

# Empirical & Molecular Formulas

**Key steps**

**Percent composition:** % element = (mass of element in 1 mol ÷ molar mass) × 100

**Empirical formula:** (1) assume 100 g, so % = grams; (2) grams ÷ molar mass = moles; (3) divide every value by the smallest; (4) if a ratio ends in .5, .33 or .25, multiply all by 2, 3 or 4.

**Molecular formula:** n = molar mass ÷ empirical formula mass; multiply every subscript by n.

**Molar masses (g/mol):** H 1.01, C 12.01, N 14.01, O 16.00, Na 22.99, Mg 24.31, Al 26.98, S 32.07, Cl 35.45, K 39.10, Ca 40.08, Fe 55.85, Cu 63.55

**A Percent composition**

4 marks

1. Find the percent composition of H<sub>2</sub>O.

\_\_\_\_\_

2. Find the percent composition of CO<sub>2</sub>.

\_\_\_\_\_

3. Find the percent composition of NaCl.

\_\_\_\_\_

4. Find the percent composition of CaCO<sub>3</sub>.

\_\_\_\_\_

**B Write the empirical formula**

4 marks

5. C<sub>6</sub>H<sub>12</sub>O<sub>6</sub> \_\_\_\_\_

6. H<sub>2</sub>O<sub>2</sub> \_\_\_\_\_

7. C<sub>2</sub>H<sub>6</sub> \_\_\_\_\_

8. N<sub>2</sub>O<sub>4</sub> \_\_\_\_\_

**C Empirical formula from data**

10 marks

2 marks each: show the mole ratio, then the formula.

9. A compound contains 40.0% C, 6.7% H and 53.3% O. Find its empirical formula.

\_\_\_\_\_  
\_\_\_\_\_

10. A compound contains 75.0% C and 25.0% H. Find its empirical formula.

\_\_\_\_\_  
\_\_\_\_\_

11. A compound contains 2.43 g of Mg combined with 1.60 g of O. Find its empirical formula.

\_\_\_\_\_  
\_\_\_\_\_

12. A compound contains 52.9% Al and 47.1% O. Find its empirical formula.

\_\_\_\_\_  
\_\_\_\_\_

13. A compound contains 63.6% N and 36.4% O. Find its empirical formula.

\_\_\_\_\_  
\_\_\_\_\_

## D Molecular formula

6 marks

14. Empirical formula  $\text{CH}_2\text{O}$ , molar mass 180.18 g/mol. Find the molecular formula.

---

---

15. Empirical formula  $\text{CH}$ , molar mass 78.12 g/mol. Find the molecular formula.

---

---

16. Empirical formula  $\text{NO}_2$ , molar mass 92.02 g/mol. Find the molecular formula.

---

---

## E Put it all together

2 marks

17. A hydrocarbon is 85.6% carbon and 14.4% hydrogen by mass. Its molar mass is 56.12 g/mol. Find its empirical and molecular formulas.

---

---

---

## F Spot the mistake

2 marks

18. A student finds a mole ratio of C 1 : H 1.33 and writes the empirical formula as  $\text{CH}$ . Explain the error and correct it.

---

---

19. A student writes the empirical formula of  $\text{C}_6\text{H}_{12}\text{O}_6$  as  $\text{C}_3\text{H}_6\text{O}_3$ . Explain the error and correct it.

---

---

## G Challenge: hydrates

2 marks

20. A 2.50 g sample of hydrated copper(II) sulfate,  $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$ , is heated until all the water is driven off. 1.60 g of anhydrous  $\text{CuSO}_4$  remains. Find  $x$ .

---

---

21. What is the percent by mass of water in  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ?

---

---

**Empirical & Molecular Formulas****ANSWER KEY****Key steps****Percent composition:** % element = (mass of element in 1 mol ÷ molar mass) × 100**Empirical formula:** (1) assume 100 g, so % = grams; (2) grams ÷ molar mass = moles; (3) divide every value by the smallest; (4) if a ratio ends in .5, .33 or .25, multiply all by 2, 3 or 4.**Molecular formula:** n = molar mass ÷ empirical formula mass; multiply every subscript by n.**Molar masses (g/mol):** H 1.01, C 12.01, N 14.01, O 16.00, Na 22.99, Mg 24.31, Al 26.98, S 32.07, Cl 35.45, K 39.10, Ca 40.08, Fe 55.85, Cu 63.55**A Percent composition**

4 marks

- Find the percent composition of H<sub>2</sub>O.  
%H = 11.2%, %O = 88.8%
- Find the percent composition of CO<sub>2</sub>.  
%C = 27.3%, %O = 72.7%
- Find the percent composition of NaCl.  
%Na = 39.3%, %Cl = 60.7%
- Find the percent composition of CaCO<sub>3</sub>.  
%Ca = 40.0%, %C = 12.0%, %O = 48.0%

**B Write the empirical formula**

4 marks

- |                                                  |                   |                                  |                 |
|--------------------------------------------------|-------------------|----------------------------------|-----------------|
| 5. C <sub>6</sub> H <sub>12</sub> O <sub>6</sub> | CH <sub>2</sub> O | 6. H <sub>2</sub> O <sub>2</sub> | HO              |
| 7. C <sub>2</sub> H <sub>6</sub>                 | CH <sub>3</sub>   | 8. N <sub>2</sub> O <sub>4</sub> | NO <sub>2</sub> |

**C Empirical formula from data**

10 marks

2 marks each: show the mole ratio, then the formula.

- A compound contains 40.0% C, 6.7% H and 53.3% O. Find its empirical formula.  
C:  $40.0 \div 12.01 = 3.331$ ; H:  $6.7 \div 1.01 = 6.634$ ; O:  $53.3 \div 16.00 = 3.331 \rightarrow \div 3.331 \rightarrow 1.00 : 1.99 : 1.00 \rightarrow$   
CH<sub>2</sub>O
- A compound contains 75.0% C and 25.0% H. Find its empirical formula.  
C:  $75.0 \div 12.01 = 6.245$ ; H:  $25.0 \div 1.01 = 24.752 \rightarrow \div 6.245 \rightarrow 1.00 : 3.96 \rightarrow$  CH<sub>4</sub>
- A compound contains 2.43 g of Mg combined with 1.60 g of O. Find its empirical formula.  
Mg:  $2.43 \div 24.31 = 0.100$ ; O:  $1.60 \div 16.00 = 0.100 \rightarrow \div 0.100 \rightarrow 1.00 : 1.00 \rightarrow$  MgO
- A compound contains 52.9% Al and 47.1% O. Find its empirical formula.  
Al:  $52.9 \div 26.98 = 1.961$ ; O:  $47.1 \div 16.00 = 2.944 \rightarrow \div 1.961 \rightarrow 1.00 : 1.50 \times 2 \rightarrow$  Al<sub>2</sub>O<sub>3</sub>
- A compound contains 63.6% N and 36.4% O. Find its empirical formula.  
N:  $63.6 \div 14.01 = 4.540$ ; O:  $36.4 \div 16.00 = 2.275 \rightarrow \div 2.275 \rightarrow 2.00 : 1.00 \rightarrow$  N<sub>2</sub>O

## D Molecular formula

6 marks

14. Empirical formula  $\text{CH}_2\text{O}$ , molar mass 180.18 g/mol. Find the molecular formula.  
 $\text{CH}_2\text{O} = 30.03 \text{ g/mol}$ ;  $180.18 \div 30.03 = 6 \rightarrow \text{C}_6\text{H}_{12}\text{O}_6$
15. Empirical formula  $\text{CH}$ , molar mass 78.12 g/mol. Find the molecular formula.  
 $\text{CH} = 13.02 \text{ g/mol}$ ;  $78.12 \div 13.02 = 6 \rightarrow \text{C}_6\text{H}_6$
16. Empirical formula  $\text{NO}_2$ , molar mass 92.02 g/mol. Find the molecular formula.  
 $\text{NO}_2 = 46.01 \text{ g/mol}$ ;  $92.02 \div 46.01 = 2 \rightarrow \text{N}_2\text{O}_4$

## E Put it all together

2 marks

17. A hydrocarbon is 85.6% carbon and 14.4% hydrogen by mass. Its molar mass is 56.12 g/mol. Find its empirical and molecular formulas.  
 $\text{C}: 85.6 \div 12.01 = 7.127$ ;  $\text{H}: 14.4 \div 1.01 = 14.257 \rightarrow \div 7.127 \rightarrow 1.00 : 2.00 \rightarrow \text{empirical } \text{CH}_2 \text{ (14.03 g/mol)}$ ;  
 $56.12 \div 14.03 = 4 \rightarrow \text{molecular } \text{C}_4\text{H}_8$

## F Spot the mistake

2 marks

18. A student finds a mole ratio of C 1 : H 1.33 and writes the empirical formula as  $\text{CH}$ . Explain the error and correct it.  
**1.33 is not close to a whole number; multiply both by 3 to get 3 : 4. Correct:  $\text{C}_3\text{H}_4$**
19. A student writes the empirical formula of  $\text{C}_6\text{H}_{12}\text{O}_6$  as  $\text{C}_3\text{H}_6\text{O}_3$ . Explain the error and correct it.  
**That ratio can still be divided by 3. Correct:  $\text{CH}_2\text{O}$**

## G Challenge: hydrates

2 marks

20. A 2.50 g sample of hydrated copper(II) sulfate,  $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$ , is heated until all the water is driven off. 1.60 g of anhydrous  $\text{CuSO}_4$  remains. Find x.  
 $\text{water} = 0.90 \text{ g} \div 18.02 = 0.0499 \text{ mol}$ ;  $\text{CuSO}_4 = 1.60 \div 159.62 = 0.0100 \text{ mol}$ ;  $\text{ratio} = 4.98 \rightarrow x = 5$   
 $(\text{CuSO}_4 \cdot 5\text{H}_2\text{O})$
21. What is the percent by mass of water in  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ?  
 $5 \times 18.02 \div 249.72 \times 100 = 36.1\%$