Worksheet: Electronic Configurations | CIE | A-Level Chemistry

Learning Objectives:

- Understand and define the terms shell, sub-shell, and atomic orbital.
- State the order of filling of electron sub-shells up to 4p.
- Write the full and shorthand (noble gas) electronic configurations for atoms and ions up to Z=36.
- Represent electronic configurations using the 'electrons in boxes' notation.
- Explain the anomalous electronic configurations of chromium (Cr) and copper (Cu).
- Relate the electronic configuration of an element to its position in the Periodic Table.

Section A: Foundational Concepts

1. Define the following terms:
   a. Atomic Orbital
   b. Principal Quantum Shell

2. State the maximum number of electrons that can occupy:
   a. An s sub-shell:
   b. A p sub-shell:
   c. A d sub-shell:
   d. The third principal quantum shell (n=3):

3. State the order in which the following sub-shells are filled with electrons:
   3s, 3p, 4s, 3d, 4p

Section B: Configurations of Neutral Atoms

1. Write the full electronic configuration for a neutral atom of each of the following elements:
   a. Magnesium (Mg, Z=12):
   b. Phosphorus (P, Z=15):
   c. Argon (Ar, Z=18):

2. Write the shorthand electronic configuration (using a noble gas core) for a neutral atom of each of the following elements:
   a. Calcium (Ca, Z=20):
   b. Scandium (Sc, Z=21):
   c. Bromine (Br, Z=35):

Section C: Configurations of Ions

1. Write the full electronic configuration for each of the following ions:
   a. O^{2-} (Z of O = 8):
   b. Al^{3+} (Z of Al = 13):

2. Write the shorthand electronic configuration for each of the following ions:
   a. Ti^{2+} (Z of Ti = 22):
   b. Fe^{3+} (Z of Fe = 26):
   c. Cu^{+} (Z of Cu = 29):

Section D: Exceptions and Patterns

1. Explain why the actual electronic configuration of a neutral **chromium (Cr)** atom is **[Ar] $3d^5 4s^1$** and not the expected [Ar] $3d^4 4s^2$.

2. An element has the electronic configuration [Ar] $3d^{10} 4s^2 4p^3$.
   a. Identify the period in which this element is found.
   b. Identify the group in which this element is found.
   c. Identify the block (s, p, or d) in which this element is found.

Section E: Application and Analysis

1. Draw the 'electrons in boxes' diagram for the valence (outer shell) electrons of a neutral sulfur atom (S, Z=16). Label the sub-shells.

2. How many unpaired electrons are there in a gaseous Co^{2+} ion? (Z of Co = 27).

Show your reasoning.

3. An element forms a stable ion with a charge of 3+ and has the electronic configuration [Ar] $3d^3$.
   a. What is the electronic configuration of the neutral atom?
   b. Identify the element.

Answer Key

Section A

1. a. Atomic Orbital: A region of space around the nucleus that can hold up to two electrons with opposite spins.
   b. Principal Quantum Shell: A main energy level occupied by electrons.
2. a. 2, b. 6, c. 10, d. 18
3. 3s, 3p, 4s, 3d, 4p

Section B

1. a. $1s^2 2s^2 2p^6 3s^2$
   b. $1s^2 2s^2 2p^6 3s^2 3p^3$
   c. $1s^2 2s^2 2p^6 3s^2 3p^6$
2. a. [Ar] $4s^2$
   b. [Ar] $3d^1 4s^2$
   c. [Ar] $3d^{10} 4s^2 4p^5$

Section C

1. a. $1s^2 2s^2 2p^6$
   b. $1s^2 2s^2 2p^6$
2. a. [Ar] $3d^2$
   b. [Ar] $3d^5$
   c. [Ar] $3d^{10}$

Section D

1. This configuration gives a **half-filled d sub-shell** ([Ar] $3d^5 4s^1$), which is an

arrangement of **lower energy** and therefore **greater stability** compared to the expected configuration ([Ar] $3d^4 4s^2$).

2. a. Period 4
   b. Group 15
   c. p-block

Section E

1. **Sulfur (S)** valence electrons ($3s^2 3p^4$):
   - **3s:** | ↑↓ |
   - **3p:** | ↑↓ | ↑ | ↑ |
2. 3 unpaired electrons. A neutral Co atom is [Ar] $3d^7 4s^2$. To form Co^{2+}, the two 4s electrons are lost. The resulting configuration is [Ar] $3d^7$. The 3d sub-shell will have two pairs of electrons and three unpaired electrons.
3. a. [Ar] $3d^5 4s^1$
   b. Chromium (Cr)