

Topic 1.5: Electron Configuration

Worksheet · AP Chemistry

UNIT 1 · ATOMIC STRUCTURE AND PROPERTIES

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[Next Worksheet: Topic 1.6](#) · [Unit 1: All Topics](#) · [AP Chemistry Home](#)

How to Use This Worksheet

Work through the sections in order. Section A checks the ideas, Section B builds fluency with configurations, and Section C mixes everything the way an exam would.

For every configuration you write, check that the superscripts add up to the number of electrons before you move on. For unpaired electrons, always sketch the subshell as boxes: one arrow in each box first, then pair.

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 answer.

Section A: Recall and Concepts

A1. State the maximum number of electrons that can occupy an s, a p, a d and an f subshell, and explain where each number comes from.

A2. State the three rules that govern how electrons fill orbitals, in your own words.

A3. The 4s subshell fills before the 3d subshell, even though 3d belongs to a lower shell. State what this tells you about their relative energies when empty, and explain why Fe^{2+} is nevertheless written $[\text{Ar}] 3d^6$ rather than $[\text{Ar}] 4s^2 3d^4$.

A4. Define valence electrons and core electrons. Identify both sets for the phosphorus atom, P ($Z = 15$).

A5. An atom has the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$. A student says it must be paramagnetic because the 3d subshell is "large". Correct the student, naming the property that decides the question.

Section B: Core Calculations

B1. Write the full electron configuration of phosphorus, P ($Z = 15$).

B2. Write the noble gas shorthand configuration of calcium, Ca ($Z = 20$), and state its number of valence electrons.

B3. An element has the configuration $1s^2 2s^2 2p^6 3s^2 3p^2$. Identify the element and its group in the periodic table.

B4. Selenium, Se ($Z = 34$), has the configuration $[\text{Ar}] 4s^2 3d^{10} 4p^4$. State its number of valence electrons and its number of core electrons, and explain why the 3d electrons are not counted as valence.

B5. Draw the orbital diagram for the 2p subshell of a nitrogen atom and state how many unpaired electrons it has.

B6. Write the full electron configuration of the chloride ion, Cl^- (Z of Cl = 17), and name the noble gas it matches.

Section C: Exam Style

C1. Iron has atomic number 26. (a) Write the noble gas shorthand configuration of an iron atom. (b) Write the configurations of Fe^{2+} and Fe^{3+} . (c) State the number of unpaired electrons in each of the three species.

C2. Chromium has atomic number 24. (a) Write the configuration predicted by the standard filling order. (b) Write chromium's actual configuration and explain the reason for the difference. (c) State the number of unpaired electrons in a chromium atom.

C3. An element has the shorthand configuration $[\text{Kr}] 5s^2 4d^{10} 5p^3$. (a) Identify the element. (b) State its number of valence electrons. (c) State its number of unpaired electrons, justifying your answer from the orbital occupancy.

Answer Key

A1. $s = 2$, $p = 6$, $d = 10$, $f = 14$. Each subshell type contains a fixed number of orbitals: s has 1, p has 3, d has 5 and f has 7. Every orbital holds at most 2 electrons, so the capacities are 1×2 , 3×2 , 5×2 and 7×2 .

A2. Aufbau principle: electrons fill the lowest energy orbitals available first. Pauli exclusion principle: an orbital holds at most two electrons, and they must have opposite spins. Hund's rule: in a subshell, electrons occupy separate orbitals singly, with parallel spins, before any orbital gets a second electron.

A3. When empty, $4s$ is lower in energy than $3d$, so it fills first. But once electrons are in place, the $4s$ electrons sit in the outermost shell, $n = 4$, and are removed first when an ion forms. Forming Fe^{2+} therefore strips both $4s$ electrons and leaves $[\text{Ar}] 3d^6$. Removal order follows the highest n , not the filling order.

A4. Valence electrons are the electrons in the outermost shell (highest n); core electrons are all the inner electrons beneath them. Phosphorus, $Z = 15$, is $1s^2 2s^2 2p^6 3s^2 3p^3$. Its valence electrons are the $n = 3$ electrons, $3s^2 3p^3$: 5 valence electrons. Its core electrons are the other 10, with the $[\text{Ne}]$ configuration.

A5. The species is diamagnetic, not paramagnetic. Magnetism is decided by unpaired electrons, not by the size of any subshell. Here every subshell is completely filled ($3d^{10}$ included), so all electrons are paired and there are no unpaired electrons at all.

B1. $1s^2 2s^2 2p^6 3s^2 3p^3$. Check: $2 + 2 + 6 + 2 + 3 = 15$ electrons. ✓

B2. $[\text{Ar}] 4s^2$. The argon core accounts for 18 electrons and the $4s^2$ adds the remaining 2. Valence electrons: 2, those in the $n = 4$ shell.

B3. The superscripts sum to $2 + 2 + 6 + 2 + 2 = 14$ electrons, so the element is silicon, Si. Its outer pattern is $ns^2 np^2$, placing it in Group 14.

B4. Valence electrons: 6, the electrons in the highest shell, $n = 4$, namely $4s^2$ and $4p^4$. Core electrons: $34 - 6 = 28$. The $3d$ electrons sit in shell $n = 3$, inside the $n = 4$ shell; they are shielded core electrons and do not take part in selenium's bonding behaviour, which is set by the outer shell.

B5. The $2p$ subshell has three orbitals. Nitrogen has 3 electrons in $2p$ (configuration $1s^2 2s^2 2p^3$), and Hund's rule places one in each orbital, all spins parallel: $[\uparrow][\uparrow][\uparrow]$. Unpaired electrons: 3.

B6. Cl^- has $17 + 1 = 18$ electrons: $1s^2 2s^2 2p^6 3s^2 3p^6$. This is exactly the configuration of argon, Ar.

C1. (a) Fe: $[\text{Ar}] 4s^2 3d^6$ ($18 + 2 + 6 = 26$ electrons ✓). (b) Cations lose the highest n electrons first, so both $4s$ electrons leave before any $3d$ electron: Fe^{2+} is $[\text{Ar}] 3d^6$; Fe^{3+} loses one further electron from $3d$: $[\text{Ar}] 3d^5$. (c) Fe atom: the $4s$ pair is paired, and $3d^6$ spreads as one pair plus four singles, so 4

unpaired. Fe^{2+} ($3d^6$): also 4 unpaired. Fe^{3+} ($3d^5$): one electron in each of the five d orbitals, so 5 unpaired.

C2. (a) Predicted: $[\text{Ar}] 4s^2 3d^4$. (b) Actual: $[\text{Ar}] 4s^1 3d^5$. One electron is promoted from 4s into 3d because a half filled subshell, $3d^5$, with one electron in every orbital, is especially stable, and that stability outweighs the small energy cost of the promotion. (c) The $4s^1$ electron is unpaired, and each of the five 3d electrons sits alone in its own orbital: $1 + 5 = 6$ unpaired electrons.

C3. (a) Electron count: 36 (Kr core) + 2 + 10 + 3 = 51, so the element is antimony, Sb. (b) Valence electrons are those in the highest shell, $n = 5$: $5s^2$ and $5p^3$ give 5 valence electrons. (The filled $4d^{10}$ set belongs to shell $n = 4$ and is core.) (c) The $5p^3$ electrons occupy the three p orbitals singly, by Hund's rule, so all 3 are unpaired. The $5s^2$ pair is paired. Unpaired electrons: 3.

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[Previous Worksheet: Topic 1.4 Mixtures](#)

[Next Worksheet: Topic 1.6 Photoelectron Spectroscopy](#)