Determining the Empirical Formula of a Compound

Problem: Can you determine the simplest, whole-number ratio between the moles of each element in a compound from experimental data?

The simplest, whole-number ratio between the moles of each element in a compound is called the empirical formula. By experimentally measuring the masses of each component of a compound, and then converting the masses into an equivalent number of moles using molar mass as a conversion factor, the ratio of moles of each component can be calculated. When this mole ratio is expressed as whole numbers, then the empirical formula can be written.

Procedure and Results:
Record all data in a clearly labeled chart! Show ALL WORK for calculated values including units and labels!

Part I: Empirical Formula of Mn_xCl_y

1. Mass a 100 mL beaker and watch glass(for a lid). Add 1.0 to 1.2 g of manganese metal to the beaker and re-mass. Calculate the exact mass of Mn metal used (±0.01g).

2. Add 10 mL of hydrochloric acid, which will be an excess amount of acid needed for a complete reaction to occur in this experiment. Vigorous bubbling should occur initially as the metal starts to dissolve and hydrogen gas is produced. Place a watch glass over the beaker as a lid and place the beaker aside to allow the mixture to react while you begin to set up Part II of this lab. **Go to Part II Step 1**

3. The reaction between Mn and HCl(aq) should have subsided by this point. Use either a hot plate or a lab burner to gently warm the solution in the beaker with the watch glass on top for about 5 minutes. (**Caution:** Avoid breathing the vapors which may contain a trace amount of excess acid.) Now begin boiling the solution, under a fume hood, if available.

3. As the liquid evaporates, solid Mn_xCl_y will begin to form. At this point, start heating gently again to prevent the solid from popping and spattering, like popcorn. Remove the watch glass lid, and continue to heat gently, while stirring the mixture with a stirring rod.

4. Once all the liquid is gone, resume strong heating until the solid is completely dehydrated(no more steam is being driven off). Use a metal spatula to try to stir the solid sticking to the bottom of the beaker and to break up any lumps that may have formed. The solid should be a fine powder once it is totally dehydrated. Allow the beaker to cool to the touch, then re-mass. In order to be sure that all of the trapped water is gone, reheat for 3 minutes, cool and re-mass. Continue this process until a constant mass value (±0.02 g) is achieved. Calculate the mass of Mn_xCl_y produced. **Note:** The Mn_xCl_y will re-absorb moisture from the air and should be stored in a dessicator if allowed to sit overnight.)

5. Calculate the mass of chloride ions in the new compound, then determine the empirical formula. Enter your data into the class spreadsheet for further analysis.

Part II: Empirical Formula of a Hydrated Compound, $MgSO_4 \cdot xH_2O$

1. Mass a 250 mL beaker with a watch glass for a lid, then add 3 to 5 g of Epsom salt $MgSO_4 \cdot xH_2O$) to the beaker and re-mass. Calculate the exact mass of $MgSO_4 \cdot xH_2O$ used (±0.01g).

2. Using a bunsen burner or hot plate set at 350ºC or higher, gently warm the solid in the beaker. Continue heating the solid until all of the water vapor is gone (no more steam is being driven off). Use a metal spatula to try to stir the solid and break up any lumps that may have formed. Allow the beaker to cool and re-mass. In order to be sure that all of the trapped water has been removed, reheat for 3 minutes, cool and re-mass. Continue this process until a constant mass value (±0.02 g) is achieved. Calculate the mass of dehydrated $MgSO_4$ that remains.

3. Calculate the mass of water driven off, then determine the empirical formula for the hydrated Epsom salt. Enter your data into the class spreadsheet for further analysis.
   Go to Part I Step 4

Results:

Record all of your measurements in a clearly labeled data table. Show all of your calculations in a clear and organized fashion, including units and labels. If time permits, enter your data into a class spreadsheet to analyze the group's results and determine the precision of the experiment.

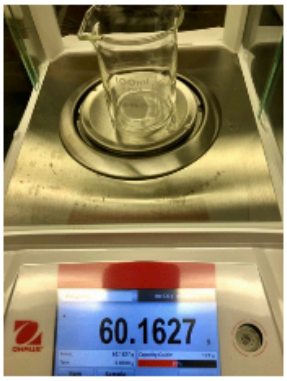
Conclusions:

Use the possible oxidation states for manganese and chlorine to predict all possible empirical formulas that may occur. Does your experimental empirical formula match one of these possibilities? If some of the water remained trapped within the solids in Parts I or II above, how would that effect the mole ratios determined for the empirical formulas? Justify your answer.

Watch the video found at https://youtu.be/8UYzFCoFZLA to view the procedures used in this experiment and record observations about the chemical and physical changes that were involved. Sample data is included on the next page of this lab.

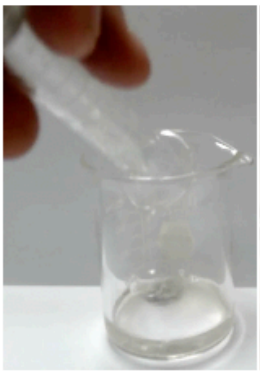
Empirical Formula Data for Mn_xCl_y and Epsom Salt

Part I Data: Mn_xCl_y



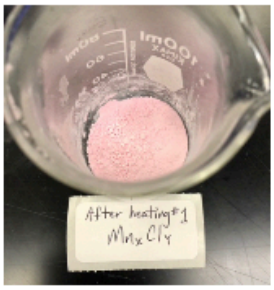
mass empty beaker

mass beaker & Mn



10 mL HCl added

mass beaker & Mn_xCl_y after 1st heating

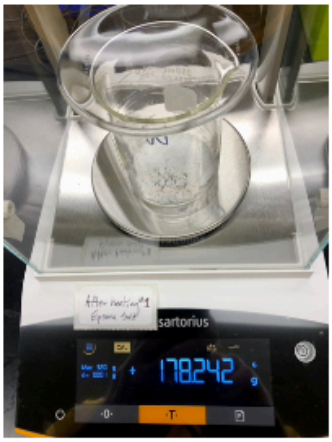


after 2nd heating mass = 62.6753 g

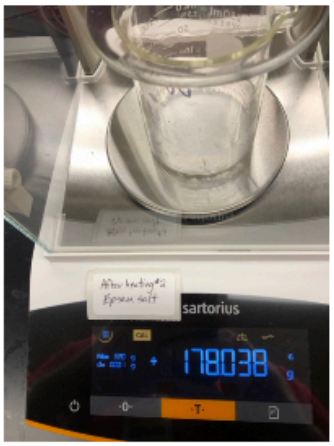
Part II Data: Epsom Salt $MgSO_4 \bullet xH_2O$

mass of empty beaker and watch glass

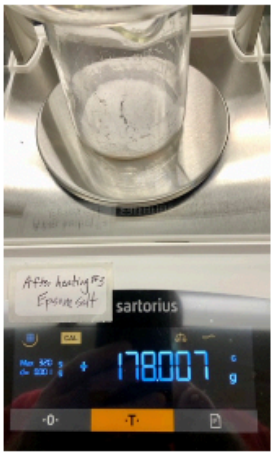
mass of beaker, watch glass & Epsom salt



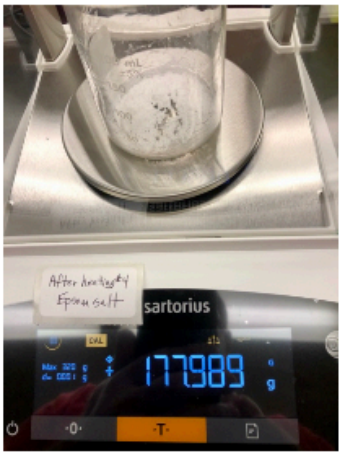
mass beaker, watch glass, Epsom salt after 1st heating



mass beaker, watch glass, Epsom salt after 2nd heat



mass beaker, watch glass, Epsom salt after 3rd heat



mass beaker, watch glass, Epsom salt after 4th heat
(Note: hotplate temperature raised to 400ºC)