AP Chemistry • Unit 1: Atomic Structure and Properties

Topic 1.2

Mass Spectroscopy

The Chemist's Molecular Scale

📚 What You'll Master in This Guide

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🔬 Concept 1: What is Mass Spectroscopy?

📖 Introduction to Mass Spectroscopy

Mass spectroscopy (also called mass spectrometry) is an analytical technique used to measure the **mass-to-charge ratio (m/z)** of ions. It's essentially a sophisticated "atomic scale" that allows chemists to:

- Identify unknown substances by their mass
- Determine the isotopic composition of elements
- Calculate accurate atomic and molecular masses
- Analyze the structure of molecules

⚡ The Four Essential Steps of Mass Spectroscopy

1	→	2	→	3	→	4
Ionization		**Acceleration**		**Deflection**		**Detection**
Atoms lose e^- → cations		Electric field speeds ions		Magnetic field separates		Ions counted

🔋 Step 1: Ionization

The sample is bombarded with high-energy electrons, which knock out electrons from the atoms, creating **positive ions (cations)**.

$$M(g) + e^- \rightarrow M^+(g) + 2e^-$$

M = atom or molecule being analyzed

💡 **Why Positive Ions?**

Positive ions are easier to manipulate with electric and magnetic fields. The charge allows us to accelerate and deflect the particles in predictable ways.

🚀 Step 2: Acceleration

The positive ions are attracted toward negatively charged plates, accelerating them to very high speeds. All ions gain the **same kinetic energy** regardless of their mass.

$$KE = ½mv^2$$

All ions get the same KE, so lighter ions travel faster!

⚠️ **Common Misconception**

All ions do NOT travel at the same speed! Since KE is constant, lighter ions (smaller m) must have higher velocity (larger v) to maintain KE = $½mv^2$.

🧲 Step 3: Deflection

The accelerated ions pass through a magnetic field, which causes them to curve. The amount of deflection depends on the **mass-to-charge ratio (m/z)**.

Lighter ions
Deflected MORE (curve more sharply)

Heavier ions
Deflected LESS (curve more gently)

🎯 The Key Principle

Deflection ∝ 1/mass — Think of it like bowling: a lighter ball is easier to curve than a heavy one!

📡 Step 4: Detection

By adjusting the magnetic field strength, different ions can be focused onto the detector. The detector counts how many ions of each mass hit it, producing a **mass spectrum**.

📊 What the Detector Records

- **X-axis:** Mass-to-charge ratio (m/z) — usually just the mass number for singly-charged ions
- **Y-axis:** Relative abundance (%) — how common each mass is
- **Tallest peak:** Set to 100% (called the "base peak")

🔍 Why Do We Use Mass Spectroscopy?

1. Identify isotopes
See which isotopes exist

2. Measure abundance
Determine isotope ratios

3. Calculate atomic mass
Find weighted averages

4. Analyze molecules
Determine structure

⚡ Quick Recap: The 4 Steps (Remember: I-A-D-D)

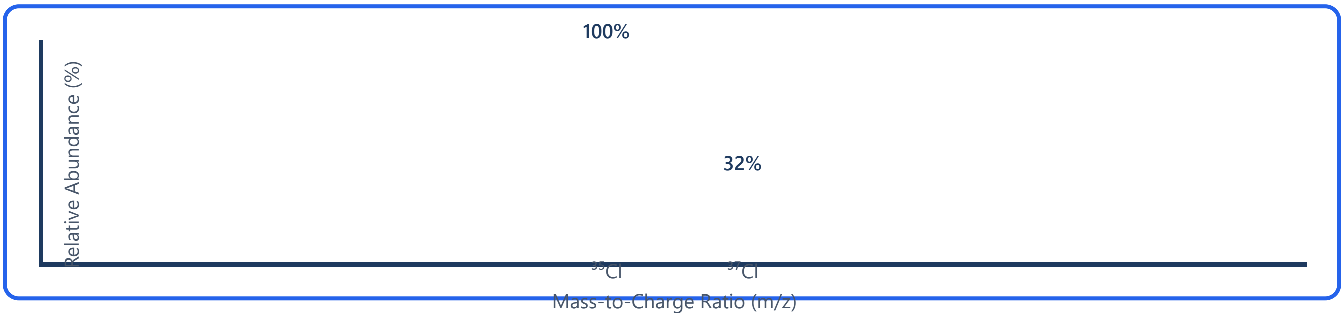
✓ **Ionize:** Knock out electrons to make positive ions
✓ **Accelerate:** Speed up ions with electric field (same KE for all)
✓ **Deflect:** Separate by mass using magnetic field (light = more curve)
✓ **Detect:** Count ions to create mass spectrum graph

📊 Concept 2: Reading Mass Spectra

📈 Understanding the Mass Spectrum

A mass spectrum is a bar graph that shows the distribution of isotopes in a sample. Each peak represents a different isotope, and the height shows how abundant that isotope is.

🎯 Example: Chlorine Mass Spectrum



Chlorine has two naturally occurring isotopes: ^{35}Cl (abundant) and ^{37}Cl (less common)

🔑 How to Read a Mass Spectrum

📋 Step-by-Step Interpretation

Step 1: Look at the x-axis — each peak position gives you the mass number

Step 2: Look at the y-axis — the height tells you relative abundance

Step 3: The tallest peak is set to 100% (base peak)

Step 4: Count the number of peaks = number of isotopes

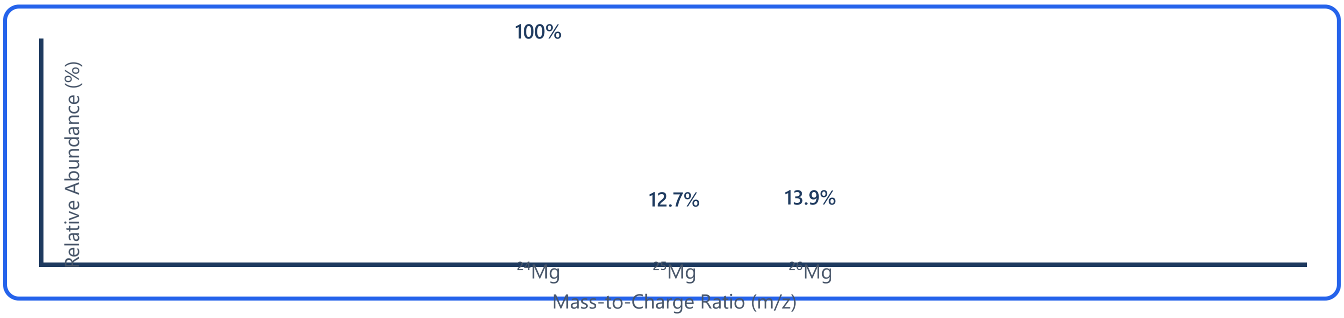
💡 Key Insight: m/z Ratio

For singly-charged ions (most common in AP Chemistry), the m/z ratio equals the mass number. If an ion has charge +1, then m/z = m. A peak at m/z = 35 means the isotope has mass number 35.

🧪 What Each Peak Tells You

Peak Feature	What It Represents	Example (Chlorine)
Position (m/z)	Mass number of isotope	35 and 37
Height (%)	Relative abundance	100% and 32%
Number of peaks	Number of isotopes	2 isotopes

🎯 Example: Magnesium Mass Spectrum



Magnesium has three naturally occurring isotopes: ^{24}Mg, ^{25}Mg, and ^{26}Mg

📝 Interpreting the Magnesium Spectrum

Three peaks → Three isotopes of magnesium exist

Peak at m/z = 24 is tallest (100%) → ^{24}Mg is the most abundant

Peaks at 25 and 26 are similar heights → ^{25}Mg and ^{26}Mg have similar (low) abundances

Conclusion: Most Mg atoms in nature are ^{24}Mg!

🔄 Converting to Actual Percentages

Mass spectra show *relative* abundance (tallest = 100%). To get *actual* percentages, you need to normalize:

$$\text{Actual \%} = (\text{Peak Height} / \text{Sum of All Heights}) \times 100$$

📊 Magnesium Calculation

Total relative abundance = 100 + 12.7 + 13.9 = 126.6

^{24}Mg actual % = (100/126.6) × 100 = **79.0%**

^{25}Mg actual % = (12.7/126.6) × 100 = **10.0%**

^{26}Mg actual % = (13.9/126.6) × 100 = **11.0%**

⚠️ AP Exam Trap

Don't confuse relative abundance (from spectrum) with actual abundance (percentage)! If a question asks for "percent abundance," you may need to convert from relative to actual values.

⚡ Spectrum Reading Checklist

- ✓ Number of peaks = number of isotopes
- ✓ Peak position (m/z) = mass number of each isotope
- ✓ Peak height = relative abundance (not actual %)
- ✓ Tallest peak = most abundant isotope = 100%
- ✓ To get actual %, divide each by sum of all heights

Concept 3: Isotopes & Relative Abundance

What Are Isotopes?

Isotopes are atoms of the **same element** (same number of protons) that have **different numbers of neutrons**. This means they have different mass numbers but identical chemical properties.

$$\text{Mass Number (A)} = \text{Protons} + \text{Neutrons}$$

Isotopes differ in mass number because they have different neutrons

Relative Abundance Explained

Relative abundance is the percentage of atoms in a natural sample that are a particular isotope. Nature doesn't create all isotopes equally — some are much more common than others!

Carbon Example

^{12}C: 98.9% abundance

^{13}C: 1.1% abundance

Hydrogen Example

^{1}H: 99.98% abundance

^{2}H (D): 0.02% abundance

Why Isotopes Matter on the AP Exam

The AP exam loves to test your understanding that atomic mass on the periodic table is a **weighted average** of all isotopes, NOT just the mass number of the most common isotope!

Common Elements with Multiple Isotopes

Element	Isotopes	Most Abundant	Abundance (%)
Carbon	^{12}C, ^{13}C, ^{14}C	^{12}C	98.9%
Chlorine	^{35}Cl, ^{37}Cl	^{35}Cl	75.8%
Bromine	^{79}Br, ^{81}Br	^{79}Br	50.7%
Copper	^{63}Cu, ^{65}Cu	^{63}Cu	69.2%
Silver	^{107}Ag, ^{109}Ag	^{107}Ag	51.8%

Practice: Identifying Isotopes from Mass Spectrum

If you see peaks at m/z = 63 and m/z = 65 for copper:

→ There are **2 isotopes** of copper

→ ^{63}Cu has 29 protons + 34 neutrons

→ ^{65}Cu has 29 protons + 36 neutrons

→ Both have identical chemical properties (same electron configuration)

🎯 Working with Relative Abundance Data

Mass spectrometry gives us precise data about isotopes. Here's how to interpret real data:

📊 Example: Zirconium Isotope Data

Isotope	Mass Number	Relative Abundance	Actual Abundance (%)
^{90}Zr	90	100.0	51.45%
^{91}Zr	91	21.8	11.22%
^{92}Zr	92	33.3	17.15%
^{94}Zr	94	33.7	17.38%
^{96}Zr	96	5.44	2.80%

📝 Converting Relative to Actual Abundance

Step 1: Sum all relative abundances: 100.0 + 21.8 + 33.3 + 33.7 + 5.44 = 194.24

Step 2: For ^{90}Zr: (100.0 ÷ 194.24) × 100 = 51.45%

Step 3: For ^{91}Zr: (21.8 ÷ 194.24) × 100 = 11.22%

Continue for all isotopes...

⚠️ Don't Mix Up These Terms!

Relative abundance: The spectrum reading where tallest peak = 100
Actual abundance (%): The true percentage that sums to 100%
Fractional abundance: The decimal form (e.g., 0.5145 for 51.45%)

🔬 Why Different Abundances Exist

Isotope abundances are determined by nuclear stability and how elements were formed:

More Stable Nuclei

Even numbers of protons and/or neutrons tend to be more stable and therefore more abundant

Stellar Nucleosynthesis

Elements were created in stars; the process favored certain isotope ratios

⚡ Isotope Facts to Remember

- ✓ Same element, different neutrons = isotopes
- ✓ Isotopes have identical chemical properties
- ✓ Isotopes have different physical properties (mass, radioactivity)
- ✓ Most elements have 2-3 stable isotopes
- ✓ Some elements (like tin) have 10+ stable isotopes!

Concept 4: Calculating Average Atomic Mass

The Weighted Average Concept

The atomic mass on the periodic table is NOT the mass of any single atom. It's a **weighted average** of all naturally occurring isotopes, weighted by their relative abundance.

$$\text{Average Atomic Mass} = \Sigma\ (\text{mass} \times \text{fractional abundance})$$

Or: Avg Mass = $(m_1 \times f_1) + (m_2 \times f_2) + (m_3 \times f_3) + \ldots$

Understanding Fractional Abundance

Fractional abundance = percentage ÷ 100
Example: If ^{35}Cl is 75.76% abundant, its fractional abundance = 0.7576

Example 1: Chlorine

Isotope	Exact Mass (amu)	Abundance (%)	Fractional Abundance
^{35}Cl	34.969	75.76%	0.7576
^{37}Cl	36.966	24.24%	0.2424

Calculation

Average Atomic Mass = (34.969 × 0.7576) + (36.966 × 0.2424)
= 26.496 + 8.961
= **35.457 amu** ✓ (matches periodic table: 35.45)

Example 2: Copper

Isotope	Exact Mass (amu)	Abundance (%)
^{63}Cu	62.930	69.17%
^{65}Cu	64.928	30.83%

Calculation

Average = (62.930 × 0.6917) + (64.928 × 0.3083)
= 43.524 + 20.021
= **63.545 amu** ✓ (matches periodic table: 63.55)

⚠️ Common Error Alert

Never use mass NUMBER in calculations — always use the exact MASS in amu! Mass number (35, 37) is an integer approximation. Exact mass (34.969, 36.966) is what you need for accurate calculations.

Reverse Calculation: Finding Unknown Abundance

A common AP exam question type gives you the average atomic mass and asks you to find an unknown abundance. Here's the strategy:

Example: Finding Unknown Abundance

Problem: Boron has two isotopes: ^{10}B (mass = 10.013 amu) and ^{11}B (mass = 11.009 amu). The average atomic mass of boron is 10.81 amu. Find the percent abundance of each isotope.

Step 1: Let x = fractional abundance of ^{10}B

Then (1 - x) = fractional abundance of ^{11}B

Step 2: Set up equation:

$10.013x + 11.009(1 - x) = 10.81$

Step 3: Solve:

$10.013x + 11.009 - 11.009x = 10.81$

$-0.996x = -0.199$

$x = 0.200$

Answer: ^{10}B = 20.0%, ^{11}B = 80.0%

Quick Check Tip

The average atomic mass should fall between the two isotope masses, closer to the more abundant isotope. For boron: 10.81 is closer to 11 than to 10, so ^{11}B must be more abundant. ✓

Three-Isotope Problems

For elements with three isotopes, you may need to use given abundances or set up a system with known percentages:

Silicon Example

^{28}Si: 27.977 amu, 92.23%

^{29}Si: 28.976 amu, 4.67%

^{30}Si: 29.974 amu, 3.10%

Average:

$= (27.977 \times 0.9223) + (28.976 \times 0.0467) + (29.974 \times 0.0310)$

$= 25.803 + 1.353 + 0.929 =$ **28.085 amu**

For 2 isotopes: If avg is closer to $mass_1$, then $isotope_1$ is more abundant

This is a great way to quickly check your answers!

Average Atomic Mass Calculation Checklist

✓ Convert percentages to decimals (divide by 100)

✓ Use exact masses, NOT mass numbers

✓ Multiply each mass by its fractional abundance

✓ Sum all products for the average

✓ Check: average should be between highest and lowest masses

📋 Quick Reference Summary

🔬 Mass Spectroscopy: The 4 Steps (I-A-D-D)

I	→	A	→	D	→	D
Ionization		Acceleration		Deflection		Detection

📊 Reading Mass Spectra

- **X-axis:** m/z (mass-to-charge)
- **Y-axis:** Relative abundance
- **# of peaks:** # of isotopes
- **Peak height:** Abundance
- **Tallest peak:** 100% (base peak)

⚛️ Isotopes

- Same protons, different neutrons
- Same chemical properties
- Different masses
- Different nuclear properties
- Natural abundance varies

$$\text{Average Atomic Mass} = \Sigma\ (\text{mass} \times \text{fractional abundance})$$

⚡ Key Formulas & Relationships

Concept	Formula/Rule
Ionization	$M + e^- \rightarrow M^+ + 2e^-$
Kinetic Energy	$KE = \frac{1}{2}mv^2$ (same for all ions)
Deflection	Lighter ions deflect MORE
Fractional abundance	% abundance ÷ 100
Relative → Actual %	(height ÷ Σheights) × 100
Average mass location	Closer to more abundant isotope

🚫 Common Mistakes to Avoid

- Don't use mass numbers in calculations — use exact masses
- Don't confuse relative abundance with actual percentage
- Don't assume all ions travel at the same speed (lighter = faster)
- Don't forget to check: average mass should be between isotope masses

🎯 AP Exam Focus Areas

Expect questions on: interpreting mass spectra, calculating average atomic mass from isotope data, determining isotope abundances from average mass, and explaining the mass spectrometer process.

Question 1

What is the first step in mass spectrometry?

A) Deflection

B) Ionization

C) Detection

D) Acceleration

Question 2

In a mass spectrum, what does the x-axis represent?

A) Relative abundance

B) Number of protons

C) Mass-to-charge ratio (m/z)

D) Atomic number

Question 3

Isotopes of the same element have the same number of:

A) Neutrons

B) Protons

C) Mass numbers

D) Nucleons

Question 4

In a mass spectrometer, which ions are deflected the MOST by the magnetic field?

A) Heavier ions

B) Lighter ions

C) Neutral atoms

D) All ions deflect equally

Question 5

The tallest peak in a mass spectrum is assigned a relative abundance of:

A) 50%

B) 75%

C) 100%

D) It varies

Question 6

If a mass spectrum shows 3 peaks, this indicates the element has:

A) 3 protons

B) 3 neutrons

C) 3 isotopes

D) 3 electrons

Question 7

During ionization in mass spectrometry, atoms:

A) Gain electrons

B) Lose electrons

C) Gain protons

D) Lose protons

Question 8

The atomic mass on the periodic table represents:

A) Mass of the most common isotope

B) Weighted average of all isotopes

Question 9

What is fractional abundance?

A) Percentage divided by 100

B) Percentage multiplied by 100

C) Mass divided by abundance

D) Number of atoms divided by total

Question 10

^{12}C and ^{13}C are isotopes because they have:

A) Same neutrons, different protons

B) Same protons, different neutrons

C) Same electrons, different protons

D) Same mass, different atomic numbers

Question 11

In the acceleration step of mass spectrometry, ions gain:

A) Mass

B) Charge

C) Kinetic energy

D) Neutrons

Question 12

If element X has isotopes with masses 20 and 22, and the average atomic mass is 20.2, which isotope is more abundant?

A) Mass 20 isotope

B) Mass 22 isotope

C) They are equally abundant

D) Cannot be determined

Question 13

What type of field is used to separate ions in a mass spectrometer?

A) Gravitational field

B) Electric field only

C) Magnetic field

D) Nuclear field

Question 14

For singly-charged ions (charge = +1), the m/z ratio equals:

A) The atomic number

B) The mass number

C) The number of electrons

D) The number of neutrons

Question 15

Isotopes of an element have identical:

A) Mass numbers

B) Physical properties

C) Chemical properties

D) Nuclear stability

Question 16

Chlorine has two isotopes: ^{35}Cl (75.76%) and ^{37}Cl (24.24%). What is the average atomic mass?

A) 35.00 amu
B) 35.48 amu
C) 36.00 amu
D) 36.48 amu

Question 17

A mass spectrum shows peaks at m/z = 24 (100%), 25 (12.7%), and 26 (13.9%). What is the actual percent abundance of the m/z = 24 isotope?

A) 100%
B) 79.0%
C) 50.0%
D) 33.3%

Question 18

In mass spectrometry, if all ions receive the same kinetic energy, which statement is true?

A) All ions travel at the same speed
B) Heavier ions travel faster
C) Lighter ions travel faster
D) Speed is independent of mass

Question 19

Copper's average atomic mass is 63.55 amu. It has isotopes ^{63}Cu and ^{65}Cu. Which isotope is more abundant?

A) ^{65}Cu
B) ^{63}Cu
C) Equal abundance
D) Cannot determine

Question 20

An element has two isotopes with masses 10.013 amu (20%) and 11.009 amu (80%). The average atomic mass is:

A) 10.51 amu
B) 10.81 amu
C) 10.61 amu
D) 11.01 amu

Question 21

Why must atoms be ionized before entering a mass spectrometer?

A) To increase their mass
B) To make them neutral
C) So they can be accelerated and deflected by fields
D) To break chemical bonds

Question 22

Bromine has two isotopes: ^{79}Br and ^{81}Br with nearly equal abundance. The expected average atomic mass would be closest to:

A) 79.0 amu
B) 79.9 amu
C) 80.0 amu
D) 81.0 amu

Question 23

A mass spectrum shows two peaks of equal height at m/z = 107 and m/z = 109. What is the fractional abundance of each isotope?

Question 24

Element Z has an average atomic mass of 28.09 amu. If ^{28}Z is 92.2% abundant and ^{30}Z is 3.1% abundant, what is the approximate abundance of ^{29}Z?

A) 2.7%
B) 4.7%
C) 6.7%
D) 8.7%

Question 25

In a mass spectrometer, increasing the magnetic field strength would cause ions to:

A) Deflect less
B) Deflect more
C) Speed up
D) Slow down

Question 26

The mass spectrum of neon shows peaks at m/z = 20, 21, and 22 with heights in ratio 90.9:0.3:8.8. The most abundant isotope has how many neutrons?

A) 10
B) 11
C) 12
D) 20

Question 27

If element X has average atomic mass of 69.72 amu with isotopes ^{69}X and ^{71}X, the percent abundance of ^{69}X is approximately:

A) 40%
B) 50%
C) 60%
D) 70%

Question 28

Two ions, $^{24}Mg^{+}$ and $^{12}C^{+}$, enter a mass spectrometer with the same kinetic energy. Which has greater velocity?

A) $^{24}Mg^{+}$
B) $^{12}C^{+}$
C) Same velocity
D) Cannot determine

Question 29

The atomic mass of lithium is 6.94 amu. If ^{6}Li has mass 6.015 amu and ^{7}Li has mass 7.016 amu, what is the approximate percent abundance of ^{7}Li?

A) 7.5%
B) 50%
C) 92.5%
D) 94%

Question 30

A doubly-charged ion ($^{2+}$) with mass 40 would appear at what m/z value?

A) 20
B) 40
C) 80
D) 42

Question 31

A sample of strontium has four stable isotopes. The mass spectrum shows: ^{84}Sr (0.56%), ^{86}Sr (9.86%), ^{87}Sr (7.00%), and ^{88}Sr (82.58%). Calculate the average atomic mass to the nearest 0.01 amu.

A) 86.95 amu
B) 87.62 amu
C) 87.13 amu
D) 88.00 amu

Question 32

The mass spectrum of an element shows two peaks at m/z = 63 and 65 with relative abundances of 69.17 and 30.83 respectively. If the exact masses are 62.930 and 64.928 amu, which calculation correctly determines the average atomic mass?

A) (63 × 0.6917) + (65 × 0.3083)
B) (62.930 × 0.6917) + (64.928 × 0.3083)
C) (62.930 × 69.17) + (64.928 × 30.83)
D) (62.930 + 64.928) / 2

Question 33

A mass spectrum of diatomic chlorine (Cl_2) would show peaks at m/z values of approximately:

A) 35 and 37 only
B) 70, 72, and 74
C) 35, 37, 70, 72, and 74
D) 70 only

Question 34

Element Q has two isotopes: ^{150}Q and ^{152}Q. If the average atomic mass is 151.0 amu, and the exact masses are 149.92 and 151.92 amu respectively, what is the percent abundance of ^{152}Q?

A) 46%
B) 50%
C) 54%
D) 58%

Question 35

In analyzing a sample by mass spectrometry, a chemist observes that ions with the same charge but different masses reach the detector at different times. Ions with higher mass reach the detector:

A) Earlier, because they have more momentum
B) Later, because they travel slower
C) At the same time as lighter ions
D) Earlier, because they deflect less

Question 36

The mass spectrum of a pure element shows four peaks at m/z = 50, 52, 53, and 54 with relative abundances of 4.35, 83.79, 9.50, and 2.36 respectively. Which of the following is closest to the average atomic mass?

A) 51.0 amu
B) 52.0 amu
C) 52.5 amu
D) 53.0 amu

Question 37

An unknown element has an atomic mass of 191.22 amu. Its mass spectrum shows two peaks at m/z = 191 and 193 with abundances of 37.4% and 62.6%. If the exact mass of the ^{191} isotope is 190.96 amu, what is the exact mass of the ^{193} isotope?

A) 192.38 amu
B) 192.97 amu
C) 193.00 amu
D) 191.38 amu

Question 38

A sample contains atoms of element X with a natural distribution of isotopes. If ^{58}X (57.935 amu) is 68.1% abundant, ^{60}X (59.931 amu) is 26.2% abundant, and the remaining isotopes have an average mass of 61.5 amu, what is the average atomic mass of X?

A) 58.69 amu
B) 58.89 amu
C) 59.09 amu
D) 59.29 amu

Question 39

In time-of-flight (TOF) mass spectrometry, the time for an ion to reach the detector is related to its mass by $t \propto \sqrt{m}$. If $^{12}C^{+}$ takes 20.0 μs to reach the detector, how long would $^{48}Ti^{+}$ take (assuming same charge)?

A) 40.0 μs
B) 80.0 μs
C) 28.3 μs
D) 56.6 μs

Question 40

The mass spectrum of a sample of rubidium shows two peaks. The peak at m/z = 85 has a relative abundance of 72.17, and the peak at m/z = 87 has a relative abundance of 27.83. A student calculates the average atomic mass as follows: (85 × 72.17) + (87 × 27.83) = 8557.66 amu. What error did the student make?

A) Used mass numbers instead of exact masses
B) Failed to convert to fractional abundances
C) Added instead of multiplied
D) Used the wrong isotope masses

FRQ 1: Magnesium Isotopes

7 Points

Magnesium exists naturally as three isotopes: ^{24}Mg, ^{25}Mg, and ^{26}Mg. A mass spectrometer analysis produces the following data:

Isotope	Exact Mass (amu)	Relative Abundance
^{24}Mg	23.985	100.00
^{25}Mg	24.986	12.66
^{26}Mg	25.983	13.94

(a) Explain why all three isotopes of magnesium have identical chemical properties. *(2 points)*

(b) Convert the relative abundances to actual percent abundances for each isotope. *(2 points)*

(c) Calculate the average atomic mass of magnesium. Show all work. *(2 points)*

(d) Explain why the average atomic mass is closer to 24 than to 25 or 26. *(1 point)*

FRQ 2: Chlorine Mass Spectrum

6 Points

The mass spectrum of chlorine shows two peaks at m/z = 35 and m/z = 37 with relative abundances of 100 and 32 respectively.

(a) Calculate the actual percent abundance of each isotope. *(2 points)*

(b) Calculate the average atomic mass of chlorine using mass numbers as approximate masses. *(2 points)*

(c) Determine the number of protons and neutrons in each isotope of chlorine. *(2 points)*

FRQ 3: Mass Spectrometer Operation

8 Points

A chemistry student is learning how a mass spectrometer works and how to interpret its output.

(a) Describe the four main steps in mass spectrometry. For each step, briefly explain what happens to the sample. *(4 points)*

(b) Explain why atoms must be ionized before they can be analyzed in a mass spectrometer. *(1 point)*

(c) In a mass spectrum, what does the x-axis represent? What does the y-axis represent? *(2 points)*

(d) A mass spectrum of an element shows four peaks. What can you conclude about this element? *(1 point)*

📝 Scoring Guidelines - Easy FRQs

FRQ 1: (a) 1 pt: Same protons/atomic number; 1 pt: Same electrons/configuration | (b) 1 pt: Total=126.6; 1 pt: ^{24}Mg=79.0%, ^{25}Mg=10.0%, ^{26}Mg=11.0% | (c) 1 pt: Correct setup; 1 pt: 24.31 amu | (d) 1 pt: ^{24}Mg most abundant

FRQ 2: (a) 1 pt: Total=132; 1 pt: ^{35}Cl=75.8%, ^{37}Cl=24.2% | (b) 1 pt: Setup; 1 pt: 35.48 amu | (c) 1 pt: Both have 17 protons; 1 pt: ^{35}Cl has 18n, ^{37}Cl has 20n

FRQ 3: (a) 1 pt each for: Ionization, Acceleration, Deflection, Detection | (b) 1 pt: Charged particles can be manipulated by electric/magnetic fields | (c) 1 pt: m/z ratio; 1 pt: Relative abundance | (d) 1 pt: Element has 4 isotopes

FRQ 4: Unknown Element Analysis

10 Points

An unknown element X has two stable isotopes. Mass spectrometry analysis reveals: • Peak 1: m/z = 69, relative abundance = 60.1 • Peak 2: m/z = 71, relative abundance = 39.9 The average atomic mass from the periodic table is 69.72 amu.

(a) Calculate the actual percent abundance of each isotope from the relative abundances. *(2 points)*

(b) Using the mass numbers as approximate masses, calculate the average atomic mass. Explain why this differs slightly from the periodic table value. *(3 points)*

(c) Identify element X and determine how many protons and neutrons are in each isotope.