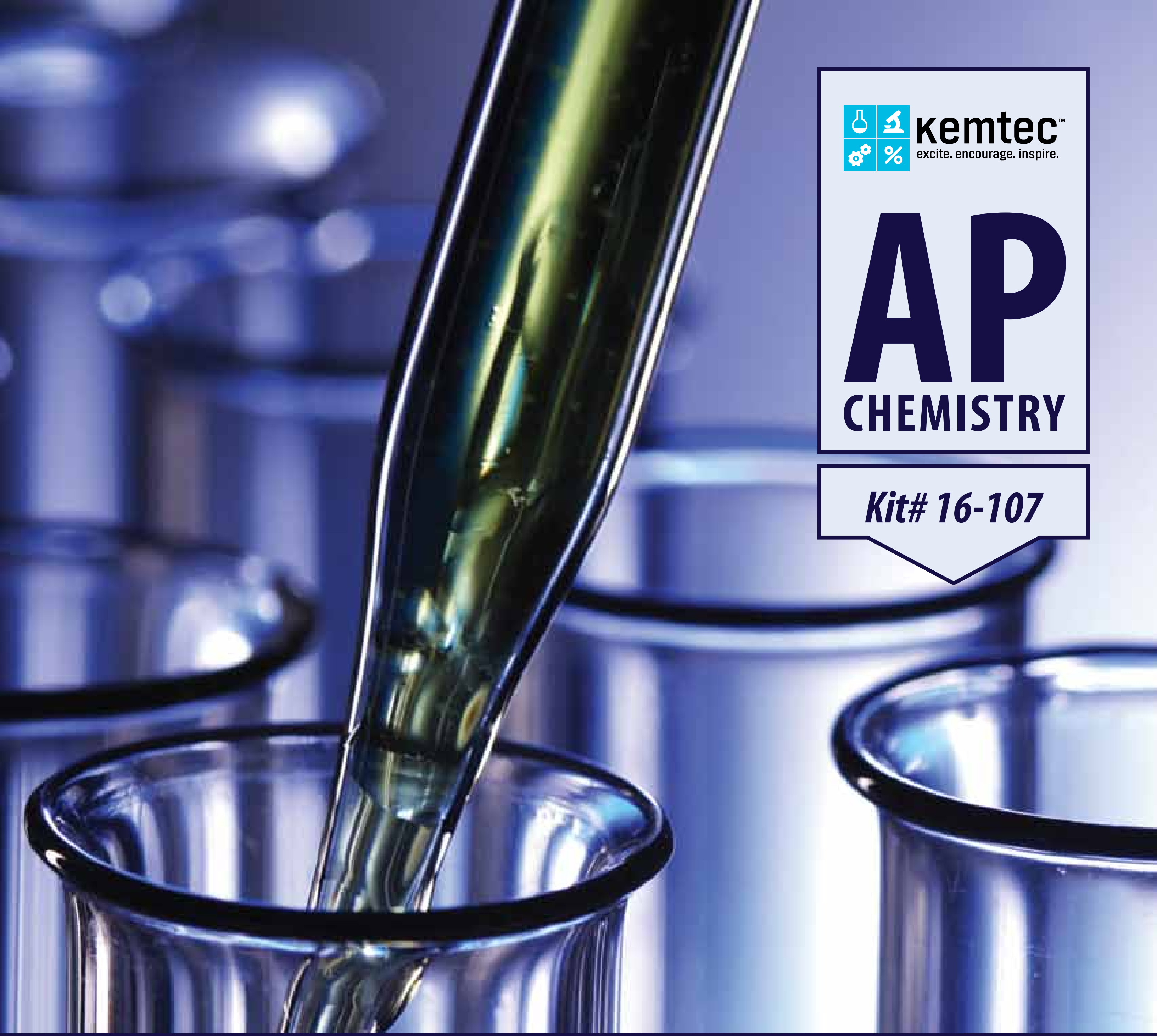

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AP CHEMISTRY

Kit# 16-107

Stoichiometry: Mole Ratio of an Unknown

Teacher's Manual

WARNING - This kit contains chemicals that may be harmful if misused. Please read individual bottle warnings to ensure that all items are handled safely and appropriately. Adult supervision required.

00 LAB SECTIONS

Continuous-Variation Method

The continuous-variation method (also called the Job's method[17]) is a simple and effective way to determine the mole ratio of an unknown reactant. It requires just one more mathematical treatment. Equation 1c on page 3 can be rewritten by simplifying the coefficient for A to 1 and changing the other coefficients to fractions. This produces an equation that focuses on the fractional coefficient for B and is as follows:

$$A + \frac{\mathbf{b}}{\mathbf{a}}\, B \rightarrow \frac{d}{a}\, D \qquad \text{(Eq. 3)}$$

The continuous-variation method uses the concept that a *limiting reactant* ***lowers*** product yield and that there exists a mole ratio of reactants, r, which produces the highest **product yield**. To determine the best mole ratio of an unknown reactant, **four steps** are undertaken.

First, a series of solutions is prepared. Fortunately, instead of making more than 30 solutions like in the "trial-and-error" method, just five to seven solutions are made. One restriction is imposed on each solution: each solution must contain the **<u>same</u> total number of moles** of A and B. Each of the solutions has a *different* mole ratio, r, for unknown B.

$$r = \frac{n_B}{n_A} \qquad \text{(Eq. 4)}$$

Some of these solutions will have $n_A < n_B$ and some will have $n_A > n_B$.

Second, a specific property (mass, temperature, etc.) is determined to assess product yield. Five to seven trials are then performed. A graph of product yield versus number of moles of n_A is plotted.

Third, values are extrapolated to reveal the highest product yield on the plot. The intersection point of the two lines reveals the condition (i.e., ratio of moles of reactants) necessary for maximum yield of the desired product. At this graph peak, the ratio of moles of reactants becomes the **optimal ratio**, r_{opt}. That is to say, r_{opt} equals the actual mole ratio for the unknown reactant, B, found in the balanced equation – as shown by the following equation:

$$r_{opt} = \frac{\mathbf{b}}{\mathbf{a}} \qquad \text{(Eq. 5)}$$

Intuitively, this expression makes sense. The perfect mole ratio for unknown reactant B should produce the best yield. When one reactant (or the other) becomes a limiting reactant, the amount of product decreases. Equation 5 can be proven mathematically but a graph illustrates it better. The sample graph below shows how adjusting the amount of each reactant uncovers the optimal mole ratio for unknown B:

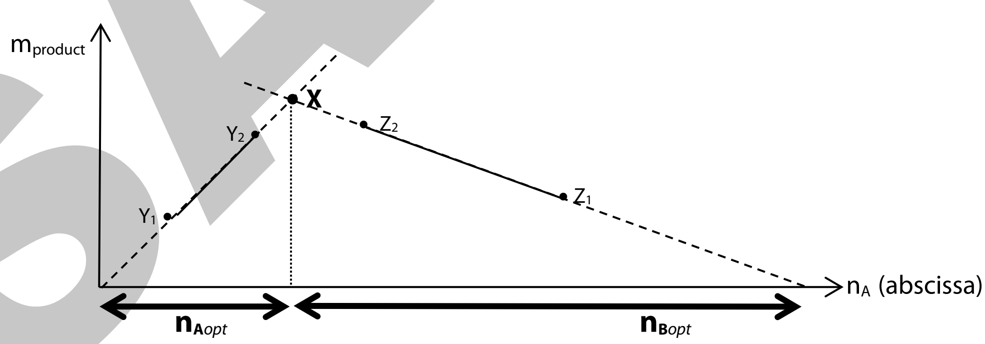


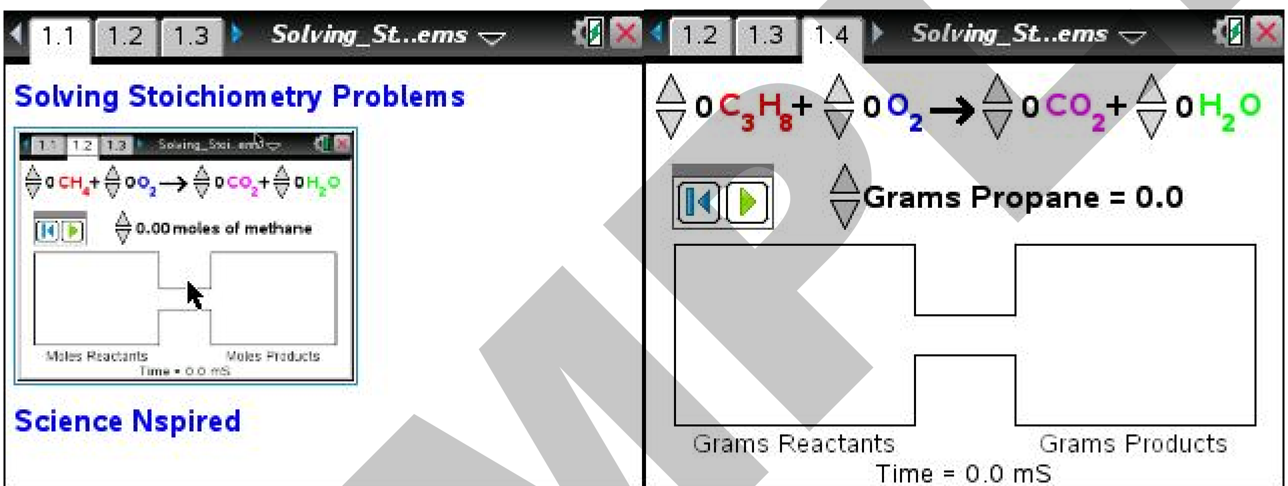
Figure 2. Mass of a product versus moles of A, using the continuous-variation method

[17] The method of continuous variations was first introduced by I. Ostromisslensky in 1911 and was first used by P. Job in 1928.

Infusion of Technology:

Multimedia:

1. *Theodore L. Brown, H. Eugene LeMay, Jr. & Bruce E. Bursten*. Circa 2006. Basic Media Pak, Chemistry: The Central Science (10th Edition). Pearson Prentice Hall. Upper Saddle River, NJ. ISBN 0-13-186753-9. MediaPak includes (a) Student Accelerator CD, (b) Virtual ChemLab Workbook, (c) Virtual ChemLab Cd, and (d) student access code to companion website with "GradeTeacher."
2. Visuals and Videos:
   "OSMTech Lab #9: Determining the Stoichiometry of Chemical Reactions."
   YouTube. *http://www.youtube.com/watch?v=DXwBf8vX5u0*.
   "Transparency Pack." Chemistry: the Central Science. Prentice Hall. Upper Saddle River, NJ.
3. Power Point. *May be provided by instructor*.
4. Texas Instruments Nspire™ Calculator Tutorials



Websites:

1. The National Science Digital Library. *NSDL.org*. This site is a good starting point for finding appropriate AP Chemistry sources on-line.
2. Colorimeter: Job's Method (Method of Continuous Variation). May 11, 2011. YouTube. *http://www.youtube.com/watch?v=Wn6PS-oTSyM*.
3. Texas Instruments TI Science Nspire™ Simulations
   http://education.ti.com/en/tisciencenspired/us/chemistry/chemical-equations-and-reactions

Determining the Mole Ratio of the Unknown Reactant

$$NaOH + \frac{b}{a}\ \textit{unknown} \rightarrow \text{product} \qquad \text{(Eq. 7)}$$

1. Transfer about 175mL NaOH solution to the 250mL beaker labeled "1.0 *M* NaOH".
2. Transfer about 175mL unknown solution to the 250mL beaker labeled "1.0 *M* Unknown (A, B or C)."
3. Record the initial temperature of 1.0 *M* NaOH. Rinse and dry the thermometer
4. Record the initial temperature of 1.0 *M* unknown solution.
5. Put parafilm over your solutions to prevent evaporation. They will be used to test your optimum mole ratio for validity
6. Photograph the assembly (optional).
7. Perform the first four of seven trials. For the **first four** trials, add the **1.0 *M* unknown** to the Styrofoam cup **first** because it has the larger volume.
   a. Add **45mL** 1.0 *M* unknown, using the 50mL graduated cylinder, to the Styrofoam cup. Measure and record the temperature in Data Table 2.
   b. Add **5mL** of 1.0 *M* NaOH to the unknown solution.
   [illegible]

   the temperature every 4 seconds for the next 20 seconds (or longer if the temperature continues to rise).
   d. Identify the highest temperature by placing an asterisk next to the value.
   e. Photograph the assembly (optional).
   f. Empty the contents of the Styrofoam cup into the "Waste" beaker.
   g. Rinse and dry the Styrofoam cup.
   h. Rinse and dry the thermometer.
12. Repeat steps 10a through 10h with **40mL** 1.0 *M* NaOH and **10mL** of 1.0 *M* unknown.
13. Repeat steps 10a through 10h with **45mL** 1.0 *M* NaOH and **5mL** of 1.0 *M* unknown.
14. Record the temperatures of unused 1.0 *M* NaOH and 1.0 *M* unknown and note if they differ from the initial temperatures.
15. Record the temperature of the room and note if the room changed temperature during the experiment.

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