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 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 O₂ → 2 Al₂O₃

How many grams of Al₂O₃ can be made from 12.0 g of Al?

12.0 g known                   ? g unknown

4 Al       +  3 O₂ → 2 Al₂O₃

1 mole Al = 27.0 g               1 mole Al₂O₃ = 102 g

U₉ = grams of unknown, what we are trying to find.
K₉ = 12.0 g; we know we have 12 grams of Al.
Cₙ = the unknown is Al₂O₃ - there’s a 2 in front of it in the equation.
Cₖ = the known is Al - there’s a 4 in front of it in the equation.
Mₙ = 1 mole of Al₂O₃ = 102 g
Mₖ = 1 mole of Al = 27.0 g

U₉ = K₉CₙMₙ
    MₖCₖ

U₉ = \frac{(12.0)(2)(102)}{(27.0)(4)} = 22.7 \text{ g Al}_2\text{O}_3

Thus, from 12.0 g of Al, we can obtain 22.7 g of Al₂O₃.
$3 \text{Mg} + 2 \text{CrCl}_3 \rightarrow 2 \text{Cr} + 3\text{MgCl}_2$

How many grams of CrCl$_3$ are needed to make 0.840 g of MgCl$_2$?

**Solution**

\[
\begin{align*}
\text{?g unknown} & \quad 0.840 \text{g known} \\
3 \text{Mg} + 2 \text{CrCl}_3 & \rightarrow 2 \text{Cr} + 3\text{MgCl}_2 \\
\text{CrCl}_3 & = 159 \text{g/mole} \\
\text{MgCl}_2 & = 95.3 \text{g/mole}
\end{align*}
\]

\[
\begin{align*}
\text{?g} & = \frac{K_g \times C_u \times M_u}{M_k \times C_k} \\
K_g & = 0.840 \text{ g} \\
C_u & = 2 \\
C_k & = 3 \\
M_u & = 159 \text{ g/mole} \\
M_k & = 95.3 \text{ g/mole}
\end{align*}
\]

\[
\begin{align*}
\text{?g} & = \frac{(0.840)(2)(159)}{(95.3)(3)} \\
& = 0.934 \text{ g CrCl}_3
\end{align*}
\]
2H₂O → 2H₂ + O₂

A sample of H₂O is broken into its elements and yields 4.70 g of H₂. How many grams of O₂ are also produced?

Solution

\[ \text{H}_2 = 2.02 \text{ g/mole} \quad \text{O}_2 = 32.0 \text{ g/mole} \]

\[ u_g = ? \]

\[ K_g = 4.70 \text{ g} \]

\[ C_u = 1 \]

\[ C_k = 2 \]

\[ M_u = 32.0 \text{ g/mole} \]

\[ M_k = 2.02 \text{ g/mole} \]

\[ u_g = \frac{K_g C_u M_u}{M_k C_k} \]

\[ u_g = \frac{(4.70)(1)(32.0)}{(2.02)(2)} = 37.2 \text{ g O}_2 \]