Advance Study Assignment

To help you formulate an experimental and computational strategy, answer the following questions

1. Write two balanced "molecular" equations, one for the reaction of aluminum with hydrochloric acid and the other for the reaction of zinc with hydrochloric acid.

$$2\,Al_{(s)} + 6\,HCl_{(aq)} \rightarrow 2\,AlCl_{3\,(aq)} + 3\,H_{2\,(g)}$$

$$Zn_{(s)} + 2\,HCl_{(aq)} \rightarrow ZnCl_{2\,(aq)} + H_{2\,(g)}$$

2. Write down the relationship between the number of moles of H_2 formed and the number of moles of Zn reacted, assuming a complete reaction. Similarly, write down the relationship between the number of moles of H_2 formed and the number of moles of Al reacted. $n_{H_2} = n_{Zn}$ $n_{H_2} = \frac{3}{2} n_{Al}$

Note that these relationships are key to this experiment.

3. Write the equation that you will use to calculate the number of moles of H_2 present in a known volume of hydrogen gas. What other variables must be known to permit this calculation? $PV = nRT$ need to also measure P and T

4. (a) A student performing this experiment on a sample of pure Zn decides that she wants to generate 150 mL of H_2 measured at a barometric pressure of 743.3 mm Hg and a temperature of 22.0°C. Calculate the mass of Zn required.

$$n = \frac{PV}{RT} = 743.3\,\text{mmHg}\left(\frac{\text{atm}}{760\,\text{mmHg}}\right)(150\,\text{mL})\left(\frac{\text{L}}{10^3\,\text{mL}}\right)\left(\frac{\text{mol K}}{0.08206\,\text{L atm}}\right)\left[\frac{1}{(22.0+273.15)\text{K}}\right]$$

$$n = 6.06\times10^{-3}\,\text{mol } H_2\left(\frac{1\,\text{mol Zn}}{\text{mol } H_2}\right)\left(\frac{65.39\,\text{g Zn}}{\text{mol Zn}}\right) = \boxed{0.40\,\text{g Zn}}$$

(150 mL has 2 sig figs)

10/29/02 I should have corrected for the vapor pressure of H_2O. According to Dalton's Law of partial pressure,

$P_{barometer} = P_{H_2} + P_{H_2O} \Rightarrow P_{H_2} = 743.3\ \text{Torr} - 19.827\ \text{Torr} = 723.473\ \text{Torr}$ (non-significant figures)

$\therefore n_{H_2} = 5.89_6\times10^{-3}$ mol

$\Rightarrow \boxed{0.39\,\text{g Zn}}$

(b) Assume the student wishes to use ten times as many moles of HCl as Zn. What volume of 6 M HCl would be required?

$$6.06\times10^{-3}\,\text{mol } H_2\left(\frac{10\,\text{mol HCl}}{1\,\text{mol } H_2}\right)\left(\frac{\text{L sol'n}}{6\,\text{mol HCl}}\right)\left(\frac{10^3\,\text{mL}}{\text{L}}\right) = \boxed{10\,\text{mL sol'n}}$$

Advance Study Assignment—continued

5. Now consider an alloy (of mass m_o) containing only aluminum and zinc. Both the Al and Zn react completely with HCl to form H_2. Derive an equation that expresses the number of moles of hydrogen gas formed as a function of the mass percent of aluminum in the alloy sample and the total mass m_o of the alloy. (Please talk with one of the Chemistry 11 instructors or the tutors at the MAX Center if you get stuck!)

If alloy were pure Al, $n_{H_2} = \frac{3}{2} n_{Al}$. If alloy were pure Zn, $n_{H_2} = n_{Zn}$.

But in general, the alloy is a mixture: $n_{H_2} = \frac{3}{2} n_{Al} + n_{Zn}$ [1]

Re-express moles in terms of masses:

$$\boxed{\text{mass \% Al} \equiv X} = \frac{\text{mass (Al)}}{m_o} \times 100 = \frac{n_{Al} \overset{\text{molar mass}}{M_{Al}}}{m_o} \times 100 \Rightarrow n_{Al} = \frac{m_o X}{100 M_{Al}} \quad [2]$$

$$\text{and mass \% Zn} \equiv y = \frac{n_{Zn} M_{Zn}}{m_o} \times 100 \Rightarrow n_{Zn} = \frac{m_o y}{100 M_{Zn}} \quad [3]$$

Substitute [2] and [3] into [1]:

$$n_{H_2} = \frac{3}{2}\left(\frac{m_o X}{100 M_{Al}}\right) + \frac{m_o y}{100 M_{Zn}} \quad \text{and} \quad y = 100 - X \quad (\text{\% Al} + \text{\% Zn} = 100\%)$$

$$\Rightarrow n_{H_2} = \frac{3}{2}\left(\frac{m_o X}{100(26.98)}\right) + \frac{m_o}{100(65.39)}(100 - X) = (5.5597 \times 10^{-4}) m_o X + 0.015293 m_o - 1.5293 \times 10^{-4} m_o X$$

6. Rearrange the equation from number 5 so that it expresses the mass percent of aluminum as a function of moles of hydrogen formed.

$$\boxed{n_{H_2} = (4.0304 \times 10^{-4}) m_o X + 0.015293 m_o}$$

$$\Downarrow$$

$$n_{H_2} - 0.015293 m_o = 4.0304 \times 10^{-4} m_o X$$

$$\boxed{X = \frac{n_{H_2} - 0.015293 m_o}{4.0304 \times 10^{-4} m_o}}$$