Solving a Limiting Reactant Problem with Lego™ or Gum Drop Models

Objective: Students will use models to explore each step in solving a limiting reactant problem. The reaction is a double displacement reactant forming a solid precipitate from ionic solutions.

Supplies: Each student will need an ample supply of four different colors of either lego or gum drops.

Problem: 120 mL of 0.10 M Potassium Carbonate are mixed with 75 mL of 0.20 M Cobalt (III) Chloride. Find the mass of precipitate formed and the concentration of all remaining ions in the solution when the reaction is complete.

1. Write the formula for the following ions and assign a color to each ion.

   Chloride Ion: _____ Potassium Ion: _____
   Cobalt (III) Ion: _____ Carbonate Ion: _____

2. Write the formulas for: potassium carbonate **K_2CO_3** cobalt chloride **$CoCl_3$**

3. For each mmole of compound in the reactant solutions – build a model of the compound. Use the color you assigned for each ion. Polyatomic ions are represented by one model piece only. How many mmoles of each compound did you build? potassium carbonate: **12** cobalt chloride: **15**
   (Show your calculations).
   120 mL X 0.10 M K_2CO_3 = 12 mmoles K_2CO_3
   75 mL X 0.20 M $CoCl_3$ = 15 mmoles $CoCl_3$

4. Write a balanced equation for a double displacement reaction between these two compounds. Identify all states of matter – aqueous, solid, liquid, gas.

   $3K_2CO_{3(aq)} + 2CoCl_{3(aq)} \rightarrow Co_2(CO_3)_{3(s)} + 6KCl_{(aq)}$

5. Write the net ionic equation for this reaction. What is the name of the solid product? **Cobalt (III) Carbonate**

   $2Co^{3+} + 3CO_3^{2-} \rightarrow Co_2(CO_3)_{3(s)}$

6. What is the total volume of the solution after the two reactant solutions have been mixed? **195mL**

7. Take apart the models you have constructed and place all "ions" into one container. Then use this container of ions to build as many "mmoles" of solid product as possible and remove them from the container. How many "mmoles" is it possible to build? **four (4)**

8. What is the molar mass of the product? **297.89 g/mol** How many grams of product are present at the end of the reaction? (show the calculation) **19 g Cobalt (III) Carbonate**

   0.0040 mol X 297.89 g/mol = 19 g (two significant figures)

9. Of the two ions that form the product, which ion remains (in excess) in the container after all possible product has been formed? **7 cobalt ions remain in the container. All the carbonate ions are used.**

10. Which reactant is the limiting reactant? **Potassium Carbonate (K_2CO_3)** Explain your answer.

    To make the four mmoles of product required 12 carbonate mmols of ions since each product compound has 3 carbonate ions. 3 X 4 = 12 and this represents all of the carbonate ions available. To make four mmoles of product required 8 cobalt ions since each product compound has 2 cobalt ions in it. We have 15 cobalt ions and if we use 8 then 7 remain.

11. Which ions were not used to make the product? **potassium and chloride**
    These ions are known as spectator ions. They do not appear in the net ionic equation.

12. Count the numbers of each ion still in the container and use this information to determine the concentration of all ions in solution at the completion of the reaction by dividing it by the total solution volume. Show all calculations.

    15 mmoles X 3 = 45 mmoles chloride ions **45 mmoles / 195mL = 0.23 M**

    12mmoles X 2 = 24 mmoles potassium ions **24 mmoles / 195mL = 0.12 M**

    7 mmoles unreacted cobalt ions **7 mmoles / 195 mL = 0.036 M**

    The concentration of carbonate ion is 0M