

## DEFINITE PROPORTIONS

### PROBLEM PRESENTATION / EXPLORATION

- A. At each of six stations will be a balance, a bag of Tinker Toy<sup>®</sup> spools, and a bag of Tinker Toy<sup>®</sup> spokes.
1. Students are to find the mass of the bag of spools, and the mass of the bag of spokes, separately.
  2. Each team of students should predict the mass of wheels they think can be constructed with their spools and spokes.
  3. Each team is then instructed to fill all the holes in the spools with spokes until they run out of materials.
  4. Next, the total mass of the wheels built is to be determined.
  5. Finally, the mass of any unused spokes or spools is to be determined
- B. As the groups finish, have them transfer their findings to the class master transparency.

Mass of Spools	Mass of Spokes	Mass of Wheels	Mass of Unused Spools	Mass of Unused Spokes

### CLASS RESPONSE / CONCEPT INVENTION

- A. Ask the class what pattern they see in the reported data. The conclusion you hope they give at this stage is that there is a constant ratio between the mass of spools to the mass of spokes. In other words, whenever you make wheels from this kind of spools and spokes, you always get the same ratio of mass of spools to mass of spokes. [*This is our version of the Law of Definite Proportions.*]

Station #	Number of Spools	Number of Spokes	Number of Wheels	# Spools Left Over	# Spokes Left Over
1	3	18	3	0	0
2	3	24	3	0	6
3	3	30	3	0	12
4	4	12	2	2	0
5	5	12	2	3	0
6	6	12	2	4	0

1. In two of the stations three spools and an excess of spokes were provided so that the spools were the limiting factor in the construction of wheels. [There doesn't have to be the same mass of spokes at each station as long as it is in excess.]
2. In two of the stations 12 spokes and an excess of spools were provided so that the spokes were the limiting factor in the construction of wheels. There doesn't have to be the same mass of spools at each station as long as it is in excess.
3. Ask them why the mass of wheels didn't turn out to be simply the sum of the starting masses of the spools and spokes. Try to show them that this is the kind of evidence that led the *Fathers of Modern Chemistry* to suspect that matter doesn't mix in a continuous way, but combines in definite proportions.

Their only explanation for this was that matter is made up of individual particles that can combine in a definite ratio.

- B. Turn the students' attention to a chemical situation to investigate whether chemical reactions work the same way as Tinker Toys<sup>®</sup>.
- Set up twelve stations. At each station there will be a test tube rack containing one test tube, a buret of solution labeled Solution A, and a second buret of solution labeled Solution B.
  - Students are to add the number of mL of Solution A and mL of solutions B into the test tube according to the following table.

Station #	mL Solution A	mL Solution B	Ht. of Ppt (mm)
1	10	2	
2	8	4	
3	6	6	
4	5	7	
5	4	8	
6	3	9	
7	2	10	
8	1	11	

- After carefully adding the appropriate amounts of Solution A and Solution B the stopper is to be tightly inserted into the test tube and the test tube shaken for one minute.
- The test tube is to be placed into the test tube rack and the precipitate allowed to settle for a few minutes. When most of the floating particles in the solution have settled, the height of the precipitate is to be measured and recorded.
- The data from each station is to be transferred to the class master transparency for the whole class to see.
- At which station(s) did we get the maximum amount of precipitate? (Station # 5 should give the maximum amount of precipitate.) Why did we get more precipitate here? [At this station we have mixed the solutions in the proper ratio to completely use up all of Solution A and all of Solution B with no excess of either A or B left over. In all other test tubes either A or B is in excess. Therefore this station give us the best approximation of the Definite Proportion for the precipitate formed.]
- If we only knew the mass of each of the chemicals in Solution A and in Solution B, we could figure out the Definite Proportion mass ratio for the precipitate. Tell them at this point what the concentration was for the two solutions. Indicate this in grams of solute per mL of solution.
  - Solution A can be made up by dissolving 82.8 g of lead nitrate,  $\text{Pb}(\text{NO}_3)_2$ , in water to make a total volume of 500 mL of solution. There is 0.1036 g lead per mL of solution in solution A.

**CAUTION:** Lead compounds are toxic and accumulate in body tissues. Wear gloves when preparing these solutions.

- Solution B can be made up by dissolving 41.5 g of potassium iodide in water to make a total volume of 500 mL of solution. There is 0.06345 g iodide per mL of solution in solution A.
- Therefore, the Definite Proportion for the precipitate Lead Iodide can be found in the following way:  
 $(0.1036 \text{ g /mL Pb}) (4 \text{ mL}) = 0.4144 \text{ g Pb}$   
 $(0.06345 \text{ g/mL I}) (8 \text{ mL}) = 0.5076 \text{ g I}$

The ratio is  $0.4144 \text{ g Pb} / 0.5076 \text{ g I} = \mathbf{0.8164 \text{ g Pb} : 1.0000 \text{ g I}}$

## 8. Disposal

The Lead Iodide formed here must be disposed of carefully. Collect all waste material from the experiment in a waste container especially for this purpose. It should be converted into its most insoluble form and then buried in a landfill approved for the disposal of hazardous waste. Any waste solution should be treated with a threefold excess of sodium sulfide or thioacetamide and stirred occasionally for about one hour. Adjust the pH to neutral with 3M sodium hydroxide solution to complete the precipitation of the lead compound. Separate the solid lead sulfide by filtration and allow it to dry. Place the lead sulfide in a plastic container of appropriate size, and bury it in a landfill approved for such waste. The filtrate should be added slowly with stirring to an excess of ferric chloride. A precipitate will form. Neutralize the remaining solution with sodium carbonate (some evolution of  $\text{CO}_2$  will occur). Allow the precipitate to settle. Flush the neutral solution down the drain with excess water. Allow the precipitate to dry and dispose of in an appropriate landfill.

**CONCEPT EXTENSION**

A. We have seen that one way to find out the definite proportion of two elements that have reacted is to react solutions with known amounts of the two elements dissolved in them in different proportions until we find the proportion giving the greatest amount of solid product. Another way to go about determining the correct proportion of two compounds reacting is to once again vary the proportion of two substances but instead of measuring the amount of solid product formed, measure the amount of heat given off. The correct proportion will give off the most heat.

1. Prepare a solution of 0.50 M sodium hypochlorite, NaOCl. (This is the active ingredient of Clorox.) Also prepare a 0.50 M solution of sodium thiosulfate,  $\text{Na}_2\text{S}_2\text{O}_3$ . (This is the substance that a photographer calls "fixer".)
2. Measure the NaOCl indicated in the chart into a Styrofoam cup. Measure the  $\text{Na}_2\text{S}_2\text{O}_3$  indicated in the chart into a beaker. Place a thermometer that can be read to a tenth of a degree in the Styrofoam cup. Pour the solution in the beaker into the Styrofoam cup and swirl it for two seconds. Immediately note the temperature on the thermometer. Determine the highest temperature reached and record it.

Station #	mL NaOCl	mL $\text{Na}_2\text{S}_2\text{O}_3$	Starting T	Highest T
1	10	90		
2	20	80		
3	30	70		
4	40	60		
5	50	50		
6	60	40		
7	70	30		
8	80	20		
9	90	10		

3. Analysis of the table will tell you which proportion of solutions gave the largest change in temperature. This will be the correct proportion of the two compounds needed to react and form the product.
- B. If you did not carry out the determination of the percentage of water in Epson salts in the Law of Conservation of Mass experiment, this would be a good time to perform this determination. Instructions are given on page 19.