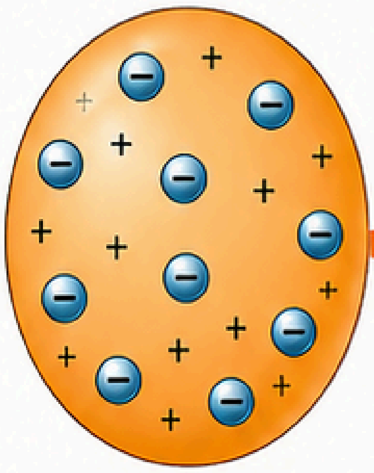
DEVELOPMENT OF ATOMIC MODELS

Scientists have proposed different models to explain the structure of an atom. Each model improved our understanding of the atom.

1 J.J. THOMSON (1897)

PLUM PUDDING MODEL



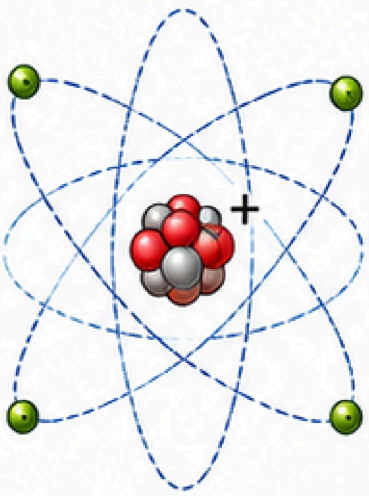
A positively charged sphere with electrons embedded in it.

KEY FEATURES

- Atom is a sphere of positive charge.
- Electrons (–) are embedded in it like plums in a pudding.
- Overall, the atom is electrically neutral.

2 ERNEST RUTHERFORD (1911)

NUCLEAR MODEL



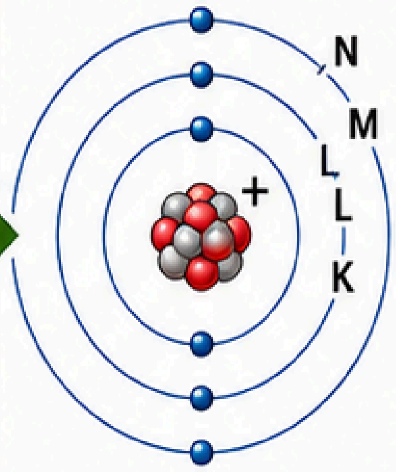
Atom has a small, dense, positively charged nucleus at the center.

KEY FEATURES

- Most of the atom is empty space.
- A tiny, dense, positively charged nucleus is present at the center.
- Electrons revolve around the nucleus.
- Could not explain the stability of electrons.

3 NIELS BOHR (1913)

BOHR MODEL



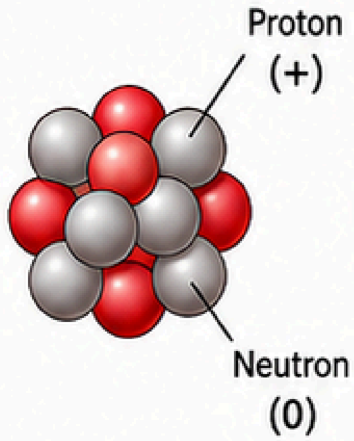
Electrons revolve around the nucleus in fixed circular orbits (shells) with definite energy.

KEY FEATURES

- Electrons revolve in fixed circular paths called shells (K, L, M, N...).
- Each shell has a fixed energy.
- Electrons can jump from one shell to another by absorbing or releasing energy.
- Explain the stability of atoms and line spectra.

4 JAMES CHADWICK (1932)

NEUTRON DISCOVERY



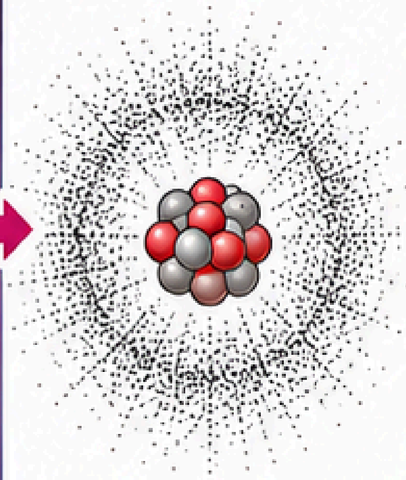
Discovered neutrons in the nucleus.

KEY FEATURES

- Neutrons (neutral particles) are present in the nucleus along with protons.
- Helped to explain the mass of the nucleus.
- Gave a more complete picture of atomic structure.

5 MODERN ATOMIC MODEL

QUANTUM MECHANICAL MODEL (MODERN MODEL)



Electrons exist in probability clouds (orbitals) around the nucleus.

KEY FEATURES

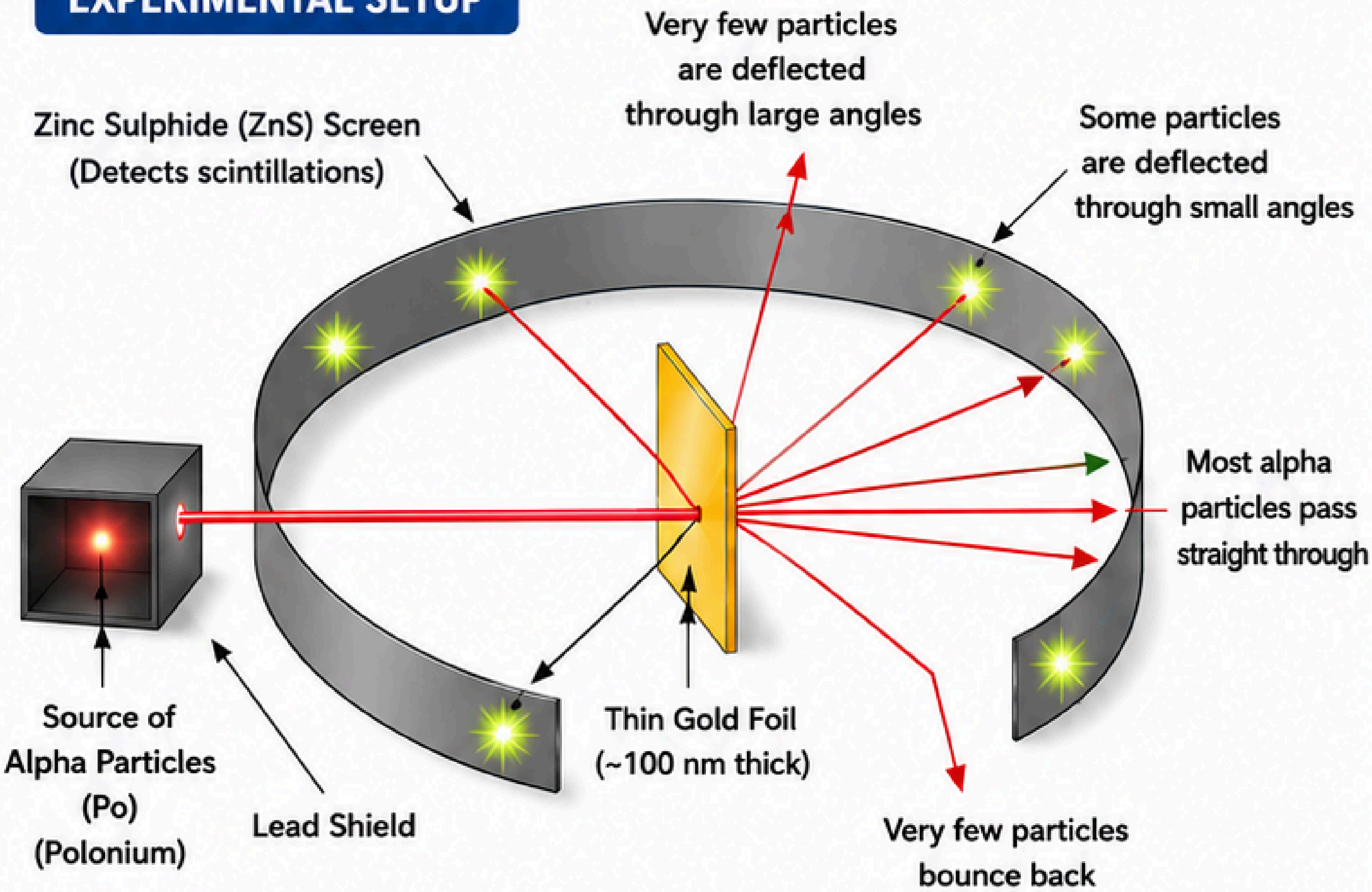
- Electrons do not move in fixed paths.
- They exist in regions of space called orbitals.
- Based on quantum mechanics.
- Most accurate model available today.

SUMMARY: Our understanding of the atom improved step by step. From Thomson's idea of a positively charged sphere to Rutherford's nucleus, Bohr's energy levels, Chadwick's neutrons, and the modern quantum model – each contribution brought us closer to the true nature of the atom.

RUTHERFORD GOLD FOIL EXPERIMENT

In 1911, Ernest Rutherford performed an experiment to study the structure of an atom.
He bombarded a thin gold foil with **alpha (α) particles** and observed how they scattered.

EXPERIMENTAL SETUP



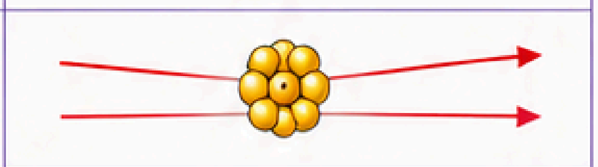
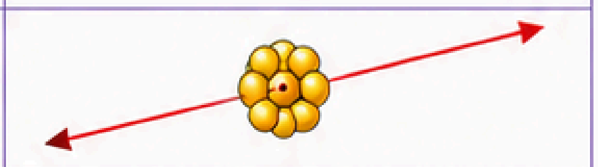
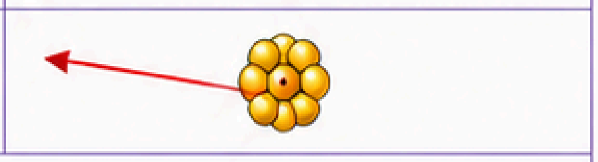
OBSERVATIONS

1. Most of the alpha particles (about 99%) passed straight through the gold foil without any deflection.
2. Some alpha particles were deflected through small angles.
3. Very few alpha particles were deflected through large angles.
4. Very few alpha particles (about 1 in 20,000) bounced back in the direction opposite to the incident beam.

CONCLUSION

- An atom has a tiny, dense, positively charged nucleus at the center.
- Most of the space in an atom is empty.
- Alpha particles pass through the empty space without any deflection.
- Large deflection or bouncing back occurs only when alpha particles come very close to the nucleus.

DIAGRAMMATIC SUMMARY OF RESULTS

Most particles pass straight through (no deflection)	
Some particles are deflected through small angles	
Very few particles are deflected through large angles	
Very few particles bounce back	

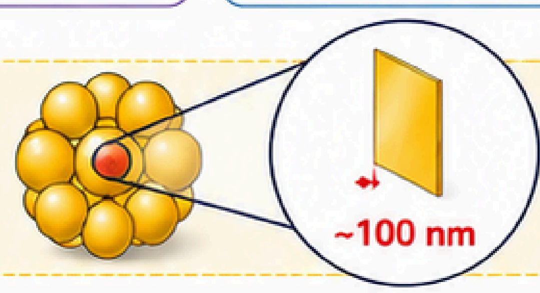
Path of alpha particle   Nucleus

IMPORTANCE

- This experiment disproved J.J. Thomson's "plum pudding" model of the atom.
- It led to Rutherford's nuclear model of the atom.
- It was a major step in understanding the structure of the atom.

KEY FACT

The gold foil used was extremely thin (~100 nm = 1×10^{-7} m) so that alpha particles could pass through it.



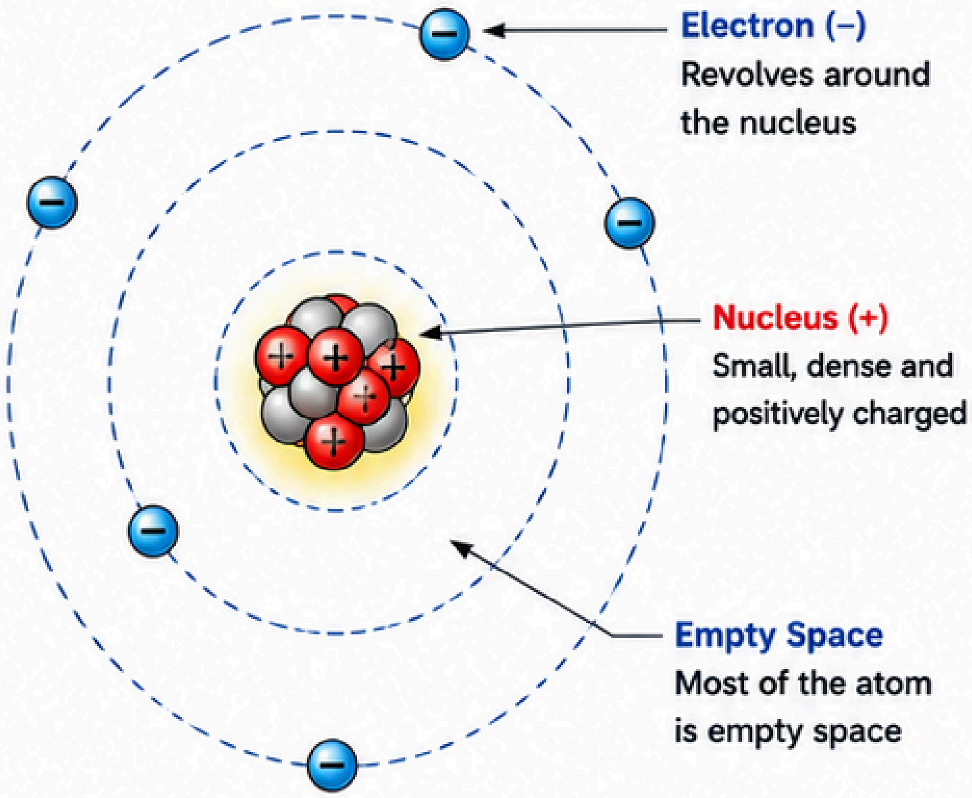
RUTHERFORD ATOMIC MODEL

Based on the results of the gold foil experiment, Ernest Rutherford proposed a new model of the atom in 1911.

STRUCTURE OF RUTHERFORD ATOMIC MODEL

- An atom has a small, dense, positively charged nucleus at the center.
- Electrons revolve around the nucleus in circular paths.
- Most of the space in an atom is empty.
- The mass of the atom is concentrated in the nucleus.
- The number of electrons is equal to the number of protons, so the atom is electrically neutral.

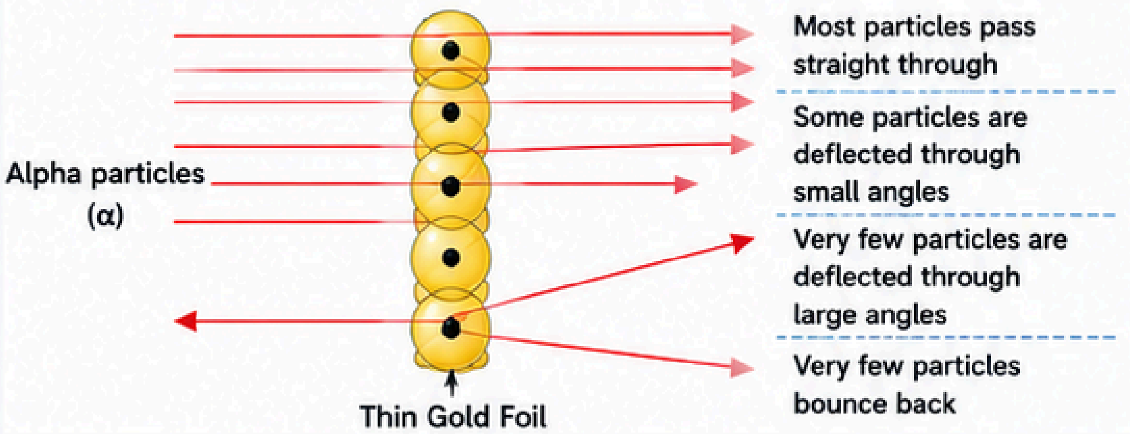
DIAGRAM OF RUTHERFORD ATOMIC MODEL



KEY FEATURES

- Tiny, dense, positively charged nucleus at the center.
- Electrons revolve around the nucleus.
- Most of the space in an atom is empty.
- Explains the large deflection of alpha particles in the gold foil experiment.
- Could not explain the stability of atoms (electrons should lose energy and fall into the nucleus according to classical physics).

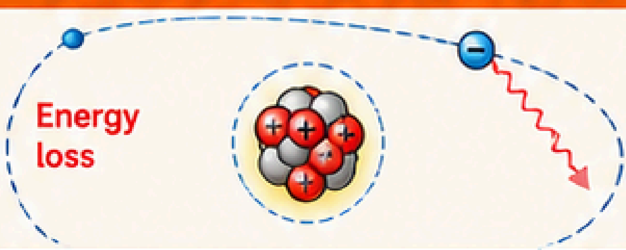
EXPLANATION OF GOLD FOIL EXPERIMENT BY THIS MODEL



IMPORTANCE

- ★ It replaced J.J. Thomson's "plum pudding" model of the atom.
- ★ It established the concept of a nucleus in an atom.
- ★ It was the first nuclear model of the atom and a major step towards modern atomic theory.

LIMITATION OF RUTHERFORD MODEL



According to classical physics, an electron moving in a circular path should continuously lose energy and finally spiral into the nucleus. But atoms are stable. This model could not explain the stability of atoms or the line spectra of elements.

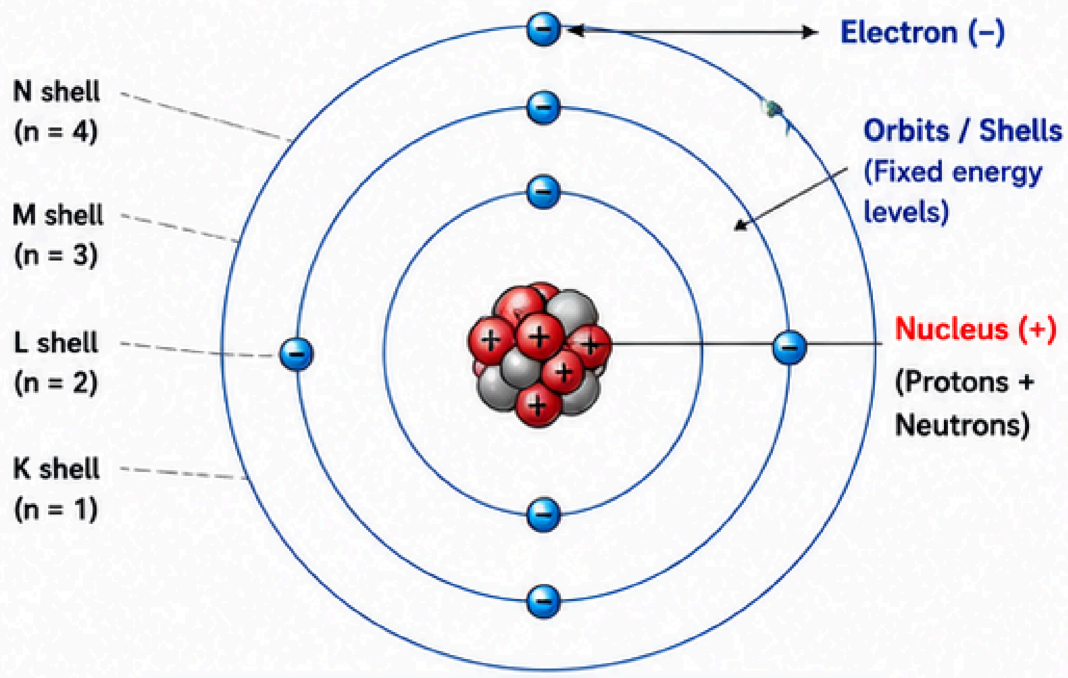
SUMMARY: Rutherford's atomic model introduced the idea of a small, dense, positively charged nucleus with electrons revolving around it. It successfully explained the results of the gold foil experiment but could not explain the stability of atoms.

BOHR ATOMIC MODEL

In 1913, Niels Bohr proposed a new model of the atom.
He explained that electrons revolve around the nucleus in **fixed orbits (shells)** with **definite energy**. Each shell has a fixed energy.

NIELS BOHR
(1885–1962)

BOHR MODEL OF AN ATOM



K, L, M, N are the shells. Their energies increase with distance from the nucleus (K < L < M < N).

KEY POSTULATES OF BOHR MODEL

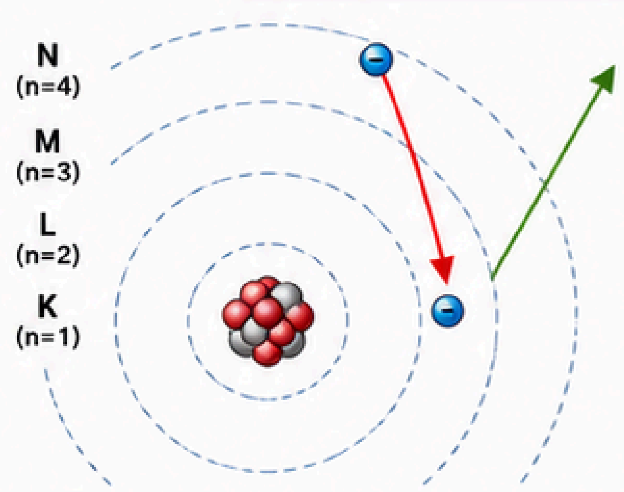
1. Electrons revolve around the nucleus in fixed circular orbits called shells.
2. Each shell has a definite (fixed) amount of energy. Electrons in a particular shell do not radiate energy.
3. The shells are represented by K, L, M, N ... or n = 1, 2, 3, 4 ... (principal quantum number).
4. The energy of shells increases as we go away from the nucleus.
   K < L < M < N
5. Electrons can jump from one shell to another by absorbing or releasing energy. Radiation is emitted or absorbed only during such jumps.

ELECTRON DISTRIBUTION IN SHELLS

Shell	Maximum number of electrons	General formula	n (Principal quantum number)
K	2	$2n^2$	1
L	8	$2n^2$	2
M	18	$2n^2$	3
N	32	$2n^2$	4

The maximum number of electrons in a shell = $2n^2$
where n = shell number (1 for K, 2 for L, 3 for M, 4 for N ...)

TRANSITIONS OF ELECTRONS



Emission of energy
(When electron jumps from higher shell to lower shell)

Energy released in the form of light (photon)

Absorption of energy
(When electron jumps from lower shell to higher shell)

Energy absorbed in the form of light (photon)

FIRST 18 ELEMENTS – ELECTRONIC CONFIGURATION

Element	K	L	M	(Electronic configuration)
1. H (1)	1	–	–	1
2. He (2)	2	–	–	2
3. Li (3)	2	1	–	2, 1
4. Be (4)	2	2	–	2, 2
5. B (5)	2	3	–	2, 3
6. C (6)	2	4	–	2, 4
7. N (7)	2	5	–	2, 5
8. O (8)	2	6	–	2, 6
9. F (9)	2	7	–	2, 7
10. Ne (10)	2	8	–	2, 8

Element	K	L	M	(Electronic configuration)
11. Na (11)	2	8	1	2, 8, 1
12. Mg (12)	2	8	2	2, 8, 2
13. Al (13)	2	8	3	2, 8, 3
14. Si (14)	2	8	4	2, 8, 4
15. P (15)	2	8	5	2, 8, 5
16. S (16)	2	8	6	2, 8, 6
17. Cl (17)	2	8	7	2, 8, 7
18. Ar (18)	2	8	8	2, 8, 8

Note: After M shell, electrons start entering the N shell.

IMPORTANCE OF BOHR MODEL

- It explained the stability of atoms.
- It successfully explained the line spectra of hydrogen (Balmer series).
- It introduced the concept of fixed energy levels (shells).
- It laid the foundation for modern atomic theory.

LIMITATION

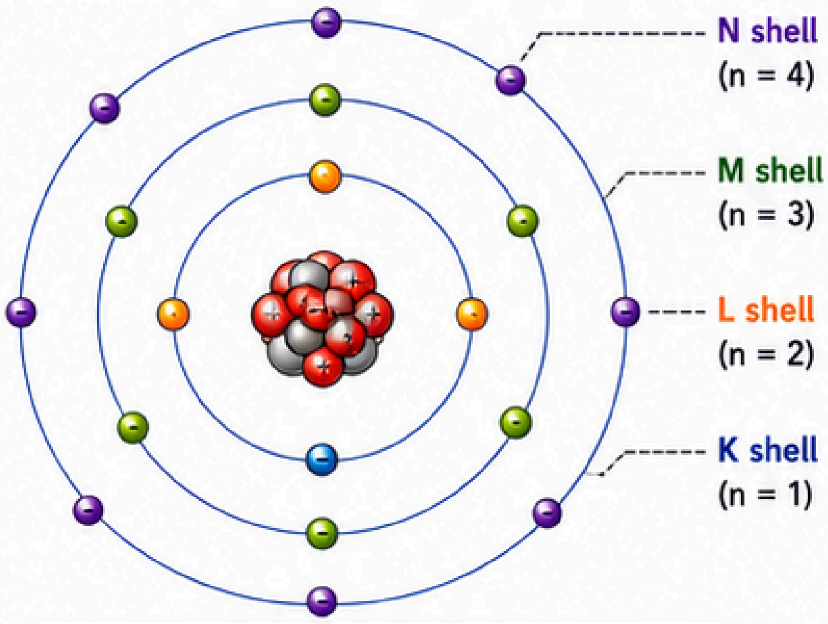
It could not explain the spectra of multi-electron atoms and the fine structure of spectral lines. Later, quantum mechanics gave a more complete explanation.

SUMMARY: Bohr's atomic model states that electrons revolve around the nucleus in fixed orbits (shells) with definite energy. Electrons can jump between shells by absorbing or emitting energy. This model explained the stability of atoms and the line spectra of hydrogen.

ELECTRON DISTRIBUTION IN SHELLS

Electrons revolve around the nucleus in fixed circular paths called **shells** or **energy levels**. The maximum number of electrons that a shell can hold is fixed.

ATOMIC STRUCTURE (SHELLS)



K, L, M, N are the shells.
Their energies increase with distance from the nucleus.

MAXIMUM NUMBER OF ELECTRONS IN SHELLS

Shell	Principal Quantum Number (n)	General Formula	Maximum Number of Electrons ($2n^2$)
K	1	$2n^2$	$2 \times 1^2 = 2$ **2**
L	2	$2n^2$	$2 \times 2^2 = 8$ **8**
M	3	$2n^2$	$2 \times 3^2 = 18$ **18**
N	4	$2n^2$	$2 \times 4^2 = 32$ **32**

General formula: Maximum number of electrons in a shell = $2n^2$
where n = principal quantum number (1, 2, 3, 4 …)

ELECTRON DISTRIBUTION IN THE FIRST 18 ELEMENTS

Atomic Number	Element	Symbol	Distribution of Electrons in Shells			Atomic Number	Element	Symbol	Distribution of Electrons in Shells		
			K	L	M				K	L	M
1	Hydrogen	H	1	–	–	10	Neon	Ne	2	8	–
2	Helium	He	2	–	–	11	Sodium	Na	2	8	1
3	Lithium	Li	2	1	–	12	Magnesium	Mg	2	8	2
4	Beryllium	Be	2	2	–	13	Aluminium	Al	2	8	3
5	Boron	B	2	3	–	14	Silicon	Si	2	8	4
6	Carbon	C	2	4	–	15	Phosphorus	P	2	8	5
7	Nitrogen	N	2	5	–	16	Sulfur	S	2	8	6
8	Oxygen	O	2	6	–	17	Chlorine	Cl	2	8	7
9	Fluorine	F	2	7	–	18	Argon	Ar	2	8	8

KEY POINTS

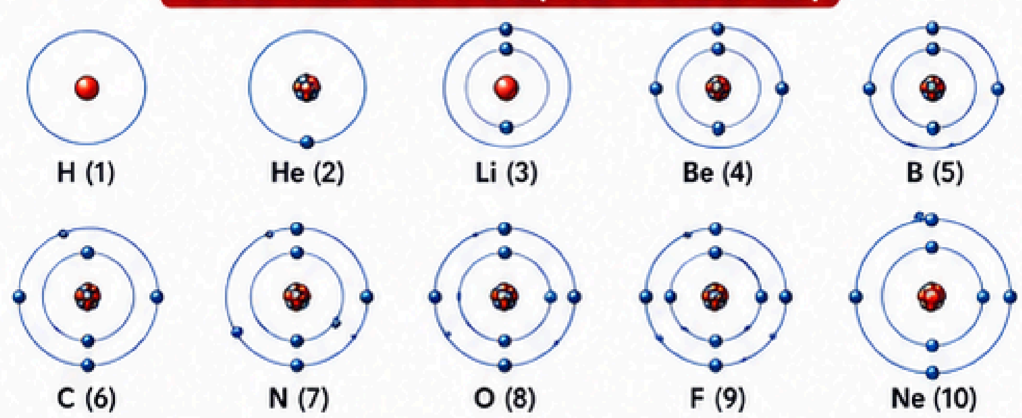
- Electrons are arranged in shells around the nucleus.
- Each shell can hold a fixed maximum number of electrons.
- The outermost shell is called the valence shell.
- The number of shells occupied in an atom = Period number.

IMPORTANT NOTES

- K shell can hold maximum 2 electrons.
- L shell can hold maximum 8 electrons.
- M shell can hold maximum 18 electrons.
- N shell can hold maximum 32 electrons.

Note: M shell starts filling only after L shell is completely filled (8 electrons).

VISUAL REPRESENTATION (FIRST 10 ELEMENTS)



IN SHORT: Electrons revolve around the nucleus in fixed shells (K, L, M, N …).
The maximum number of electrons in a shell is given by $2n^2$.

K = 2, L = 8, M = 18, N = 32 …

FIRST 18 ELEMENTS – ELECTRONIC CONFIGURATION
(BOHR MODEL)

Electrons revolve around the nucleus in fixed shells (K, L, M, N ...) with a definite energy.
The maximum number of electrons in a shell is given by $2n^2$, where n = shell number.

FIRST 18 ELEMENTS – ELECTRONIC CONFIGURATION (BOHR MODEL)

Atomic Number (Z)	Element	Symbol	Electronic Configuration (K, L, M shells)	Shell-wise Distribution K	L	M	Total Electrons	Valence Electrons (Outer Shell)
1	Hydrogen	H	1	1	–	–	1	1
2	Helium	He	2	2	–	–	2	2
3	Lithium	Li	2, 1	2	1	–	3	1
4	Beryllium	Be	2, 2	2	2	–	4	2
5	Boron	B	2, 3	2	3	–	5	3
6	Carbon	C	2, 4	2	4	–	6	4
7	Nitrogen	N	2, 5	2	5	–	7	5
8	Oxygen	O	2, 6	2	6	–	8	6
9	Fluorine	F	2, 7	2	7	–	9	7
10	Neon	Ne	2, 8	2	8	–	10	8
11	Sodium	Na	2, 8, 1	2	8	1	11	1
12	Magnesium	Mg	2, 8, 2	2	8	2	12	2
13	Aluminium	Al	2, 8, 3	2	8	3	13	3
14	Silicon	Si	2, 8, 4	2	8	4	14	4
15	Phosphorus	P	2, 8, 5	2	8	5	15	5
16	Sulfur	S	2, 8, 6	2	8	6	16	6
17	Chlorine	Cl	2, 8, 7	2	8	7	17	7
18	Argon	Ar	2, 8, 8	2	8	8	18	8

MAXIMUM ELECTRONS IN SHELLS

Shell (n)	Formula $2n^2$	Maximum Electrons
K (n = 1)	$2(1)^2$	2
L (n = 2)	$2(2)^2$	8
M (n = 3)	$2(3)^2$	18
N (n = 4)	$2(4)^2$	32

NOTE

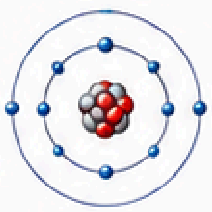
The M shell starts filling only after L shell is completely filled (8 electrons).

EXAMPLES

- **Sodium (Na, Z = 11)**

  Electronic configuration = 2, 8, 1

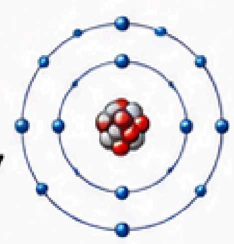
  Shell-wise: K = 2, L = 8, M = 1



- **Chlorine (Cl, Z = 17)**

  Electronic configuration = 2, 8, 7

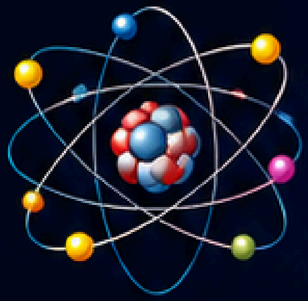
  Shell-wise: K = 2, L = 8, M = 7



KEY POINTS

- Electrons are arranged in shells (K, L, M ...) around the nucleus.
- The maximum number of electrons in a shell is $2n^2$.
- The outermost shell is called the valence shell.
- Elements in the same group have the same number of valence electrons.
- A completely filled shell is stable.

IN SHORT: For the first 18 elements, electrons fill the shells in the order K → L → M.
K can hold 2, L can hold 8, M can hold 18 electrons.



ISOTOPES

Atoms of the same element having the same atomic number but different mass numbers are called isotopes.

KEY TERMS

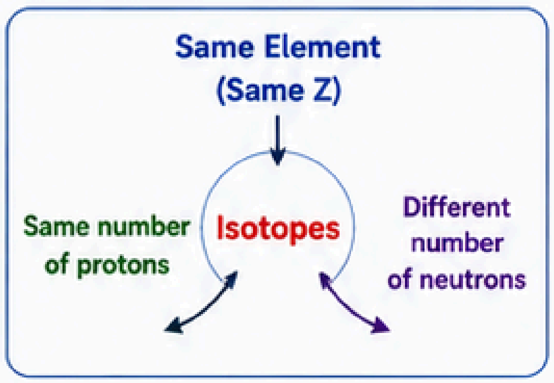
Atomic number (Z)
= Number of protons

Mass number (A)
= Protons + Neutrons

DEFINITION

Isotopes are atoms of the same element that have:

- Same atomic number (same number of protons)
- Different mass numbers (different number of neutrons)



GENERAL REPRESENTATION

Isotopes of an element X can be represented as:

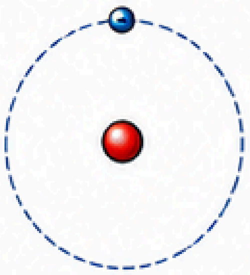
$^{A}_{Z}X$

- A — Mass number (Protons + Neutrons)
- Z — Atomic number (Number of Protons)

For isotopes of the same element:
Z (atomic number) = same
A (mass number) = different

EXAMPLE: ISOTOPES OF HYDROGEN

1. Protium ($^{1}_{1}H$)



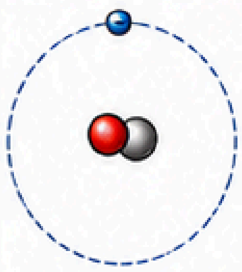
Atomic number (Z) = 1
(Protons = 1)

Mass number (A) = 1
(Protons + Neutrons = 1)

Neutrons = 0

$^{1}_{1}H$ → 1 proton, 0 neutrons, 1 electron

2. Deuterium ($^{2}_{1}H$)



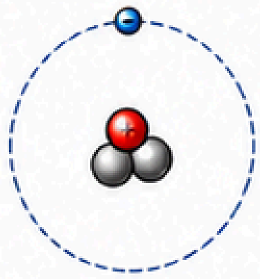
Atomic number (Z) = 1
(Protons = 1)

Mass number (A) = 2
(Protons + Neutrons = 2)

Neutrons = 1

$^{2}_{1}H$ → 1 proton, 1 neutron, 1 electron

3. Tritium ($^{3}_{1}H$)



Atomic number (Z) = 1
(Protons = 1)

Mass number (A) = 3
(Protons + Neutrons = 3)

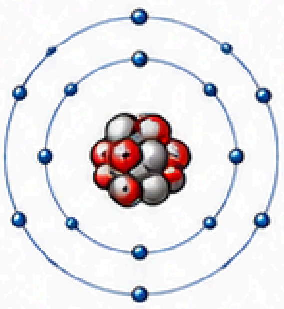
Neutrons = 2

$^{3}_{1}H$ → 1 proton, 2 neutrons, 1 electron

All three are isotopes of hydrogen because they have the same atomic number (Z = 1) but different mass numbers (A = 1, 2, 3).

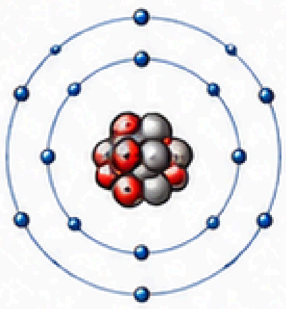
ANOTHER EXAMPLE: ISOTOPES OF CHLORINE

Chlorine-35 ($^{35}_{17}Cl$)



Z = 17 (Protons = 17)
A = 35 (Protons + Neutrons = 35)
Neutrons = 35 − 17 = 18

Chlorine-37 ($^{37}_{17}Cl$)



Z = 17 (Protons = 17)
A = 37 (Protons + Neutrons = 37)
Neutrons = 37 − 17 = 20

Both have the same atomic number (17) but different mass numbers (35 and 37). Therefore, they are isotopes of chlorine.

KEY POINTS

- ✓ Isotopes have same atomic number (Z) but different mass numbers (A).
- ✓ They have the same number of electrons (for neutral atoms) but different number of neutrons.
- ✓ Isotopes have similar chemical properties but different physical properties.
- ✓ They occur naturally in nature.

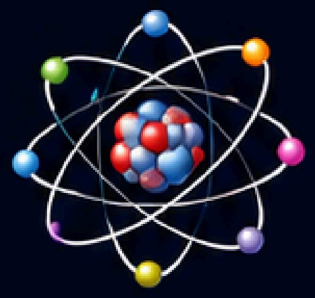
USES / IMPORTANCE

- Isotopes are used in medicine (e.g., Iodine-131 in treatment of thyroid).
- Used in agriculture (for tracing nutrients and improving crop yield).
- Used in industry (to detect leakage, thickness measurement, and safety).
- Used in scientific research (age determination, study of chemical reactions).

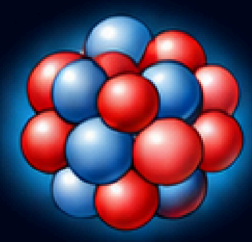
IN SHORT:

Isotopes are atoms of the same element that have the same number of protons but different number of neutrons, resulting in different mass numbers.

Same element	Same Z (protons)	Different neutrons	Different A (mass number)
X	✓	✓	✓



ISOBARS



Atoms of different elements having the same mass number but different atomic numbers are called isobars.

DEFINITION

- Isobars are atoms of different elements that have the **same mass number (A)** but **different atomic numbers (Z).**

For isobars:
A (mass number) = same
Z (atomic number) = different

★ **Mass number (A)**
= Protons + Neutrons

★ **Atomic number (Z)**
= Number of Protons

GENERAL REPRESENTATION

$^{A}_{Z}X$

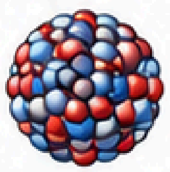
- **Mass number** (Protons + Neutrons)
- **Atomic number** (Number of Protons)
- Symbol of the element

Isobars → Same A, Different Z
Therefore, different elements.

EXAMPLES OF ISOBARS

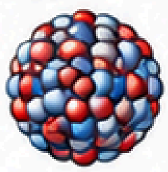
1. Argon-40 and Calcium-40

$^{40}_{18}Ar$



Z = 18 (Protons)
N = 22 (Neutrons)
A = 40 (Mass number)

$^{40}_{20}Ca$

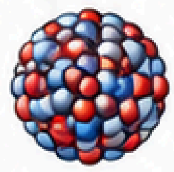


Z = 10 (Protons)
N = 20 (Neutrons)
A = 40 (Mass number)

Same mass number (A = 40)
but different atomic numbers (18 and 20).
Therefore, $^{40}_{18}Ar$ and $^{40}_{20}Ca$ are isobars.

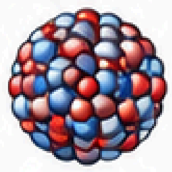
2. Iron-58 and Nickel-58

$^{58}_{26}Fe$



Z = 26 (Protons)
N = 32 (Neutrons)
A = 40 (Mass number)

$^{58}_{28}Ni$

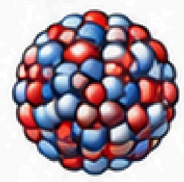


Z = 28 (Protons)
N = 30 (Neutrons)
A = 58 (Mass number)

Same mass number (A = 58)
but different atomic numbers (26 and 28).
Therefore, $^{58}_{26}Fe$ and $^{58}_{28}Ni$ are isobars.

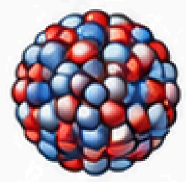
3. Krypton-86 and Strontium-86

$^{86}_{36}Kr$



Z = 36 (Protons)
N = 50 (Neutrons)
A = 86 (Mass number)

$^{86}_{38}Sr$



Z = 38 (Protons)
N = 48 (Neutrons)
A = 86 (Mass number)

Same mass number (A = 86)
but different atomic numbers (36 and 28).
Therefore, $^{56}_{36}Kr$ and $^{86}_{38}Sr$ are isobars.

MORE EXAMPLES OF ISOBARS

Mass Number (A)	Isobars (Atomic Number Z)	Elements
14	$^{14}_{6}C$ and $^{14}_{7}N$	Carbon-14 and Nitrogen-14
22	$^{22}_{10}Ne$ and $^{22}_{11}Na$	Neon-22 and Sodium-22
44	$^{44}_{20}Ca$ and $^{44}_{22}Ti$	Calcium-44 and Titanium-44
60	$^{60}_{28}Ni$ and $^{60}_{30}Zn$	Nickel-60 and Zinc-60
90	$^{90}_{38}Sr$ and $^{90}_{40}Zr$	Strontium-90 and Zirconium-90

KEY POINTS

- Isobars have same mass number (A) but different atomic numbers (Z).
- They belong to different elements placed in different positions in the periodic table.
- Physical and chemical properties of isobars are different.
- Isobars were discovered by Frederick Soddy (1913).

IMPORTANCE

- Helps in understanding the structure of atomic nuclei.
- Useful in nuclear physics and radioactive decay studies.
- Important in medical isotopes and nuclear medicine.
- Helps in identifying unknown nuclei in research.

IN SHORT:

Isobars are atoms of different elements that have the same mass number (A = Protons + Neutrons) but different atomic numbers (Z = Number of Protons).

Isobars:
Same Mass Number (A) ✓
Different Atomic Number (Z) ✓

$^{A}_{Z_1}X_1$ and $^{A}_{Z_2}X_2$

$(Z_1 \neq Z_2)$