Chem 116
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Assignment 2 – Solution to Extra Problem

Rephrasing problem

- Magnesium metal (0.500 grams) reacts with sulfuric acid. Magnesium is the limiting reagent.
- Hydrogen gas is produced and captured in the inverted jar.
- Some water vapor is also in the inverted jar.
- The gas mixture in the inverted jar is at p_{total} = 752 mmHg and T = 22ºC.
- The question is: what is the total volume of gas collected? (The total volume includes both the hydrogen gas and the water vapor.)

Strategy

- Use the mass of Mg to calculate the moles of H_2 produced.
- From the temperature, it is possible to look up the vapor pressure of water.
- Since we know total pressure and also partial pressure of water vapor, we can calculate the partial pressure of hydrogen gas because $p_{total} = p_{watervapor} + p_{hydrogen}$
- Convert the temperature to Kelvin.
- There are three valid ideal gas law equations (the reason all of them use V_{total} is that gases expand to occupy all the space available to them)
    1. $p_{total}V_{total} = n_{total}RT$
    2. $p_{watervapor}V_{total} = n_{watervapor}RT$
    3. $p_{hydrogen}V_{total} = n_{hydrogen}RT$
- All of these will give us the total volume. Which one to use? So far, the information we have is:
    - moles of hydrogen, $n_{hydrogen}$
    - total pressure, p_{total}
    - partial pressure of water vapor, $p_{watervapor}$
    - partial pressure of hydrogen, $p_{hydrogen}$
    - temperature, T
- So, here's where we are with each equation:
    1. we're missing two things (total volume and total moles)
    2. we're missing two things (total volume and moles of water vapor)
    3. we're only missing one thing (total volume)
- Use the third equation

Solution

$$0.500g\ \text{Mg} \times \frac{1mol\ \text{Mg}}{24.31g\ \text{Mg}} \times \frac{1mol\ \text{H}_2}{1mol\ \text{Mg}} = 2.057 \times 10^{-3} mol$$

Looking at water vapor pressure table, when T = 22ºC, $p_{watervapor}$ = 19.8 mmHg

$p_{total} = p_{watervapor} + p_{hydrogen} \Rightarrow p_{hydrogen} = 752 - 19.8 \text{ mmHg} = 732 \text{ mmHg}$

$T = 22 + 273 = 295K$

and finally,

$$p_{hydrogen}V_{total} = n_{hydrogen}RT \Rightarrow V_{total} = \frac{n_{hydrogen}RT}{p_{hydrogen}}$$

$$V_{total} = \frac{(2.057 \times 10^{-3} mol)\left(0.08206 \frac{L \bullet atm}{mol \bullet K}\right)(295K)}{\left(732 \text{ mmHg} \times \frac{1 atm}{760 \text{ mmHg}}\right)} = 0.0517L$$

and, changing this to mL :

$$0.0517L \times \frac{1000\text{mL}}{1L} = 51.7 \text{ mL}$$