^\circ\mathrm{C}}\right)(Tf - 20.0^\circ\mathrm{C})\right]$$

$$9.6535T_f - 965.35 = -552.288T_f + 11045.76$$

$$561.9415T_f = 12011.11$$

$$T_f = 21.4^\circ\mathrm{C}$$

2. **What mass of ice can be melted with the same quantity of heat as required to raise the temperature of 3.50 mol H 2 O (l) by 50.0˚C? ($\Delta_H$fusion for H_2O (s) = 6.01 kJ mol^{-1})**

First, find the amount of energy needed to raise the temperature of liquid water.

$$q = mc\Delta T$$

$$3.50\ mol\ H_2O * \frac{18.02\ g\ H_2O}{1\ mol\ H_2O} = 63.07\ g\ H_2O$$

$$q = (63.07\ g)\left(4.184\frac{J}{g℃}\right)(50.0\ ℃) = 13194.244\ J$$

$$13194.244\ J * \frac{1\ mol\ H_2O}{6010\ J} * \frac{18.02\ g\ H_2O}{1\ mol\ H_2O} = 39.6\ g\ H_2O$$

3. **Menthol, the substance we can smell in mentholated cough drops, is composed of C, H, and O. A 0.1005-g sample of menthol is combusted, producing 0.2829 g of CO_2 and 0.1159 g of H_2O. What is the empirical formula for menthol? If menthol has a molar mass of 156 g/mol, what is its molecular formula?**

$$0.1159\ g\ H_2O * \frac{1\ mol\ H_2O}{18.02\ g\ H_2O} * \frac{2\ mol\ H}{1\ mol\ H_2O} = 0.01286\ mol\ H * \frac{1.008\ g\ H}{1\ mol\ H}$$
$$= 0.01297\ g\ H$$

$$0.2829\ g\ CO_2 * \frac{1\ mol\ CO_2}{44.01\ g\ CO_2} * \frac{1\ mol\ C}{1\ mol\ CO_2} = 0.006428\ mol\ C * \frac{12.011\ g\ C}{1\ mol\ C}$$
$$= 0.07721\ g\ C$$

$$Mass\ O = Mass\ sample - Mass\ C - Mass\ H = 0.1005\ g - 0.07721\ g - 0.01297\ g$$
$$= 0.01032\ g\ O$$

$$0.01032\ g\ O * \frac{1\ mol\ O}{15.9994\ g\ O} = 0.000645\ mol\ O$$

Take mole ratios to find empirical formula!

$$C: \frac{0.006428}{0.000645} = 10$$

$$H: \frac{0.01286}{0.000645} = 20$$

$$O: \frac{0.000645}{0.000645} = 1$$

Empirical formula: $C_{10}H_{20}O$

$$\frac{Molar\ mass}{Empirical\ formula\ mass} = \frac{156\frac{g}{mol}}{156\frac{g}{mol}} = 1$$

Molecular formula: $C_{10}H_{20}O$

4. **It takes 83 mL of a 0.45 M NaOH solution to neutralize 235 mL of an HCl solution. What is the concentration of the HCl solution?**

Always write the balanced equation first!

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

$$\frac{0.45\ mol\ NaOH}{1\ L} * 0.083\ L = 0.03735\ mol\ NaOH * \frac{1\ mol\ OH^-}{1\ mol\ NaOH} * \frac{1\ mol\ HCl}{1\ mol\ OH^-}$$
$$= 0.03735\ mol\ HCl$$

0.03735 mol of HCl was neutralized.

$$[HCl] = \frac{0.037535\ mol\ HCl}{0.235\ L} = 0.16\ M$$

5. **A solution of 100.0 mL of 0.200 M KOH is mixed with a solution of 200.0 mL of 0.150 M $NiSO_4$**

   a. **Write the balanced chemical equation for the reaction that occurs.**

$$NiSO_4(aq) + 2KOH(aq) \rightarrow Ni(OH)_2(s) + K_2SO_4(aq)$$

   b. **What precipitate forms? Write the net ionic equation**

Nickel hydroxide is the precipitate!

Total ionic:

$$Ni^{2+}(aq) + SO_4^{2-}(aq) + 2K^+(aq) + 2OH^-(aq) \rightarrow Ni(OH)_2(s) + 2K^+(aq) + SO_4^{2-}(aq)$$

Net ionic:

$$Ni^{2+}(aq) + 2OH^-(aq) \rightarrow Ni(OH)_2(s)$$

   c. **How many grams of this precipitate form?**

Remember to calculate the limiting reactant!

$$0.200\ M\ KOH = \frac{0.200\ mol\ KOH}{1\ L} * 0.100\ L * \frac{1\ mol\ Ni(OH)_2}{2\ mol\ KOH} = 0.01\ mol\ Ni(OH)_2$$

$$0.150\ M\ NiSO_4 = \frac{0.150\ mol\ NiSO_4}{1\ L} * 0.200\ L * \frac{1\ mol\ Ni(OH)_2}{1\ mol\ NiSO_4} = 0.03\ mol\ Ni(OH)_2$$

KOH is the limiting reactant!

$$0.01\ mol\ Ni(OH)_2 * \frac{92.71\ g\ Ni(OH)_2}{1\ mol\ Ni(OH)_2} = 0.927\ g\ Ni(OH)_2$$

d. What is the concentration of each ion that remains in solution?

OH^-: Is part of the limiting reactant, and all goes into forming the precipitate

$$[OH^-] = 0$$

K^+: Is part of the limiting reactant, but is simply a spectator ion.

$$\frac{0.200\ mol\ KOH}{1\ L} * 0.100\ L * \frac{1\ mol\ K^+}{1\ mol\ KOH} = 0.02\ mol\ K^+$$

$$[K^+] = \frac{0.02\ mol\ K^+}{0.300\ L} = 0.0667\ M$$

$NiSO_4$ is not the limiting reactant. First, with respect to SO_4^{2-}, it is a spectator ion, so its initial mole amount will equal its final mole amount.

$$0.150\ M\ NiSO_4 = \frac{0.150\ mol\ NiSO_4}{1\ L} * 0.200\ L * \frac{1\ mol\ SO_4^{2-}}{1\ mol\ NiSO_4} = 0.03\ mol\ SO_4^{2-}$$

$$[SO_4^{2-}] = \frac{0.03\ mol\ SO_4^{2-}}{0.300\ L} = 0.100\ M$$

For Ni, some of it is going into forming the precipitate, but there will be some left over. First, find out how much is being used up:

$$0.02\ mol\ KOH * \frac{1\ mol\ NiSO_4}{2\ mol\ KOH} * \frac{1\ mol\ Ni^{2+}}{1\ mol\ NiSO_4} = 0.01\ mol\ Ni^{2+}\ used\ up$$

$$0.150\ M\ NiSO_4 = \frac{0.150\ mol\ NiSO_4}{1\ L} * 0.200\ L * \frac{1\ mol\ Ni^{2+}}{1\ mol\ NiSO_4}$$
$$= 0.03\ mol\ Ni^{2+}\ initially$$

Thus, 0.02 mol remain.

$$[Ni^{2+}] = \frac{0.02\ mol\ Ni^{2+}}{0.300\ L} = 0.0667\ M$$

6.

a. **You have a stock solution of 14.8 M NH_3. How many milliliters of this solution should you dilute to make 1000.0 mL of 0.250 M NH_3?**

$$0.250\ M\ NH_3 = \frac{0.250\ mol\ NH_3}{1\ L} * 1\ L = 0.250\ mol\ NH_3\ required$$

$$0.250\ mol\ NH_3 * \frac{1\ L}{14.8\ mol\ NH_3} * \frac{1000\ mL}{1\ L} = 16.89\ mL\ for\ dilution$$

b. **If you take a 10.0-mL portion of the stock solution and dilute it to a total volume of 0.500 L, what will be the concentration of the final solution?**

First, find out how many moles you have taken out in that 10.0 mL portion.

$$\frac{14.8\ mol\ NH_3}{1\ L} * 0.01\ L = 0.148\ mol\ NH_3$$

$$Final\ solution\ concentration = \frac{0.148\ mol\ NH_3}{0.500\ L} = 0.296\ M\ NH_3$$