Honors Chemistry Hour\_\_\_\_\_ Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  
Dr. Wexler  
Lab: Determining the Formula of a Hydrate  
Date\_\_\_\_\_\_\_

We have previously established that we can predict the mass of water lost from a hydrate if we are given its molecular formula, including the molar ratio of water to salt (hydration coefficient, h, which is the number of water molecules per formula unit of salt). For example, copper sulfate pentahydrate, CuSO4•5H2O has a 5:1 ratio of water to salt. Once the mass % of water is known, then one can easily predict the water content in a given mass of hydrate (ex. 0.51% H2O x 100g hydrate = 51g water lost when the salt is heated).

In this case, we are interested in experimentally determining the molar ratio of water to salt when only the formula of the salt is known. You will determine the mass % of water in a hydrate by heating it. The mass % is then used along with the molar mass of the salt to calculate the hydration coefficient.

For example:  
Assume you don’t know the hydration coefficient (h) of CuSO4•hH2O and you want to find out.  
Also assume you don’t know the molar mass of the hydrate.  
A. You calculate that the molar mass of CuSO4 is 159.6 g/mol.  
B. The molar mass of H2O is 18.0 g/mol

Experimentally, after you heat 3.00g of hydrate you find that 1.92 g of solid remain.   
C. You calculate that the mass of water in the hydrate = 3.00 g – 1.92 g = 1.08 g H2O  
D. You calculate that the mass % of water in the hydrate = 100 (1.08g/3.00g) = 36.0% = 0.36 in decimal form.

To calculate the hydration coefficient:  
E. Define: molar mass of hH2O in the hydrate = X  
F. Define: molar mass of hydrate = molar mass of CuSO4 + molar mass of hH2O = 159.609 + X  
  
G. Experimental mass % H2O = 0.36 in decimal form (see D above)  
H. Mass % is also = X/(159.609 + X) in decimal form  
I. Therefore, X/(159.609 + X) = 0.36  
  
J. Cross-multiplying and distributing: X = 0.36(159.609 + X) = 57.46 + 0.36X  
K. Solving for X: X – 0.36X = 57.46 🡪 0.64X = 57.46 🡪 X = 57.46/.64 = 89.8 g/mol hH2O

L. Solve for the hydration coefficient (h) by dividing the molar mass of hH2O (X above) by the molar mass of 1H2O:

89.8/18.015 = 4.99

Rounding, the hydration coefficient is 5, and the formula for the hydrate is CuSO4•5H2O

Do a different example by yourself: ammonium chromate  
1. You weigh out 3.00 g hydrate into an evaporating dish. The formula of your hydrate is (NH4)2CrO4•hH2O

2. You heat the hydrate until completely dry

3. You determine the hydration coefficient as follows:

A. You calculate that the molar mass of (NH4)2CrO4 is \_\_\_\_\_\_\_\_\_\_\_\_\_\_ g/mol.  
Show calculations below:

B. You calculate that the molar mass of H2O is 18.0 g/mol

C. Experimentally, after you heat 3.00g of hydrate you discover that 2.05 g of solid remains.   
  
D. The mass of water in the hydrate = 3.00 g – 2.05 g = \_\_\_\_\_\_\_ g H2O  
  
E. You calculate that the mass % of water in the hydrate = 100 (\_\_\_\_\_\_\_g/3.00g) = \_\_\_\_\_\_\_% = \_\_\_\_\_\_\_\_ as a decimal.

To calculate the hydration coefficient:  
  
F. Experimental mass % H2O = \_\_\_\_\_\_\_\_\_\_\_ as a decimal (see E above)  
  
G. Mass % is also = X/(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + X) as a decimal  
  
H. Therefore, X/(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + X) = \_\_\_\_\_\_\_\_\_\_\_\_

I. Cross-multiplying and distributing: X =

J. Solving for X:

K. Divide this by the molar mass of water to calculate the hydration coefficient:

Therefore, the formula for the hydrate is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Procedure:  
You are given a salt with an unknown hydration coefficient. Your job is to determine the hydration coefficient and therefore the formula of the hydrate.

1. Weigh out 3.00 g hydrate into an evaporating dish. The formula of your salt is\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. Heat the hydrate until completely dry. This will take anywhere from 5 to 10 minutes. Stop heating if the salt appears to turn brown at the edges. You are done.

3. Let cool and scrape the solids into a zeroed weigh boat on a digital scale. Record the mass = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ g.

4. Calculate the hydration coefficient:

A. You calculate that the molar mass of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is \_\_\_\_\_\_\_\_\_\_\_\_\_\_ g/mol.  
Show calculations below:

B. You calculate that the molar mass of H2O is 18.015 g/mol

C. Experimentally, after you heated 3.00g of hydrate you found that \_\_\_\_\_\_\_\_\_ g of solid remain.   
  
D. The mass of water in the hydrate = 3.00 g – \_\_\_\_\_\_\_\_\_ g = \_\_\_\_\_\_\_ g H2O  
  
E. You calculate that the mass % of water in the hydrate = 100 (\_\_\_\_\_\_\_g/3.00g) = \_\_\_\_\_\_\_% = \_\_\_\_\_\_\_\_ as a decimal.

To calculate the hydration coefficient:  
  
F. Experimental mass % H2O = \_\_\_\_\_\_\_\_\_\_\_ (see above)  
  
G. Mass % is also = X/(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + X)  
  
H. Therefore, X/(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + X) = \_\_\_\_\_\_\_\_\_\_\_\_

I. Cross-multiplying and distributing: X =

J. Solving for X:

K. Divide this by the molar mass of water to calculate the hydration coefficient:

Therefore, the formula for the hydrate is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_