

Percent Composition & Percent Yield

Key formulas

Percent composition = mass of element in 1 mol ÷ molar mass of compound × 100 · From lab data: % element = mass of element ÷ mass of sample × 100

Theoretical yield: grams of reactant ÷ molar mass → × mole ratio → × molar mass = grams of product

Percent yield = actual yield ÷ theoretical yield × 100 · Give answers to 3 significant figures.

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

A Percent composition from a formula

8 marks

2 marks each. Find the molar mass first, then the percent of every element. Check that they add to about 100%.

1. Find the percent composition of NH_3 .

2. Find the percent composition of Fe_2O_3 .

3. Find the percent composition of $\text{Ca}(\text{OH})_2$.

4. Find the percent composition of KNO_3 .

B Using percent composition

6 marks

5. A 4.00 g sample of a copper oxide contains 3.20 g of copper. Find the percent copper. Is the oxide CuO or Cu_2O ? (2 marks)

6. What mass of iron is in 50.0 g of iron(III) oxide, Fe_2O_3 ? (2 marks)

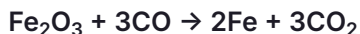
7. Ammonium nitrate, NH_4NO_3 , is used as a fertilizer. What mass of nitrogen does a 25.0 g scoop contain? (2 marks)

C Theoretical yield and percent yield

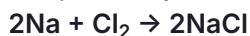
8 marks

Show grams → moles → mole ratio → grams for the theoretical yield, then use the percent yield formula.

8. In a blast furnace, 80.0 g of Fe_2O_3 reacts with excess carbon monoxide and 49.7 g of iron is collected. Find the theoretical yield and the percent yield. (2 marks)



9. 4.60 g of sodium reacts with excess chlorine gas and 10.4 g of NaCl is collected. Find the theoretical yield and the percent yield. (2 marks)



10. Yeast ferments 90.0 g of glucose and 37.5 g of ethanol, $\text{C}_2\text{H}_5\text{OH}$, is collected. Find the theoretical yield and the percent yield. (2 marks)



11. 6.80 g of hydrogen peroxide decomposes and 2.70 g of oxygen gas is collected. Find the theoretical yield and the percent yield. (2 marks)



D Working backwards

4 marks

12. A reaction has a theoretical yield of 40.0 g and usually gives a 75.0% yield. What mass of product should a student expect to collect? (2 marks)

13. A chemist needs 10.0 g of NaCl. The reaction $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$ gives an 80.0% yield. What mass of sodium should she start with? (2 marks)

E Explain the yield

2 marks

14. Give two reasons the actual yield of a reaction is usually less than the theoretical yield.

15. A student's dried precipitate gives a percent yield of 112%. Suggest two possible causes.

F Spot the mistake

2 marks

16. A student finds the percent oxygen in water as $1 \text{ atom} \div 3 \text{ atoms} \times 100 = 33.3\%$. Explain the error and correct it.

17. A student collects 15.3 g of product with a theoretical yield of 18.0 g and writes $18.0 \div 15.3 \times 100 = 118\%$. Explain the error and correct it.

Percent Composition & Percent Yield**ANSWER KEY****Key formulas**

Percent composition = mass of element in 1 mol ÷ molar mass of compound × 100 · From lab data: % element = mass of element ÷ mass of sample × 100

Theoretical yield: grams of reactant ÷ molar mass → × mole ratio → × molar mass = grams of product

Percent yield = actual yield ÷ theoretical yield × 100 · Give answers to 3 significant figures.

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

A Percent composition from a formula

8 marks

2 marks each. Find the molar mass first, then the percent of every element. Check that they add to about 100%.

1. Find the percent composition of
- NH_3
- .

$$M = 17.04 \text{ g/mol. N: } 14.01 \div 17.04 \times 100 = 82.2\%; \text{ H: } 3 \times 1.01 \div 17.04 \times 100 = 17.8\%$$

2. Find the percent composition of
- Fe_2O_3
- .

$$M = 159.70 \text{ g/mol. Fe: } 2 \times 55.85 \div 159.70 \times 100 = 69.9\%; \text{ O: } 3 \times 16.00 \div 159.70 \times 100 = 30.1\%$$

3. Find the percent composition of
- $\text{Ca}(\text{OH})_2$
- .

$$M = 74.10 \text{ g/mol. Ca: } 40.08 \div 74.10 \times 100 = 54.1\%; \text{ O: } 2 \times 16.00 \div 74.10 \times 100 = 43.2\%; \text{ H: } 2 \times 1.01 \div 74.10 \times 100 = 2.7\%$$

4. Find the percent composition of
- KNO_3
- .

$$M = 101.11 \text{ g/mol. K: } 39.10 \div 101.11 \times 100 = 38.7\%; \text{ N: } 14.01 \div 101.11 \times 100 = 13.9\%; \text{ O: } 3 \times 16.00 \div 101.11 \times 100 = 47.5\%$$

B Using percent composition

6 marks

5. A 4.00 g sample of a copper oxide contains 3.20 g of copper. Find the percent copper. Is the oxide
- CuO
- or
- Cu_2O
- ? (2 marks)

$$3.20 \div 4.00 \times 100 = 80.0\% \text{ Cu. CuO is 79.9\% Cu and Cu}_2\text{O is 88.8\% Cu, so the oxide is CuO.}$$

6. What mass of iron is in 50.0 g of iron(III) oxide,
- Fe_2O_3
- ? (2 marks)

$$\% \text{ Fe} = 2 \times 55.85 \div 159.70 \times 100 = 69.9\%; 50.0 \text{ g} \times 0.6994 = 35.0 \text{ g Fe}$$

7. Ammonium nitrate,
- NH_4NO_3
- , is used as a fertilizer. What mass of nitrogen does a 25.0 g scoop contain? (2 marks)

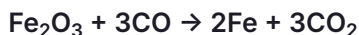
$$\% \text{ N} = 2 \times 14.01 \div 80.06 \times 100 = 35.0\%; 25.0 \text{ g} \times 0.3500 = 8.75 \text{ g N (there are 2 N atoms)}$$

C Theoretical yield and percent yield

8 marks

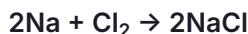
Show grams → moles → mole ratio → grams for the theoretical yield, then use the percent yield formula.

8. In a blast furnace, 80.0 g of
- Fe_2O_3
- reacts with excess carbon monoxide and 49.7 g of iron is collected. Find the theoretical yield and the percent yield. (2 marks)



$$80.0 \text{ g} \div 159.70 = 0.501 \text{ mol Fe}_2\text{O}_3; \times 2/1 = 1.00 \text{ mol Fe}; \times 55.85 = 56.0 \text{ g Fe} = \text{theoretical yield } 56.0 \text{ g. } 49.7 \div 56.0 \times 100 = 88.8\%$$

9. 4.60 g of sodium reacts with excess chlorine gas and 10.4 g of
- NaCl
- is collected. Find the theoretical yield and the percent yield. (2 marks)



$$4.60 \text{ g} \div 22.99 = 0.200 \text{ mol Na}; \times 2/2 = 0.200 \text{ mol NaCl}; \times 58.44 = 11.7 \text{ g NaCl} = \text{theoretical yield } 11.7 \text{ g. } 10.4 \div 11.7 \times 100 = 88.9\%$$

10. Yeast ferments 90.0 g of glucose and 37.5 g of ethanol,
- $\text{C}_2\text{H}_5\text{OH}$
- , is collected. Find the theoretical yield and the percent yield. (2 marks)



$$90.0 \text{ g} \div 180.18 = 0.500 \text{ mol C}_6\text{H}_{12}\text{O}_6; \times 2/1 = 0.999 \text{ mol C}_2\text{H}_5\text{OH}; \times 46.08 = 46.0 \text{ g C}_2\text{H}_5\text{OH} = \text{theoretical yield } 46.0 \text{ g. } 37.5 \div 46.0 \times 100 = 81.5\%$$

11. 6.80 g of hydrogen peroxide decomposes and 2.70 g of oxygen gas is collected. Find the theoretical yield and the percent yield. (2 marks)



$$6.80 \text{ g} \div 34.02 = 0.200 \text{ mol H}_2\text{O}_2; \times 1/2 = 0.0999 \text{ mol O}_2; \times 32.00 = 3.20 \text{ g O}_2 = \text{theoretical yield } 3.20 \text{ g. } 2.70 \div 3.20 \times 100 = 84.4\%$$

D Working backwards

4 marks

12. A reaction has a theoretical yield of 40.0 g and usually gives a 75.0% yield. What mass of product should a student expect to collect? (2 marks)

$$\text{actual} = 75.0\% \times 40.0 \text{ g} = 0.750 \times 40.0 = 30.0 \text{ g}$$

13. A chemist needs 10.0 g of NaCl. The reaction $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$ gives an 80.0% yield. What mass of sodium should she start with? (2 marks)

$$\begin{aligned} \text{theoretical needed} &= 10.0 \div 0.800 = 12.5 \text{ g NaCl}; 12.5 \\ &\div 58.44 = 0.214 \text{ mol NaCl} = 0.214 \text{ mol Na (1 : 1); } \times \\ &22.99 = 4.92 \text{ g Na} \end{aligned}$$

E Explain the yield

2 marks

14. Give two reasons the actual yield of a reaction is usually less than the theoretical yield.

Any two: the reaction is incomplete or reversible; side reactions make other products; product is lost when filtering, transferring or rinsing.

15. A student's dried precipitate gives a percent yield of 112%. Suggest two possible causes.

The product was still wet, or it contains impurities such as unreacted reactant; a weighing error is also possible.

F Spot the mistake

2 marks

16. A student finds the percent oxygen in water as $1 \text{ atom} \div 3 \text{ atoms} \times 100 = 33.3\%$. Explain the error and correct it.

Percent composition is by mass, not by number of atoms: $\% \text{ O} = 16.00 \div 18.02 \times 100 = 88.8\%$.

17. A student collects 15.3 g of product with a theoretical yield of 18.0 g and writes $18.0 \div 15.3 \times 100 = 118\%$. Explain the error and correct it.

The fraction is upside down. Percent yield = $\text{actual} \div \text{theoretical} \times 100 = 15.3 \div 18.0 \times 100 = 85.0\%$.