Chemistry Lecture #74: Gas Stoichiometry Shortcuts

The factor-label method is the standard method of solving gas stoichiometry problems. Some students have difficulty using the factor-label method, so I came up with some formulas that can be used to convert volume to mass, mass to volume, and volume to volume. These formulas can be used only at Standard Temperature and Pressure (STP).

Formulas are easier to use, but you need to memorize the formula and learn how to use them.

For a volume to mass conversion, we can use the formula

$$U_g = \frac{K_L\, C_u\, M_u}{(22.4\text{ L})\, C_k}$$

U_g = grams of unknown
K_L = liters of unknown
C_u = coefficient of unknown
M_u = molar mass of unknown
C_k = coefficient of the known

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

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.

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

H_2 is the known. The volume of the known is 15.0 L, so
K_L = 15.0 L

The coefficient in front of the known, H_2, is 3, so C_K = 3.

The unknown is NH_3. The mass of one mole of NH_3 is 17.0 g, so
M_u = 17.0 g.

The coefficient in front of the unknown, NH_3, is 2, so C_u = 2.

The overview and set up for solving the problem is:

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

K_L = 15.0 L

C_k = 3

M_u = 17.0 g (mass of 1 mole of NH_3)

C_u = 2

U_g = ?

$$U_g = \frac{K_L\, C_u\, M_u}{(22.4\text{ L})\, C_k}$$

$$U_g = \frac{(15.0\text{ L})(2)(17.0\text{ g})}{(22.4\text{ L})(3)} = 7.59\text{ g } NH_3$$

For mass to volume conversions, we use the formula

$$U_L = \frac{K_g\, C_u\, (22.4\text{ L})}{M_k\, C_k}$$

U_L = unknown in liters

K_g = known in grams

C_u = coefficient of the unknown

M_k = molar mass of the known

C_k = coefficient of the known

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

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

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

K_g = 52.0 g

M_k = 55.8 g (molar mass of Fe)

C_k = 4

C_u = 3

U_L = ?

$$U_L = \frac{K_g\, C_u\, (22.4\ L)}{M_k\, C_k}$$

$$U_L = \frac{(52.0\ g)(3)(22.4\ L)}{(55.8\ g)(4)} = 15.7\ L\ O_2$$

If you need to convert volumes of known to volumes of unknown, we use the formula

$$U_L = \frac{K_L\, C_u}{C_k}$$

U_L = unknown in liters

K_L = known in liters

C_u = coefficient of unknown

C_k = coefficient of known

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

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

Solution

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

$K_L = 8.00\ L$ $C_u = 3$

$C_k = 5$ $U_L = ?$

$$U_L = \frac{K_L\, C_u}{C_k}$$

$$U_L = \frac{(8.00\ L)\ (3)}{5} = 4.80\ L\ CO_2$$