

Topic 1.2: Mass Spectrometry

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, and write the units or the isotope symbol beside each number so your method can be followed.

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 does each peak on a mass spectrum represent? State what the position of a peak tells you and what the height of a peak tells you.

A2. ^{35}Cl and ^{37}Cl are isotopes of chlorine. State what is the same about their atoms and what is different.

A3. Explain why the atomic mass of chlorine printed on the periodic table is not a whole number.

A4. An element has only two isotopes, with masses 10 and 11. Its average atomic mass is 10.8. Which isotope is more abundant, and roughly what fraction of the atoms are that isotope?

A5. On a printed mass spectrum, the tallest peak has been scaled to a height of 100 and the other peaks are measured against it. Are those heights percentages? Explain what you must do with them before using them in a calculation.

Section B: Core Calculations

B1. Boron has two isotopes: ^{10}B (mass 10.013, abundance 19.9%) and ^{11}B (mass 11.009, abundance 80.1%). Calculate the average atomic mass of boron.

B2. Silicon has three isotopes: ^{28}Si (mass 27.977, abundance 92.23%), ^{29}Si (mass 28.976, abundance 4.67%) and ^{30}Si (mass 29.974, abundance 3.10%). Calculate the average atomic mass of silicon.

B3. A mass spectrum shows three peaks with these relative heights: mass 23.985, height 100; mass 24.986, height 12.7; mass 25.983, height 13.9. Convert the heights to fractional abundances, then calculate the average atomic mass of the element.

B4. Silver has two isotopes, ^{107}Ag (mass 106.905) and ^{109}Ag (mass 108.905), and an average atomic mass of 107.868. Calculate the percentage abundance of each isotope.

B5. Bromine has two isotopes: ^{79}Br (mass 78.918, abundance 50.69%) and ^{81}Br (mass 80.916, abundance 49.31%). Calculate the average atomic mass of bromine, and explain why it is so close to the simple mean of the two masses.

B6. Using the average atomic mass of chlorine, 35.45, and the isotope masses 34.969 (^{35}Cl) and 36.966 (^{37}Cl), solve for the percentage abundance of ^{35}Cl .

Section C: Exam Style

C1. A mass spectrum of element X shows four peaks: mass 49.946 with abundance 4.3%, mass 51.940 with abundance 83.8%, mass 52.941 with abundance 9.5%, and mass 53.939 with abundance 2.4%. (a) Calculate the average atomic mass of X. (b) Use the periodic table to identify X. (c) State which isotope of X is the most abundant.

C2. A student calculates the average atomic mass of chlorine as $(34.969 + 36.966) / 2 = 35.97$ and concludes that this is the value on the periodic table. Explain the student's error and state the correct value.

C3. Two samples of the same element, taken from different sources, are found to have slightly different average atomic masses. Suggest a reason for the difference, and state what has not changed between the samples.

Answer Key

A1. Each peak is one isotope of the element. The position of the peak (its m/z value) gives the mass of that isotope, and the height of the peak gives its relative abundance, how much of that isotope is present compared with the others.

A2. Same: the number of protons (17) and, in a neutral atom, the number of electrons. Different: the number of neutrons (18 in ^{35}Cl , 20 in ^{37}Cl), and therefore the mass of the atom.

A3. Natural chlorine is a mixture of two isotopes in roughly a 3:1 ratio. The printed value, 35.45, is the weighted average of the isotope masses, weighted by their abundances, so it falls between the two whole mass numbers instead of matching either one.

A4. The isotope of mass 11 is more abundant. The average, 10.8, is 0.8 of the way from 10 to 11, so roughly 80% of the atoms (a fraction of about 0.8) are the mass-11 isotope.

A5. No. Heights scaled to a tallest peak of 100 are relative intensities, not percentages. Divide each height by the sum of all the heights to get fractional abundances (which add to 1), then use those fractions in the weighted average.

B1. average = $(0.199 \times 10.013) + (0.801 \times 11.009) = 1.99 + 8.82 = 10.81$.

B2. average = $(0.9223 \times 27.977) + (0.0467 \times 28.976) + (0.0310 \times 29.974) = 25.80 + 1.35 + 0.93 = 28.09$. (The periodic table lists silicon as 28.085.)

B3. Total height = $100 + 12.7 + 13.9 = 126.6$. Fractions: $100/126.6 = 0.790$, $12.7/126.6 = 0.100$, $13.9/126.6 = 0.110$. average = $(0.790 \times 23.985) + (0.100 \times 24.986) + (0.110 \times 25.983) = 18.95 + 2.50 + 2.86 = 24.31$. The element is magnesium.

B4. Let x be the fraction of ^{107}Ag . $107.868 = (x \times 106.905) + ((1 - x) \times 108.905)$. Solving gives $x = 0.519$. Silver is 51.9% ^{107}Ag and 48.1% ^{109}Ag .

B5. average = $(0.5069 \times 78.918) + (0.4931 \times 80.916) = 40.00 + 39.90 = 79.90$. It is close to the simple mean because the two isotopes are almost equally abundant, so the weighting barely moves the average away from the midpoint.

B6. Let x be the fraction of ^{35}Cl . $35.45 = (x \times 34.969) + ((1 - x) \times 36.966)$. Solving gives $x = 0.759$, so ^{35}Cl is about 75.9% abundant. (The small difference from the accepted 75.77% comes from using the rounded average, 35.45.)

C1. (a) average = $(0.043 \times 49.946) + (0.838 \times 51.940) + (0.095 \times 52.941) + (0.024 \times 53.939) = 2.15 + 43.53 + 5.03 + 1.29 = 52.00$. (b) X is chromium, Cr (periodic table value 51.996). (c) The isotope at mass 51.940, ^{52}Cr , with 83.8% abundance.

C2. The student took a simple mean, which treats the two isotopes as equally common. They are not: ^{35}Cl is about three times as abundant as ^{37}Cl , so the weighted average is pulled toward 34.969. The correct average atomic mass is 35.45.

C3. The proportions of the isotopes differ slightly between sources, so the weighted average shifts slightly. The masses of the individual isotopes have not changed; only their relative abundances have.

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