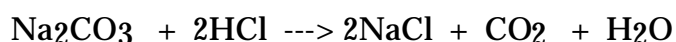


Stoichiometry a Functional Point of View Pedagogy (Math/Science Connection)

Stoichiometry problems are often solved by using dimensional analysis. Dimensional analysis is a very useful tool and was probably promoted as a reasonable strategy when using the calculator. Prior to calculators stoichiometry problems were solved by ratios (i.e. setting up proportions), and was a useful strategy for a slide rule.

While on the surface graphing calculators offer little that is new, they do offer us a way to re-examine the current algorithms used in solving stoichiometry problems by approaching stoichiometry from a mathematical function viewpoint. What results is a more obvious connection to the mathematics of stoichiometry instead of focusing on memorizing an algorithm to solve a stoichiometry problem.



To illustrate the mathematical connection, we will analyze the previous chemical equation by starting with known quantities of sodium carbonate as our limiting factor and assuming 100% yield of sodium chloride.

The molar mass of Na_2CO_3 is (nearest 0.1g) 106.0 grams, and the molar mass of NaCl is 58.5 grams.

1. On the calculator press the STAT key and press ENTER to open the STAT EDIT. Under list 1 (L1) enter the following data 0.1, 0.2, 0.3 onto and including 1.0. This will represent mole increments of Na_2CO_3 .
2. Arrow to the second list (L2) and arrow up so the cursor covers the L2 and press ENTER. The flashing cursor is now at the bottom of the calculator screen. Press the key marked 2nd and the key for #1, and multiply by 58.5 grams x 2 (L1 x 58.5 x 2). Since there were 2 moles of NaCl in the equation, we multiplied (L1 x 58.5) by 2. In L2 should be incremental data representing grams of NaCl when the coefficient is 2.
3. Move the cursor to cover L3 and press ENTER. Press keys 2nd, #1, and multiply by 106.0 and press ENTER. This provides all the masses of Na_2CO_3 associated with by mole increments of 0.1 up to 1.0 mole.
4. Construct a graph that depicts the mass of NaCl as a function of the mass of Na_2CO_3 . As a convenience we will move the data in L3 to L1 by moving the cursor so it covers L1 and press ENTER. Once the flashing cursor appears press the keys 2nd and #3 before pressing ENTER.

Now press keys 2nd and Y= to open STAT PLOT. Turn Plot 1 on, select scatter graph and next to X list press 2nd, #1 to place list 1 (the Na_2CO_3 data) on the X-axis. Next to Y-list press 2nd, #2 to enter the NaCl data. Press Graph.

5. Think about the mathematical function that would describe the relationship between Y (mass of NaCl) and X (mass of Na_2CO_3). Could you use $Y=mX+b$ to represent the

relationship? If so, what are the numerical values of m and b , and what would they represent? Record your thoughts and ideas.

5. Calculate the regression equation that fits the plotted data start by pressing STAT and arrow right to CALC, then press #4. Now press keys in the following sequence: 2nd key, #1 key, comma key, 2nd key, # 2 key, comma key, VARS key and arrow to Y-VARS and press ENTER, press ENTER, press ENTER again.

Questions

1. Record the linear regression equation ($y = ax + b$). Drop the b (the intercept) out of the equation since b approximates '0'.

2. Using the symbol "R" for reactants and "P" for products, substitute R and P for X and Y into your equation from above and write the new expression.

$Y = mX$ becomes _____ where m (slope) is a constant k .

4. Using the equation $R = k P$, where $k = 1.104$, what would be the amount of NaCl (P) produced by 13.5 g of Na_2CO_3 ?

5. What would be the amount of Na_2CO_3 , needed to produce 23.0 g of NaCl.

Recall that the $P = 2 \times 58.5$ g. See how the data for L2 (list 2) was calculated. The constant, k , equals the molar mass of 1 mole of Na_2CO_3 / molar mass of 2 moles of NaCl). What do the coefficients 1 and 2 represent in the previous equation?

To generalize:

$$\frac{R}{P} = \frac{\text{Coefficient of given substance} \times \text{MM of given substance}}{\text{Coefficient of wanted substance} \times \text{MM of wanted substance}}$$

In the equation $R = k P$, substitute in G (given) and W (wanted).

Now expand to include coefficients you obtain:

$$k = \frac{\text{coefficient of W} \times \text{molar mass of W}}{\text{coefficient of G} \times \text{molar mass of G}}$$

To solve any mass to mass equation set-up the beginning mass (G) $\times k$ or

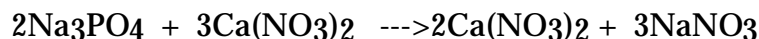
$$\text{mass of W} = \text{mass of G} \times k$$

Expanded:

$$\text{Mass(W)} = \text{Mass(G)} \times \frac{\text{coefficient(W)} \times \text{MM(W)}}{\text{coefficient(G)} \times \text{MM(G)}}$$

6. Write out the same problem using dimensional analysis. How does your set-up compare to the expanded equation?

7. Using the “new” formula solve the following stoichiometry problems:
How many grams of $\text{Ca}_3(\text{PO}_4)_2$ are produced by 15.0 g of $\text{Ca}(\text{NO}_3)_2$? See the chemical equation below:



8. This strategy can be especially helpful in question like: How many grams of $\text{Ca}(\text{NO}_3)_2$ will be needed to form for each of the following amounts of $\text{Ca}_3(\text{PO}_4)_2$?

Hint: To simplify solve for k in the equation

$$k = \frac{\text{coefficient of W} \times \text{molar mass of W}}{\text{coefficient of G} \times \text{molar mass of G}}$$

then proceed to calculate the answer for each a-e.

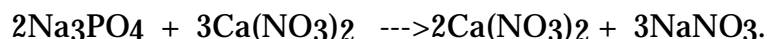
- a) 32.5 g
- b) 0.56 g
- c) 102.7 g
- d) 500.0 g
- e) 3.00×10^{-2} g

This technique can be simplified further by writing a calculator program and prompts the user for all of the variables and performs the needed calculations on demand.

This may help you validate the connection between dimensional analysis and mathematics as sometimes students get lost in the morass of cancelling without understanding.

The use of k (with some modifications) in the aforementioned can be utilized in limiting reactant problems. For example, if 23.0 of Na_3PO_4 were to react with 45.0 of $\text{Ca}(\text{NO}_3)_2$ how much $\text{Ca}_3(\text{PO}_4)_2$ would be produced?

See the equation:



Substitute and solve for k.

$$k = \frac{\text{coefficient of Reactant 1} \times \text{molar mass of Reactant 1}}{\text{coefficient of Reactant 2} \times \text{molar mass of Reactant 2}} = k = \frac{328}{429.3} = 0.764$$

If dividing 23.0 by 45.0 > k then the ratio for k is too large and there is an excess amount of reactant 1 (Na_3PO_4) and the second reactant ($\text{Ca}(\text{NO}_3)_2$) is the limiting reactant. Alternatively if dividing 23.0 by 45.0 < k then the ratio for k is too small and

the first reactant (Na_3PO_4) is the limiting reactant.

The actual quotient for 23.0/45.0 is 0.511. Therefore reactant 1 (Na_3PO_4) is the limiting reactant.

Stoichiometry Problem Solver Calculator Program by Kent Crippen

Download <http://dwb.unl.edu/calculators/programs/solve-stoich.83p.hqx>

To enter this program, select PRGM, NEW

The commands are found under their respective menus on the TI calculator. For example, the "Float" command is found by pressing MODE, maneuvering to "Float" and selecting ENTER.

This program can also be constructed on a computer (Windows or Macintosh) with the Graph Link software from Texas Instruments (free download) and downloaded to the calculator with a graph-link cable (~\$45.00 from TI).

Name = STOICH

```
ClrHome
Normal
Float
Disp "COEFF WANTED"
Input A
Disp "COEFF GIVEN"
Input B
Disp "MM WANTED"
Input C
Disp "MM GIVEN"
Input D
(A*B)/(C*D)->K
Lbl D
ClrHome
Menu("DETERMINE MASS","GIVEN",A,"WANTED",B,"QUIT",C)
Lbl A
Disp "WANTED MASS:"
Input E
K/E->F
ClrHome
Disp "GIVEN MASS:"
Goto G
Lbl B
Disp "GIVEN MASS:"
Input E
E*K->F
ClrHome
Disp "WANTED MASS:"
Goto G
Lbl G
Disp F
Output(8,5,"[ENTER]")
Pause
Goto D
Lbl C
Stop
```