Hydrates

v052813_1130am

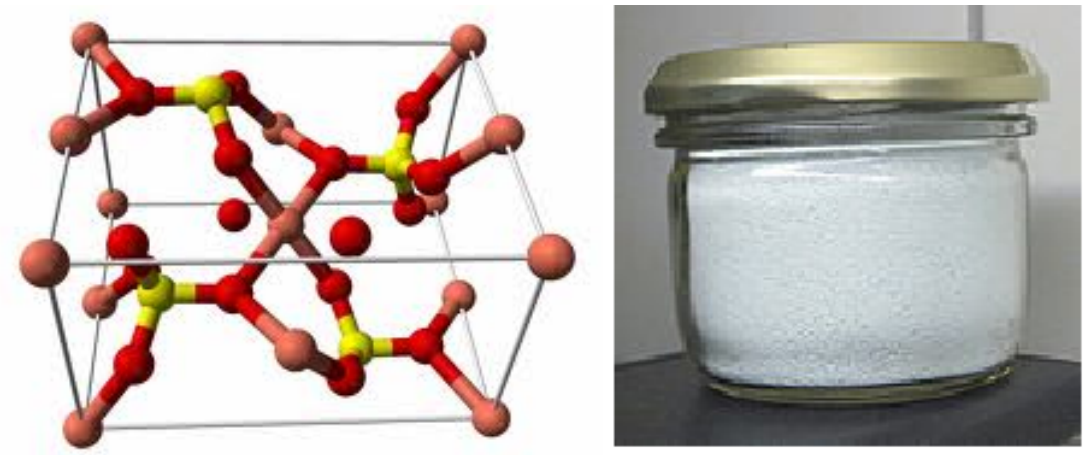
Objective: Be able to distinguish between an anhydrous ionic compound, a hydrate of an ionic compound, and a wet compound. Be able to determine the formula of an ionic hydrate and name the hydrate correctly.

Background:
Ionic compounds are substances that contain ionic bonds. Ionic bonds result from the electrostatic attraction between a cation and an anion. An **anhydrous** ionic compound is one that contains anions and cations combined in such a manner so as to achieve a charge neutral compound but the compound itself does not contain water.

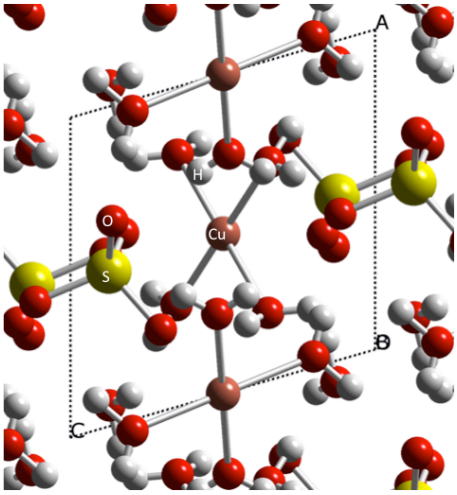
Hydrates (Chapter 3 Section 5 of Tro 2nd Edition) are compounds that contain a specific number of water molecules associated with the crystalline structure of the compound. These water molecules are known as waters of hydration. Because a quantifiable number of waters are associated with the crystalline structure, the number of waters is included as part of the formula for the compound and in the name of the compound.

- To include the waters of hydration in the formula, the formula of the compound is separated from the formula of the water using a dot and the number of waters is included as a coefficient to the water portion of the formula. Example: $CuSO_4 \cdot 5\ H_2O$.
- To name the hydrate, first name the ionic compound followed by the word hydrate. Indicate the number of waters, prior to the word hydrate, using the prefix system found on page 93 of Tro 2nd Edition. Example: copper(II) sulfate pentahydrate.

Below are crystallographic images of copper(II) sulfate and copper(II) sulfate pentahydrate along with images of the solids for comparison.



Copper(II) sulfate, $CuSO_4$

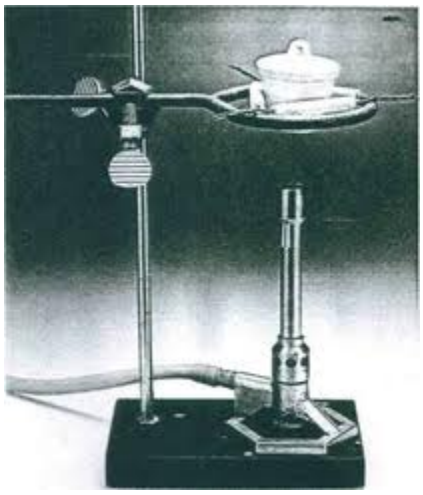


Copper(II) sulfate pentahydrate, $CuSO_4 \cdot 5\ H_2O$

It is important to differentiate between a hydrate and a compound that is simply wet. Hydrates are pure substances, because they contain a specific and reproducible number of waters in their formula. A wet compound is a mixture of two compounds that vary in their percent composition; a sample can be very wet or contain just a bit of extraneous water.

Procedure

1. Obtain a crucible and lid.
2. Thoroughly wash the crucible and lid with soap and water.
3. Rinse the crucible and lid first with tap water and then with distilled water.
4. Obtain a Bunsen burner, clay triangle, ring stand, iron ring, tongs, wire gauze, and lighter.
5. Assemble the Bunsen burner, clay triangle, ring stand, iron ring, and crucible and lid as indicated in the picture below. The crucible should be approximately _____ inches above the Bunsen burner.



6. Light the Bunsen burner and heat the crucible and lid for 5 minutes.
7. Lower the iron ring so that the base of the crucible glows orange. Heat for 10 minutes.
8. Turn off the Bunsen burner.
9. Remove the crucible and lid from the iron ring using tongs and place on the wire gauze to cool.

Use of crucible tongs

Wire Gauze

10. Allow the crucible and lid to cool to room temperature.
11. Mass the crucible and lid and record the reading as mass of crucible and lid after 1st heating.
12. Place the crucible and lid back onto the clay triangle and light the Bunsen burner.
13. Heat the crucible and lid (base should glow orange) for 5 minutes.

14. Remove the crucible and lid from the clay triangle using tongs and place on the wire gauze to cool.
15. Allow the crucible and lid to cool to room temperature.
16. Mass the crucible and lid and record the reading as mass of crucible and lid after 2nd heating.
17. Repeat steps 13-16 for 3rd and 4th until your mass is within ± 0.005 g.
18. Obtain an unknown hydrate from your instructor labeled with the formula of the anhydrous compound.
19. Record the formula of the anhydrous compound on your data sheet.
20. To your crucible add approximately 2 grams of hydrate.
21. Record as the mass of the crucible, lid, and sample before heating.
22. Place the crucible, lid, and sample onto the clay triangle and light the Bunsen burner.
23. Heat the crucible, lid, and sample for 10 minutes with the lid ajar.
24. Remove the crucible, lid, and sample from the clay triangle using tongs and place on the wire gauze to cool.
25. Allow the crucible, lid, and sample to cool to room temperature.
26. Mass the crucible, lid, and sample and record the reading as mass of crucible, lid, and sample after 1st heating.
27. Place the crucible, lid, and sample onto the clay triangle and light the Bunsen burner.
28. Heat the crucible, lid, and sample for 5 minutes.
29. Remove the crucible, lid, and sample from the clay triangle using tongs and place on the wire gauze to cool.
30. Allow the crucible, lid, and sample to cool to room temperature.
31. Mass the crucible, lid, and sample and record the reading as mass of crucible, lid, and sample after 2nd heating.
32. Repeat steps 27-31 for 3rd and 4th heating if your instructor indicates that it is necessary.
33. Clean up all supplies and put all equipment away. Dispose of anhydrous solids according to your instructor's directions.

Pre-Laboratory Questions

1. Using pages 92 and 93 in Tro 2nd Edition, name the following hydrates.

   a. $CoF_2 \cdot 4H_2O$ _____

   b. $Al(ClO)_3 \cdot 8H_2O$ _____

2. A student in a research lab performed an experiment similar to the one you will be performing. Given the following data, answer the questions that follow.

Identity of anhydrous compound	$CoCl_2$
Mass of empty crucible	10.443 g
Mass of crucible plus sample before heating	12.543 g
Mass of crucible plus sample after heating	11.589 g

   a. Mass of hydrate _____

   b. Mass of anhydrous compound _____

   c. Molar mass of anhydrous compound _____

   d. Moles of anhydrous compound _____

   e. Mass of water generated _____

   f. Molar mass of water _____

   g. Moles of water generated _____

   h. Mole ratio of water : anhydrous compound _____

   i. Formula of hydrate _____

   j. Name of hydrate

Data and Results

Data:

Chemical Formula of Anhydrous Compound: _____

Mass of crucible and lid after 1st heating: _____

Mass of crucible and lid after 2nd heating: _____

Mass of crucible and lid after 3rd heating: (if necessary) _____

Mass of crucible, lid, and sample before heating: _____

Mass of crucible, lid, and sample after 1st heating: _____

Mass of crucible, lid, and sample after 2nd heating: _____

Mass of crucible, lid, and sample after 3rd heating: (if necessary) _____

Mass of crucible, lid, and sample after 4th heating: (if necessary) _____

Results

Mass of hydrate: _____

Mass of anhydrous compound: _____

Molar mass of anhydrous compound: _____

Moles of anhydrous compound: _____

Mass of water generated: _____

% by mass of water in your hydrate: _____

Moles of water generated: _____

Mole ratio of water : anhydrous compound _____

Formula of hydrate: _____

Name of hydrate:

Post-Laboratory Questions

1. A photograph of a simple desiccator is shown. Desiccators are sealable enclosures containing a solid desiccant. Desiccants are effective at removing traces of water from an almost-dry sample and for preserving moisture-sensitive items.

   a. Would anhydrous compounds of hydrates be good desiccants? Explain.

   b. Which of the following compounds would be the best desiccant on a mole basis? Explain.

$CoCl_2 \cdot 6\ H_2O$	$CoCl_2$
$CuSO_4 \cdot 5\ H_2O$	$CuSO_4$
$MnSO_4 \cdot H_2O$	$MnSO_4$

2. Write the balanced chemical equation for the dehydration of $BaCl_2 \cdot 2H_2O$ (include the symbol for heat).

3. Why was it necessary to heat the empty crucible to constant mass?

4. Why was it necessary to heat the crucible and compound to constant mass?