Unit 8: Moles and Solutions

Name: KEY

Learning Targets
1. *I CAN report my answer to a calculation in the correct number of significant digits *review*
2. *I CAN write a given value in scientific notation *review*
3. I CAN define the mole and describe it's use in chemistry
4. *I CAN solve a problem using dimensional analysis (multi-step conversions) *review*
5. I CAN calculate the molar mass (formula weight) of a compound
6. I CAN describe a hydrate and calculate its molar mass
7. I CAN convert in between mass, moles, and atoms/molecules.
8. I CAN calculate the percent composition of an element in a compound
9. I CAN use data collected in lab to determine the empirical formula for a compound
10. I CAN use data collected in lab to determine the molecular formula for a compound
11. I CAN describe the components of a solution (solute, solvent)
12. I CAN describe the solubility of a compound in water using a saturation curve (unsaturated, saturated, or supersaturated)
13. I CAN calculate the concentration of a solution (moles and mass of solute, volume of solvent, molarity)
14. I CAN calculate the amount of water needed to dilute a solution

Chemistry Important Dates!

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
March 27	28	29	30	31	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16

Notes on What is a Mole?

Inquiry into "The Mole"

No… Not this kind of mole!

Purpose/Objective
Understand the relationship between the mass of an element and the number of particles (the mole).

The Model

		
Beaker 1	**Beaker 2**	**Beaker 3**
55.8 g of iron	111.6 g of iron	112 g of cadmium
1 mole of iron	2 mole of iron	1 mole of cadmium
6.02×10^{23} atoms of iron	12.04×10^{23} atoms of iron	6.02×10^{23} atoms of cadmium

Use "The Model" on the previous page to answer the following questions:

1. Which beaker (1 or 2) has more **atoms** of iron? Beaker 2

2. How many **grams** of iron are in
   Beaker 1? 55.8 g
   Beaker 2? 111.6g

3. How many **moles** of iron are in:
   Beaker 1? 1 mole
   Beaker 2? 2 mole

4. How many **atoms** of iron are in
   Beaker 1? 6.02×10^{23} atoms
   Beaker 2? 12.04×10^{23} atoms

Exploring the Model

5. Write an equality statement between grams of iron and moles of iron in Beaker 1. 55.8g = 1 mole

   Write an equality statement between grams of iron and moles of iron in Beaker 2. 111.6g = 2 mole

   Is there a relationship between the equality for Beaker 1 and Beaker 2? Yes, Beaker 2 is twice the amount of Beaker 1.

6. Write the equality between grams of cadmium and moles of cadmium.
   112 g = 1 mole

7. Write the equalities above (problems 5 and 6) as conversion factors.
   Iron: $\frac{55.8\text{g}}{1\text{mole}}$ or $\frac{1\text{mole}}{55.8\text{g}}$ Cadmium: $\frac{112\text{g}}{1\text{mole}}$ or $\frac{1\text{mole}}{112\text{g}}$

8. Compare this information for each element above to the information on the periodic table. Is there a relationship between the information given and your answers to number 7?
   The average atomic mass is the mass of 1 mole of an element.

Evaluate Your Understanding

9. If you are given a mole of atoms of each of the following, what would the mass (grams) be?
   a. Carbon 12.01 g/mol
   b. Potassium 39.10 g/mol
   c. Chlorine 35.45 g/mol

   6
   C
   12.01

   This is called "molar mass"

10. So, how many particles (atoms/molecules/bicycles, etc) in one mole? 6.02×10^{23} particles = 1 mole

Exercising Your Knowledge

11. Different elements, their masses and numbers of particles and moles are listed below. Complete the table with the missing information for each element. **DO NOT USE A CALCULATOR.**

Element	Mass of Sample	Number of Particles in Sample	Number of Moles in Sample
Magnesium	24.31 grams	6.02×10^{23} atoms	1.00 moles
Arsenic	150. grams	1.204×10^{24} atoms	2.00 moles
Sodium	23.0 grams	6.02×10^{23} atoms	1.00 moles
Lithium	13.9 grams	1.204×10^{24} atoms	2.00 moles
Barium	34.3 grams	1.505×10^{23} atoms	0.25 moles
Boron	5.40 grams	3.01×10^{23} atoms	0.50 moles
Silicon	56.2 grams	1.204×10^{24} atoms	2.00 moles
Neon	40.4 grams	1.204×10^{24} atoms	2.00 moles
Iodine	31.7 grams	1.505×10^{23} atoms	0.25 moles
Mercury	100. grams	3.01×10^{23} atoms	0.50 moles

12. If you have two different samples, the first with an actual mass of 100.0 g of silver and the second with an actual mass of 100.0 g of gold, which sample has more atoms (or are they the same)? Explain your answer.
Hint: Set up conversion factors for each substance.

$100.0\,g\ Ag \times \frac{6.02\times10^{23}\ atoms}{107.87\,g\ Ag} \approx 1\ mole$ $\qquad$ $100.0\,g\ Au \times \frac{6.02\times10^{23}\ atoms}{196.97\,g\ Au} \approx 0.5\ mole$

Silver has more atoms because it has a smaller molar mass than gold.

13. You have half a mole of M & M's, how many M & M's do you have?

3.01×10^{23} M&Ms

14. If you have 3.01×10^{23} apples, how many moles of apples do you have?

0.50 mol Apples

Summarizing Your Thoughts

15. Based on what you thought in question 12, explain why it is difficult to compare chemical quantities using only the mass of samples. Every element has a different amount of protons and neutrons which results in a different molar mass. They cannot be compared by mass – only be the amount of atoms present (mole).

16. Consider the number of hydrogen atoms needed for a mass of 1 gram. How would that compare to the amount of jelly beans you needed to have a mass of 1 gram?

Hydrogen atoms are teeny tiny! You would need 6.02×10^{23} atoms to make 1 gram, versus only a few jelly beans.

17. What do you think might be the benefit of working in terms of moles when using chemicals?

You can compare amounts of atoms without dealing with masses.

18. Complete the following:

a. For **any** element, one mole is equal to its <u>molar mass</u> which can be found on the periodic table.

b. One mole = <u>6.02×10^{23}</u> particles

Notes on Molar Mass

Molar Mass (Formula Weight) Calculations

Directions: Determine the Molar Mass (the mass of one mole) of each of the compounds below.

Formula	Molar Mass	
1. $KMnO_4$	39.10 + 54.94 + 16(4) =	158.04 g/mol
2. KCl	39.10 + 35.45 =	74.55 g/mol
3. Na_2SO_4	22.99(2) + 32.07 + 16(4) =	142.05 g/mol
4. $Ca(NO_3)_2$	40.08 + 14.01(2) + 16(6) =	164.16 g/mol
5. $Al_2(SO_4)_3$	26.98(2) + 32.07(3) + 16(12) =	~~310.10~~ g/mol 342.
6. $(NH_4)_3PO_4$	14.01(3) + 1.01(8) + 30.97 + 16(4) =	145.08 g/mol
7. H_2CO_3	1.01(2) + 12.01 + 16(3) =	62.03 g/mol
8. $Mg_3(PO_4)_2$	24.31(3) + 30.97(2) + 16(8) =	262.75 g/mol
9. $Fe_2(SO_3)_3$	55.85(2) + 32.07(3) + 16(9) =	335.91 g/mol

Notes on Hydrates

Hydrates Molar Mass Practice

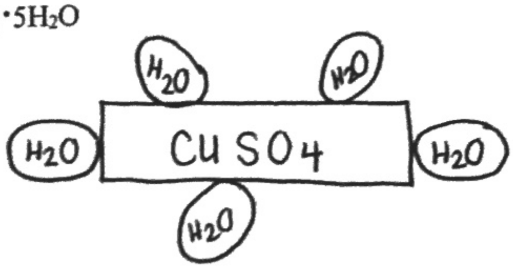
1 water molecule = 18.02 g/mol

1. $Zn_3(PO_4)_2 \cdot 4H_2O$	65.39 (3) + 30.97(2) + 16(8) + 4(18.02) = $\boxed{458.19 \text{ g/mol}}$
2. $Zn(CH_3COO)_2 \cdot 2H_2O$	65.39 + 12.01 (4) + 1.01 (6) + 16(4) + 2(18.02) = $\boxed{219.53 \text{ g/mol}}$
3. $Hg_2Cr_2O_7$	200.59 (2) + 52.00 (2) + 16(7) = $\boxed{617.18 \text{ g/mol}}$
4. $Ba(ClO_3)_2$	137.33 + 35.45 (2) + 16(6) = $\boxed{304.23 \text{ g/mol}}$
5. $CuSO_4 \cdot 5H_2O$	63.55 + 32.07 + 16(4) + 5(18.02) = $\boxed{249.72 \text{ g/mol}}$
6. $NH_4C_2H_3O_2$	14.01 + 1.01 (4) + 12.01(2) + 1.01 (3) + 16(2) = $\boxed{77.10 \text{ g/mol}}$

What is a Hydrate?

A salt (ionic compound) that is stored with water molecules attached to it for storage purposes, as it absorbs water from the atmosphere.

Draw a representation of $CuSO_4 \cdot 5H_2O$



Mole Road: One-Step Conversions

Directions: Set up all problems using dimensional analysis (conversion factors). **NO WORK = NO CREDIT!**

1. How many moles is each of the following?

a. 4.81×10^{24} atoms of Li $\times \frac{1\text{ mole Li}}{6.02 \times 10^{23}\text{ atoms Li}} = \boxed{7.99\text{ mol Li}}$

b. 2.408×10^{24} atoms of aluminum $\times \frac{1\text{ mole Al}}{6.02 \times 10^{23}\text{ atoms Al}} = \boxed{4.000\text{ mol Al}}$

c. 4.816×10^{22} atoms of hydrogen $\times \frac{1\text{ mol H}}{6.02 \times 10^{23}\text{ atoms H}} = \boxed{0.08000\text{ mol H}}$

d. 6.02×10^{22} molecules Br_2 $\times \frac{1\text{ mole } Br_2}{6.02 \times 10^{23}\text{ mc } Br_2} = \boxed{0.100\text{ mol } Br_2}$

e. 1.5×10^{23} molecules NH_3 $\times \frac{1\text{ mole } NH_3}{6.02 \times 10^{23}\text{ mc } NH_3} = \boxed{0.25\text{ mol } NH_3}$

2. How many atoms are in each of the following?

a. 4.2 moles of manganese $\times \frac{6.02 \times 10^{23}\text{ atoms Mn}}{1\text{ mole Mn}} = \boxed{2.5 \times 10^{24}\text{ atoms Mn}}$

b. 7.5 moles of iodine $\times \frac{6.02 \times 10^{23}\text{ atoms I}}{1\text{ mole I}} = \boxed{4.5 \times 10^{24}\text{ atoms I}}$

3. How many moles is each of the following?

a. 13.95 grams of phosphorous $\times \frac{1\text{ mole P}}{30.97\text{ g P}} = \boxed{0.4504\text{ mol P}}$

b. 24 grams of Br_2 $\times \frac{1\text{ mole } Br_2}{159.8\text{ g } Br_2} = \boxed{0.15\text{ mol } Br_2}$

c. 68.95 g of gold $\times \frac{1\text{ mole Au}}{196.97\text{ g Au}} = \boxed{0.3500\text{ mol Au}}$

d. 160 g of copper $\times \frac{1\text{ mole Cu}}{63.55\text{ g Cu}} = \boxed{2.5\text{ mol Cu}}$

e. 25.6 g of sulfur $\times \frac{1\text{ mole S}}{32.07\text{ g S}} = \boxed{0.798\text{ mol S}}$

4. What is the mass (in grams) of:

a. 1.2 mol of iron? $\times \frac{55.85\text{ g Fe}}{1\text{ mole Fe}} = \boxed{67\text{ g Fe}}$

b. 2.5 moles of platinum $\times \frac{195.08\text{ g Pt}}{1\text{ mole Pt}} = \boxed{490\text{ g Pt}}$

c. 0.3 moles of bromine $\times \frac{79.90\text{ g Br}}{1\text{ mole Br}} = \boxed{20\text{ g Br}}$

d. 2.408×10^{23} atoms of oxygen? $\times \frac{1\text{ mole O}}{6.02 \times 10^{23}\text{ atoms O}} \times \frac{16.00\text{ g O}}{1\text{ mole O}} = \boxed{6.400\text{ g O}}$

Mole Road: One-Step and Two-Step Conversions

Directions: Set up all problems using dimensional analysis (conversion factors). **NO WORK = NO CREDIT!**

1. Find the number of atoms in:
   a. 402 grams of mercury $\times \frac{1\text{ mole Hg}}{200.59\text{ g Hg}} \times \frac{6.02\times10^{23}\text{ atoms Hg}}{1\text{ mole Hg}} = \boxed{1.21\times10^{24}\text{ at Hg}}$

   b. 204 grams of magnesium $\times \frac{1\text{ mol Mg}}{24.31\text{ g Mg}} \times \frac{6.02\times10^{23}\text{ atoms Mg}}{1\text{ mol Mg}} = \boxed{5.05\times10^{24}\text{ at. Mg}}$

2. Determine the number of moles in each of the quantities below
   a. 25g NaCl $\times \frac{1\text{ mole NaCl}}{58.44\text{ g NaCl}} = \boxed{0.43\text{ mol NaCl}}$

   b. 125g of H_2SO_4 $\times \frac{1\text{ mol } H_2SO_4}{98.09\text{ g } H_2SO_4} = \boxed{1.27\text{ mol } H_2SO_4}$

   c. 100.g of $KMnO_4$ $\times \frac{1\text{ mol } KMnO_4}{158.04\text{ g } KMnO_4} = \boxed{0.633\text{ mol } KMnO_4}$

   d. 74g of KCl $\times \frac{1\text{ mol KCl}}{74.55\text{ g KCl}} = \boxed{0.99\text{ mol KCl}}$

   e. 35g of $CuSO_4\cdot5H_2O$ $\times \frac{1\text{ mol } CuSO_4\cdot5H_2O}{249.72\text{ g } CuSO_4\cdot5H_2O} = \boxed{0.14\text{ mol } CuSO_4\cdot5H_2O}$

3. Determine the number of grams in each of the quantities below.

   a. 3.2×10^{23} formula units $CuSO_4\cdot5H_2O$ $\times \frac{1\text{ mol } CuSO_4\cdot5H_2O}{6.02\times10^{23}\text{ F.U.N } CuSO_4\cdot5H_2O} \times \frac{249.72\text{ g } CuSO_4\cdot5H_2O}{1\text{ mol } CuSO_4\cdot5H_2O} = \boxed{130\text{ g } CuSO_4\cdot5H_2O}$

   b. 2.81×10^{24} molecules of H_2SO_4 $\times \frac{1\text{ mol } H_2SO_4}{6.02\times10^{23}\text{ mc } H_2SO_4} \times \frac{98.09\text{ g } H_2SO_4}{1\text{ mol } H_2SO_4} = \boxed{458\text{ g } H_2SO_4}$

   c. 1.70×10^{22} formula units of $KMnO_4$ $\times \frac{1\text{ mol } KMnO_4}{6.02\times10^{23}\text{ FUN } KMnO_4} \times \frac{158.04\text{ g } KMnO_4}{1\text{ mol } KMnO_4} = \boxed{4.46\text{ g } KMnO_4}$

   d. 3.85×10^{23} formula units of KCl $\times \frac{1\text{ mol KCl}}{6.02\times10^{23}\text{ FUN KCl}} \times \frac{74.55\text{ g KCl}}{1\text{ mol KCl}} = \boxed{47.7\text{ g KCl}}$

   e. 1.461×10^{23} atoms of Mn $\times \frac{1\text{ mol Mn}}{6.02\times10^{23}\text{ atoms Mn}} \times \frac{54.94\text{ g Mn}}{1\text{ mol Mn}} = \boxed{13.33\text{ g Mn}}$

Not Required – Extra Practice!

Mole Practice!

Directions: Set up all problems using dimensional analysis (conversion factors). **NO WORK = NO CREDIT!**

1. Calculate the formula weights or Molar Masses of the following:
   a. H_3PO_4 $\boxed{98.00\ g/mol}$
   b. $K_2C_4H_4O_6$ $\boxed{226.28\ g/mol}$
   c. $(NH_4)_3PO_4$ $\boxed{149.12\ g/mol}$
   d. $CuSO_4 \cdot 5H_2O$ $\boxed{249.72\ g/mol}$

2. How many **moles** are contained in: **SHOW ALL OF YOUR WORK!**
   a. 15.56g Al_2O_3 $\times \frac{1\ mole\ Al_2O_3}{101.96g\ Al_2O_3} = \boxed{0.1526\ mol\ Al_2O_3}$
   b. 4.40 x 10^{-2}g CO_2 $\times \frac{1\ mol\ CO_2}{44.01g\ CO_2} = \boxed{10.0 \times 10^{-4}\ mol\ CO_2}$
   c. 95.4g C_2H_6 $\times \frac{1\ mol\ C_2H_6}{30.08g\ C_2H_6} = \boxed{3.17\ mol\ C_2H_6}$
   d. 2.45 g H_2SO_4 $\times \frac{1\ mol\ H_2SO_4}{98.09g\ H_2SO_4} = \boxed{0.0250\ mol\ H_2SO_4}$
   e. 8.00 g H_2O_2 $\times \frac{1\ mol\ H_2O_2}{34.02g\ H_2O_2} = \boxed{0.235\ mol\ H_2O_2}$
   f. 2.45 g H_3PO_4 $\times \frac{1\ mol\ H_3PO_4}{98.00g\ H_3PO_4} = \boxed{0.0255\ mol\ H_3PO_4}$
   g. 1.25 g Fe_2O_3 $\times \frac{1\ mol\ Fe_2O_3}{159.7g\ Fe_2O_3} = \boxed{0.00783\ mol\ Fe_2O_3}$
   h. 47.5 g F_2 $\times \frac{1\ mol\ F_2}{38.00g\ F_2} = \boxed{1.25\ mol\ F_2}$

3. How many **grams** are contained in: **SHOW ALL OF YOUR WORK!**
   a. 0.258 moles Al_2O_3 $\times \frac{101.96g\ Al_2O_3}{1\ mol\ Al_2O_3} = \boxed{26.3g\ Al_2O_3}$
   b. 4.40 x 10^{-2} moles SO_2 $\times \frac{64.07g\ SO_2}{1\ mol\ SO_2} = \boxed{2.82g\ SO_2}$
   c. 95.4 moles C_3H_8 $\times \frac{44.11g\ C_3H_8}{1\ mol\ C_3H_8} = \boxed{4200g\ C_3H_8}$
   d. 0.245 moles H_2SO_4 $\times \frac{98.09g\ H_2SO_4}{1\ mol\ H_2SO_4} = \boxed{24.0g\ H_2SO_4}$
   e. 0.800 moles $CaSO_4$ $\times \frac{136.15g\ CaSO_4}{1\ mol\ CaSO_4} = \boxed{109g\ CaSO_4}$
   f. 2.45 moles H_2CO_3 $\times \frac{62.03g\ H_2CO_3}{1\ mol\ H_2CO_3} = \boxed{152g\ H_2CO_3}$
   g. 1.25 moles Co_2O_3 $\times \frac{165.86g\ Co_2O_3}{1\ mol\ Co_2O_3} = \boxed{207g\ Co_2O_3}$
   i. 50 moles H_3PO_4 $\times \frac{98.00g\ H_3PO_4}{1\ mol\ H_3PO_4} = \boxed{4,900g\ H_3PO_4}$
   j. 29 moles $K_2C_4H_4O_6$ $\times \frac{226.28\ g\ K_2C_4H_4O_6}{1\ mol\ K_2C_4H_4O_6} =$ $\boxed{6600\ g\ K_2C_4H_4O_6}$
   k. 56 moles $(NH_4)_3PO_4$ $\times \frac{149.12g\ (NH_4)_3PO_4}{1\ mol\ (NH_4)_3PO_4} =$ $\boxed{8400g\ (NH_4)_3PO_4}$

EVEN Mole Practice! * Not required – Extra Practice! *

Directions: Set up all problems using dimensional analysis (conversion factors). **NO WORK = NO CREDIT!**

What is the molar mass of:

a. H_2 $\boxed{2.02\ g/mol}$

b. $Mg(OH)_2$ $\boxed{58.33\ g/mol}$

c. CO_2 $\boxed{44.01\ g/mol}$

d. NH_4Cl $\boxed{53.50\ g/mol}$

e. $CuSO_4$ $\boxed{159.62\ g/mol}$

f. $AgNO_3$ $\boxed{169.88\ g/mol}$

2. Convert each of the following:

a. How many moles is 12.5 g of magnesium hydroxide?

$$12.5\ g\ Mg(OH)_2 \times \frac{1\ mol\ Mg(OH)_2}{58.33\ g\ Mg(OH)_2} = \boxed{0.214\ mol\ Mg(OH)_2}$$

b. How many moles is 1.46 g of hydrogen gas (H_2)?

$$1.46\ g\ H_2 \times \frac{1\ mol\ H_2}{2.02\ g\ H_2} = \boxed{0.723\ mol\ H_2}$$

c. How many grams are in 4.3 moles of ammonium chloride?

$$4.3\ mol\ NH_4Cl \times \frac{53.50\ g\ NH_4Cl}{1\ mol\ NH_4Cl} = \boxed{230\ g\ NH_4Cl}$$

d. How many molecules are in 2.0 moles of hydrogen gas (H_2)?

$$2.0\ mol\ H_2 \times \frac{6.02 \times 10^{23}\ mc\ H_2}{1\ mol\ H_2} = \boxed{1.2 \times 10^{24}\ mc\ H_2}$$

e. How many moles is 2.0×10^{25} molecules of silver nitrate?

$$2.0 \times 10^{25}\ mc\ AgNO_3 \times \frac{1\ mol\ AgNO_3}{6.02 \times 10^{23}\ mc\ AgNO_3} = \boxed{33\ mol\ AgNO_3}$$

f. How many atoms of oxygen are in 2.4×10^{23} molecules of copper(II) sulfate?

$$2.4 \times 10^{23}\ mc\ CuSO_4 \times \frac{4\ atoms\ O}{1\ mc\ CuSO_4} = \boxed{9.6 \times 10^{23}\ atoms\ O}$$

g. How many molecules are in 96 g of carbon dioxide?

$$96\ g\ CO_2 \times \frac{1\ mol\ CO_2}{44.01\ g\ CO_2} \times \frac{6.02 \times 10^{23}\ mc\ CO_2}{1\ mol\ CO_2} = \boxed{1.3 \times 10^{23}\ mc\ CO_2}$$

h. How many oxygen atoms are in 96 g of CO_2?

$$96\ g\ CO_2 \times \frac{1\ mol\ CO_2}{44.01\ g\ CO_2} \times \frac{6.02 \times 10^{23}\ mc\ CO_2}{1\ mol\ CO_2} \times \frac{2\ atoms\ O}{1\ mc\ CO_2} = \boxed{2.6 \times 10^{23}\ at\ O}$$

i. How many grams would 1.0×10^{25} molecules of copper (II) sulfate weigh?

$$1.0 \times 10^{25}\ mc\ CuSO_4 \times \frac{1\ mol\ CuSO_4}{6.02 \times 10^{23}\ mc\ CuSO_4} \times \frac{159.62\ g\ CuSO_4}{1\ mol\ CuSO_4} = \boxed{2700\ g\ CuSO_4}$$

j. How much does each individual molecule of copper (II) sulfate weigh?

$$1\ mc\ CuSO_4 \times \frac{1\ mol\ CuSO_4}{6.02 \times 10^{23}\ mc\ CuSO_4} \times \frac{159.62\ g\ CuSO_4}{1\ mol\ CuSO_4} = \boxed{3 \times 10^{-22}\ g\ CuSO_4}$$

Notes on Empirical and Molecular Formulas

Empirical and Molecular Formula Practice: <u>**SHOW ALL OF YOUR WORK!**</u>

1. Find the **empirical** formula of the following compound from its percent composition.

   52.8% Sn, 12.4% Fe, 16.0% C and 18.8% N

$52.8g\ Sn \times \frac{1 mol\ Sn}{118.71g\ Sn} = \frac{0.445 mol\ Sn}{0.222 mol} = 2\ Sn$

$12.4g\ Fe \times \frac{1 mol\ Fe}{55.85g\ Fe} = \frac{0.222 mol\ Fe}{0.222 mol} = 1\ Fe$

$16.0g\ C \times \frac{1 mol\ C}{12.01g\ C} = \frac{1.33 mol\ C}{0.222 mol} = 6\ C$

$18.8g\ N \times \frac{1 mol\ N}{14.01g\ N} = \frac{1.34 mol\ N}{0.222 mol} = 6\ N$

Formula: $Sn_2FeC_6N_6$

empirical formula

2. Determine the **molecular** formula of the following compound.

   54.5% C, 13.6% H and 31.8% N; Molar Mass = 88g

$54.5g\ C \times \frac{1 mol\ C}{12.01g\ C} = \frac{4.54 mol\ C}{2.27 mol} = 2\ C$

$13.6g\ H \times \frac{1 mol\ H}{1.01g\ H} = \frac{13.47 mol\ H}{2.27 mol} = 6\ H$

$31.8g\ N \times \frac{1 mol\ N}{14.01g\ N} = \frac{2.27 mol\ N}{2.27 mol} = 1\ N$

Empirical Formula = C_2H_6N

molar mass = 44.09 g/mol

$\frac{\text{EF mass } 88g}{\text{MF mass } 44g} = 2$ → multiply subscripts by 2!

Formula: $C_4H_{12}N_2$

molecular Formula

3. How are the empirical and molecular formulas of a compound related?

The empirical formula is the lowest whole number ratio of atoms that make up a compound.

This is related to a molecular formula by molar mass; the molecular formula will always be a multiple of the molar mass of the empirical formula.

The Strange Case of Mole Airlines Flight 1023

Scene of the Crash
6:02 a.m. you and your team of medical examiners are called to the scene of a plane crash. You find evidence of a pre-crash explosion. At the site of the explosion a material has been found. Subsequent chemical analysis of the material shows it was:

C 37.01% **H 2.22%** **N 18.5%** **O 42.27%**

The mangled passengers are found in and around the crash. They must be identified by the substances found in their belongings or in their bodies, since they are not recognizable and their dental records are not available. Upon further investigation one passenger was suspected of having been murdered before the crash - the time of death was approximated at one hour prior to the crash.

Your Job:

1) Use the percent composition data in Table 3 to determine formulas for the compounds found with or in the passengers. Do the work on a separate paper and record the empirical formula in the column to the right on table 3. Make sure to show all of your work as it is your work that will be graded. Match these formulas with the identity of each compound listed in Table 1. Be certain to use the number of significant figures in the analysis to determine the number of significant figures you need to use from the periodic table. **For example:** If four significant figures are given in the data, use four significant figures from the periodic table.
2) Use the personal data in Table 2 to make a *probable* identification of each passenger.
   - Record the identifications on the Victim Identification Form.
   - Include the evidence that supports your identification. The solution to the mystery is the one that the evidence points to by logical deduction.
   - Determine who was murdered.
   - Determine who is *most likely* to have committed the murder.
   - Determine the identity of the substance that was found at the site of the explosion.

Table 1: Possible Compounds

Identity	Formula	Notes
Codeine	$C_{18}H_{21}NO_3$	Pain killer, prescription controlled
Cocaine	$C_{17}H_{21}NO_4$	Narcotic, illegal
Aspirin	$C_9H_8O_4$	Pain killer
Aspartame	$C_{14}H_{18}N_2O_5$	Artificial sweetener
Vanilla	$C_8H_8O_3$	Flavoring
Trinitrotoluene	$C_7H_5N_3O_6$	Explosive (TNT-dynamite)
Nitroglycerine	$C_3H_5N_3O_9$	Explosive, heart medication
Curare	$C_{40}H_{44}N_4O$	Poison
Thiobromine	$C_7H_8N_4O_2$	Chocolate (flavoring)
Strychnine	$C_{21}H_{22}N_2O_2$	Rat poison
Dimetacrine	$C_{10}H_{13}N^*$	Prescription drug, antidepressant
Acetaminophen	$C_8H_9NO_2$	Pain killer (Tylenol)

***the empirical formula rather than the actual formula is used.**

Table 2: Personal Data

Passengers & Crew	Notes
Redd D. Tocroak	Has a heart condition
Polly Pillcounter	Pharmacist
Hoagie Bunn	Baker
Archie Givengrades	Teacher, addicted to sugar free drinks
Threwit Allaway	Professional athlete, just suspended for drug violations
Ivy Isa Nissue	Environmental engineer, severely depressed
Iselle Ubye	Suspected drug dealer
Norm Anderson	Suspected leader of a terrorist organization

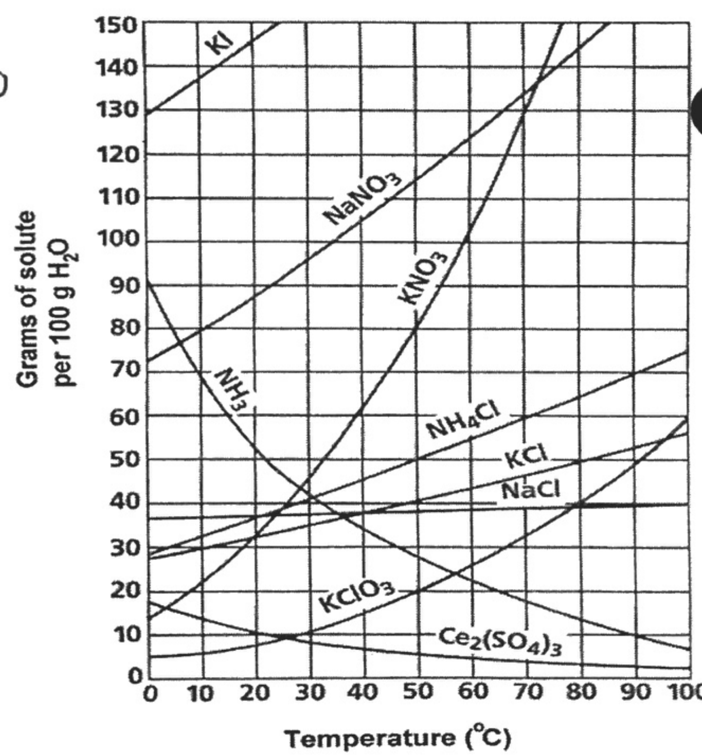
Table 3: Percent Composition Data of the Compounds Found in or with the Passengers' Bodies

Passenger	Compound Analysis (%)				Location	Empirical Formula and Substance ID
	C	H	N	O		
1	67.31	6.98	4.62	21.10	Blood	$C_{17}H_{21}NO_4$
2	63.15	5.30	--	31.55	Face	$C_8H_8O_3$
2	46.66	4.48	31.1	17.76	Stomach	$C_7H_8N_4O_2$
3	72.15	7.08	4.68	16.03	Pockets (2000 tablets	$C_{18}H_{21}NO_3$
4	15.87	2.22	18.15	63.41	Blood and Pockets	$C_3H_5N_3O_9$
5	75.42	6.63	8.38	9.57	Blood	$C_{21}H_{22}N_2O_2$
5	37.01	2.22	18.5	42.27	Pockets	$C_7H_5N_3O_6$
6	57.14	6.16	9.52	27.18	Pockets	$C_{14}H_{18}N_2O_5$
7	81.19	7.51	9.39	2.68	Pockets	$C_{40}H_{44}N_4O$
7	81.58	8.90	9.52	--	Pockets	$C_{10}H_{13}N$
8	60.00	4.48	--	35.53	Pocket	$C_9H_8O_4$
8	63.56	6.00	9.27	21.17	Pocket	$C_8H_9NO_2$

Notes on Parts of Solutions and Solubility

Solubility Graph Practice

1. What are the two axis of the graph?
   x = temperature
   y = grams of solute dissolved in H_2O
2. The curve represents what?
   Solubility of a substance (saturation line)
3. Any amount of solute below the line indicates what type of solution?
   unsaturated
4. Any amount of solute above the line represents what type of solution?
   Supersaturated
5. Solutes whose curves move upward are indicating that solubility increases as temperature increases.
6. Solutes whose curves move downward indicate that solubility decreases as temperature increases.

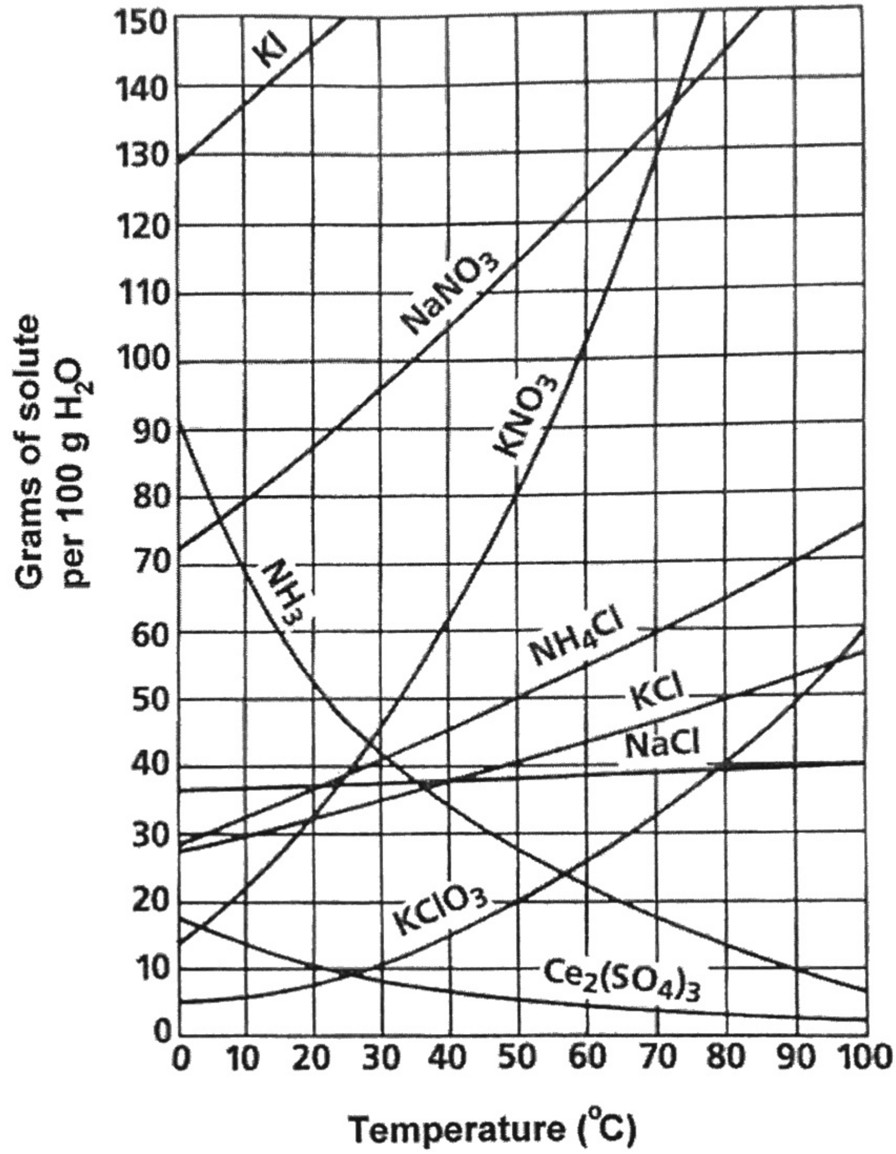


Solubility Problems to solve

7. At 10°C, how many grams of $NaNO_3$ will dissolve in 100 mL of water? 80 grams
8. What temperature would be required to completely dissolve 100 grams of Sodium Nitrate? 35 °C
9. If 30 grams of Sodium Chloride dissolved in 100 grams of water at 30 degrees, what type of solution would it be?
   unsaturated

Solubility Practice

1. Which of the salts shown on the graph is the least soluble in water at 10°C?
   $KClO_3$
2. Which of the salts has the greatest solubility at 10°C?
   KI
3. Which of the salts has its solubility affected the least by a change in temperature?
   NaCl
4. How many grams of sodium nitrate must be added to 100 ml to saturate the solution at 50°C?
   115 g
5. At what temperature do saturated solutions of potassium nitrate and sodium nitrate contain the same weight of solute per 100 mL of water?
   74°C
6. What two salts have the same degree of solubility at approximately 19°C?
   KNO_3 and KCl
7. A saturated solution of potassium nitrate is prepared at 60°C using 100.mL of water. How many grams of solute will precipitate out of solution if the temperature is suddenly cooled to 30°C?
   55g
8. How many more grams of Potassium Nitrate will dissolve when the temperature of water increases from e temperature range of 60°C to 70°C?
   30 g
9. If 50. mL of water that is saturated with $KClO_3$ at 25°C is slowly evaporated to dryness, how many grams of the dry salt would be recovered?
   5 g



10. Thirty grams of KCl are dissolved in 100 mL of water at 45°C. How many additional grams of KCl are needed to make the solution saturated at 80°C?
   20 g
11. Are the following solutions saturated, unsaturated or supersaturated (assume that all three could form supersaturated solutions)
    a. 40. g of KCl in 100 mL of water at 80°C unsaturated
    b. 120. g of KNO_3 in 100 mL of water at 60°C saturated
    c. 80. g of $NaNO_3$ in 100 mL of water at 10°C saturated

12. Based on the curve of NH_3, we can assume that it is a ____gas____. (solid or gas)

Notes on Concentration (% by Mass and Molarity)

Concentration Practice

Determine the molarity of the following solutions. **SHOW ALL OF YOUR WORK.**

1. Determine the percent composition by mass of a 100 g salt solution that contains 20 g of salt.

$$X \% \text{ salt} = \frac{20 g}{100 g} \times 100 \qquad \% \text{ salt} = 20\%$$

2. Calculate the mass of solvent in grams in a solution containing 3.0 grams of Tylenol if the mass percent is 3.5%.

$$3.5\% = \frac{3.0 g}{x + 3.0 g} \times 100 \qquad x \text{ solvent} = 83 g \text{ water}$$

3. 0.50 moles of sodium chloride is dissolved to make 0.75 liters of solution.

$$\frac{0.50 \text{ mol}}{0.75 L} = 0.67 M$$

4. 0.50 grams of sodium chloride is dissolved to make 0.075 liters of solution.

$$0.50 g\ NaCl \times \frac{1 \text{ mol } NaCl}{58.41 g\ NaCl} = 0.0086 \text{ mol } NaCl \qquad \frac{0.0086 \text{ mol}}{0.075 L} = 0.011 M$$

Molarity Practice

1. 0.50 grams of sodium chloride is dissolved to make 0.075 mL of solution.

$0.50\,g\,NaCl \times \frac{1\,mol\,NaCl}{58.44\,g\,NaCl} = 0.0086\,mol\,NaCl$ $\quad \frac{0.0086\,mol\,NaCl}{7.5 \times 10^{-4}\,L\,soln'} = \boxed{1.1 \times 10^{3}\,M}$

2. 734 grams of lithium sulfate are dissolved to make 875 mL of solution.

$734\,g\,Li_2SO_4 \times \frac{1\,mol\,Li_2SO_4}{109.95\,g\,Li_2SO_4} = 6.68\,mol\,Li_2SO_4$ $\quad \frac{6.68\,mol\,Li_2SO_4}{0.875\,L\,soln'} = \boxed{7.63\,M}$

3. 6.7×10^{-2} grams of $Pb(C_2H_3O_2)_4$ are dissolved to make 3.5 mL of solution.

$6.7 \times 10^{-2}\,g\,Pb(C_2H_3O_2)_4 \times \frac{1\,mol\,Pb(C_2H_3O_2)_4}{443.4\,g\,Pb(C_2H_3O_2)_4} = 1.5 \times 10^{-4}\,mol$ $\quad \frac{1.5 \times 10^{-4}\,mol\,Pb(C_2H_3O_2)_4}{0.0035\,L\,soln'} = \boxed{0.043\,M}$

4. I have two solutions. In the first solution, 1.0 moles of sodium chloride is dissolved to make 1.0 liters of solution. In the second one, 1.0 moles of sodium chloride is added to 1.0 liters of water. Is the molarity of each solution the same? Explain your answer. NO. The first solution would have a molarity = 1M But the second solution would have a less concentrated molarity as the volume of solute + volume of water would make the total volume larger than 1.0 L

5. How many grams of potassium carbonate are needed to make 200 mL of a 2.5 M solution?

$0.200\,L \times \frac{2.5\,mol\,K_2CO_3}{1\,L\,soln'} \times \frac{138.21\,g\,K_2CO_3}{1\,mol\,K_2CO_3} = \boxed{69.1\,g\,K_2CO_3}$

6. How many liters of 4 M solution can be made using 100 grams of lithium bromide?

$100\,g\,LiBr \times \frac{1\,mol\,LiBr}{86.84\,g\,LiBr} \times \frac{1\,L\,soln'}{4\,mol\,LiBr} = \boxed{0.3\,L\,soln'}$

7. What is the concentration of a 450 mL solution that contains 200 grams of iron (II) chloride?

$200\,g\,FeCl_2 \times \frac{1\,mol\,FeCl_2}{126.75\,g\,FeCl_2} = 2\,mol\,FeCl_2$ $\quad \frac{2\,mol\,FeCl_2}{0.45\,L\,soln'} = \boxed{4.4\,M}$

8. How many grams of ammonium sulfate are needed to make a 0.25 M solution with 2.5 L

$2.5\,L\,soln' \times \frac{0.25\,mol\,(NH_4)_2SO_4}{1\,L\,soln'} \times \frac{132.17\,g\,(NH_4)_2SO_4}{1\,mol\,(NH_4)_2SO_4} = \boxed{83\,g\,(NH_4)_2SO_4}$

9. What is the concentration of a solution that has a volume of 2.5 L and contains 660 grams of calcium phosphate?

$660\,g\,Ca_3(PO_4)_2 \times \frac{1\,mol\,Ca_3(PO_4)_2}{270.1\,g\,Ca_3(PO_4)_2} = 2.4\,mol$ $\quad \frac{2.4\,mol\,Ca_3(PO_4)_2}{2.5\,L\,soln'} = \boxed{0.96\,M}$

10. How many grams of copper (II) fluoride are needed to make 6.7 liters of a 1.2 M solution?

$6.7\,L\,soln' \times \frac{1.2\,mol\,CuF_2}{1\,L\,soln'} \times \frac{101.5\,g\,CuF_2}{1\,mol\,CuF_2} = \boxed{818.06\,g\,CuF_2}$

11. How many liters of 0.88 M solution can be made with 25.5 grams of lithium fluoride?

$25.5\,g\,LiF \times \frac{1\,mol\,LiF}{25.94\,g\,LiF} \times \frac{1\,L\,soln'}{0.88\,mol\,LiF} = \boxed{1.12\,L\,soln'}$

12. What is the concentration of a solution that with a volume of 660 ml that contains 33.4 grams of aluminum acetate?

$33.4\,g\,Al(C_2H_3O_2)_3 \times \frac{1\,mol\,Al(C_2H_3O_2)_3}{204.13\,g\,Al(C_2H_3O_2)_3} = 0.164\,mol$ $\quad \frac{0.164\,mol\,Al(C_2H_3O_2)_3}{0.66\,L\,soln'} =$

$\boxed{0.25\,M}$

Unit

Notes on Dilutions

Dilutions Practice

1. If I add 25 mL of water to 125 mL of a 0.15 M NaOH solution, what will the molarity of the diluted solution be?

$$M_1 V_1 = M_2 V_2$$

$$\frac{(0.15M)(125\cancel{mL})}{150\cancel{mL}} = \frac{M_2\ (15\cancel{0}mL)}{15\cancel{0}mL}$$

$$\boxed{M_2 = 0.13M}$$

2. If I add water to 100.0 mL of a 0.15 M NaOH solution until the final volume is 150 mL, what will the molarity of the diluted solution be?

$$\underline{(0.15M)(100.0mL)} = M_2\ \underline{(150\ mL)}$$

$$\boxed{M_2 = 0.10\ M}$$

3. How much 0.05 M HCl solution can be made by diluting 250 mL of 10 M HCl?

$$(10M)(250mL) = (0.05M)\ V_2$$

$$\boxed{V_2 = 50,000\ mL}$$

4. I have 345 mL of a 1.5 M NaCl solution. If I boil the water until the volume of the solution is 250 mL, what will the molarity of the solution be?

$$(1.5M)(345mL) = M_2(250mL)$$

$$\boxed{M_2 = 2.1M}$$

Unit 8 Review: Moles and Solutions

Find the molar mass of:

1. CH_4 $\boxed{16.05\ g/mol}$

2. $Ca(NO_3)_2$ $\boxed{164.06\ g/mol}$

3. iron(II) oxide $\boxed{71.85\ g/mol}$

4. How many moles are in 75.1g of FeO?

$$75.1\,g\ FeO \times \frac{1\,mol\ FeO}{71.85\,g\ FeO} = \boxed{1.05\,mol\ FeO}$$

5. How many grams are in 2.5 moles of CH_4?

$$2.5\,mol\ CH_4 \times \frac{16.05\,g\ CH_4}{1\,mol\ CH_4} = \boxed{40.\,g\ CH_4}$$

6. a. How many molecules of $Ca(NO_3)_2$ in 10.9 moles?

$$10.9\,mol\ Ca(NO_3)_2 \times \frac{6.02\times10^{23}\,mc\ Ca(NO_3)_2}{1\,mol\ Ca(NO_3)_2} = \boxed{6.56\times10^{24}\,mc\ Ca(NO_3)_2}$$

b. How many oxygen atoms are there?

$$6.56\times10^{24}\,mc\ Ca(NO_3)_2 \times \frac{6\ O\ atoms}{1\,mc\ Ca(NO_3)_2} = \boxed{3.94\times10^{25}\,atoms\ O}$$

7. How many grams of FeO are in 1.96 x 10^{24} molecules?

$$1.96\times10^{24}\,mc\ FeO \times \frac{1\,mole\ FeO}{6.02\times10^{23}\,mc\ FeO} \times \frac{71.85\,g\ FeO}{1\,mole\ FeO} = \boxed{234\,g\ FeO}$$

8. How many molecules are in 72.6g of CH_4?

$$72.6\,g\ CH_4 \times \frac{1\,mol\ CH_4}{16.05\,g\ CH_4} \times \frac{6.02\times10^{23}\,mc\ CH_4}{1\,mol\ CH_4} = \boxed{2.72\times10^{24}\,mc\ CH_4}$$

9. What is the molarity of a 50.0mL solution that contains 29.04g NaCl?

$$29.04\,g\ NaCl \times \frac{1\,mol\ NaCl}{58.44\,g\ NaCl} = 0.4969\,mol\ NaCl \qquad \frac{0.4969\,mol\ NaCl}{0.0500\,L\ Soln'} = \boxed{9.94M}$$

10. Narcotics agents confiscated an unknown substance that was suspected to be methaqualone. Its molecular formula is $C_{16}H_{14}N_2O$. Analysis found the sample to have 77% carbon, 5.5% hydrogen, 15.3% nitrogen, and the rest oxygen. Was it methaqualone?

$$77\,g\ C \times \frac{1\,mole\ C}{12.01\,g\ C} = \frac{6.41\,mol\ C}{0.1375\,mol} = 47 \qquad 15.3\,g\ N \times \frac{1\,mole\ N}{14.01\,g\ N} = \frac{1.09\,mol\ N}{0.1375\,mol} = 8$$

$$5.5\,g\ H \times \frac{1\,mole\ H}{1.01\,g\ H} = \frac{5.45\,mol\ H}{0.1375\,mol} = 40 \qquad 2.2\,g\ O \times \frac{1\,mole\ O}{16.00\,g\ O} = \frac{0.1375\,mol\ O}{0.1375\,mol} = 1$$

$\boxed{\text{Empirical Formula} = C_{47}H_{40}N_8O \quad \underline{\text{NOT}}\ \text{methaqualone}}$

11. What mass of CO_2 has the same number of molecules as 192g of H_2O?

$$192\,g\ H_2O \times \frac{1\,mol\ H_2O}{18.02\,g\ H_2O} \times \frac{6.02\times10^{23}\,mc\ H_2O}{1\,mol\ H_2O} \times \frac{1\,mc\ CO_2}{1\,mc\ H_2O} \times \frac{1\,mol\ CO_2}{6.02\times10^{23}\,mc\ CO_2} \times \frac{44.01\,g\ CO_2}{1\,mol\ CO_2} = \boxed{469\,g\ C}$$

12. A gas containing carbon and oxygen is decomposed and is found to contain 0.36g of carbon and 0.48g of oxygen. What is the empirical formula of this gas?

$$0.36g\ C \times \frac{1\ mole\ C}{12.01\ g\ C} = \frac{0.030\ mol\ C}{0.030\ mol} = 1\ C$$

$$0.48g\ O \times \frac{1\ mole\ O}{16.00g\ O} = \frac{0.030\ mol\ O}{0.030\ mol} = 1\ O$$

$\boxed{\text{empirical Formula} = CO}$

14. The empirical formula of a compound is CH_2O_2. The actual molar mass of this compound is 184g. What is the molecular formula of the compound?

	Empirical	Multiplier	Molecular
Formula	CH_2O_2	$\times 4$	? = $\boxed{C_4H_8O_8}$
Mass	46.03 g	$\frac{184g}{46.03g} = 4$	184g

15. A 31.0g sample of rust (an iron oxide) is composed of 21.7g of iron. Determine the empirical formula of this rust and give the correct chemical name.

$$31.0g - 21.7g\ Fe = 9.3g\ O$$

$$21.7g\ Fe \times \frac{1 mol\ Fe}{55.85g\ Fe} = \frac{0.389 mol\ Fe}{0.389 mol} = 1 Fe \quad \times 2 = 2Fe$$

$$9.3g\ O \times \frac{1 mol\ O}{16.00g\ O} = \frac{0.581 mol\ O}{0.389\ mol} = 1.50 \quad \times 2 = 3O$$

$\boxed{\text{empirical Formula} = Fe_2O_3}$

iron (III) oxide

16. Caffeine contains 49.98% C, 5.15% H, 28.87% N, and 16.49% O, and has a molar mass of 194.2 g/mol. What is its molecular formula?

$$49.98g\ C \times \frac{1 mole\ C}{12.01g\ C} = \frac{4.16\ mol\ C}{1.03\ mol} = 4$$

$$5.15g\ H \times \frac{1 mole\ H}{1.01\ g\ H} = \frac{5.10\ mol\ H}{1.03 mol} = 5$$

$$28.87g\ N \times \frac{1 mole N}{14.01g\ N} = \frac{2.06 mol\ N}{1.03\ mol} = 2$$

$$16.49g\ O \times \frac{1 mole\ O}{16.00g\ O} = \frac{1.03 mol\ O}{1.03 mol} = 1$$

Empirical Formula = $C_4H_5N_2O$

molar mass = 97.11 g/mol

$$\frac{194.2\ g/mol}{97.11\ g/mol} = 2$$ multiply subscripts

$\boxed{C_8H_{10}N_4O_2 = \text{molecular Formula}}$

Answer Key: 1. **16.0 g/mol** 2. **164.1 g/mol** 3. **71.8 g/mol** 4. **1.05 moles** 5. **40.g** 6a. **6.56×10^{24} molecules** 6b. **3.94×10^{25} atoms O** 7. **234g** 8. **2.73×10^{24}** 9. **9.94M** 10. **No** 11. **469g** 12. **CO** 13. **17.5g $Mg(OH)_2$** 14. **$C_4H_8O_8$** 15. **empirical = Fe_2O_3 name = iron(III) oxide** 16. **$C_8H_{10}N_4O_2$**