

Topic 1.1: Moles and Molar Mass

Worksheet · AP Chemistry

UNIT 1 · ATOMIC STRUCTURE AND PROPERTIES

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How to Use This Worksheet

Work through the sections in order. Section A checks the ideas, Section B builds the calculation method, and Section C mixes everything the way an exam would.

Use a periodic table and a calculator. Show every step of your working, use dimensional analysis, and let the units cancel so you can see the method is right before you trust the number.

Do not look at the answer key until you have attempted every question. The key gives full working, so compare your method, not just your final number.

Section A: Recall and Concepts

A1. What is a mole? How many molecules are in 1 mol of CO_2 , and how many atoms are there in total in 1 mol of CO_2 ?

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A2. Sodium chloride, NaCl , is counted in formula units rather than molecules. Explain why.

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A3. A student says: "One mole of H_2 and one mole of O_2 have the same mass, because both are one mole." Correct the statement.

A4. Which sample contains more atoms: 1 mol of helium, He , or 1 mol of hydrogen gas, H_2 ? Explain your answer.

A5. A question gives a mass in grams and asks for a number of molecules. Explain why the calculation must pass through moles, and name the two conversion factors involved.

Section B: Core Calculations

B1. Calculate the amount, in moles, in a sample containing 3.011×10^{23} atoms of iron.

B2. How many molecules are there in 2.50 mol of H_2O ?

B3. Calculate the molar mass of calcium hydroxide, $\text{Ca}(\text{OH})_2$.

B4. What is the mass of 0.250 mol of sodium carbonate, Na_2CO_3 ?

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B5. How many moles are there in 50.0 g of calcium carbonate, CaCO_3 ?

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B6. How many formula units are there in 5.85 g of NaCl ?

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Section C: Exam Style

C1. A sample of aluminium sulfate, $\text{Al}_2(\text{SO}_4)_3$, has a mass of 17.1 g. (a) Calculate the amount, in moles, of $\text{Al}_2(\text{SO}_4)_3$ in the sample. (b) Calculate the amount, in moles, of oxygen atoms in the sample. (c) Calculate the number of sulfate ions in the sample.

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C2. Flask A contains 10.0 g of hydrogen gas, H_2 . Flask B contains 10.0 g of oxygen gas, O_2 . Which flask contains more molecules, and by roughly what factor? Show your working.

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C3. A student is given 0.500 mol of the hydrate $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. (a) Calculate the mass of the sample. (b) Calculate the amount, in moles, of water molecules in the sample. (c) The student calculates the mass as $0.500 \times 159.62 = 79.8$ g. Explain the error.

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Answer Key

A1. A mole is the amount of substance that contains 6.022×10^{23} representative particles (Avogadro's number). One mole of CO_2 contains 6.022×10^{23} molecules. Each molecule holds 3 atoms, so the sample contains 3 mol of atoms, which is $3 \times 6.022 \times 10^{23} = 1.81 \times 10^{24}$ atoms in total.

A2. NaCl is an ionic compound. Its solid is a continuous lattice of Na^+ and Cl^- ions in a 1:1 ratio, with no separate NaCl molecules anywhere in it. The particle that the formula describes is the formula unit, the simplest whole number ratio of the ions.

A3. One mole of each gas contains the same number of molecules, 6.022×10^{23} , but the masses differ because the molar masses differ. One mole of H_2 has a mass of 2.016 g, while one mole of O_2 has a mass of 32.00 g. The mole fixes the count, never the mass.

A4. The H_2 sample, with twice as many atoms. One mole of He is 1 mol of atoms, 6.022×10^{23} atoms. One mole of H_2 is 1 mol of molecules, and each molecule holds 2 atoms, so it contains 2 mol of atoms, 1.20×10^{24} atoms.

A5. There is no direct conversion between grams and particles. Mass converts to moles using the molar mass ($n = m / M$), and moles convert to particles using Avogadro's number ($N = n \times N_a$). The mole is the only quantity connected to both, so every route passes through it.

B1. $n = N / N_a = (3.011 \times 10^{23}) / (6.022 \times 10^{23} \text{ mol}^{-1}) = 0.500 \text{ mol}$.

B2. $N = n \times N_a = 2.50 \text{ mol} \times 6.022 \times 10^{23} \text{ molecules/mol} = 1.51 \times 10^{24} \text{ molecules}$.

B3. $M(\text{Ca}(\text{OH})_2) = 40.08 + 2(16.00) + 2(1.008) = 40.08 + 32.00 + 2.02 = 74.10 \text{ g/mol}$. The subscript 2 outside the bracket doubles both the oxygen and the hydrogen.

B4. $M(\text{Na}_2\text{CO}_3) = 2(22.99) + 12.01 + 3(16.00) = 45.98 + 12.01 + 48.00 = 105.99 \text{ g/mol}$. $m = n \times M = 0.250 \text{ mol} \times 105.99 \text{ g/mol} = 26.5 \text{ g}$.

B5. $M(\text{CaCO}_3) = 40.08 + 12.01 + 3(16.00) = 100.09 \text{ g/mol}$. $n = m / M = 50.0 \text{ g} / 100.09 \text{ g/mol} = 0.500 \text{ mol}$.

B6. $M(\text{NaCl}) = 22.99 + 35.45 = 58.44 \text{ g/mol}$. $n = 5.85 \text{ g} / 58.44 \text{ g/mol} = 0.100 \text{ mol}$. $N = 0.100 \text{ mol} \times 6.022 \times 10^{23} \text{ formula units/mol} = 6.03 \times 10^{22} \text{ formula units}$.

C1. $M(\text{Al}_2(\text{SO}_4)_3) = 2(26.98) + 3(32.06) + 12(16.00) = 53.96 + 96.18 + 192.00 = 342.14 \text{ g/mol}$. (a) $n = 17.1 \text{ g} / 342.14 \text{ g/mol} = 0.0500 \text{ mol}$. (b) Each formula unit holds 12 oxygen atoms, so moles of O atoms = $0.0500 \times 12 = 0.600 \text{ mol}$. (c) Each formula unit holds 3 sulfate ions, so moles of $\text{SO}_4^{2-} = 0.0500 \times 3 = 0.150 \text{ mol}$, and the number of ions = $0.150 \times 6.022 \times 10^{23} = 9.03 \times 10^{22} \text{ ions}$.

C2. Flask A: $n(\text{H}_2) = 10.0 \text{ g} / 2.016 \text{ g/mol} = 4.96 \text{ mol}$. Flask B: $n(\text{O}_2) = 10.0 \text{ g} / 32.00 \text{ g/mol} = 0.313 \text{ mol}$. Flask A contains more molecules, by a factor of $4.96 / 0.313 \approx 16$. Equal masses do not mean equal counts: the lighter gas packs far more molecules into the same mass.

C3. (a) $M(\text{CuSO}_4 \cdot 5\text{H}_2\text{O}) = 63.55 + 32.06 + 4(16.00) + 5(18.02) = 249.71 \text{ g/mol}$, so $m = 0.500 \text{ mol} \times 249.71 \text{ g/mol} = 124.9 \text{ g}$. (b) Each formula unit carries 5 water molecules, so moles of $\text{H}_2\text{O} = 0.500 \times$

5 = 2.50 mol. (c) The student used the molar mass of anhydrous CuSO_4 , 159.62 g/mol, and left out the five waters of hydration. The dot in $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ is part of the formula, and its mass, $5 \times 18.02 = 90.10$ g/mol, must be included.

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