P E3 (pg 1 of 3) **Formula of a Hydrate** Name______________________Per____

If you are having difficulty please make use of the examples provided in NS F.4 Show your work clearly and carefully on an extra piece of paper so that you can refer to it later to check for mistakes, use for review and/or share your expertise with others.

1. Consider aluminum nitrate **nono**hydrate. $Al(NO_3)_3$ • ____ H_2O
   a. Calculate the theoretical % of water this hydrate.
   b. If you were given 10.0 g of this hydrate, when heated to dryness, what would be the remaining mass of anhydrate?

2. Bert and Ernie were working with an unknown hydrate. They each had their own individual samples.
   a. Bert's sample weighed 1.46 g and then after heating the dried salt (the anhydrate) had a mass of 1.25 g, calculate the % of water in the hydrate.
   b. Ernie's hydrate sample weighed 3.62 g, what water can he expect to remove from his sample?

3. Determine the formula for a calcium sulfate hydrate $CaSO_4$ • ____ H_2O that was determined to be 44 % water.

4. Determine the formula for a lead(II) acetate hydrate $Pb(C_2H_3O_2)_2$ • ____H_2O that had an original mass of 1.21 g and when heated, its mass decreased by 0.17 g

5. 12.25 g of a hydrate compound was heated and the anhydrate weighed 8.93 g. The anhydrate was further analyzed and determined to be 2.06 g iron and 1.55 g nitrogen, and the rest oxygen. Determine the formula of this hydrate. What is the name of this hydrate?

6. A hydrate was determined to be 44.9 % water. The anhydrate was analyzed to be 37.9% nickel, 20.7% sulfur, and 41.4% oxygen. Determine the formula of this hydrate.

7. Determine the formula of a hydrate that was only 17.97 % copper, 1.13 % hydrogen, 9.05 % oxygen, and the rest iodine. Assume that the anhydrate is a made of just copper and iodine.

8. The iron(II) chloride hydrate is heated to remove its water, the water removed is nearly the same mass as the anhydrate itself. What is the formula of this hydrate? $FeCl_2$ • ____ H_2O

This problem is a bit tricky…give it a try after you are feeling confident.

9. A chromium, sulfur, oxygen hydrate was was analyzed and found to be 14.59% chromium, 18.00% sulfur, 62.87% oxygen and 4.54% hydrogen. Determine the formula of this hydrate.

Formula of a Hydrate

ANSWERS

1. *First you need to write the correct formula for the salt:* $Al(NO_3)_3 \cdot 9\ H_2O$

   a. $Al(NO_3)_3$ 26.98 + 3(14.01) + 9(16) = 213.01 and 9 H_2O 9[2(1.01) + 16.0] = 162.18 The hydrate total = 375.19

   $$\frac{162.18g}{375.19g}\times 100 = 43.2\% water$$

   b. 43.2 % water means that the hydrate is 56.8 % anhydrate. Thus $10g \times 0.568 = 5.68g\ of Anhydrate$

2. *Although we do not know the identity of this hydrate, we can calculate the percent of its parts, water and anhydrate.*

   a. 1.46 – 1.25 = 0.21 g water $\frac{0.21g}{1.46g}\times 100 = 14.4\% water$

   b. $3.62g \times 0.144 = 0.521g\ of Water$

3. If hydrate is said to be 44% water, then we know that 56% is the anhydrate.
   $CaSO_4 \cdot ?\ H_2O$ $CaSO_4$ 40.08 + 32.07 + 4(16) = 136.15 g/mol water = 18.02 g/mol

   $$56g(\%)\times\frac{1mol}{136.15g} = 0.411mol \qquad \frac{0.411}{0.411} = 1$$

   $$44g(\%)\times\frac{1mol}{18.02g} = 2.44mol \qquad \frac{2.44}{0.411} = 5.94 \Rightarrow 6$$

   Thus $\mathbf{CaSO_4 \cdot 6\ H_2O}$

4. 1.21 g − 0.17 g decrease (water removed) = 1.04 g of the anhydrate ($Pb(C_2H_3O_2)_2$)
   Thus $Pb(C_2H_3O_2)_2 \cdot ?\ H_2O$ $Pb(C_2H_3O_2)_2$ 207.2 + 4(12.01) + 6(1.01) + 4(16) = 325.29 g/mol water = 18.02 g/mol

   $$1.04g\times\frac{1mol}{325.29g} = 0.003197mol \qquad \frac{0.003197}{0.003197} = 1$$

   $$0.17\times\frac{1mol}{18.02g} = 0.009433mol \qquad \frac{0.009433}{0.003197} = 2.95 \Rightarrow 3$$

   Voilà $\mathbf{Pb(C_2H_3O_2)_2 \cdot 3H_2O}$

5. *In this problem it is important to recognize that you must determine the empirical formula of the anhydrate before proceeding on to the formula of the entire hydrate.*

   $$2.06\times\frac{1mol}{55.85g} = 0.0369mol \qquad \frac{0.0369}{0.0369} = 1$$

   $$1.55\times\frac{1mol}{14.01g} = 0.111mol \qquad \frac{0.111}{0.0369} = 3$$

   $$5.32\times\frac{1mol}{16g} = 0.3325mol \qquad \frac{0.3325}{0.0369} = 9$$

   Voilà $FeN_3O_9 \cdot ?\ H_2O$

   Next you must proceed on to the hydrate part of the problem.

   12.25 g − 8.93 g = 3.32 g of water FeN_3O_6 55.85 + 3(14.01) + 9(16) = 241.88 g/mol water = 18.02 g/mol

   $$8.93g\times\frac{1mol}{241.88g} = 0.0369mol \qquad \frac{0.0369}{0.0369} = 1$$

   $$3.32\times\frac{1mol}{18.02g} = 0.1842mol \qquad \frac{0.1842}{0.0369} = 5$$

   $FeN_3O_6 \cdot \mathbf{5\ H_2O}$ **tetra**hydrate

Formula of a Hydrate

ANSWERS

6. *In this problem it is important to recognize that you must determine the empirical formula of the anhydrate before proceeding on to the formula of the entire hydrate. All of the percentages given in the problem would add up to more than 100% and must be treated separately.*

$$37.9g(\%)\times\frac{1mol}{58.69g}=0.646mol \qquad \frac{0.646}{0.645}=1$$

a. $$20.7g(\%)\times\frac{1mol}{32.07}=0.645mol \qquad \frac{0.645}{0.645}=1 \quad \text{Thus} \quad NiSO_4$$

$$41.4g(\%)\times\frac{1mol}{16}=2.59mol \qquad \frac{2.59}{0.645}=4$$

b. *Next you must proceed on to the hydrate part of the problem.* 100% − 44.9% water = 55.1 % anhydrate.

$NiSO_3$ 58.69 + 32.07 + 4(16) = 154.76 g/mol

$$55.1g(\%)\times\frac{1mol}{154.76g}=0.356mol \qquad \frac{0.356}{0.356}=1$$

$$44.9g(\%)\times\frac{1mol}{18.02g}=2.49mol \qquad \frac{2.49}{0.356}=7$$

Voilà **$NiSO_4 \cdot 7\ H_2O$**

7. *In this problem, the fundamental difference is that the water and anhydrate are not given as separate percentages to those of the formula of the compound, and should be treated all together. You are given the hint that the anhydrate is a binary ionic compound, thus telling you that the anhydrate only includes copper and iodine.*

$$17.97g(\%)\times\frac{1mol}{63.55g}=0.283mol \qquad \frac{0.411}{0.283}=1$$

$$71.85g(\%)\times\frac{1mol}{126.9g}=0.566mol \qquad \frac{0.566}{0.283}=2$$

$$1.13g(\%)\times\frac{1mol}{1.01g}=1.12mol \qquad \frac{1.12}{0.283}=4$$

$$9.05g(\%)\times\frac{1mol}{16g}=0.566mol \qquad \frac{0.566}{0.283}=2$$

Voilà **$CuI_2 \cdot 2\ H_2O$**

8. *We are told the compound is iron(II) chloride, thus $FeCl_2$ and since we are told the water removed is nearly the same as the remaining anhydrate, we can assum 50% of each.*

$$50g(\%)\times\frac{1mol}{126.75g}=0.394mol \qquad \frac{0.394}{0.394}=1$$

$$50g(\%)\times\frac{1mol}{18.02g}=2.77mol \qquad \frac{2.77}{0.394}=7$$

Voilà **$FeCl_2 \cdot 7\ H_2O$**

9. *This problem is the trickiest of the bunch. It is very similar to #7, however, this time the anhydrate includes oxygen. The amount of oxygen in the anhydrate and water must be separated. Since the problem tells you that the hydrate contains chromium, sulfur, and oxygen, we know that ALL the hydrogen is in the water, H_2O.*

$$14.59g(\%)\times\frac{1mol}{52g}=0.2805mol \qquad \frac{0.2805}{0.2805}=1$$

$$18.00g(\%)\times\frac{1mol}{32.07g}=0.561mol \qquad \frac{0.561}{0.2805}=2$$

$$62.87g(\%)\times\frac{1mol}{16g}=3.929mol \qquad \frac{3.929}{0.2805}=14$$

$$4.54g(\%)\times\frac{1mol}{1.01g}=4.495mol \qquad \frac{4.495}{0.2805}=16$$

Now how to figure whether the O's are in the water or the anydrate…

In the problem, and stated above, ALL the hydrogen is in the water, H_2O. From the mole numbers calculated above we know that all 16 H's must be in the water, and that 16 H's would require 8 O's to go with them. Thus we know that 6 O's must be in the anhydrate portion of the compound.

Voilà $CrS_2O_6 \cdot 8\ H_2O$