

Topic 1.4: Composition of Mixtures

Revision Notes · AP Chemistry

UNIT 1 · ATOMIC STRUCTURE AND PROPERTIES

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Mixtures Are Not Compounds

A pure substance has a fixed composition. Water is always 11.2% hydrogen by mass, and calcium carbonate is always 40.0% calcium, because their formulas fix the ratios.

A mixture has no formula. It is two or more substances physically combined, and its composition depends on how much of each part went in. Seawater, air, alloys and ores are all mixtures, and no two samples need match exactly.

Topic 1.4 is about describing that composition precisely, and about moving between the mass of a mixture, the mass of one component inside it, and the mass of one element inside that component.

Mass percent of a component. Mass percent = (mass of the component ÷ total mass of the mixture) × 100. Every mass percent in this topic is a mass ratio, never a mole ratio, unless a question says otherwise.

Worked Example: Mass Percent in Both Directions

A salt solution is made by dissolving 18.0 g of sodium chloride in water to give 120.0 g of solution in total.

Finding the percent. Mass percent = $18.0 \div 120.0 \times 100 = 15.0\%$. Note the denominator: the mass of the whole solution, water included, not the mass of water alone.

Running it in reverse. How much of this solution contains 5.00 g of salt? Mass of solution = $5.00 \div 0.150 = 33.3$ g. A percent is a conversion factor between component mass and mixture mass, and it works in both directions.

A second reverse. A brass alloy is 65.0% zinc by mass. A 240 g fitting therefore holds $0.650 \times 240 = 156$ g of zinc, and 84 g of copper. The components' percentages must sum to 100, so one percent gives the other free.

The Tracer Element Method

Exam questions rarely hand you the mass of a component directly. More often they give the mass of one element and expect you to work back to the component that contains it.

The setup. This works when the element appears in only one component of the mixture. That element is a tracer: every atom of it in the sample came from that one component.

The two steps. First, find what fraction of the component's mass is the tracer element, using its formula: $\text{fraction} = (\text{atoms of the element} \times \text{its molar mass}) \div (\text{molar mass of the component})$. Second, divide the measured element mass by that fraction to get the component mass.

Worked example. A 5.00 g rock sample is a mixture of calcium carbonate and sand, SiO_2 . Analysis finds 1.20 g of calcium in the sample. Sand contains no calcium, so calcium is the tracer for CaCO_3 .

The fraction of Ca in CaCO_3 is $40.08 \div 100.09 = 0.4004$. The mass of CaCO_3 is therefore $1.20 \div 0.4004 = 3.00$ g, and the sample is $3.00 \div 5.00 \times 100 = 59.9\%$ calcium carbonate by mass.

Ores, Purity and Impure Samples

Ores. A metal ore is a mixture of a metal compound and waste rock. Finding the mass of metal in an ore takes the tracer method and one more step: percent of the compound in the ore, then the element fraction inside the compound.

Worked example. A 2.50 g iron ore sample is 68.0% Fe_2O_3 by mass. The mass of Fe_2O_3 is $0.680 \times 2.50 = 1.70$ g. Iron's fraction inside Fe_2O_3 is $2(55.85) \div 159.70 = 0.6994$. The mass of iron is $1.70 \times 0.6994 = 1.19$ g.

Purity. Percent purity is mass percent by another name: $(\text{mass of the pure substance} \div \text{mass of the impure sample}) \times 100$. A reagent that is 92.0% pure delivers only 0.920 g of the substance per gram weighed out.

Purity matters before any mole calculation. Convert the weighed mass to the pure mass first, then to moles. Moles calculated from the impure mass are always too large.

Drying and mass loss. When a wet sample is dried, the mass lost is the water. A 2.40 g soil sample that dries to 2.04 g lost 0.36 g of water, so the original sample was $0.36 \div 2.40 \times 100 = 15.0\%$ water by mass. The denominator is the original, wet mass.

Traps That Cost Marks in Topic 1.4

Reporting the compound's mass as the element's mass. "The sample contains 1.70 g of Fe_2O_3 " is not "the sample contains 1.70 g of iron". The element is only a fraction of its compound, 0.6994 here, and stopping one step early is the most common error in this topic.

Dividing by the wrong total. Mass percent uses the mass of the whole mixture, solution or sample, including every component and the solvent. Using just the water, or just the other component, as the denominator breaks the definition.

Choosing a tracer that is not unique. The tracer method fails if the element appears in two components. Oxygen, for example, can almost never be a tracer in a mixture of oxides, because every component contains it.

Forgetting purity before moles. A question that gives an impure mass and asks for moles, particles or a reacting mass expects the purity correction first. The impurity is inert filler; it contributes mass and nothing else.

Confusing mass percent with mole percent. Composition data in this topic is by mass. Two components at 50% by mass are not present in equal moles unless their molar masses happen to match.

Using the dry mass as the denominator for water content. Percent water in a wet sample is water mass divided by the original wet mass. Dividing by the dried mass answers a different question.

Key Relationships to Remember

- Mass percent of a component = $(\text{mass of component} \div \text{total mass of mixture}) \times 100$; all components' percents sum to 100
- Component mass = mass percent (as a decimal) $\times$ total mixture mass
- Tracer method: mass of component = mass of tracer element $\div$ (mass fraction of the element in the component), valid only when the element occurs in just one component
- Mass fraction of an element in a compound = $(\text{atoms} \times \text{atomic mass}) \div \text{molar mass of the compound}$
- Pure mass = percent purity (as a decimal) $\times$ impure sample mass; apply purity before converting to moles
- Percent lost on drying = $(\text{mass lost} \div \text{original mass}) \times 100$

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