Chemistry Lecture #59: Stoichiometric Shortcut, Mass-to-Mass

Students who plan to pursue a science, math, or engineering degree should solve stoichiometric problems by factor-labeling. Factor-labeling is used quite often in science courses because it is a useful tool for solving a variety of conversion problems.

But some students have difficulty solving stoichiometric problems by factor-labeling. I've come up with a formula that can be used to solve stoichiometric mass-to-mass problems. I've found that that students who have difficulty with stoichiometry problems are successful when they use this formula.

The formula is not a magic cure-all that makes it easy to solve problems - it just makes it easier. The student must still take the time and effort to memorize the formula, and how to substitute the correct numbers into the appropriate variables.

The formula is

$$U_g = \frac{K_g C_u M_u}{M_k C_k}$$

where U_g = grams of unknown

K_g = grams of known

C_u = coefficient in front of the unknown substance

C_k = coefficient in front of the known substance

M_u = molar mass of the unknown substance

M_k = molar mass of the known substance

To understand how to use the formula, let's solve a problem.

$4\ Al + 3\ O_2 \rightarrow 2\ Al_2O_3$

How many grams of Al_2O_3 can be made from 12.0 g of Al?

12.0 g known ? g unknown

$4\ Al + 3\ O_2 \rightarrow 2\ Al_2O_3$

1 mole Al = 27.0 g 1 mole Al_2O_3 = 102 g

U_g = grams of unknown, what we are trying to find.
K_g = 12.0 g; we know we have 12 grams of Al.
C_u = the unknown is Al_2O_3 - there's a 2 in front of it in the equation.
C_k = the known is Al - there's a 4 in front of it in the equation.
M_u = 1 mole of Al_2O_3 = 102 g
M_k = 1 mole of Al = 27.0 g

$$U_g = \frac{K_g C_u M_u}{M_k C_k}$$

$$U_g = \frac{(12.0)(2)(102)}{(27.0)(4)} = 22.7\ \text{g}\ Al_2O_3$$

Thus, from 12.0 g of Al, we can obtain 22.7 g of Al_2O_3.

$$3\ Mg + 2\ CrCl_3 \rightarrow 2\ Cr + 3MgCl_2$$

How many grams of $CrCl_3$ are needed to make 0.840 g of $MgCl_2$?

Solution

$$3\ Mg + 2\ \overset{?g\ \text{unknown}}{CrCl_3} \rightarrow 2\ Cr + \overset{0.840\ g\ \text{known}}{3MgCl_2}$$

$CrCl_3$ = 159 g/mole $MgCl_2$ = 95.3 g/mole

U_g = ?
K_g = 0.840 g
C_u = 2
C_k = 3
M_u = 159 g/mole
M_k = 95.3 g/mole

$$U_g = \frac{K_g C_u M_u}{M_k C_k}$$

$$U_g = \frac{(0.840)(2)(159)}{(95.3)(3)} = 0.934\ g\ CrCl_3$$

$$2H_2O \rightarrow 2H_2 + O_2$$

A sample of H_2O is broken into its elements and yields 4.70 g of H_2. How many grams of O_2 are also produced?

Solution

$$2H_2O \rightarrow \overset{\text{4.70 g known}}{2H_2} + \overset{\text{? g uknown}}{O_2}$$

H_2 = 2.02 g/mole

O_2 = 32.0 g/mole

U_g = ?
K_g = 4.70 g
C_u = 1
C_k = 2
M_u = 32.0 g/mole
M_k = 2.02 g/mole

$$U_g = \frac{K_g C_u M_u}{M_k C_k}$$

$$U_g = \frac{(4.70)(1)(32.0)}{(2.02)(2)} = 37.2 \text{ g } O_2$$