

Chapter	2 Atomic Structure	Class	1 st Year	Subject	Chemistry
---------	--------------------	-------	----------------------	---------	-----------

Give Short Answers of the Following Questions

1. There are three orientations of p-orbital due to three values of magnetic quantum number. Justify it.

Ans. It is correct. There are three orientations of the p-orbital due to the three values of the magnetic quantum number (m_l). Here's the justification in simple scientific terms:

Quantum Numbers:

Each electron in an atom is described by four quantum numbers:

1. **Principal quantum number (n)** _ energy level
2. **Azimuthal / angular quantum number (l)** _ shape of orbital
3. **Magnetic quantum number (m_l)** – orientation of orbital
4. **Spin quantum number (m_s)** _ spin direction of electron

For a p-orbital:

- The azimuthal quantum number (l) = 1
- (Because p-orbitals correspond to $l = 1$)
- The magnetic quantum number (m_l) can have three values:
 $m_l = -1, 0, +1$

2. 'I₃' of Mg is much bigger than its 'I₂'. Justify.

Ans. The third ionization energy (I_3) of magnesium (Mg) is much bigger than its second ionization energy (I_2). Here's the scientific justification:

- **Ionization energy** is the energy needed to remove one electron from an atom or ion.
- **I₁:** Remove 1st electron
- **I₂:** Remove 2nd electron
- **I₃:** Remove 3rd electron

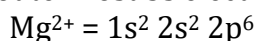
Electronic Configuration of Magnesium:

Neural Mg atom:

Mg ($Z = 12$) = $1s^2 2s^2 2p^6 3s^2$

- **First ionization (I₁)** remove one electron from $3s^2 \rightarrow$ becomes Mg^+
- **Second ionization (I₂)** removes second 3s electron $\rightarrow$ become Mg^{2+}
- **Third ionization (I₃)** would now try to remove an electron from the $2p^6$ (inner, noble gas core)

After removing two outermost 3s electrons, Mg^{2+} has the stable configuration of Neon (Ne):



Now, the third electron to be removed is from a completely filled inner shell (2p) which:

- Is very stable (noble gas configuration)
- Is closer to the nucleus
- Is more strongly attracted by nuclear charge

Hence, much more energy is needed to remove this tightly bound electron.

3. Among the elements Li, K, Ca, S and Kr which one has the lowest first ionization energy? Which has the highest first ionization?

Ans. Ionization Energy Trend Recap:

- **Increases across a period** (left $\rightarrow$ right) due to increasing nuclear charge.
- **Decreases down a group** (top $\rightarrow$ bottom) as outer electrons are farther from the nucleus and

Chapter	2 Atomic Structure	Class	1 st Year	Subject	Chemistry
---------	--------------------	-------	----------------------	---------	-----------

more shielded.

4. Consider the electronic configuration of the potassium atom (atomic number 19).

Ans. Element: Potassium (K)

Atomic Number: 19

So it has 19 electrons.

Electronic Configuration:

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

5. Write the full electronic configuration of potassium using s, p, d, f notation.

Ans. Element: Potassium (K)

Atomic Number: 19

So it has 19 electrons.

Electronic Configuration:

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

6. Explain why the 4s subshell is filled before the 3d subshell in potassium, even though the principal quantum number of the 3d subshell is lower.

Ans. Even though:

- 3d has a lower principal quantum number ($n = 3$)
 - 4d has a lower principal quantum number ($n = 4$)
- The 4s subshell has lower energy than 3d at the time potassium's electrons are being placed.

Key Principle:

1. Aufbau principle

Electrons fill orbitals in order of increasing energy, not just by n value. According to the Aufbau (building-up) principle.

$1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p$

As you can see, 4s comes before 3d.

2. Energy Level Overlap

- 4s orbital is farther from the nucleus but has less electron-electron repulsion, making it lower in energy than 3d.
- So, the first 19 electrons (in potassium) go into the 4s before starting to fill 3d.

Potassium ($Z = 19$):

- **Configuration:** $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
- The 3d subshell remains empty in potassium because it's higher in energy at this point.

Conclusion:

The 4s subshell is filled before 3d in potassium because, despite having a higher principal quantum number, it is lower in energy at the point when electrons are added, following the Aufbau principle.

7. An atom of element X has an atomic number of 17 and a mass number of 35. Determine the number of protons, neutrons, and electrons in this atom.

Ans. Number of protons = Atomic number

Protons = 17

Number of neutrons = Mass number – Atomic number

Chapter	2 Atomic Structure	Class	1 st Year	Subject	Chemistry
----------------	--------------------	--------------	----------------------	----------------	-----------

Neutron = 18

Number of electrons = Number of protons (in a neutral atom)

Electrons = 17

8. If this element forms an ion with a charge of -1, how many protons, neutrons, and electrons will be present in the ion?

Ans. X element has:

- Atomic number = 17
- Mass number = 35

We previously identified it as chlorine (Cl).

Now, let's consider the Cl⁻ ion (chloride ion), which has a - 1 charge.

Protons

- The number of protons never changes, even when forming ions.

Protons = 17

Neutrons

- Mass number = 35, Atomic number = 17

Neutrons = 18

Electrons (for Cl⁻ ion)

- Neutral chlorine atom has 17 electrons
- A - 1 charge means it has gained one extra electron

Electron = 17 + 1 = 18

9. In the ground state of mercury ⁸⁰Hg:

Ans. In the ground state of mercury (Hg), which has an atomic number of 80, we can determine several important features of the atom, such as its electron configuration, and the number of protons, neutrons, and electrons.

Basic information for Mercury (Hg):

- Symbol:** Hg
- Atomic number (Z):** 80 → Protons = 80, Electrons = 80 (in a neutral atom)
- Mass number (most common isotope):** 200 → So, Neutrons = 200 - 80 = 120

Ground- State Electron Configuration:

Mercury is a transition metal, and its full electron configuration is:

1s² 2s² 2p⁶ 3s² 3p⁶ 4s² 3d¹⁰ 4p⁶ 5s² 4d¹⁰ 5p⁶ 6s² 4f¹⁴ 5d¹⁰

In noble gas short hand:

[Xe] 4f¹⁴ 5d¹⁰ 6s²

10. How many electron occupy atomic orbitals with n = 3?

Ans. Electrons can occupy atomic orbitals where the principal quantum number n = 3n = 3n = 3

For **n = 3n = 3n = 3**, the possible **subshells** (values of l) are:

- L = 0 \ell = 0l=0 → 3s
- L = 1 \ell = 1l=1 → 3p
- L = 2 \ell = 02=0 → 3d

Each subshell has a certain number of orbital, and each orbital holds **2 electrons**:

Subshell	Orbitals	Electrons
3s	1	2
3p	3	6
3d	5	10

Chapter	2 Atomic Structure	Class	1 st Year	Subject	Chemistry
---------	--------------------	-------	----------------------	---------	-----------

Total electrons when $n = 3$ $n = 3$ $n = 3$:

$$2(3s) + 6(3p) + 10(3d) = 18 \text{ electrons}$$

So, **18 electrons** can occupy atomic orbitals with **principal quantum number $n = 3$ $n = 3$ $n = 3$**

11. How many electrons occupy 4d atomic orbitals?

Ans. The 4d atomic orbitals can hold a maximum of 10 electrons. This is because the 4d subshell consists of 5 orbitals (each orbital can hold a maximum of 2 electron), so 5 orbitals x 2 electrons = 10 electrons in total.

12. How many electrons occupy 4d atomic orbitals?

Ans. The 4p atomic orbital can hold a maximum of 2 electrons. Each atomic orbital, including the 4p orbital, can accommodate up to 2 electrons, with each electron having opposite spins.

13. How many electrons in the valence shell have spin “up” ($s = -\frac{1}{2}$)?

Ans. In an atomic orbital, each electron can have one of two possible spins: “up” {denoted as $s = +\frac{1}{2}$ } or “down” (denoted as $s = -\frac{1}{2}$).

If you are asking how many electrons have a spin of $s = -\frac{1}{2}$ in a particular orbital, it depends on how many electrons are present in that orbital. For example.

In a single atomic orbital (such as the 4p orbital), a maximum of 2 electrons can occupy it one with spin $+\frac{1}{2}$ and one with spin $-\frac{1}{2}$.

If there are multiple orbitals (such as in a subshell like the 4d or 4p), the electrons will fill the orbitals according to the Pauli exclusion principle, with one electron having spin $+\frac{1}{2} + \frac{1}{2} + \frac{1}{2}$ and the other having spin $-\frac{1}{2}$ in each orbital.

So, in general, half of the electrons in any set of orbitals would have spin $s = -\frac{1}{2}$, assuming the electrons are paired and fill orbitals according to Hund’s rule and the Pauli exclusion principle. Conclusion: 80 electrons in total and thus 40 orbital in Hg.

14. The successive ionization energies for an unknown element are

$$I_1 = 896 \text{ kJ / mol}$$

$$I_2 = 1752 \text{ kJ / mol}$$

$$I_3 = 14,807 \text{ kJ / mol}$$

$$I_4 = 17,948 \text{ kJ / mol}$$

To which family in the periodic table, does the unknown element most likely belong?

Ans. As there is greatest difference between 2nd and 3rd ionization energies, it means this element belongs to group 2A (Alkaline Earth’s metal).

i. Consider the following ionization energies for aluminum:



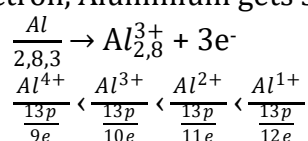
Chapter	2 Atomic Structure	Class	1 st Year	Subject	Chemistry
---------	--------------------	-------	----------------------	---------	-----------

- (i) Account for the trend in the values of the ionization energies.
- (ii) Explain the large increase between I_3 and I_4 .
- (iii) List the four aluminum ions given in order of increasing size, and explain your ordering.

(i) $I_4 > I_3 > I_2 > I_1$

(ii) As there is greatest difference between 3rd and 4th ionization energies, it means this element belongs to group 3A (Boron family).

(iii) After losing 3rd electron, Aluminium gets stable electronic configuration of noble gas.



In Al^{+1} there are 13 protons and 12 electrons so, control of nucleus is lesser on outer electrons so its size greatest among above.

In Al^{+4} there are 13 protons and 9 electrons, there is more imbalance between proton to electron ratio so, control of nucleus is greatest and its size is the least among above.

15. (i) State the general order of filling orbitals up to the 4p subshell.
- (ii) Explain why the 4s subshell is filled before the 3d subshell, according to the Aufbau principle.

Ans. (i) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$

(ii) The 4s subshell is filled before the 3d subshell according to the Aufbau principle because the 4s orbital is lower in energy than the 3d orbital when these orbitals are empty or partially filled neutral atoms.

1. Energy considerations:

- Even though 4s has a higher principal quantum number ($n = 4$) than 3d ($n = 3$), the energy of an orbital depends on both the principal quantum number n and the azimuthal quantum number l .
- For 4s: $n = 4, l = 0$, so $n + l = 4$
- For 3d: $n = 3, l = 2$, so $n + l = 5$
- According to the $(n + l)$ rule (used in the Aufbau principle), orbitals with a lower $n + l$ value are filled first.

2. Electron Shielding and Penetration:

- The 4s orbital penetrates closer to the nucleus and experiences less shielding than the 3d orbital.
- As a result, electrons in the 4s orbital are more tightly held and thus occupy a lower energy level initially.

However, once electrons are added to the 3d subshell, the energy level shift slightly. In ions of transition metals, for example, the 4s electrons are usually lost before the 3d electrons, because the 4s orbital becomes higher in energy after the 3d subshell is filled or partially filled.

Chapter	2 Atomic Structure	Class	1 st Year	Subject	Chemistry
----------------	--------------------	--------------	----------------------	----------------	-----------

16. Draw the orbital box diagram for the valence electrons of a phosphorus atom (atomic number 15), ensuring that your diagram adheres the Hund's rule and the Pauli exclusion principle.

Ans.

Phosphorus (P):

15 electrons
 $1s^2 2s^2 2p^6 3s^2 3p^3$

