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.

   \[ 2 \text{Al}(s) + 6 \text{HCl}(aq) \rightarrow 2 \text{AlCl}_3(aq) + 3 \text{H}_2(g) \]

   \[ \text{Zn}(s) + 2 \text{HCl}(aq) \rightarrow \text{ZnCl}_2(aq) + \text{H}_2(g) \]

2. Write down the relationship between the number of moles of H\textsubscript{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\textsubscript{2} formed and the number of moles of Al reacted:

   \[ n_{\text{H}_2} = n_{\text{Zn}} \]

   \[ n_{\text{H}_2} = \frac{3}{2} n_{\text{Al}} \]

   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\textsubscript{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\textsubscript{2} measured at a barometric pressure of 743.3 mm Hg and a temperature of 22.0°C. Calculate the mass of Zn required.

   \[ n = \frac{PV}{RT} = \frac{743.3 \text{ mm Hg} \times (150 \text{ mL})}{360 \text{ mm Hg} \times (22.0 + 273.15 \text{ K})} \]

   \[ n = 6.06 \times 10^{-3} \text{ mol H}_2 \]

   \[ \text{P}_{\text{Zn}} = \frac{1 \text{ mol Zn}}{\text{mol H}_2} \times \left( \frac{65.39 \text{ g Zn}}{\text{mol Zn}} \right) = 0.40 \text{ g Zn} \]

   \[ \text{P}_{\text{H}_2} + \text{P}_{\text{H}_2O} = \text{P}_{\text{total}} = 743.3 \text{ Torr} - 19.82 \text{ Torr} = 723.47 \text{ Torr} \]

   (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?

   \[ 6.06 \times 10^{-3} \text{ mol H}_2 \left( \frac{10 \text{ mol HCl}}{1 \text{ mol H}_2} \right) \left( \frac{4 \text{ mL HCl}}{6 \text{ mol HCl}} \right) \left( \frac{10^3 \text{ mL}}{1} \right) = 10 \text{ mL soln} \]

   \[ n_{\text{H}_2} = 5.896 \times 10^{-3} \text{ mol} \]

   \[ \Rightarrow 0.39 \text{ g Zn} \]
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:

\[
\text{mass } 90 \text{ Al } \equiv x = \frac{\text{mass (Al)}}{m_o} \times 100 = \frac{n_{Al} M_{Al}}{m_o} \times 100 \implies n_{Al} = \frac{100 x}{M_{Al}} \quad [2]
\]

and \(\text{mass } 90 \text{ Zn } \equiv y = \frac{n_{Zn} M_{Zn}}{m_o} \times 100 \implies n_{Zn} = \frac{100 y}{M_{Zn}} \quad [3]\)


\[
n_{H_2} = \frac{3}{2} \left( \frac{m_o x}{100 M_{Al}} \right) + \frac{m_o y}{100 M_{Zn}}
\]

and \(y = 100 - x\) (70 Al + 70 Zn = 100%)

\[
\approx n_{H_2} = \frac{3}{2} \left( \frac{m_o x}{100(26.98)} \right) + \frac{m_o y}{100(65.39)} (100 - x) = (5.5597 \times 10^{-4}) m_o x + 0.015293 m_o - 1.5293 \times 10^{-4} m_o x
\]

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

\[
n_{H_2} = (4.0304 \times 10^{-4}) m_o x + 0.015293 m_o
\]

\[
\frac{n_{H_2} - 0.015293 m_o}{4.0304 \times 10^{-4} m_o}
\]

\[
\chi = \frac{\frac{n_{H_2} - 0.015293 m_o}{4.0304 \times 10^{-4} m_o}}{n_{H_2} - 0.015293 m_o} = 4.0304 \times 10^{-4} m_o x
\]