

Electron configurations, PES and periodic trends

AP Chemistry · Worksheet answers

Each answer gives the result in bold with a short reason. For explanation problems, check that you named the charge, the distance and the shielding, because those three ideas earn the marks.

Level: AP Chemistry · **Curriculum:** AP Chem Unit 1

Problem 1 Configuration of sulfur

1. $1s^2 2s^2 2p^6 3s^2 3p^4$.
2. **6 valence electrons** ($3s^2 3p^4$).
3. **[Ne] $3s^2 3p^4$** .

Problem 2 Configuration of a cation

1. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 = [\text{Ar}] 4s^2$.
2. The two 4s electrons leave: **$1s^2 2s^2 2p^6 3s^2 3p^6$** .
3. **Argon**.

Problem 3 Chromium and copper

1. **[Ar] $4s^1 3d^{10}$** .
2. A completely full 3d subshell lowers the energy, so one 4s electron moves to 3d to complete it.

Problem 4 Unpaired electrons in nitrogen

1. 2p: $\uparrow \uparrow \uparrow$ (three orbitals, one electron each, all with the same spin).
2. **3 unpaired electrons**.
3. **Hund's rule**: orbitals of equal energy are filled singly before pairing.

Problem 5 Identify the element from PES

1. From the left: 1s, 2s, 2p, 3s.
2. Heights 2 : 2 : 6 : 1 give $1s^2 2s^2 2p^6 3s^1$, so the element is **sodium**.
3. The **3s peak at 5.1 eV**, the lowest binding energy.

Problem 6 Coulomb's law quick checks

1. $F \propto 1/r^2$, so the force is **one quarter**.
2. $F \propto q$, so the force is **doubled**.
3. Factor $2 \times 4 = 8$ **times** bigger.

Problem 7 Which atom is bigger?

1. **Sodium** has the larger radius.
2. Both have three shells, but Z_{eff} is about 1 for Na and about 7 for Cl. The larger Z_{eff} pulls the electrons of Cl closer.

Problem 8 Effective nuclear charge

1. Mg: $12 - 10 = 2$. Si: $14 - 10 = 4$. Cl: $17 - 10 = 7$.
2. **Chlorine** has the smallest radius (largest Z_{eff}).
3. **Chlorine** has the greatest ionisation energy of these.

Problem 9 Successive ionisation energies

1. The jump comes after the **third** electron ($2745 \rightarrow 11577$).
2. **3 valence electrons**.
3. **Aluminium**.

Problem 10 Comparing two spectra

1. A is **aluminium** (13 electrons); B is **phosphorus** (15 electrons).
2. B has 15 protons against 13, so the core 1s electrons feel a stronger Coulomb attraction.
3. B's 3p peak is three electrons high against one, so **B has three valence p electrons**.

Problem 11 Isoelectronic ions

1. Each has **10 electrons**.
2. **F⁻, then Na⁺, then Mg²⁺** (largest first).
3. They have identical electron structure but nuclear charge 9, 11 and 12. The larger nuclear charge pulls the same electron cloud in more.

Problem 12 Ionisation energy exceptions

1. The Al valence electron is in 3p, which is higher in energy and shielded by the 3s electrons, so it is **easier to remove**.
2. In O the fourth 2p electron pairs with another in the same orbital. The repulsion between the paired electrons makes it easier to remove.

Problem 13 Transition-metal ions

1. Fe^{3+} : $[\text{Ar}] 3d^5$, **5 unpaired**.
2. Zn^{2+} : $[\text{Ar}] 3d^{10}$, **0 unpaired**.
3. Cu^+ : $[\text{Ar}] 3d^{10}$, **0 unpaired**.

Problem 14 Kinetic energy of photoelectrons

1. $\text{KE} = \text{photon energy} - \text{binding energy}$.
2. $\text{KE}(2s) = 1500 - 118 = \mathbf{1382 \text{ eV}}$.
3. $\text{KE}(2p) = 1500 - 73 = \mathbf{1427 \text{ eV}}$.

Problem 15 Ionisation energy across period 3

1. IE_1 **generally increases** from Na to Ar as Z_{eff} grows and the radius shrinks.
2. The electron in Al is in 3p, which sits higher than 3s and is partly shielded by the 3s electrons, so IE_1 is **below Mg**.
3. In S two electrons share a 3p orbital, and their repulsion makes removal easier, so IE_1 is **below P**.

Problem 16 Force between ions

1. $F = k e^2/r^2 = 8.99 \times 10^9 \times (1.602 \times 10^{-19})^2 / (2.76 \times 10^{-10})^2 = \mathbf{3.03 \times 10^{-9} \text{ N}}$.
2. $F = 8.99 \times 10^9 \times 4 \times (1.602 \times 10^{-19})^2 / (2.10 \times 10^{-10})^2 = \mathbf{2.09 \times 10^{-8} \text{ N}}$.
3. $\text{Ratio} = 2.09 \times 10^{-8} / 3.03 \times 10^{-9} = \mathbf{6.9}$. Stronger ionic attraction gives higher melting points for MgO than for NaCl.

Problem 17 Ranking ionisation energies

1. **Be, Mg, Li, Na, K** (highest first).
2. Down a group the valence electron is in a higher shell, farther from the nucleus and shielded, so IE falls.
3. Beryllium and magnesium have a larger nuclear charge than their group-1 neighbours in the same period, with the electron in the same shell, so the pull is stronger.

Problem 18 Interpreting a sulfur spectrum

1. The heights 2 : 2 : 6 : 2 : 4 give $1s^2 2s^2 2p^6 3s^2 3p^4$, which is **sulfur**.
2. The 1s peak for chlorine would appear at a **higher** binding energy, about 2820 eV.
3. Chlorine has one more proton, so the 1s electrons are held more strongly by the nucleus.

Problem 19 Why two electrons then a jump?

1. The first electron comes from the 3s valence shell. The second for sodium comes from the 2p shell, closer to the nucleus with less shielding, so it needs **far more energy**.
2. Magnesium loses two 3s electrons, both in the same shell, so IE_2 is only **moderately**

larger than IE_1 as the ion is positive.

3. IE_3 takes an electron from the 2p shell, so it is **larger than 4562 kJ/mol** (the real value is about 7730 kJ/mol).

Problem 20 Paragraph argument

Across a period (Na to Cl) electrons are added to the same shell and shield each other only weakly, while the nuclear charge increases from +11 to +17. By Coulomb's law the attraction between the nucleus and the valence electrons rises, so the radius decreases. Down a group (Li to Cs) each new element adds a shell, so the valence electron is farther away and shielded by more core electrons. The attraction, which falls with $1/r^2$, is weaker and the radius increases. **Radius is set by Z_{eff} across a period and by shell number down a group.**