Name_____

# EMPIRICAL FORMULA WORKSHEET

**Problems that involve percentages, mass or moles of elements:  Follow the poem.  Show your work. Fill in the chart.  Sometimes, the multiplier is 1.  After awhile, you will not need the chart to help you with the problems. One last reminder: the empirical formula and the molecular formula are related by a whole number ratio**

1. A compound is 24.7% Calcium, 1.2% Hydrogen, 14.8% Carbon, and 59.3% Oxygen. Write the empirical formula and name the compound.

| | %→mass | | mass→moles | Divide by small | Multiply until whole | Final ratio |
|---|---|---|---|---|---|---|
| Element | Mass | Molar mass | moles | Mole ratio | | |
| C | | 12.01 g/mol | | | | |
| H | | | | | | |
| O | | | | | | |
| Ca | | | | | | |

Show your work for the calculation of empirical formula here

2. Excessive physical activity, lactic acid molecular mass 90.08 g per mole, forms in muscle tissues and is responsible for muscle soreness. Elemental analysis shows that this compound has 40.0% carbon 6.71% hydrogen and 53.3% oxygen. Determine the empirical formula of lactic acid. Determine the molecular formula.

| | %→mass | | mass→moles | Divide by small | Multiply until whole | Final empirical ratio |
|---|---|---|---|---|---|---|
| Element | Mass | Molar mass | moles | Mole ratio | | |
| C | | 12.01g/mol | | | | |
| H | | | | | | |
| O | | | | | | |

Show your work for the calculation of empirical formula here

Show your work for the calculation of the molecular formula here

3.  A compound is 21.20% Nitrogen, 6.06% Hydrogen, 24.30% Sulfur, and 48.45% Oxygen. Write the empirical formula for the compound.

| | %→mass | | mass→moles | Divide by small | Multiply until whole | Final empirical ratio |
|---|---|---|---|---|---|---|
| Element | Mass | Molar mass | moles | Mole ratio | | |
| N | | | | | | |
| H | | | | | | |
| S | | | | | | |
| O | | | | | | |

Show your work for the calculation of empirical formula here

4. Nicotine is an addictive compound found in tobacco leaves. Elemental analysis of nicotine gives the following data: 74.0 % C, 8.65 % H, 17.35 % N. What is the empirical formula of nicotine? The molar mass of nicotine is less than 170 g/mol. What is the molecular formula?

| | %→mass | | mass→moles | Divide by small | Multiply until whole | Final empirical ratio |
|---|---|---|---|---|---|---|
| Element | Mass | Molar mass | moles | Mole ratio | | |
| C | | | | | | |
| H | | | | | | |
| N | | | | | | |

Show your work for the calculation of empirical formula here

Show your work for the calculation of the molecular formula here

5.  A sample of an unknown compound contains 0.21 moles of zinc, 0.14 moles of phosphorus, and 0.56 moles of oxygen. What is the empirical formula?

| | %→mass | | mass→moles | Divide by small | Multiply until whole | Final empirical ratio |
|---|---|---|---|---|---|---|
| Element | Mass | Molar mass | moles | Mole ratio | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

Show your work for the calculation of empirical formula here

**Combustion problems:  combustion analysis problems are more challenging, but with a little practice and organization of data, you will find they are similar to the percentage problems.**
Some helpful rules:

    a.  You are working backwards from $CO_2$ and $H_2O$.
    b.  Convert grams of $CO_2$ to grams and moles of C
    c.  Convert grams of $H_2O$ to grams and moles of H (not $H_2$)
    d.  Mass of the C and mass of the H should add to the mass of the sample.  If it does not, the mass that is missing is oxygen (again, O not $O_2$)
    e.  Convert grams of oxygen to moles of oxygen.
    f.  Now divide by small and multiple until whole.
    g.  Sometimes the element left over is not oxygen, so read the question carefully!
    h.  Use the chart!
    i.  And no, you can't use stoichiometry.  You don't have a balanced equation.

I have started most of the problem below using the rules.  Let's finish it.  You need to fill in the chart with the calculated data.  Then find the ratios.  Once you find the ratios, you can find the empirical and the molecular formula.

1.  Vitamin C, $M$= 176.12 g/mol, is a compound of composed of carbon, hydrogen, and oxygen. Vitamin C is found in many natural sources especially citrus fruits. When a 1.000-g sample of vitamin C is burned in a combustion apparatus 1.50 g of $CO_2$ and 0.410 g of $H_2O$ are produced. What is the empirical formula of Vitamin C?  What is the molecular formula of Vitamin C?

|        | Mass     | Molar mass   | moles    | Mole ratio | Multiply until whole | Final empirical ratio |
|--------|----------|--------------|----------|------------|----------------------|-----------------------|
| $CO_2$ | 1.50 g   | 44.01g/mol   |          |            |                      |                       |
| $H_2O$ | 0.410 g  | 18.02 g/mol  |          |            |                      |                       |
| C      | 0.4093 g | 12.01g/mol   | 0.03408  |            |                      |                       |
| H      |          | 1.008 g/mol  |          |            |                      |                       |
| O      |          | 16.00 g/mol  |          |            |                      |                       |

The answers are in bold

| 1.50 g $CO_2$ | 1 mol $CO_2$ | 1 mol C | **0.03408 mol C** | | 0.03408 mol C | 12.01g C | **0.4093g C** |
|---|---|---|---|---|---|---|---|
|  | 44.01 g $CO_2$ | 1 mol $CO_2$ | | | | 1 mol C | |

| 0.410g$H_2O$ | 1 mol $H_2O$ | 2 mol H | **0.0455 mol H** | | 0.0455 mol H | 1.008g H | **0.0459g H** |
|---|---|---|---|---|---|---|---|
|  | 18.02g $H_2O$ | 1 mol $H_2O$ | | | | 1 mol H | |

| 1.000g CHO — (0.0459 g H + 0.4093g C) = | | | 0.5448g O | 0.5448 g O | 1 mol O | **0.03405 mol O** |
|---|---|---|---|---|---|---|
|  | | | | | 16.00g O | |

Re-write set-ups, show your work, finish the vitamin C problem here

2. Sometimes, athletes illegally use anabolic steroids to increase muscle strength. A forensic chemist analyzes some tablets suspected of being a popular steroid. He determined that the substance in the tablets contains only carbon, hydrogen, and oxygen in and has a molar mass of 300.14 g/mole.  When a 1.200 g sample of this study by combustion analysis, 3.516 g of $CO_2$ and 1.007 g of $H_2O$ are collected. What is the molecular formula for the substance?

|  | Mass | Molar mass | moles | Mole ratio | Multiply until whole | Final empirical ratio |
|---|---|---|---|---|---|---|
| $CO_2$ |  | 44.01g/mol |  |  |  |  |
| $H_2O$ |  | 18.02 g/mol |  |  |  |  |
| C |  | 12.01g/mol |  |  |  |  |
| H |  | 1.008 g/mol |  |  |  |  |
| O |  | 16.00 g/mol |  |  |  |  |

_____ g $CO_2$ | 1 mol $CO_2$ | 1 mol C | _____ mol **C**        _____ mol C | 12.01g C | _____ **g C**

| 44.01 g $CO_2$ | 1 mol $CO_2$ |                               | 1 mol C |


_____ g $H_2O$ | 1 mol $H_2O$ | 2 mol H | _____ **Mol H**        _____ mol H | 1.008g H | _____ **g H**

| 18.02g $H_2O$ | 1 mol $H_2O$ |                               | 1 mol H |


_____ g CHO — (_____ g H + _____ g | _____ g O        _____ g 0 | 1 mol O
C)

                                                                                **mol O**

                                                        | 16.00g O |

3. 0.487 g sample of quinine 324g/mol is combusted and found to produce 1.321 g carbon dioxide 0.325 g water and 0.0421 g nitrogen. Determine in empirical and molecular formula (hint there is one element missing!)

4. After combustion with excess oxygen, a 12.501 g of a petroleum compound produced 38.196 g of carbon dioxide and 18.752 of water. A previous analysis determined that the compound does not contain oxygen. Establish the empirical formula of the compound

5. A hydrocarbon fuel is fully combusted with 22.000 g of oxygen to yield 23.118 g of carbon dioxide and 4.729 g of water. Find the empirical formula for the hydrocarbon.

6. 12.915 g of a biochemical substance was burned in an atmosphere of 50.123 g of oxygen. Subsequent analysis of the gaseous result yielded 18.942 g carbon dioxide, 7.749 g of water and 36.347 g of oxygen. Determine the empirical formula of the substance.

7. A 12.00 gram sample of a smelly compound was tested by combustion analysis. The products were 21.41 grams of $CO_2$, 14.59 grams of $H_2O$, and 17.51 grams of $N_2O_5$. Further analysis showed that oxygen was NOT present in the molecule. What is the empirical formula of the compound?

8. When a 10.0 g sample of an unknown organic acid is subjected to combustion analysis 21.2 grams of $CO_2$ and 3.25 g of $H_2O$ are produced. What is the empirical formula of the acid?

**Answers:**
3. $C_{10}H_{12}N_0$, $C_{20}H_{24}N_2O_2$
4. $C_5H_{12}$ when I re-did the answer, I noticed that the ratio was off. The answer is not $C_3H_7$
5. CH, there is no oxygen in the compound and the amount of oxygen reacted is excess.
6. $CH_2O$, oxygen is in excess. You can't use it to find the amount of oxygen in the compound.
7. $C_3H_{10}N$
8. $C_4H_3O_2$