Molarity Problems

Another type of problem that benefits from this process is using a downward arrow through the data for a given gas and using stoichiometry to solve for the molarity of a solution.

If .033 L of hydrogen is collected at 0 °C and 1.00 atm from the reaction of solid aluminum and .500-M hydrochloric acid, what volume of .500-M HCl reacted?

Step 1: Write the balanced chemical equation.

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

Step 2: Write what is given and what needs to be calculated (moles go under the equation all other units go above the equation).

\[ X \text{ L} \quad .033 \text{ L} \]

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

Step 3: Draw the path from the given data to what needs to be calculated.

\[ X \text{ L} \quad .033 \text{ L} \]

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

Step 4: Perform the calculations.

The first arrow goes only through the gas \( \text{H}_2 \) and points to moles of (underneath) \( \text{H}_2 \), so the ideal gas law has to be solved for “moles of \( \text{H}_2 \)” \((n = PV/RT)\). Since this is a gas law, I will use the * to represent the multiplication in the gas law and the typical “x” as the stoichiometric multiplication.

\[ n = \frac{PV}{RT} = \frac{1.00 \text{ atm} \times .033 \text{ L}}{.08206 \text{ L atm/mol K} \times 273 \text{ K}} = .001473057773 \text{ mol H}_2 \]

The second arrow goes from under \( \text{H}_2 \) (mol \( \text{H}_2 \)) to under \( \text{HCl} \) (mol \( \text{HCl} \)).

\[ .001473057773 \text{ mol H}_2 \times 6 \text{ mol HCl} = \frac{3 \text{ mol H}_2}{3} \]

The third arrow goes through an aqueous solution of HCl. When a vertical arrow goes through an aqueous solution, its molarity needs to be used. Since the solution is .500-M HCl, 1 L of this solution contains .500 moles of HCl. (.500 mol HCl = 1-L HCl solution)
\[
\frac{0.01473057773 \text{ mol H}_2 \times 6 \text{ mol HCl} \times 1 \text{ L HCl}}{3 \text{ mol H}_2 \cdot 0.500 \text{ mol HCl}} = 0.0059 \text{ L or 5.9 mL HCl}
\]

This problem also illustrates a way to use the molar volume of any gas at STP as 22.4 L/mol. Since H\textsubscript{2} is 0.033 L of a gas at STP, the student could also change liters of H\textsubscript{2} to moles of H\textsubscript{2} in the following manner and then finish the problem as previously shown:

\[
\frac{0.033 \text{ L H}_2 \times \frac{1 \text{ mol H}_2}{22.4 \text{ L H}_2} \times 6 \text{ mol HCl} \times \frac{1 \text{ L HCl}}{3 \text{ mol H}_2 \cdot 0.500 \text{ mol HCl}}} = 0.0059 \text{ L or 5.9 mL HCl}
\]