

Moles, isotopes and chemical formulas

AP Chemistry · Worksheet answers

Each answer shows the conversion, the substitution and the final value in bold. Compare your method as well as your result, since free-response scoring awards marks for each correct step.

Level: AP Chemistry · **Curriculum:** AP Chem Unit 1

Problem 1 Molar mass

- $M = 40.08 + 2(16.00 + 1.008) = 40.08 + 34.016 = \mathbf{74.10 \text{ g/mol}}$.
- Each formula unit holds 2 OH^- , so **2 mol** of hydroxide ions per mole of compound.

Problem 2 Water in moles

- $n = m/M = 54.0/18.015 = \mathbf{3.00 \text{ mol}}$.
- $N = nN_A = 3.00 \times 6.022 \times 10^{23} = \mathbf{1.81 \times 10^{24} \text{ molecules}}$.

Problem 3 Mass from moles

- $m = nM = 0.250 \times 40.00 = \mathbf{10.0 \text{ g}}$.
- One Na^+ per formula unit: $N = 0.250 \times 6.022 \times 10^{23} = \mathbf{1.51 \times 10^{23} \text{ ions}}$.

Problem 4 Iron nails

- $N = 0.500 \times 6.022 \times 10^{23} = \mathbf{3.01 \times 10^{23} \text{ atoms}}$.
- $m = nM = 0.500 \times 55.85 = \mathbf{27.9 \text{ g}}$.

Problem 5 Reading a mass spectrum

- There are **two** peaks, so two isotopes.
- Average = $0.692 \times 62.93 + 0.308 \times 64.93 = 43.55 + 20.00 = \mathbf{63.55 \text{ u}}$.
- The value matches **copper**.

Problem 6 Percent composition of carbon dioxide

- $\%C = 12.011/44.009 \times 100 = \mathbf{27.29 \%}$.
- $\%O = 100 - 27.29 = \mathbf{72.71 \%}$.

Problem 7 Pure or mixed?

- Distilled water: pure substance. Brass: mixture (alloy of copper and zinc). Seawater: mixture. Gold bar: pure substance (if 24 carat). Air: mixture. **Pure: water, gold; mixtures:**

brass, seawater, air.

2. Evaporate a measured sample: it leaves a solid residue, and its boiling temperature is not fixed. **A pure liquid leaves no residue.**

Problem 8 Formula of an iron oxide

1. $n(\text{Fe}) = 5.58/55.845 = 0.0999 \text{ mol}$; $n(\text{O}) = 2.40/15.999 = 0.150 \text{ mol}$.

2. Ratio Fe : O = 0.0999 : 0.150 = 1 : 1.5 = 2 : 3. **Fe₂O₃.**

3. **Iron(III) oxide.**

Problem 9 From empirical to molecular formula

1. $12.011 + 2(1.008) = \mathbf{14.03 \text{ g/mol}}$.

2. $70.1/14.03 = 5.0$, so the formula is $(\text{CH}_2)_5 = \mathbf{\text{C}_5\text{H}_{10}}$.

Problem 10 Nitrogen in a fertiliser

1. $M = 2(14.007 + 4 \times 1.008) + 32.06 + 4(15.999) = 36.078 + 32.06 + 63.996 = \mathbf{132.13 \text{ g/mol}}$.

2. $\%N = 28.014/132.13 \times 100 = \mathbf{21.2 \%}$.

3. $m(\text{N}) = 0.2120 \times 250 = \mathbf{53.0 \text{ g}}$.

Problem 11 Chlorine isotopes

1. ^{35}Cl (34.97 u) 75.8 % and ^{37}Cl (36.97 u) 24.2 %.

2. Average = $0.758 \times 34.969 + 0.242 \times 36.966 = 26.51 + 8.95 = \mathbf{35.45 \text{ u}}$.

3. No atom has this mass: it is a weighted average of the two isotopes, so the spectrum shows only the real atomic masses.

Problem 12 Water of crystallisation

1. $3.50 - 1.710 = \mathbf{1.790 \text{ g}}$.

2. $n(\text{H}_2\text{O}) = 1.790/18.015 = 0.0994 \text{ mol}$; $n(\text{MgSO}_4) = 1.710/120.37 = 0.01421 \text{ mol}$.

3. Ratio = $0.0994/0.01421 = 7.0$, so **x = 7**.

Problem 13 Combustion of a hydrocarbon

1. $n(\text{C}) = n(\text{CO}_2) = 0.880/44.009 = \mathbf{0.0200 \text{ mol}}$.

2. $n(\text{H}) = 2 \times 0.360/18.015 = \mathbf{0.0400 \text{ mol}}$.

3. C : H = 0.0200 : 0.0400 = 1 : 2. Empirical formula **CH₂**.

Problem 14 Salt and sand

1. $8.00 - 5.20 = \mathbf{2.80 \text{ g}}$.

2. $2.80/8.00 \times 100 = \mathbf{35.0 \%}$.

3. $n = 2.80/58.44 = \mathbf{0.0479 \text{ mol}}$.

Problem 15 A gas mixture

1. $m(\text{N}_2) = 0.300 \times 28.014 = 8.40 \text{ g}$; $m(\text{O}_2) = 0.100 \times 31.998 = 3.20 \text{ g}$. Total = 11.60 g.

2. $\% \text{N}_2 = 8.40/11.60 \times 100 = \mathbf{72.4 \%}$.

3. $x(\text{N}_2) = 0.300/0.400 = \mathbf{0.750}$.

Problem 16 Isotope abundances from an average

1. $68.926x + 70.925(1 - x) = 69.72$.

2. $70.925 - 1.999x = 69.72$, so $x = 1.205/1.999 = \mathbf{0.603}$.

3. **Gallium-69: 60.3 %; gallium-71: 39.7 %**.

Problem 17 Mass spectrum of a diatomic molecule

1. The molecule can contain $^{79}\text{Br}^{79}\text{Br}$, $^{79}\text{Br}^{81}\text{Br}$ or $^{81}\text{Br}^{81}\text{Br}$, with masses **158, 160, 162**.

2. $P(158) = 0.507^2 = 0.257$; $P(160) = 2 \times 0.507 \times 0.493 = 0.500$; $P(162) = 0.493^2 = 0.243$.

Ratio about 1 : 2 : 1.

3. The figure shows 25.7 %, 50.0 % and 24.3 %, which agrees.

Problem 18 Vitamin C

1. $\text{C} = 40.9/12.011 = 3.41 \text{ mol}$; $\text{H} = 4.58/1.008 = 4.54 \text{ mol}$; $\text{O} = 54.5/15.999 = 3.41 \text{ mol}$.

2. Dividing by 3.41: 1 : 1.33 : 1. Multiply by 3: 3 : 4 : 3. **$\text{C}_3\text{H}_4\text{O}_3$** (88.06 g/mol).

3. $176/88.06 = 2.0$, so the molecular formula is **$\text{C}_6\text{H}_8\text{O}_6$** .

Problem 19 Nitrogen in a mixed fertiliser

1. $28.014/80.04 = \mathbf{0.3500}$.

2. $m(\text{NH}_4\text{NO}_3) = 2.80/0.3500 = \mathbf{8.00 \text{ g}}$.

3. $m(\text{KCl}) = 2.00 \text{ g}$, so **20.0 %**; $n = 2.00/74.55 = \mathbf{0.0268 \text{ mol}}$.

Problem 20 Combustion analysis of an organic acid

1. $m(\text{C}) = 0.7328 \times 12.011/44.009 = 0.2000 \text{ g}$; $m(\text{H}) = 0.3000 \times 2.016/18.015 = 0.0336 \text{ g}$.

2. $m(\text{O}) = 0.5000 - 0.2000 - 0.0336 = 0.2664 \text{ g}$.

3. Moles: C 0.01665, H 0.0333, O 0.01665, ratio 1 : 2 : 1. Empirical formula **CH_2O** (30.03 g/mol); $60.05/30.03 = 2$, so the molecular formula is **$\text{C}_2\text{H}_4\text{O}_2$** .