Chemistry Lecture #73: Gas Stoichiometry

In some chemical reactions, we want to know the grams of product made from liters of a gas. Or we may want to know the liters of gas made from grams of reactant. In these and other cases, we can use factor-labeling and Avogadro's principle to convert between liters and grams.

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

In the above reaction, nitrogen reacts with hydrogen to produce ammonia. If 15.0 L of H_2 reacts completely with nitrogen at a temperature of 273 K and a pressure of 760 torr, what mass of NH_3 will be made?

Solution

We first identify the known and unknown.

$$\underset{}{N_2(g)} + \overset{15.0\text{ L (known)}}{3H_2(g)} \rightarrow \overset{?\text{ g (unknown)}}{2NH_3(g)}$$

We are given L and need to convert to grams. We'll convert L to moles of known, moles of known into moles of unknown, then moles of unknown into grams of unknown

L known → moles known → moles unknown → g of unknown

273 K is the same as 0 °C, and 760 torr is the same as 1 atm, so the reaction is occurring at Standard Temperature and Pressure (STP). We can use the relationship 1 mole gas = 22.4 L. to convert liters of H_2 to moles.

3 moles of H_2 will produce 2 moles of NH_3. We'll use this relationship to convert moles of H_2 to moles of NH_3

The mass of one mole of NH_3 is 17.0 g. We use this to convert moles of unknown to grams of unknown.

The overview and set up for solving the problem is:

$$\underset{}{N_2(g)} + \overset{15.0\text{ L (known)}}{3H_2(g)} \rightarrow \overset{?\text{ g (unknown)}}{2NH_3(g)}$$

L known → moles known → moles unknown → g of unknown

1 mole H_2 = 22.4 L H_2 3 moles H_2 → 2 moles NH_3

1 mole NH_3 = 17.0 g

$$\frac{15.0\text{ L }H_2}{1} \times \frac{\text{mole }H_2}{22.4\text{ L }H_2} \times \frac{2\text{ moles }NH_3}{3\text{ moles }H_2} \times \frac{17.0\text{ g }NH_3}{\text{mole }NH_3} = 7.59\text{ g }NH_3$$

$4\ Fe(s) + 3\ O_2(g) \rightarrow 2Fe_2O_3(s)$

What volume of oxygen gas at STP is required to completely react with 52.0 g of iron to form iron (III) oxide?

Solution

52.0 g known ? L unknown

$4\ Fe(s) + 3\ O_2(g) \rightarrow 2Fe_2O_3(s)$

g known → moles known → moles unknown → L unknown

1 mole Fe = 55.8 g 4 moles Fe → 3 moles O_2

1 mole O_2 = 22.4 L O_2

$$\frac{52.0\text{ g Fe}}{1} \times \frac{\text{mole Fe}}{55.8\text{ g Fe}} \times \frac{3\text{ moles } O_2}{4\text{ moles Fe}} \times \frac{22.4\text{ L } O_2}{\text{mole } O_2} = 15.7\text{ L } O_2$$

If you need to convert volumes of known to volumes of unknown, it is not necessary to convert liters to moles. The mole ratios are the same as the volume ratios. For example, if hydrogen gas and oxygen gas react to form water vapor,

$2H_2(g) + O_2(g) \rightarrow 2\ H_2O(g)$

It takes 1 mole of O_2 to produce 2 moles of H_2O. Or, 1 L of O_2 will produce 2 L of H_2O. 2 L of O_2 will produce 4 L of H_2O, 3 L of O_2 will produce 6 L of H_2O, and so on.

You only need mole ratios to factor-label a volume-volume problem since mole ratios are the same as volume ratios.

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g)$

In the above reaction, what volume of CO_2 gas can be produced from 8.00 L of oxygen gas?

Solution

$$\underset{}{C_3H_8(g)} + \overset{8.00\text{ L known}}{5O_2(g)} \rightarrow \overset{?\text{ L unknown}}{3CO_2(g)}$$

L known $\rightarrow$ L unknown

5 L O_2 $\rightarrow$ 3 L CO_2

$$\frac{8.00\text{ L } O_2}{1} \times \frac{3\text{ L } CO_2}{5\text{L } O_2} = 4.80\text{ L } CO_2$$