

# Combustion Analysis

How can burning a substance help determine the substance's chemical formula?

## Why?



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Scientists have many techniques to help them determine the chemical formula or structure of an unknown compound. One commonly used technique when working with carbon-containing compounds is combustion analysis. Any compound containing carbon and hydrogen will burn. With an ample oxygen supply, the products of the combustion will be carbon dioxide and water. Analyzing the mass of  $\text{CO}_2$  and  $\text{H}_2\text{O}$  that are produced allows chemists to determine the ratios of elements in the compound.

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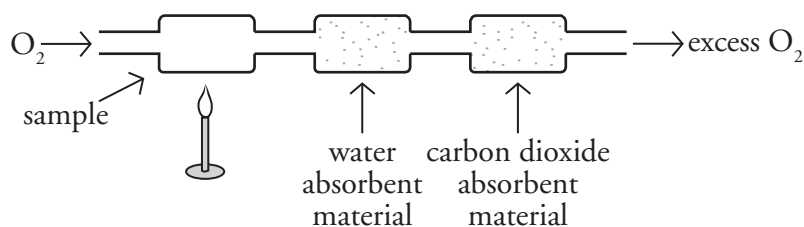
## Model 1 – Combustion Reactions



1. According to Model 1, what reactant is always required for combustion?
2. Balance the reactions in Model 1 while keeping the hydrocarbon coefficient a "1." This may require the use of fractions in other places.
-  3. How is the coefficient of  $\text{CO}_2$  in the chemical reactions in Model 1 related to the chemical formula of the hydrocarbon being analyzed?
-  4. How is the coefficient of the  $\text{H}_2\text{O}$  in the chemical reactions in Model 1 related to the chemical formula of the hydrocarbon being analyzed?



## Read This!



In a combustion analysis experiment, a hydrocarbon sample is heated in a stream of oxygen gas. As the sample burns, water and carbon dioxide is pushed through a series of chambers with materials that absorb each of the respective products. The chambers are each weighed before and after the combustion to determine the mass of each product.

### Model 2 – Combustion Analysis of $C_xH_y$ Unknowns

10.00-g Sample	Mass of $CO_2$ Produced	Moles of $CO_2$	Moles of Carbon Atoms	Mass of $H_2O$ Produced	Moles of $H_2O$	Moles of Hydrogen Atoms	Sample's Empirical Formula	Total Mass of C and H Atoms
1	27.42 g			22.46 g			$CH_4$	
2	29.26 g			17.97 g			$CH_3$	

30.00-g Sample	Mass of $CO_2$ Produced	Moles of $CO_2$	Moles of Carbon Atoms	Mass of $H_2O$ Produced	Moles of $H_2O$	Moles of Hydrogen Atoms	Sample's Empirical Formula	Total Mass of C and H Atoms
3	94.11 g			38.53 g			$CH_2$	
4	89.80 g			49.03 g			$C_3H_8$	


5. Discuss with your group how the data in Model 2 could be used to calculate the following quantities:

Moles of  $CO_2$       Moles of C atoms

Moles of  $H_2O$       Moles of H atoms

Divide the work among group members to complete those four columns in Model 2. Show work for your calculations below.



6. Discuss with your group how the data from Model 2 could be used to find the lowest whole number ratio between carbon and hydrogen atoms. This will give you the empirical formulas of the sample substances. Fill in the last column of Model 2.
7. Did you need balanced chemical combustion equations to find the empirical formulas of the unknowns in Model 2?
8. Did you need to know the mass of the samples to find the empirical formulas of the unknowns in Model 2?
9. What other information would you need to determine the molecular formulas?
-  10. A 15.00-g sample of an unknown hydrocarbon is analyzed by combustion analysis. The sample produced 50.70 grams of carbon dioxide and 10.42 grams of water. Find the empirical formula of the unknown.




11. Calculate the total mass of carbon atoms and hydrogen atoms for each sample in Model 2. Divide the work among group members. Create a new column in Model 2 for these data.
  - a.* How does the mass of carbon and hydrogen atoms compare to the mass of the original sample?
  - b.* Name the scientific law that justifies your answer to part *a.*
  - c.* Would part *a* be true if the original sample included atoms other than carbon and hydrogen? For example:  $C_2H_6O$  or  $C_2H_5NH_2$ . Justify your reasoning.

## Read This!

When the combustion analysis unknown is a compound containing only carbon and hydrogen, all of the atoms in the sample end up in either the  $\text{CO}_2$  or  $\text{H}_2\text{O}$  products. However, if the unknown contains other elements, like oxygen or nitrogen, those atoms might end up in the  $\text{CO}_2$  and  $\text{H}_2\text{O}$  products (in the case of oxygen) or they might form other gases that move through the apparatus without being captured. Additionally, O atoms may come from the atmosphere as opposed to the combusting sample. Moles of these atoms cannot be calculated by stoichiometry directly. Instead, we must use the law of conservation of mass.

### Model 3 – Combustion Analysis of $\text{C}_x\text{H}_y\text{O}_z$ Unknowns (10.00-g samples)

Sample	Mass of $\text{CO}_2$ Produced	Moles of Carbon Atoms	Mass of $\text{H}_2\text{O}$ Produced	Moles of Hydrogen Atoms	Total Mass of C and H Atoms	Mass of O Atoms	Moles of O Atoms	Sample's Empirical Formula
1	19.10 g		11.73 g					
2	14.65 g		6.00 g					
3	21.96 g		11.99 g					
4	28.05 g		5.74 g					

-  12. Four unknown hydrocarbons containing oxygen were analyzed by combustion analysis. The samples were 10.00 g each. The results are shown in Model 3. Discuss with your group what calculations would need to be performed to complete the table in Model 3. Divide the work among group members. Show work for your calculations below.



13. Did you need balanced chemical combustion equations to find the empirical formula of your unknowns in Model 3?
  
14. Did you need to know the mass of the samples to find the empirical formulas of your unknowns in Model 3?
  
15. A 15.00-g sample of a compound containing carbon, hydrogen and nitrogen is analyzed by combustion analysis. The sample produced 29.3 grams of carbon dioxide and 20.8 grams of water. Find the empirical formula of the unknown.



## Extension Questions

16. It is critical in combustion analysis procedures that the sample be dry. Discuss what errors in data would occur if the sample contained moisture. How might this affect the final empirical formula?
17. Discuss what errors in data would occur if the sample contained a carbon-based impurity. How might this affect the final empirical formula?
18. Balance the general combustion equation below using variables for the missing coefficients.

