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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 compound¹.

	%→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

¹ CaH₂C₂O₆

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2. Excessive physical activity, lactic acid² 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.³

	%→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

² same empirical formula as lactose.

³ C₂H₆O₃

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3. A compound is 21.20% Nitrogen, 6.06% Hydrogen, 24.30% Sulfur, and 48.45% Oxygen. Write the empirical formula for the compound.⁴

	%→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 H₈N₂O₄S

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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?⁵

	%→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 C₅H₇N, C₁₀H₁₄N₂

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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?⁶

	%→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

⁶ Zn₂(PO₄)₃

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:

- You are working backwards from CO_2 and H_2O .
- Convert grams of CO_2 to grams and moles of C
- Convert grams of H_2O to grams and moles of H (not H_2)
- 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)
- Convert grams of oxygen to moles of oxygen.
- Now divide by small and multiple until whole.
- Sometimes the element left over is not oxygen, so read the question carefully!
- Use the chart!
- 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.

- Vitamin C, $M = 176.12 \text{ g/mol}$, is a compound 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?⁷

	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

⁷ $\text{C}_3\text{H}_4\text{O}_3$; $\text{C}_6\text{H}_8\text{O}_6$

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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 CO₂ and 1.007 g of H₂O are collected. What is the molecular formula for the substance?⁸

	Mass	Molar mass	moles	Mole ratio	Multiply until whole	Final empirical ratio
CO ₂		44.01g/mol				
H ₂ O		18.02 g/mol				
C	0.9595	12.01g/mol	0.07989			
H	0.1127	1.008 g/mol	0.1118			
O	0.1278	16.00 g/mol	0.007988			

_____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 ₂ O	1 mol H ₂ O	2 mol H	_____Mol H	_____mol H	1.008g H	_____g H
	18.02g H ₂ O	1 mol H ₂ O			1 mol H	

_____g CHO — (_____g H + _____g C)	_____g O	_____g O	_____g O	1 mol O	_____mol O
				16.00g O	

⁸ C₁₀H₁₄O; C₂₀H₂₈O₂

- 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!)
- After combustion with excess oxygen, a 12.501 g of a petroleum compound produced 38.130 g of carbon dioxide and 18.732 of water. A previous analysis determined that the compound does not contain oxygen. Establish the empirical formula of the compound
- 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.
- 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.
- 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?
- 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:

- $\text{C}_{10}\text{H}_{12}\text{NO}$, $\text{C}_{20}\text{H}_{24}\text{N}_2\text{O}_2$
- C_5H_{12} when I re-did the answer, I noticed that the ratio was off. The answer is not C_3H_7
- CH , there is no oxygen in the compound and the amount of oxygen reacted is excess.
- CH_2O , oxygen is in excess. You can't use it to find the amount of oxygen in the compound.
- $\text{C}_3\text{H}_{10}\text{N}$
- $\text{C}_4\text{H}_3\text{O}_2$