

## Structure of Atom — Assignment 2

Class 11 Chemistry · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.  
(2) Give all answers with correct SI units.  $g = 10 \text{ m/s}^2$  unless stated.  
(3) A final answer key is provided at the end — try the full set before checking it.

### Part A — Topic-wise challenge questions

#### Subatomic Particles and Atomic Numbers

1. Define atomic number and mass number and give the number of protons and neutrons in  $^{37}\text{Cl}$ .
2. Distinguish between isotopes and isobars with examples.
3. State the composition of  $^{23}\text{Na}$  in terms of protons, neutrons and electrons.

#### Atomic Models — Thomson and Rutherford

1. Describe Thomson's model of the atom and state its limitations.
2. State the conclusions drawn from Rutherford's alpha-particle scattering experiment.
3. State the main drawback of Rutherford's model.

#### Bohr's Model of the Atom

1. State the postulates of Bohr's model of the hydrogen atom.
2. The radius of the first Bohr orbit is  $0.53 \text{ \AA}$ . Find the radius of the second orbit.
3. Derive the expression for the energy of the electron in the  $n$ th Bohr orbit.

#### Quantum Numbers and Orbitals

1. Define the four quantum numbers and state what each represents.
2. Write the possible values of the magnetic quantum number for a d orbital.
3. How many orbitals are present in a p subshell?

#### Electronic Configuration — Aufbau, Pauli and Hund

1. State the Aufbau principle and write the electronic configuration of chlorine.
2. State Pauli's exclusion principle and Hund's rule with examples.
3. Write the electronic configuration of nitrogen, justifying each step.

#### de Broglie and Heisenberg Uncertainty

1. State the de Broglie hypothesis and write the expression for the de Broglie wavelength.
2. State Heisenberg's uncertainty principle and explain its significance.
3. Explain why the uncertainty principle is significant only for microscopic particles.

**Part B — Integrated problems (multi-topic)**

1. Calculate the wavelength of the radiation emitted when an electron in a hydrogen atom falls from  $n = 3$  to  $n = 2$ . ( $R = 1.097 \times 10^7 \text{ m}^{-1}$ )
2. How many electrons in an atom can have  $n = 3$  and  $l = 2$ ?
3. Write the electronic configuration of chromium ( $Z = 24$ ) and explain the anomalous configuration.
4. Calculate the de Broglie wavelength of an electron moving with a speed of  $10^6 \text{ m/s}$ .
5. The uncertainty in the position of an electron is  $10^{-10} \text{ m}$ . Find the minimum uncertainty in its momentum. ( $h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s}$ )

**Answer Key****Subatomic Particles and Atomic Numbers**

Atomic number  $Z$  = number of protons; mass number  $A$  = protons + neutrons.  $^{37}\text{Cl}$ : 17 protons, 20 neutrons. Isotopes: same  $Z$ , different  $A$  ( $^{12}\text{C}$ ,  $^{14}\text{C}$ ). Isobars: same  $A$ , different  $Z$  ( $^{40}\text{Ar}$ ,  $^{40}\text{K}$ ).

**Atomic Models — Thomson and Rutherford**

Thomson: positive sphere with embedded electrons; could not explain scattering. Rutherford: alpha scattering revealed a small, dense, positive nucleus; fails on atomic stability and spectra.

**Bohr's Model of the Atom**

Stationary orbits; angular momentum =  $nh/2\pi$ ; radiation on transition.  $r_n = 0.53 n^2 \text{ \AA}$ ;  $E_n = -13.6/n^2 \text{ eV}$ . First explained the hydrogen spectrum.

**Quantum Numbers and Orbitals**

$n$  (size/energy),  $l$  (shape),  $m_l$  (orientation),  $m_s$  (spin).  $p$  subshell has 3 orbitals;  $d$  subshell has 5, with  $m_l$  from  $-2$  to  $+2$ .

**Electronic Configuration — Aufbau, Pauli and Hund**

Aufbau: fill by increasing orbital energy; Pauli: no two electrons share all four quantum numbers; Hund: fill degenerate orbitals singly with parallel spins first.  $\text{Cl}$  ( $Z = 17$ ):  $1s^2 2s^2 2p^6 3s^2 3p^5$ .

**de Broglie and Heisenberg Uncertainty**

$\lambda = h/mv$ ;  $\Delta x \cdot \Delta p \geq h/4\pi$ . For macroscopic objects  $\Delta x \cdot \Delta p$  is negligible, so the uncertainty principle matters only for microscopic particles.

**Integrated problems**

1:  $1/\lambda = R(1/2^2 - 1/3^2)$   $\lambda \approx 656 \text{ nm}$ . 2:  $l = 2$  is  $d$ ; number of orbitals = 5, each holding 2 electrons = 10 electrons. 3:  $\text{Cr}$ :  $[\text{Ar}] 3d^5 4s^1$ , a half-filled  $d$  subshell is more stable. 4:  $\lambda = h/mv \approx 7.3 \times 10^{-10} \text{ m}$ . 5:  $\Delta p \geq h/(4\pi \Delta x) \approx 5.3 \times 10^{-25} \text{ kg}\cdot\text{m/s}$ .