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Unit 1: Atomic Structure & Properties

Accessible Practice Set - Building Foundations

✓ Easier Level | ⏱ 60-90 minutes | 📊 10 Questions

📋 About This Practice Set:

- **Purpose:** Build confidence with foundational Unit 1 concepts
- **Difficulty:** Easier than typical AP exam questions (scaffolded learning)
- **Focus Areas:** Moles, isotopes, electron configuration, PES, mass spectrometry
- **Question Types:** Step-by-step calculations, diagram interpretation, conceptual explanations
- **Total Points:** 60 points (designed for partial credit opportunities)
- **Materials Needed:** Calculator, periodic table

💡 Success Tips for Unit 1:

- **Electron Configuration:** Follow aufbau diagram: 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p...
- **Isotope Notation:** Mass number (top) = protons + neutrons; Atomic number (bottom) = protons
- **Mole Conversions:** Use Avogadro's number (6.022×10^{23}) and molar mass
- **PES Graphs:** Each peak = one sublevel; peak height = number of electrons
- **Mass Spectrum:** Each peak = one isotope; height = relative abundance
- **Show Your Work:** Partial credit is awarded for correct setup!

Question 1 (5 points) — Mole Calculations

A sample of pure copper (Cu) has a mass of 12.7 grams.

Given Information:
- Mass of copper sample = 12.7 g
- Molar mass of Cu = 63.55 g/mol
- Avogadro's number = 6.022×10^{23} atoms/mol

(a) Calculate the number of moles of copper in the sample. Show your work. (2 points)

Helpful Formula:

moles = mass (g) / molar mass (g/mol)

Your calculation:

(b) Calculate the number of copper atoms in the sample. Show your work. (2 points)

Helpful Formula:

atoms = moles × Avogadro's number

Your calculation:

(c) How many electrons are present in the sample? (Copper has 29 electrons per atom.) (1 point)

Your calculation:

Question 2 (6 points) — Isotopes and Atomic Structure

Consider two isotopes of chlorine:

Isotope Notation:

- Chlorine-35: ^{35}Cl (mass number 35)
- Chlorine-37: ^{37}Cl (mass number 37)
- Atomic number of chlorine = 17

(a) Complete the table below for each isotope: (3 points)

Isotope	Protons	Neutrons	Electrons
^{35}Cl			
^{37}Cl			

Remember:

Protons = Atomic number; Neutrons = Mass number − Protons; Electrons = Protons (for neutral atoms)

(b) Explain why these two isotopes have different masses but the same chemical properties. (2 points)

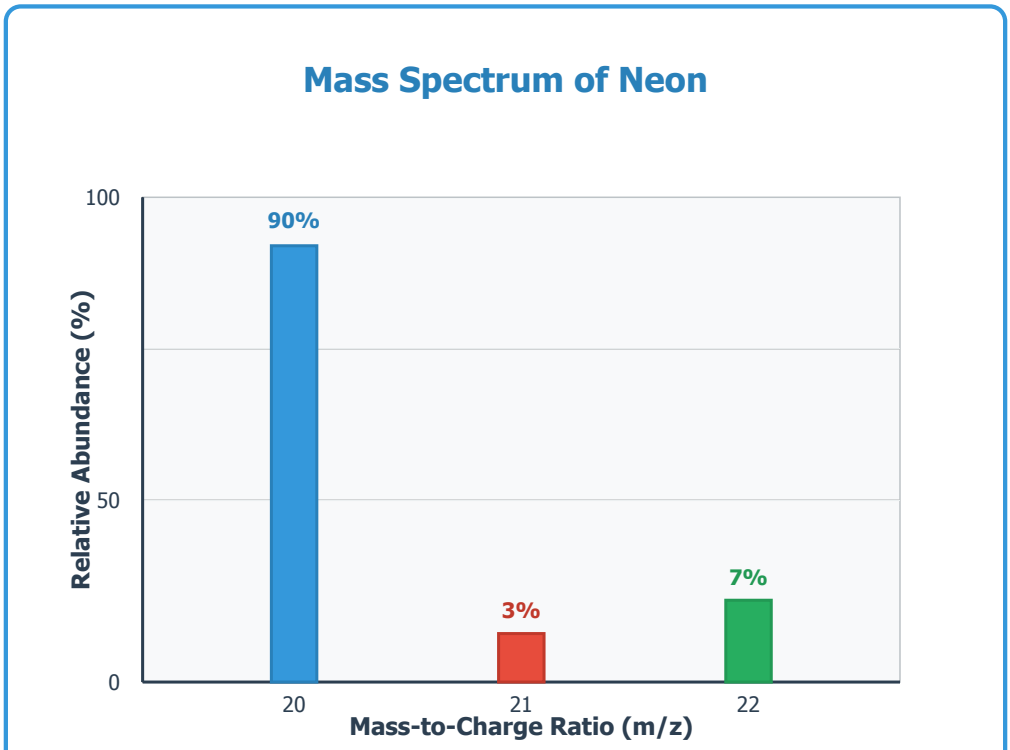
Your explanation:

(c) Write the isotope symbol for a chloride ion (Cl^-) with mass number 35. (1 point)

Your answer:

Question 3 (7 points) — Mass Spectrometry Interpretation

The mass spectrum of a sample of neon gas shows the following peaks:



(a) How many isotopes of neon are present in this sample? (1 point)

Your answer:

(b) Which isotope is the most abundant? What is its mass number? (1 point)

Your answer:

(c) Calculate the weighted average atomic mass of neon using the data from the mass spectrum. Show your work. (4 points)

Helpful Formula:

Average atomic mass = Σ(mass × abundance as decimal)

Example:

(20 × 0.90) + (21 × 0.03) + (22 × 0.07)

Your calculation:

(d) Why does the atomic mass you calculated differ from the mass numbers of individual isotopes? (1 point)

Your explanation:

Question 4 (6 points) — Electron Configuration

Write electron configurations for the following atoms and ions.

> **Aufbau Principle Reminder:**
> Order of filling: 1s → 2s → 2p → 3s → 3p → 4s → 3d → 4p → ...

(a) Write the complete electron configuration for oxygen (O, atomic number 8). (1 point)

Your answer:

(b) Write the complete electron configuration for aluminum (Al, atomic number 13). (2 points)

Your answer:

(c) Write the electron configuration for the oxide ion (O^{2-}). (2 points)

Hint:

O^{2-} means oxygen gained 2 electrons. Start with oxygen's configuration and add 2 electrons.

Your answer:

(d) How many valence electrons does aluminum have? (1 point)

Your answer:

Question 5 (6 points) — Orbital Diagrams and Hund's Rule

Draw orbital diagrams for the valence electrons of the following atoms.

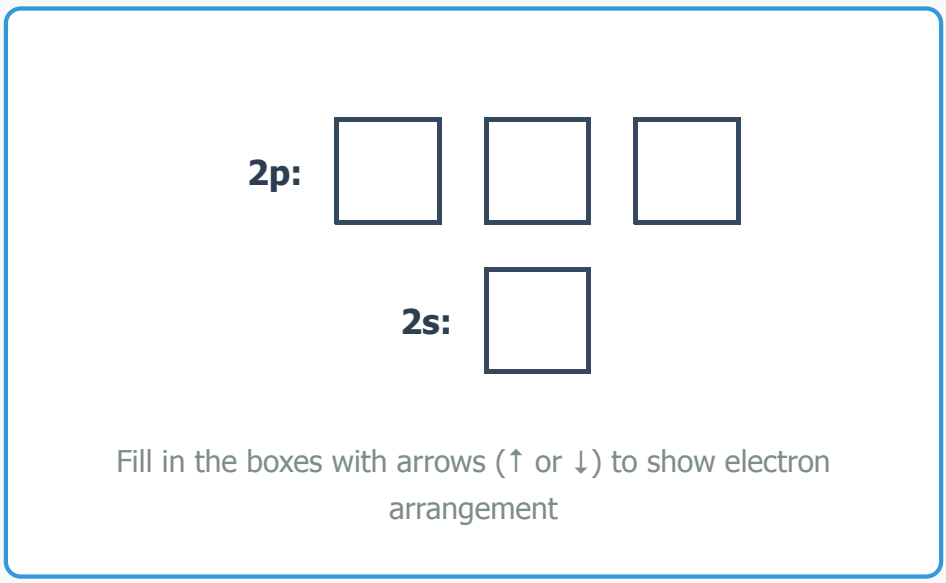
Rules to Remember:
- Each orbital can hold maximum 2 electrons (Pauli Exclusion Principle)
- Electrons fill orbitals singly before pairing (Hund's Rule)
- Use arrows: ↑ for first electron, ↓ for second electron

(a) Draw the orbital diagram for the valence electrons of nitrogen (N, atomic number 7). (2 points)

Hint:

Nitrogen's electron configuration is $1s^2\ 2s^2\ 2p^3$. Draw

only the 2s and 2p orbitals.

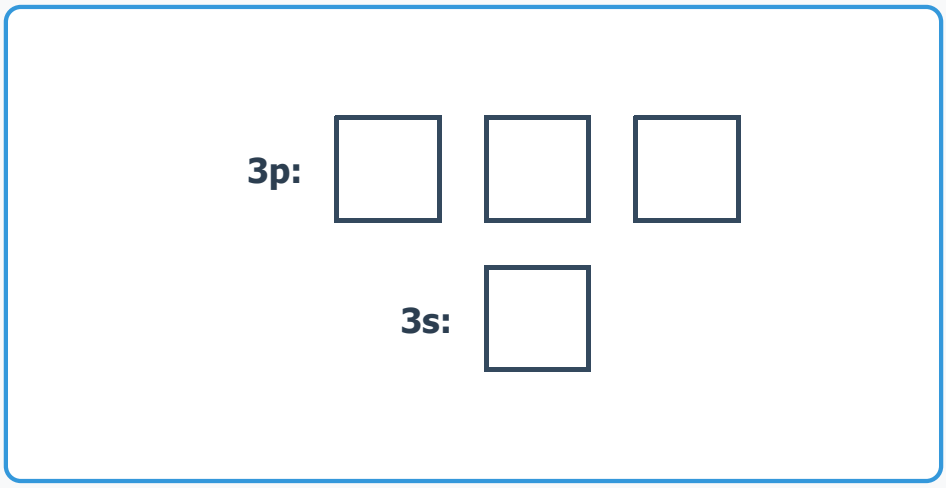


Fill in the boxes with arrows (↑ or ↓) to show electron arrangement

(b) Draw the orbital diagram for the valence electrons of sulfur (S, atomic number 16). (3 points)

Hint:

Sulfur's configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$. Draw only the 3s and 3p orbitals.



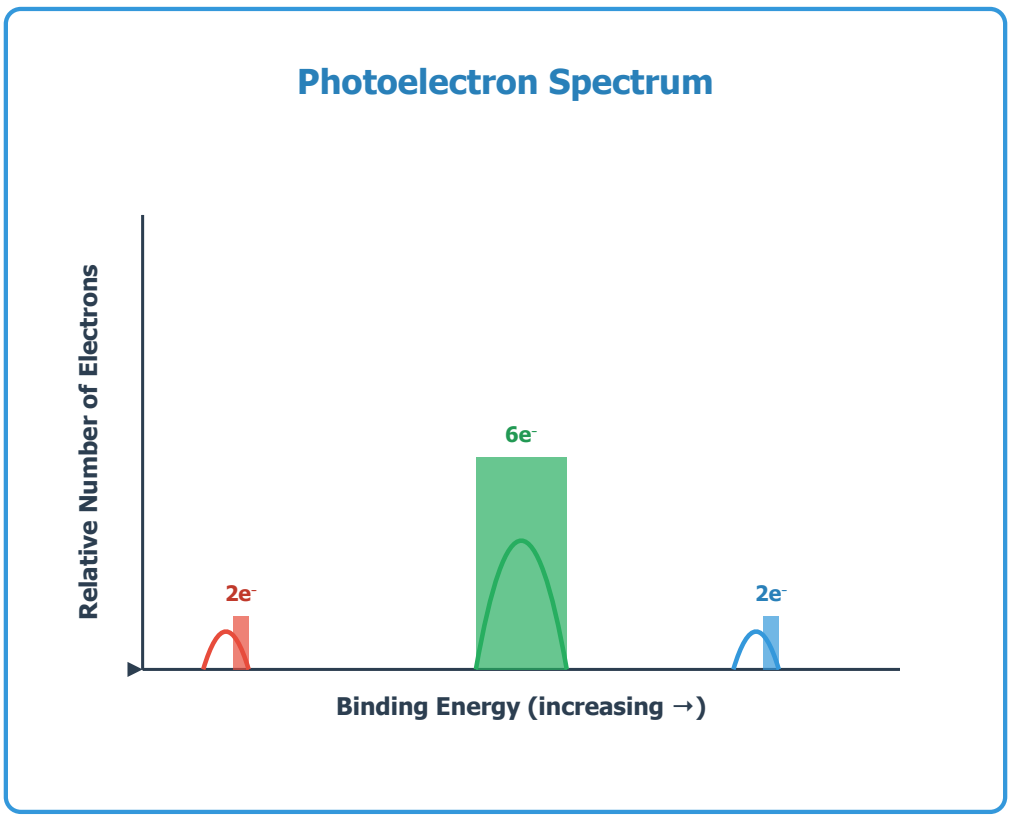
(c) Based on your orbital diagram, how many unpaired

electrons does sulfur have? (1 point)

Your answer:

Question 6 (6 points) — Photoelectron Spectroscopy (PES)

The photoelectron spectrum (PES) of an unknown element is shown below:



(a) How many electrons does this element have in total? (1 point)

Hint:

Add up the number of electrons in all three peaks

Your answer:

(b) Identify the element. Explain your reasoning. (2 points)

Your answer:

(c) Which peak (leftmost, middle, or rightmost) represents the valence electrons? Explain. (2 points)

Remember:

Valence electrons are farthest from the nucleus and require the LEAST energy to remove

Your explanation:

(d) Write the electron configuration for this element. (1 point)

Your answer:

Question 7 (6 points) — Coulombic Attraction

Consider the following ions: Na^+, Mg^{2+}, and Al^{3+} (all have 10 electrons).

Information:

- Na^+: 11 protons, 10 electrons
- Mg^{2+}: 12 protons, 10 electrons
- Al^{3+}: 13 protons, 10 electrons
- All three ions have the same electron configuration: $1s^2\ 2s^2\ 2p^6$

(a) Rank these ions in order of increasing ionic radius (smallest to largest). (2 points)

Your answer:

(b) Explain your ranking using the concept of Coulombic attraction. (3 points)

Hint:

Coulombic attraction = (charge of nucleus) × (charge of electrons) / distance
More protons = stronger pull on electrons = smaller radius

Your explanation:

(c) All three ions are isoelectronic (same number of electrons). What does this mean for the electron configuration? (1 point)

Your answer:

Question 8 (6 points) — Empirical Formula Determination

A compound contains 40.0% carbon, 6.7% hydrogen, and 53.3% oxygen by mass.

Given:

- Percent composition: 40.0% C, 6.7% H, 53.3% O
- Molar masses: C = 12.01 g/mol; H = 1.008 g/mol; O = 16.00 g/mol

(a) Assume you have 100 g of this compound. Calculate the mass of each element. (1 point)

Your answer:

(b) Calculate the number of moles of each element. Show your work. (3 points)

Your calculations:

(c) Determine the empirical formula of this compound. Show your work. (2 points)

Steps:

1) Divide all moles by the smallest number; 2) If needed, multiply all by small integer to get whole numbers

Your work:

Question 9 (6 points) — Quantum Numbers

Answer the following questions about quantum numbers.

Quantum Number Review:

- n (principal): energy level (1, 2, 3, ...)
- l (angular momentum): sublevel (s=0, p=1, d=2, f=3)
- m_l (magnetic): orbital orientation (−l to +l)
- m_s (spin): electron spin (+½ or −½)

(a) What are the possible values of l for n = 3? (2 points)

Rule:

l can be 0, 1, 2, ... up to (n−1)

Your answer:

(b) How many orbitals are in the 3p sublevel? (1 point)

Your answer:

(c) What is the maximum number of electrons that can occupy the n = 2 energy level? (2 points)

Hint:

n = 2 has 2s (2 electrons) and 2p (6 electrons) sublevels

Your answer:

(d) Can an electron have the quantum numbers n = 2, l = 2, m_l = 0, m_s = +½? Explain why or why not. (1 point)

Your explanation:

Question 10 (6 points) — Conceptual Understanding

(a) Explain why noble gases (like neon and argon) are chemically unreactive. (2 points)

Hint:

Think about their electron configurations and valence electron shells

Your explanation:

(b) Why do isotopes of the same element have identical chemical properties but different physical properties? (2 points)

Your explanation:

(c) Explain why the electron configuration $1s^2\ 2s^2\ 2p^7$ is impossible. (2 points)

Your explanation:

END OF PRACTICE SET

Review your work before checking answers!

✅ ANSWER KEY & DETAILED SOLUTIONS

Question 1: Mole Calculations - Complete Solution (5 points)

(a) Number of moles (2 points)

moles = mass / molar mass
moles = 12.7 g / 63.55 g/mol
moles = **0.200 mol**

Scoring: 1 pt for correct setup; 1 pt for correct answer

(b) Number of atoms (2 points)

atoms = moles × Avogadro's number
atoms = 0.200 mol × 6.022×10^{23} atoms/mol
atoms = **1.20×10^{23} atoms**

(c) Number of electrons (1 point)

electrons = atoms × 29 electrons/atom
electrons = $1.20 \times 10^{23} \times 29$
electrons = **3.48×10^{24} electrons**

Questions 2-10: Answer Summary

Q2 (Isotopes): (a) ^{35}Cl: 17p, 18n, 17e; ^{37}Cl: 17p, 20n, 17e; (b) Same protons/electrons → same chemical properties; different neutrons → different mass; (c) $^{35}Cl^-$ or $[^{35}_{17}Cl]^-$

Q3 (Mass Spectrum): (a) 3 isotopes; (b) ^{20}Ne, 90% abundant; (c) (20×0.90) + (21×0.03) + (22×0.07) = 18.0 + 0.63 + 1.54 = 20.17 amu; (d) Average is weighted by abundance, not simple average

Q4 (Electron Config): (a) O: $1s^2\ 2s^2\ 2p^4$; (b) Al: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$; (c) O^{2-}: $1s^2\ 2s^2\ 2p^6$; (d) 3 valence electrons

Q5 (Orbital Diagrams): (a) N: 2s: ↑↓; 2p: ↑ ↑ ↑; (b) S: 3s: ↑↓; 3p: ↑↓ ↑ ↑; (c) 2 unpaired electrons

Q6 (PES): (a) 10 electrons total; (b) Neon (Ne); 10 electrons = 10 protons; (c) Rightmost peak (lowest binding energy); (d) $1s^2\ 2s^2\ 2p^6$

Q7 (Coulombic): (a) $Al^{3+} < Mg^{2+} < Na^{+}$; (b) More protons = stronger attraction = smaller radius; Al^{3+} has most protons (13), pulls electrons closest; (c) Same electron configuration

Q8 (Empirical Formula): (a) 40.0 g C, 6.7 g H, 53.3 g O; (b) C: 3.33 mol; H: 6.65 mol; O: 3.33 mol; (c) Divide by 3.33: $C_1H_2O_1 = CH_2O$

Q9 (Quantum Numbers): (a) l = 0, 1, 2; (b) 3 orbitals (p_x, p_y, p_z); (c) 8 electrons maximum; (d) No, l cannot equal n (max l = n−1)

Q10 (Conceptual): (a) Complete valence shells (8 valence electrons); (b) Electrons determine chemistry; neutrons affect mass only; (c) p sublevel holds max 6 electrons (2 per orbital × 3 orbitals)