Using Reaction Stoichiometry To Engage Student Logic

David L. Cameron
Physical Sciences Department
Embry-Riddle Aeronautical University
Daytona Beach, FL 32114

ABSTRACT

It is suggested that teachers of college-level general chemistry have a good opportunity to engage the general logic of the student. Students must first learn some basic facts about chemical reactions, and must learn to calculate appropriate values by the unit conversion method generally referred to as dimensional analysis. Problem solving is most meaningful to the individual student, however, when he or she uses his or her own logic in solving the problem. To make a problem in reaction stoichiometry effective in this regard, solving the problem should be based on a measured fact given in the problem, not on the assumed total consumption of the limiting reagent. A sample of an effective reaction problem is given. The sample problem is solved using conventional unit conversions, supported by a conceptual method referred to as an "arrow diagram."

Using Reaction Stoichiometry To Engage Student Logic

Among the many special ideas expressed by Albert Einstein is the following: "Education is not the learning of facts. It's rather the training of the mind to think," (as quoted at www.gurteen.com). Many of the students entering a course in college-level general chemistry are unfamiliar with the basic facts applicable to chemical reactions. These facts must first be learned. Conservation of mass is a good fact to start with. Then the student must learn to calculate appropriate values with the unit conversion method usually called dimensional analysis (Figueira, 1988; Krieger, 1997; Steiner, 1986). All stoichiometric analyses of chemical reactions are dependent on unit conversion, so dimensional analysis is a very important computational method that must be well mastered in a chemistry course. Dimensional analysis itself, however, does not invoke the general logic of the student. After conservation of mass, reaction facts learned should include the fact that reactions in general proceed from a given initial state to chemical equilibrium, and that a potentially significant amount of the limiting reagent might remain in the reaction mixture at chemical equilibrium.

Many chemistry instructors focus almost total attention on the dimensional analysis method. But most students are able to learn this method reasonably well, and the dimensional analysis method does not generally require logic beyond correct application of those ideas specifically learned with that method. Problems like the following example, using a measured fact as the basis of calculations, are more effective at engaging general logical thinking by the student:

$$4\ NH_3\,(g) \; + \; 6\ NO\,(g) \; = \; 5\ N_2\,(g) \; + \; 6\ H_2O\,(l)$$

When 22.0 grams of ammonia are reacted with 35.0 grams of nitrogen oxide in a closed, expandable container kept at 25 °C, 101.3 kPa, the final volume of gas in the container is 43.66 dm^3. What mass of water is formed ?

(= 14.58 g water)

An approach called the "arrow diagram" method (Cameron, 1985) can be helpful in solving such problems with logic. The arrow diagram is a relatively straightforward representation of a chemical reaction as an active process that simultaneously changes the molar amounts of all substances in the reaction. The preliminary general form of the arrow diagram for the given reaction would be set up as shown in Fig.1:

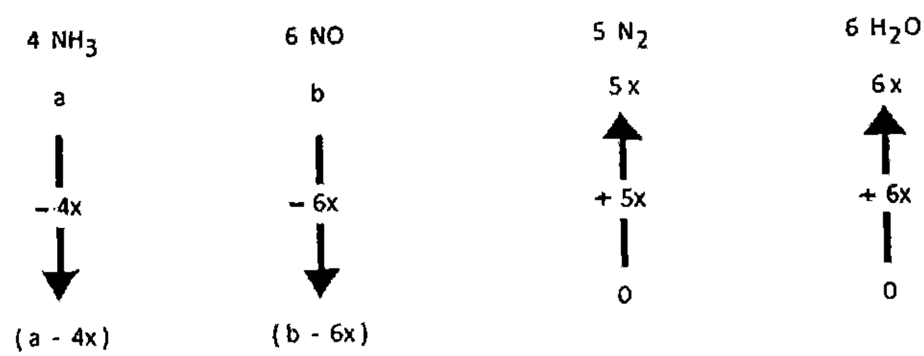

FIG 1: General set up for initial reaction mixture and changes caused by reaction

All values in the arrow diagram are assumed to be in moles of the corresponding substance. The value placed at the initial end of each arrow represents the moles initially present. The value in the middle of each arrow, comprising the stoichiometric coefficient from the balanced reaction multiplied times the unknown value " x ," represents the moles of substance used or formed by the reaction. Conventional unit conversion calculations are done to convert 22 g of ammonia and 35 g of nitrogen oxide to the number of moles put in. This advances the arrow diagram to the preliminary form for the initial state for the given problem, shown in Fig. 2:

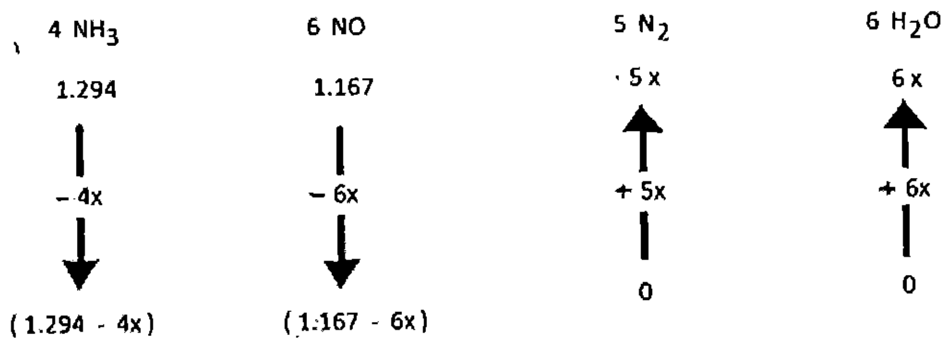

FIG. 2: Initial reaction mixture with grams put in changed to moles, and reaction changes in terms of unknown value "x"

Here's where the sample problem invokes the general logic of the student! The key logical step needed to make the arrow diagram a valuable tool in solving the problem is the recognition of the following relationship:

final total moles gas = mole NH_3 left + mole NO left + mole N_2 formed

This is just the kind of equation the student must formulate and use to logically solve a variety of realistic problems in reaction stoichiometry. Total moles of gas in the final reaction mixture can be calculated from the Ideal Gas Law:

$$n_{total} = \frac{P_{total} V_{gas}}{R\ T} = 1.786 \text{ mole gas}$$

Then, with terms taken from the arrow diagram, this gives the equation:

1.786 mole gas = (1.294 - 4x) mole NH_3 + (1.167 - 6x) mole NO + (5x) mole N_2

Solving this equation, x = 0.135, where this is the numerical value of the "x" in the arrow diagram. The calculated value of " x " is then used to calculate the value required as the answer to the problem. Moles of water formed, according to the arrow diagram, is 6 x. Then grams of water can be calculated by conventional unit conversion as

6(0.135) mole water formed(18 g/1 mole) = 14.58 grams of water.

There would be no need to fill out the arrow diagram with the value of " x " incorporated into it, but if desired, the completed arrow diagram for the reaction mixture at chemical equilibrium, would be as shown in Fig.3:

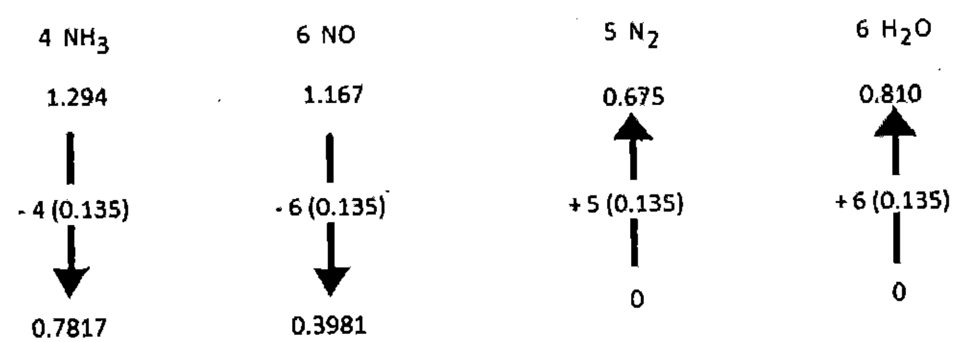

FIG. 3: Molar compisition of final reaction mixture

The purpose of problems like this is to activate the general logic of the individual student. This makes the analysis of reaction stoichiometry more real and more meaningful to the student. A similar problem, also solved with unit conversions supported by an arrow diagram, is posted at the website given as the second reference.

REFERENCES

Cameron, David (1985) A Pictorial Framework to Aid Conceptualization of Reaction Stoichiometry. *Journal of Chemical Education,* 62, 510 - 514.

Cameron, David, URL http://www.jimetherdrift2013.net (June, 2018)

Figueira, Alvaro Rocha (1988) Teaching stoichiometry. *Journal of Chemical Education*, 65 (12), 1060 - 1068.

Krieger, Carla R. (1997) Stoichiometry: A Cognitive Approach to Teaching Stoichiometry. *Journal of Chemical Education*, 74 (3), 306 - 317.

Steiner, Richard P. (1986) Teaching stoichiometry. *Journal of Chemical Education*, 63(12), 1048 - 1053.