General Chemistry

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Atomic Theory and Structure

Items

1 Early Thoughts

History of Atomic Theory

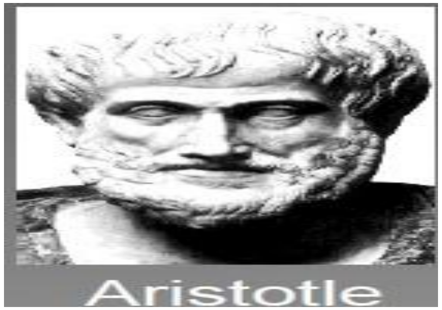
Timeline: 400 BC Scientist: Democritus

Democritus was a Greek philosopher who was the first person to use the term **atom** (atomos: meaning indivisible). He thought that if you take a piece of matter and divide it and continue

to divide it you will eventually come to a point where you could not divide it any more. This **fundamental** or **basic** unit was what Democritus called an atom.

Timeline: 350 B.C-Aristotle modified an earlier theory that matter was made of four "elements": earth, fire, water, air.

•Aristotle was wrong. However, his theory persisted for 2000 years.



2 Dalton’s Model of the Atom

Dalton's Atomic Theory

1. Atoms were solid spheres.

2. All substances are made of atoms; atoms are small particles that cannot be, divided or destroyed.

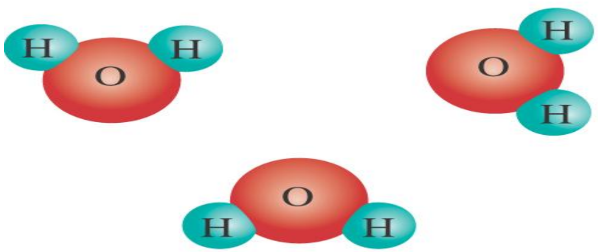
3. Atoms of the same element are alike in mass and size.

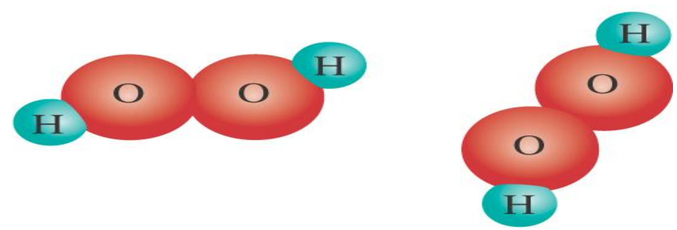
4. Atoms of different elements have different masses and sizes.

5. Chemical compounds are formed by the union of two or more atoms of different elements (atoms combined to form compounds).

Dalton's Atomic Theory

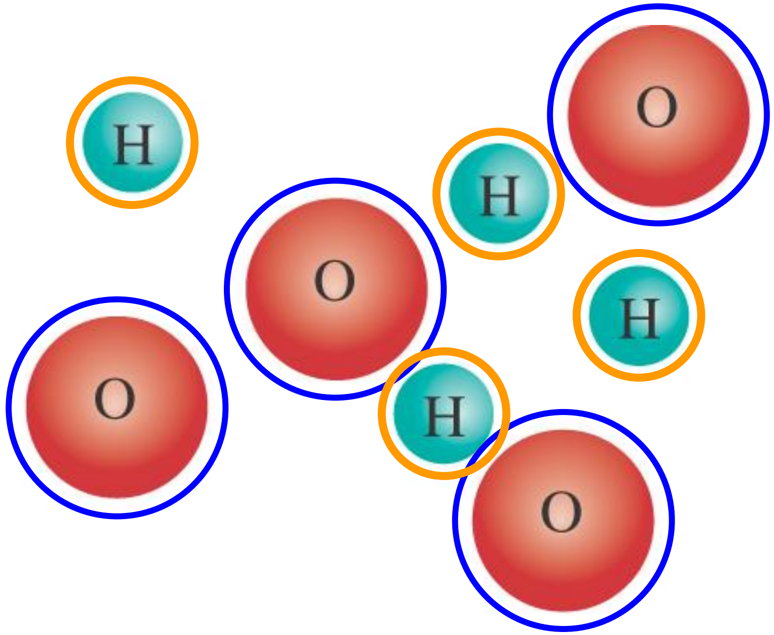
6- Atoms combine to form compounds in simple ratios, such as 1:1, 2:2, 2:3, and so on.





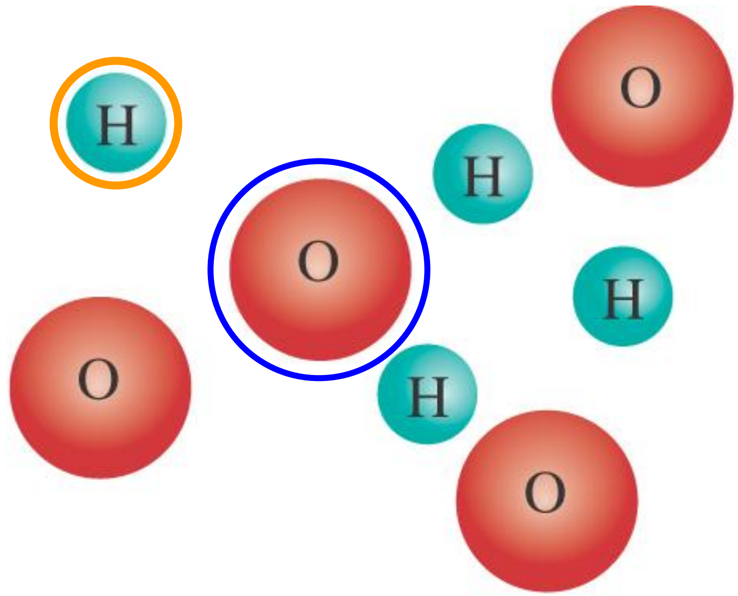
$$\frac{H}{O} = \frac{2}{1} \qquad \frac{H}{O} = \frac{1}{1}$$

7- Atoms of two elements may combine in different ratios to form more than one compound.



Dalton's atoms were individual particles.

Atoms of each element are alike in mass and size.



Dalton’s atoms were individual particles.

Atoms of different elements are not alike in mass and size.

3 Composition of Compounds

The Law of Definite Composition

A compound always contains two or more elements chemically combined in a definite proportion by mass.

Composition of Water

- Water always contains the same two elements: hydrogen and oxygen.
- The percent by mass of hydrogen in water is 11.2%.
- The percent by mass of oxygen in water is 88.8%.
- Water always has these percentages. If the percentages were different, the compound would not be water.

Composition of Hydrogen Peroxide

- Hydrogen peroxide always contains the same two elements: hydrogen and oxygen.
- The percent by mass of hydrogen in hydrogen peroxide is 5.9%.
- The percent by mass of oxygen in hydrogen peroxide is 94.1%.
- Hydrogen peroxide always has these percentages. If the percentages were different, the compound would not be hydrogen peroxide.

The Law of Multiple Proportions

Atoms of two or more elements may combine in different ratios to produce more than one compound.

Combining Masses of Hydrogen and Oxygen

	Mass Hydrogen(g)	Mass Oxygen(g)
Water	1.0	8.0
Hydrogen Peroxide	1.0	16.0

$$\frac{\text{mass of oxygen in hydrogen peroxide}}{\text{mass of oxygen in water}} = \frac{16\text{g}}{8\text{g}} = \frac{2}{1}$$

Hydrogen peroxide has twice as much oxygen (by mass) as does water.

Combining Ratios of Hydrogen and Oxygen

- Hydrogen peroxide has twice as many oxygens per hydrogen atom as does water.
- The formula for water is H_2O.
- The formula for hydrogen peroxide is H_2O_2.

Table 5.1 Selected Compounds Showing Elements That Combine to Give More Than One Compound

Compound	Formula	Percent composition
Copper(I) chloride	$CuCl$	64.2% Cu, 35.8% Cl
Copper(II) chloride	$CuCl_2$	47.3% Cu, 52.7% Cl
Methane	CH_4	74.9% C, 25.1% H
Octane	C_8H_{18}	85.6% C, 14.4% H
Methyl alcohol	CH_4O	37.5% C, 12.6% H, 49.9% O
Ethyl alcohol	C_2H_6O	52.1% C, 13.1% H, 34.7% O
Glucose	$C_6H_{12}O_6$	40.0% C, 6.7% H, 53.3% O

4 The Nature of Electric Charge

Properties of Electric Charge

- Charge may be of two types: positive and negative.
- Unlike charges attract (positive attracts negative), and like charges repel (negative repels negative and positive repels positive).
- Charge may be transferred from one object to another, by contact.
- The smaller the distance between two charges, the greater the force (F) of attraction between unlike charges (or repulsion between identical charges).

$$F = \frac{kq_1q_2}{r^2}$$

q_1 and q_2 are charges, r is the distance between charges, and k is a constant.

5 Discovery of Ions

- **Michael Faraday** discovered that certain substances, when dissolved in water, conducted an electric current.
- He found that atoms of some elements moved to the cathode (negative electrode) and some moved to the anode (positive electrode).
- He concluded they were electrically charged and called them ions.

- **Svante Arrhenius** reasoned that an ion is an atom (or a group of atoms) carrying a positive or negative electric charge.
- Arrhenius accounted for the electrical conduction of molten sodium chloride (NaCl) by proposing that melted NaCl dissociated into the charged ions Na^+ and Cl^-.

$$NaCl \xrightarrow{\Delta} Na^+ + Cl^-$$

$NaCl \rightarrow Na^+ + Cl^-$

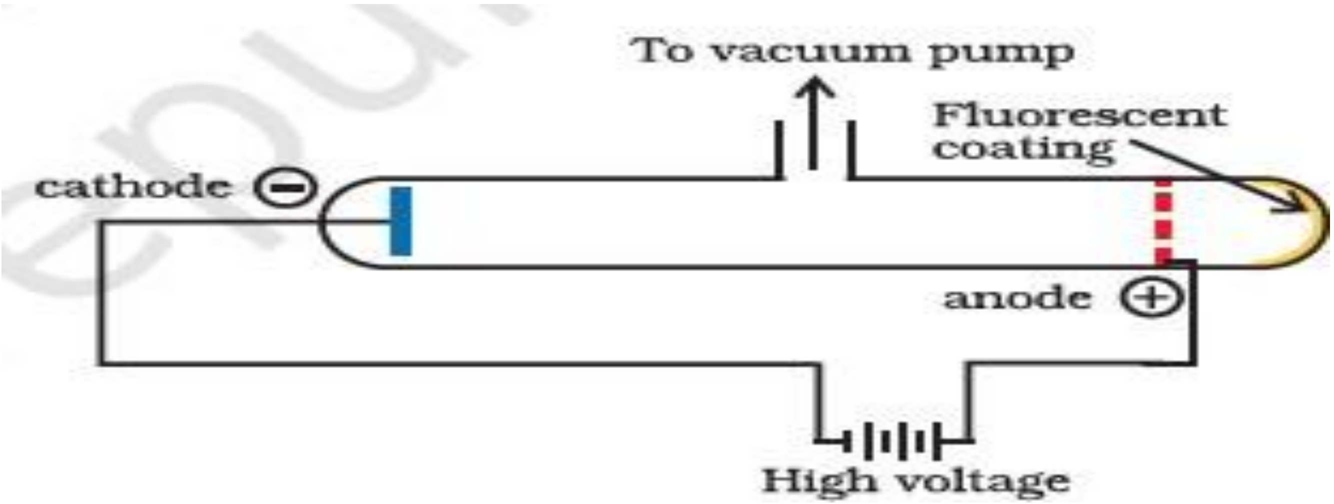
- When melted, the positive Na^+ ions moved to the *cathode* (negative electrode). Thus positive ions are called *cations*.

- When melted, the negative Cl^- ions moved to the *anode* (positive electrode). Thus negative ions are called *anions*.

Cathode Ray Discharge Tubes

Timeline: 1890's Scientist: J.J Thomson.

He used his research on cathode ray tube technology in this discovery. Cathode ray tube is made of glass containing two thin pieces of metal, called electrodes. The electrical discharge through the gases could be observed only at very low pressures and at very high voltages. The pressure of different gases could be adjusted by evacuation. When sufficiently high voltage is applied across the electrodes, current starts flowing through a stream of particles moving in the tube from the negative electrode (cathode) to the positive electrode (anode). These were called **cathode rays or cathode ray** particles.



The flow of current from cathode to anode was further checked by making a hole in the anode and coating the tube behind anode with phosphorescent material zinc sulphide. When these rays, after passing through anode, strike the zinc sulphide coating, a bright spot on the coating is developed.

The results of these experiments are summarized below.

(i) The cathode rays start from cathode and move towards the anode.

(ii)These rays themselves are not visible but their behavior can be observed with the help of certain kind of materials (fluorescent or phosphorescent) which glow when hit by them.

(iii)In the absence of electrical or magnetic field, these rays travel in straight lines

(iv)In the presence of electrical or magnetic field, the behavior of cathode rays are similar to that expected from negatively charged particles, suggesting that the cathode rays consist of negatively charged particles, called electrons.

(v)The characteristics of cathode rays (**electrons**) do not depend upon the material of electrodes and the nature of the gas present in the cathode ray tube.

Thus, we can conclude that electrons are basic constituent of all the atoms.

Proton

- positive charge
- Much heavier than electrons
- Have a mass equal to the mass of hydrogen
- Rutherford called them protons
- **Anderson** showed that atoms contained positive charges known as poistrons (have a mass equal to the mass of electrons) .

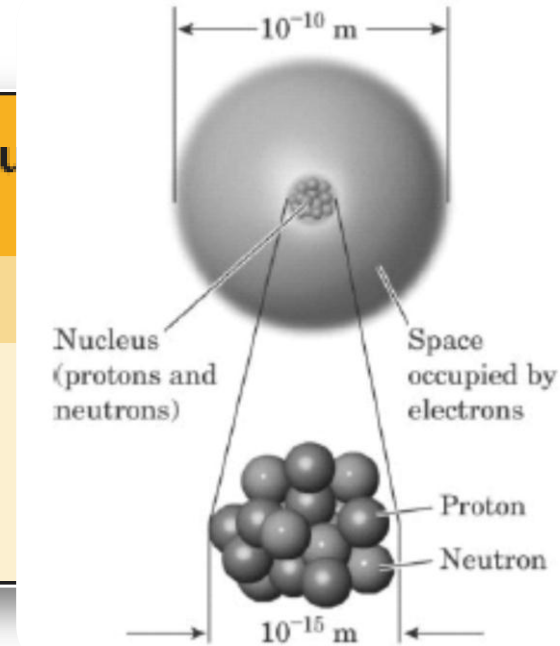
Neutron

- Do not have an electric charge
- Its mass is slightly greater than the mass of a proton.

Inside an Atom

Table 2.1 Selected Properties of the Three Basic Su Particles

Name	Charge	Mass (amu)
Electron (e)	−1	5.4×10^{-4}
Proton (p)	+1	1.00
Neutron (n)	0	1.00

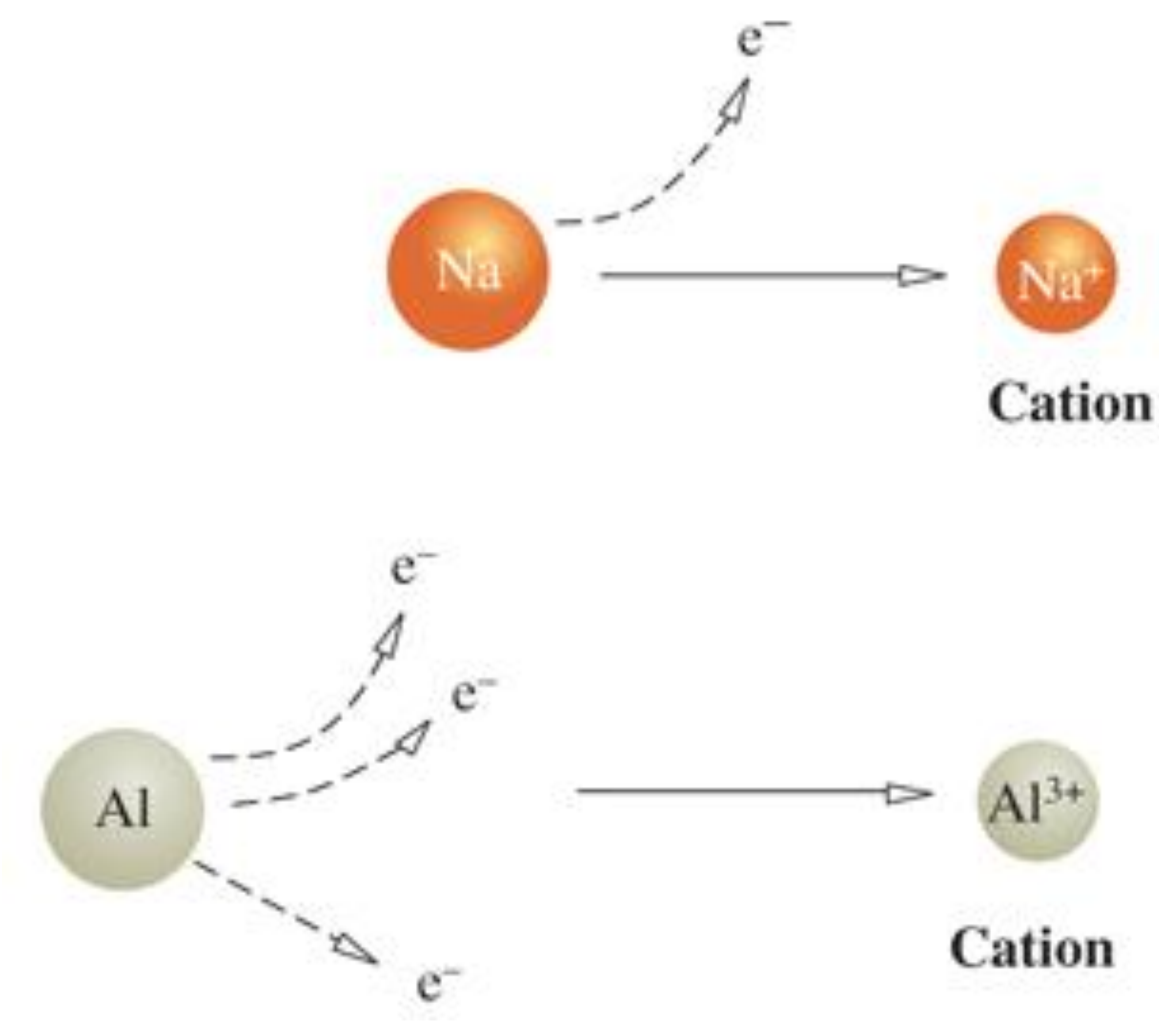


1 amu = 1.6605×10^{-24} g (amu = atomic mass unit)

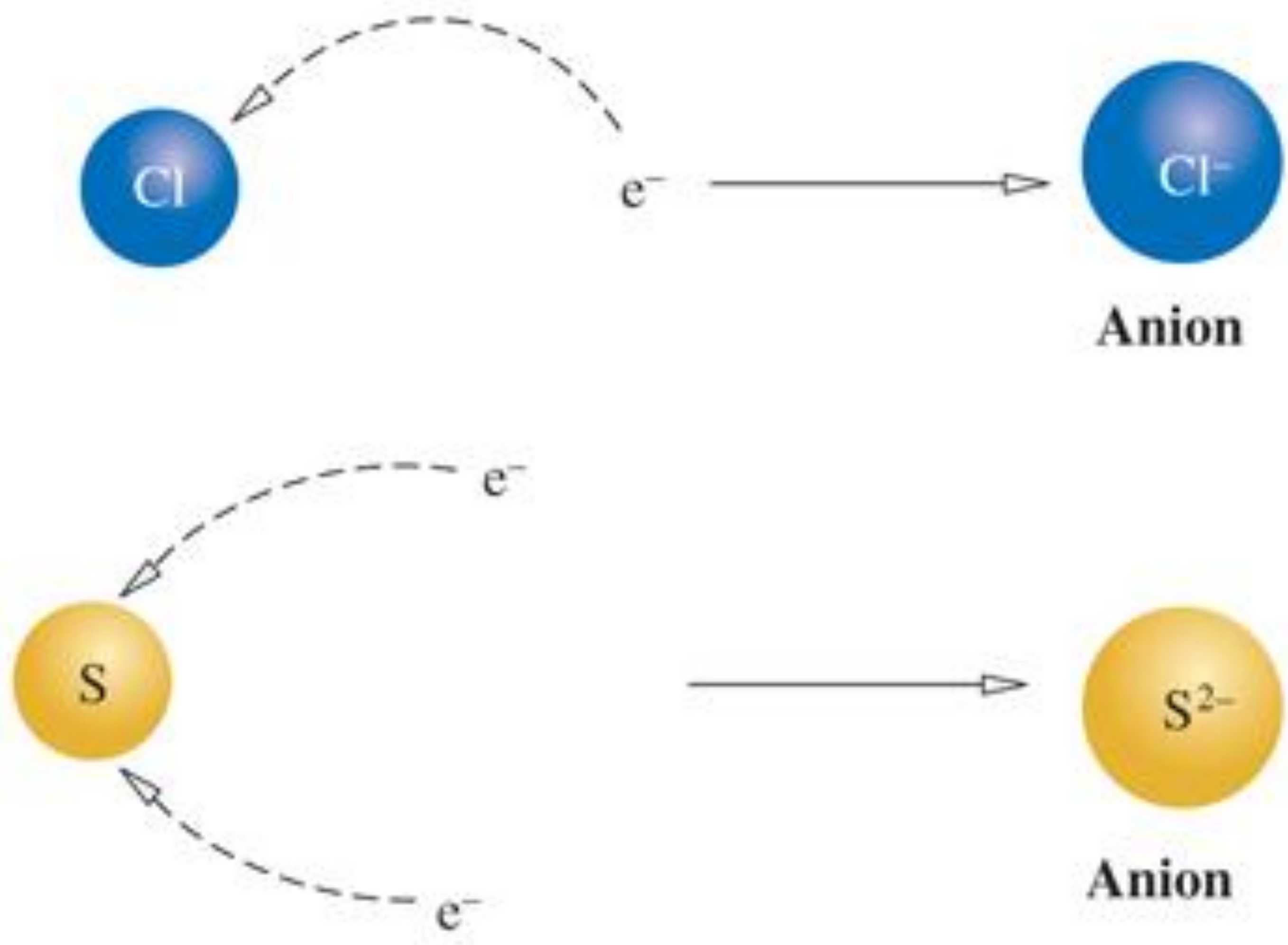
Protons and neutrons are found in the nucleus, and electrons are found as cloud outside the nucleus

Ions

- **Positive** ions were explained by assuming that a neutral atom loses electrons.
- **Negative** ions were explained by assuming that atoms gain electrons.



When one or more electrons are lost from an atom, a cation is formed.

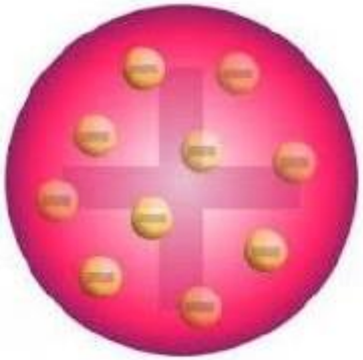


When one or more electrons are added to a neutral atom, an anion is formed.

THOMSON’S ATOMIC MODEL

THOMSON'S ATOMIC MODEL

Proved that an atom can be divided into smaller parts. And proposed that an atom possesses a spherical shape (radius approximately 10^{-10}m) in which the positive charge is uniformly distributed. The electrons are embedded into it in such a manner as to give the most stable electrostatic arrangement. Many different names are given to this model, for example, watermelon.



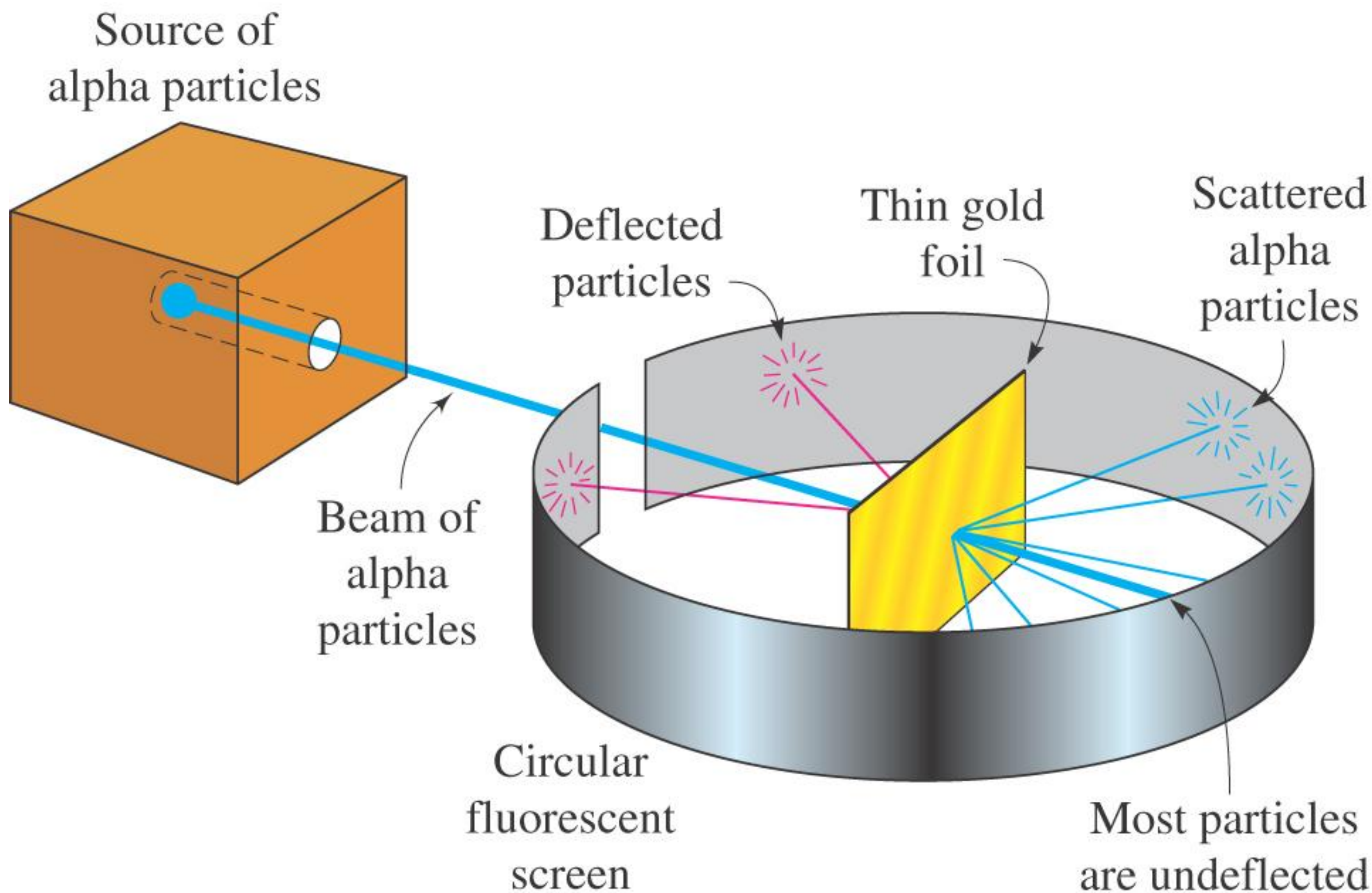
The Rutherford Experiment

- **Rutherford** in 1911 performed experiments that shot a stream of alpha particles (Helium atoms have 2 positive charges) at a gold foil.
- Whenever a α–particles struck the screen (Without putting a gold slide). a tiny flash of light was produced at that (A) point.
- After putting the foil of gold it was found that :

i. most of the a α–particles passed through the gold foil undeflected

ii. Small fraction of the a α–particles was deflected by small angles.

iii. Very few a α–particles (~1 in 20,000) bounced back, that is, were deflected by nearly 180°.



Rutherford’s alpha particle scattering experiment.

On the basis of the observations,

Rutherford drew the following conclusions regarding the structure of atom :

i.Most of the space in the atom is empty as most of the α– particles passed through the foil undeflected.

ii.A few positively charged a α–particles were reflected. The reflection must be due As a result of a colloide with a large body that can not be radiated penetrate.

iii.A few positively charged a α–particles were deflected. The deflection must be due to large repulsion force showing that the positive charge of the atom is not spread throughout the atom as Thomson had proved. The positive charge has to be concentrated in a very small volume that repelled and deflected the positively charged α–particles. This very small portion of the atom was called **nucleus**.

Rutherford's Nuclear Model of Atom

1- The Atom:

Although it has very small size but it has a complicated structure that resembles the **solar system** in which electrons revolve around the central nucleus in orbits as planets revolve around the sun.

2- The Nucleus:

Is much smaller than the atom. Located in the center of the atom with positive charge. There is a big space between the nucleus and orbits of electrons, so most of the atom is a space. Most mass of the atom is concentrated in the nucleus and the mass of electrons is very small and can be neglected.

3- Electrons:

1) Have **negligible** mass compared to that of the nucleus.

2) Number. of electrons with negative charge are equals to the number of protons with positive charge so the atom is **electrically neutral**.

3) Electrons revolve around the nucleus in a fixed orbit

4) The electrons are affected by two forces equal in strength but in opposite direction, which are :

a. Attraction Force of the nucleus to electrons.

b. Centrifugal force due to velocity of electron around the nucleus.

Objection to the Rutherford Model:

According to Maxwell's theory: If a charged electron particle moves around another particle charged with a opposite charge, the electron loses part of its energy coming out in the form of radiation, thereby reducing the orbit gradually. And that is mean the electron finally fall in nucleus (and that never done).

Bohr Model

1 -A positively charged nucleus exists in the center of the atom.

2- Atom is electrically neutral as number of protons equals to number of electron's.

3- Electrons revolve around the nucleus only in a definite allowed energy levels .

4- Electrons revolve around the nucleus in orbits due to centrifugal and attraction forces.

5- Electrons orbit the nucleus in a rapid movement without gaining or losing energy.

6- Each electron in the atom has a definite amount of energy depending on the distance between its energy level and the nucleus; the energy of any level increases as its radius increases.

6- -The maximum number of energy levels in atoms in their ground state (unexcited) is only seven (K, L, M, N, O, P, Q). Each level has energy expressed by a whole number called principle Quantium. Number from (1 to 7).

8-When atom is excited by heating (Quantum) or by electric discharge the electron will transfer to a higher enrgy. Level agrees with the absorbed quantum. The excited electron in the higher Energy. level is then unstable, so it returns to its original level losing the same quantum of energy, which it gained during excitation in the form of radiation have definite wavelength and frequency. producing a characteristic spectrum line

1-Quantum Is defined as the amount of energy gained or lost when an electron jumps from one Energy level to another.

2- The difference in energy between levels (Quantum) is not equal i.e. the difference in this energy decreases further from the nucleus.

3- The electron does not move from its level to another unless the energy absorbed or emitted is equal to the difference in energy between 2 levels i.e. one quantum

The Limitation of the Bohr model

1) Bohr failed to explain the spectrum of any other element even that of Helium except hydrogen .

2) He considered the electron as negative charged particle only and did not consider that it also has wave properties.

3) He postulated that it is possible to determine both speed and location of an electron at the same time. This is experimentally impossible.

4) He described the electron when moving in a circular planer orbit, Later it was confirmed that hydrogen atom has 3 dimensional co –ordinates

Modern Atomic Theory

1- The wave nature of the electron

All previously experimental considered the electron just a negatively charged particle but de Brawley assumed that the electron has a wave nature. Brawley considered that Every moving body (such as electron or the nucleus of an atom or whole molecule) is associated with (accompanied by) a wave motion (or matter waves) which has some properties of light waves.

1) -Electron cloud Is defined as the region of space around the nucleus where the possibility of finding the electron in all distances, and directions

2) -Orbital :The area of space around the nucles where there is a great probability for finding electrons

Quantum Numbers:

They define the energy, shape, number and direction of orbitals

1)- Principle Q.no (n)

1) The principal quantum number (n) describe **the distance of the electron from the nucleus**

Order of principle energy levels their number in the heaviest known atom in the ground state is seven

2-) Number of electrons required to fill a given energy. level = two times the square of the level no ($2n^2$).

-1st E.L	K	Is filled with	2 electrons
-2nd E.L	L	Is filled with	8 electrons
-3rd E.L	M	Is filled with	18 electrons
-4th E.L	N	Is filled with	32 electrons

2- Secondary Q.no (l)) Used to detect the number of sec. levels in each principal energy level.

1) The energy sec. levels take the symbols **s, p, d, f**

2) Number of sublevels in each energy level = order of principle energy level (n)

3) Energy of sub levels of same Energy level is different.

4- Values of sec. quantaum (l) =(n-1)

عدد الكم الأساسى	عدد الكم الثانوى	
n = 1	صفر	أى يوجد مدار واحد s
n = 2	صفر, 1	أى يوجد مدارين s, p
n = 3	صفر, 1, 2	أى يوجد ثلاث مدارت s, d
n = 4	صفر, 1, 2, 3	أى يوجد أربع مدارت s, d, f

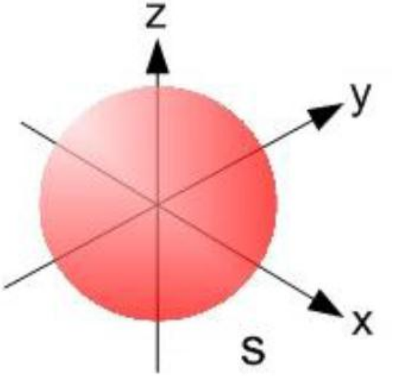
3-Magnetic Q number (m)

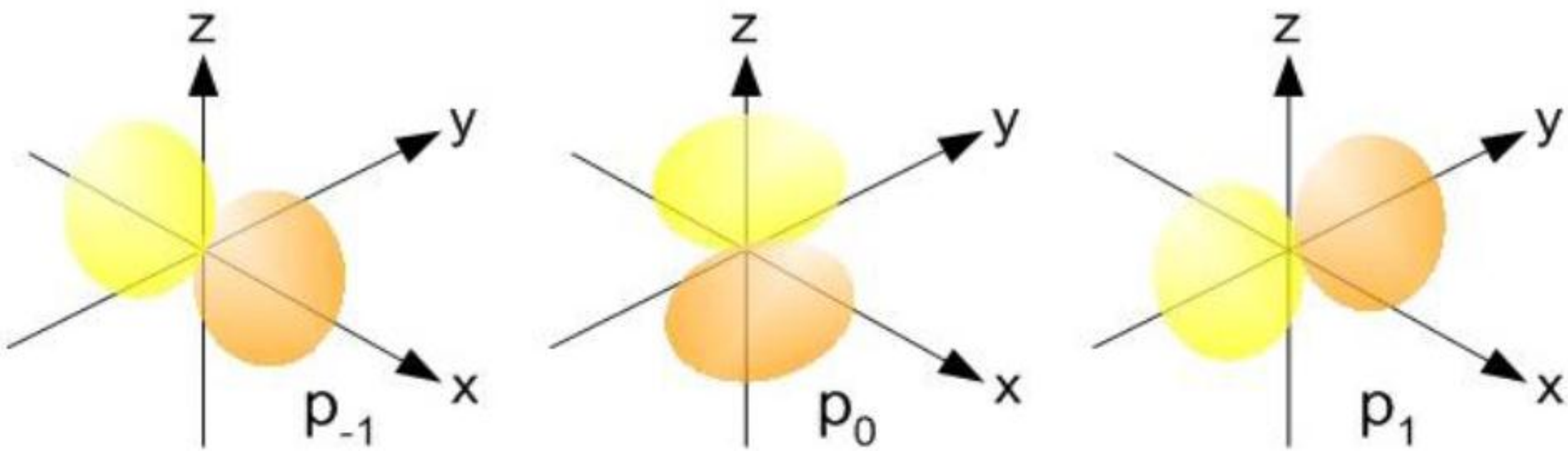
1- Used to detect no of orbitals in each energy sec. level and their direction in space. which equal to (m=2l +**1**) where (l) is the value of the number of Secondary quantum, and the value of the number of magnetic quantum range between (-l) and (+ l).

2- Sublevel (S) **(m = 2 x 0 +1 = 1)** So the level (s) has one direction in the space and as such it has a spherical shape around the nucleus

3- Sublevel (P) has 3 orbitals **(m = 2 x 1+1 = 3)**.

Therefore, the level (p) has three directions in the space (Px, Py, Pz) is perpendicular to the other two. Also P consists of two ball shaped in contact with each other and each ball can contain an electron and these two ball are meeting head to head at a point where the electron is difficult to exist (zero electron density).





4- Sublevel (d) has 5 orbitals **(m = 2 x 2+1 = 5)**

Therefore, the level (d) has five directions

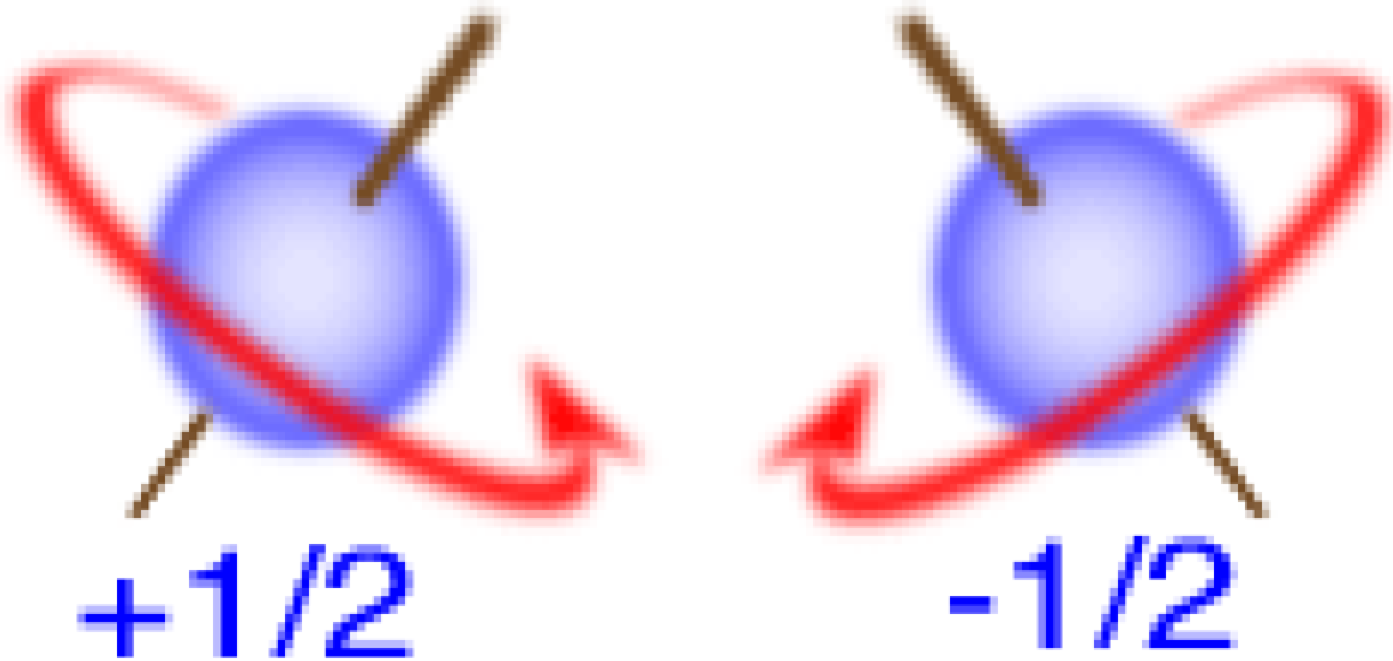
5- Sublevel (f) has 7 orbitals **(m = 2 x 3+1 = 7)**

Therefore, the level (f) has seven directions

4-Spain Q number (m)

Any orbital contain two electrons each electron spain around its axis during orbits around nucleus . Althought the electrons in the same orbitals carry the same negative charge we might exept them to repel. Yet due to the spain of electron around its axis a magnatic field will be arised so one electron spins around its axis clockwise while the other electron spins anti clockwise in order to from 2 opposite magnetic fields to decrease the force of repulsion between them which keep the atom stable.

Spain Q number **is used to d**etects the direction in which the electron spins around its axis during its rotation around the nucleus

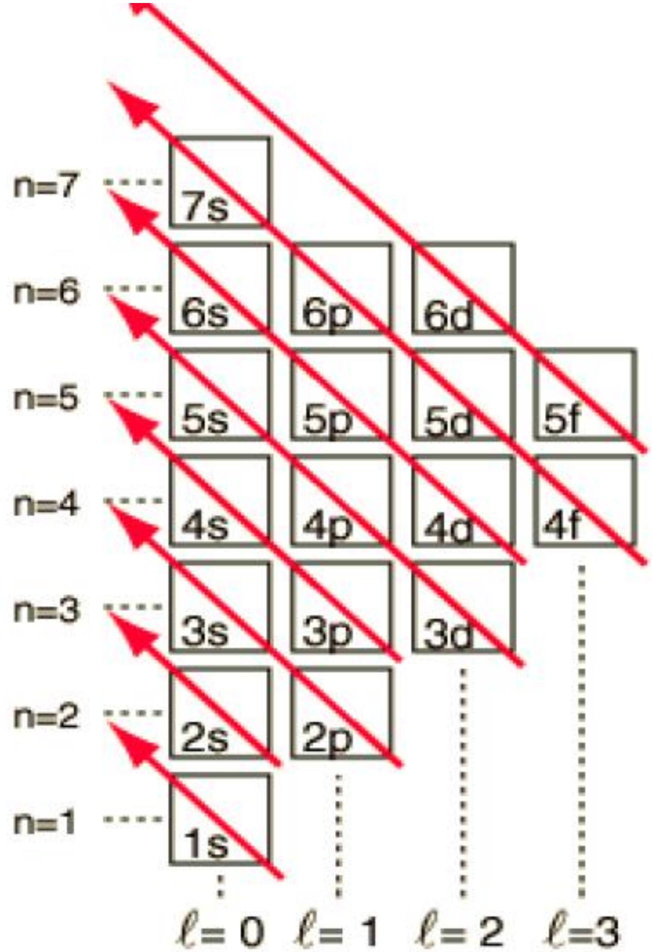


Principles of distributing electrons

There are two important rules which must be considered in distributing electrons in the atom. These rules are

1-Building-up principle

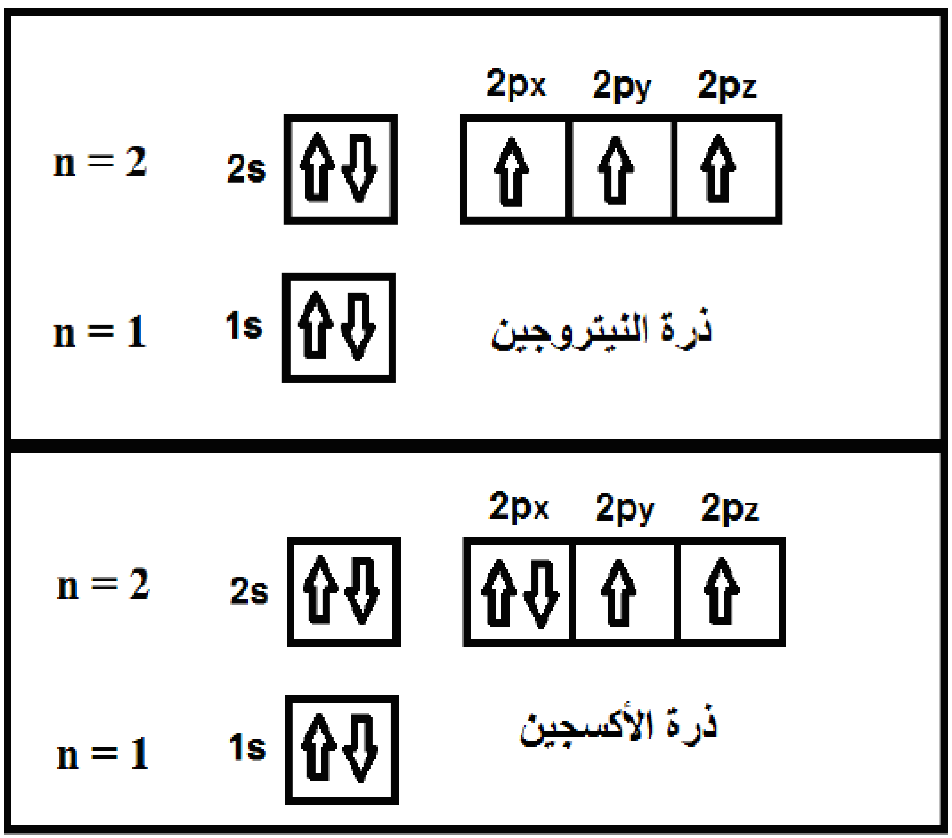
It states that electrons must fill the lower energy sub-levels with lower (n+L) first and then the higher-energy sub-levels.and if we have two orbital with same (n+L), the electron prefers to fill the orbital with lower(n)



1s ‹ 2s‹ 2p ‹ 3s ‹ 3p ‹ 4s ‹ 3d ‹ 4p ‹ 5s ‹ 4d ‹ 5p ‹ 6s ‹ 4f ‹ 5d ‹ 6p ‹ 7s ‹ 5f ‹ 6d ‹ 7p

2-Hund's Rule

No electron pairing takes place in a given sublevel until each orbital contains one electron



Atomic Numbers of the Elements

- The atomic number of an element is equal to the number of protons in the nucleus of that element.

- The atomic number of an atom determines which element the atom is.

ATOMIC NUMBER

Every atom with an atomic number of 1 is a hydrogen atom.

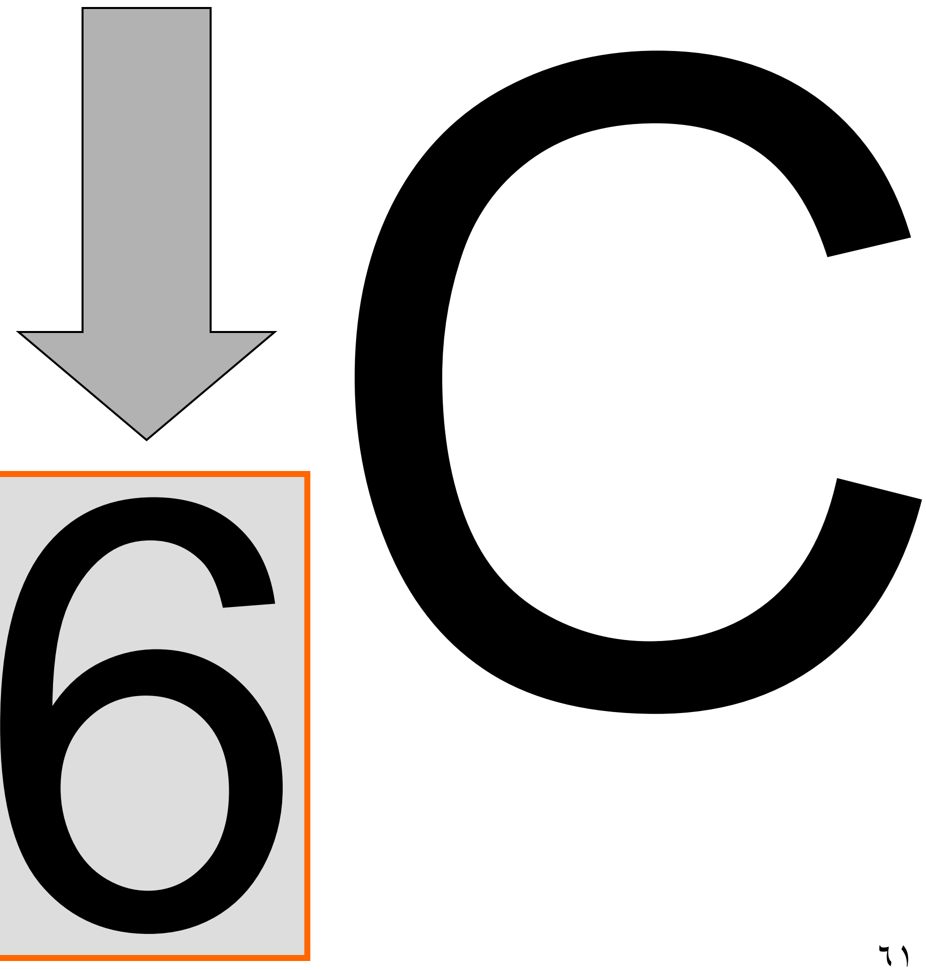
1 proton in the nucleus

1

H

ATOMIC NUMBER

Every atom with an atomic number of 6 is a carbon atom.



6 protons in the nucleus

ATOMIC NUMBER

Every atom with an atomic number of 92 is a uranium atom.

92 protons in the nucleus

92

U

8 Isotopes of the Elements

- Atoms of the same element have the same number of protons.

- Atoms of the same element can have different masses, because they can have different numbers of neutrons.

- These are ***isotopes*** of the same element.

Isotopes of the same element have:

Equal numbers of protons

Different numbers of neutrons

Isotopic Notation

Mass number
(sum of protons and
neutrons in the nucleus)

$$^{A}_{Z}\mathrm{E}$$

Symbol of element

Atomic number
(number of protons
in the nucleus)

Isotopic Notation

Mass number (sum of protons and neutrons in the nucleus) → 6 protons + 6 neutrons

$$^{12}_{6}\mathrm{C}$$

← **Symbol of element**

Atomic number (number of protons in the nucleus) → 6 protons

Isotopic Notation

Mass number (sum of protons and neutrons in the nucleus) → 6 protons + 8 neutrons

$^{14}_{6}C$ ← Symbol of element

Atomic number (number of protons in the nucleus) → 6 protons

Isotopic Notation

Mass number (sum of protons and neutrons in the nucleus) →

8 protons + 8 neutrons

$$^{16}_{8}\mathrm{O}$$

← **Symbol of element**

Atomic number (number of protons in the nucleus) →

8 protons

Isotopic Notation

Mass number (sum of protons and neutrons in the nucleus) →

8 protons + 9 neutrons

$$^{17}_{8}\mathrm{O}$$

← **Symbol of element**

Atomic number (number of protons in the nucleus) →

8 protons

Isotopic Notation

Mass number (sum of protons and neutrons in the nucleus)

8 protons + 10 neutrons

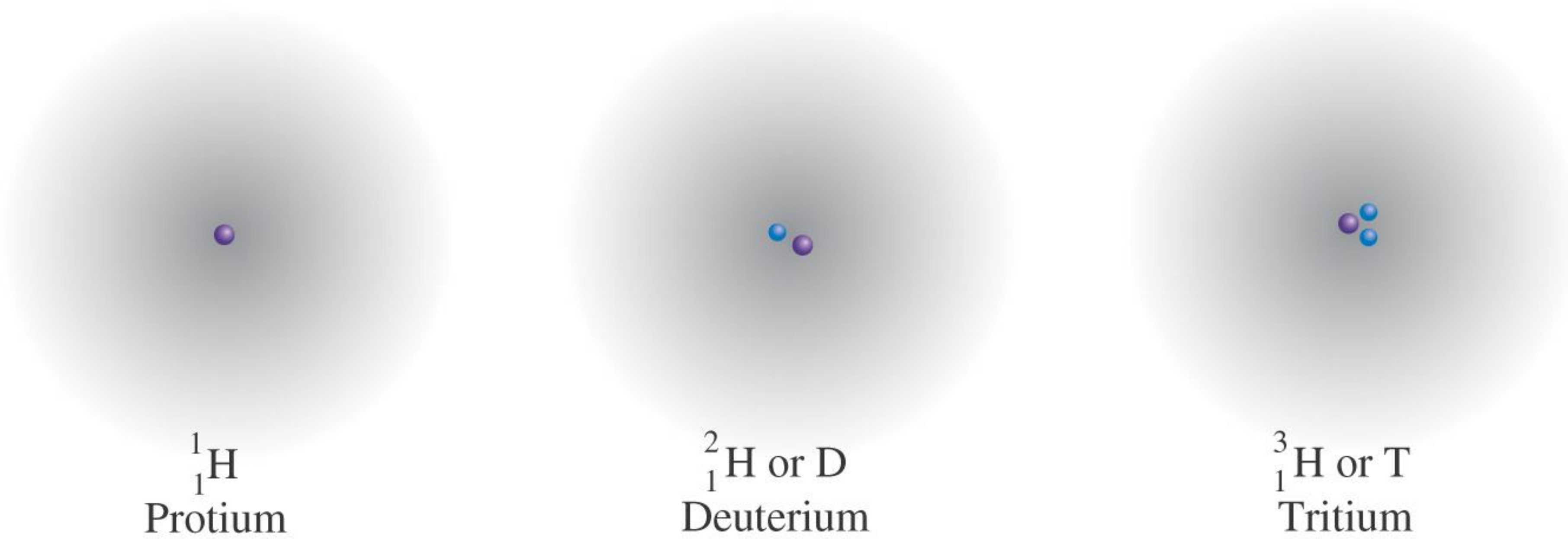
$$^{18}_{8}\mathrm{O}$$

Symbol of element

Atomic number (number of protons in the nucleus)

8 protons

Hydrogen has three isotopes



1 proton	1 proton	1 proton
0 neutrons	1 neutron	2 neutrons

Examples of Isotopes

Element	Protons	Electrons	Neutrons	Symbol
Hydrogen	1	1	0	$^{1}_{1}H$
Hydrogen	1	1	1	$^{2}_{1}H$
Hydrogen	1	1	2	$^{3}_{1}H$
Uranium	92	92	143	$^{235}_{92}U$
Uranium	92	92	146	$^{238}_{92}U$
Chlorine	17	17	18	$^{35}_{17}Cl$
Chlorine	17	17	20	$^{37}_{17}Cl$

9 Atomic Mass

- The mass of a single atom is too small to measure on a balance.
- Using a mass spectrometer, the mass of the hydrogen atom was determined.

Relationship Between Mass Number and Atomic Number

The mass number minus the atomic number equals the number of neutrons in the nucleus.

mass number

atomic number

$$^{109}_{47}\mathrm{Ag}$$

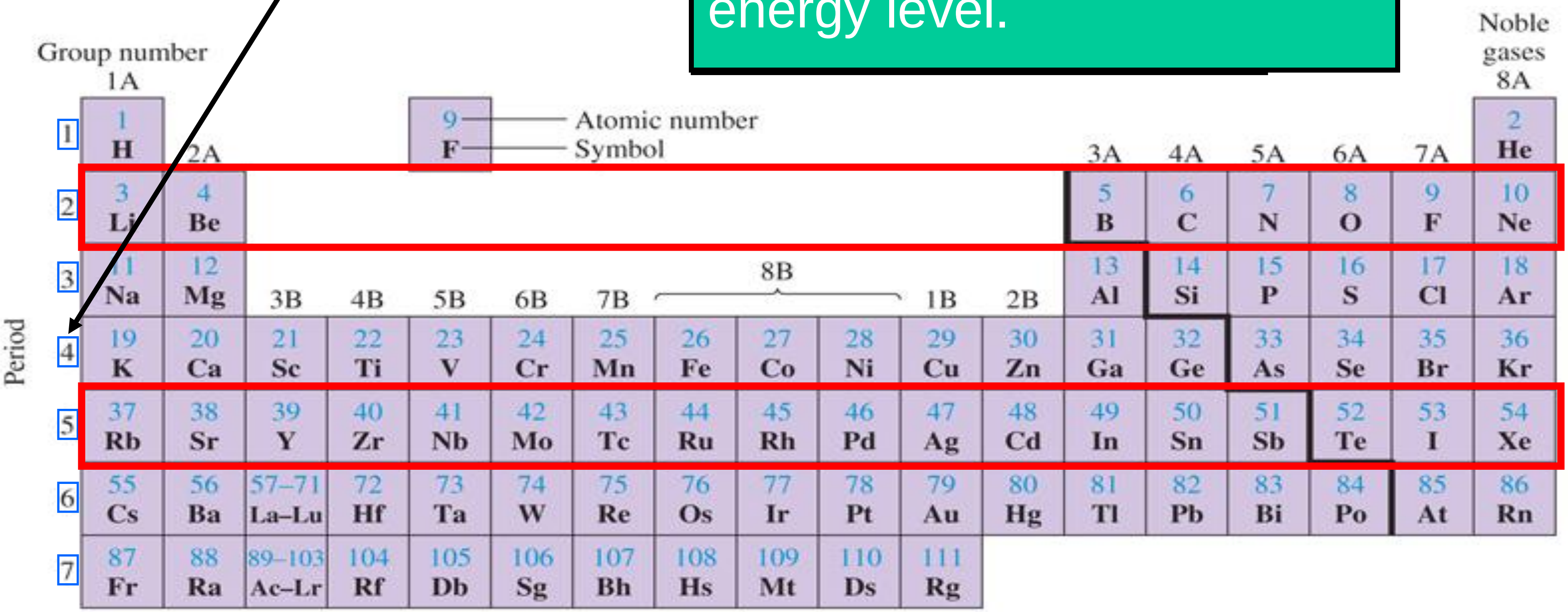
mass number	-	atomic number	=	number of neutrons
109	-	47	=	62

6 Electron Structures and the Periodic Table

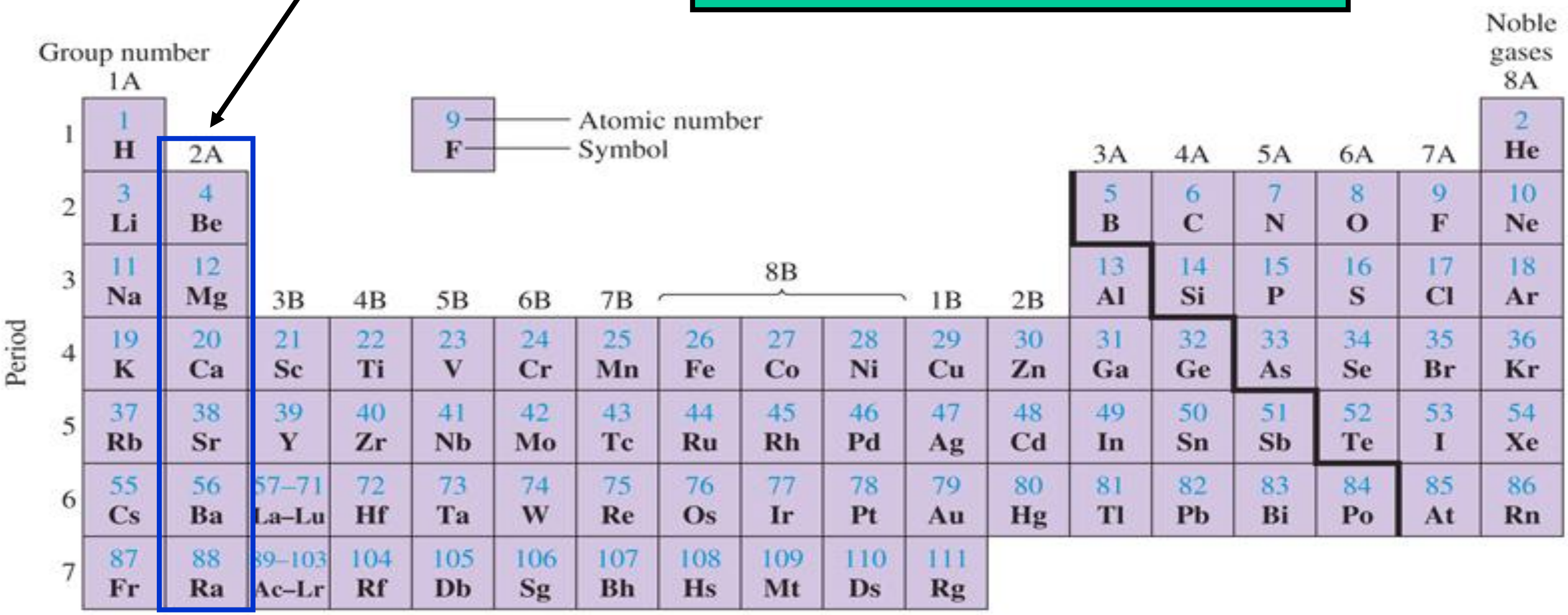
In 1869 Dimitri Mendeleev of Russia and Lothar Meyer of Germany independently published periodic arrangements of the elements based on increasing atomic masses.

Mendeleev's arrangement is the precursor to the modern periodic table.

Period numbers correspond to the highest occupied energy level.



Elements with similar properties are organized in groups or families.



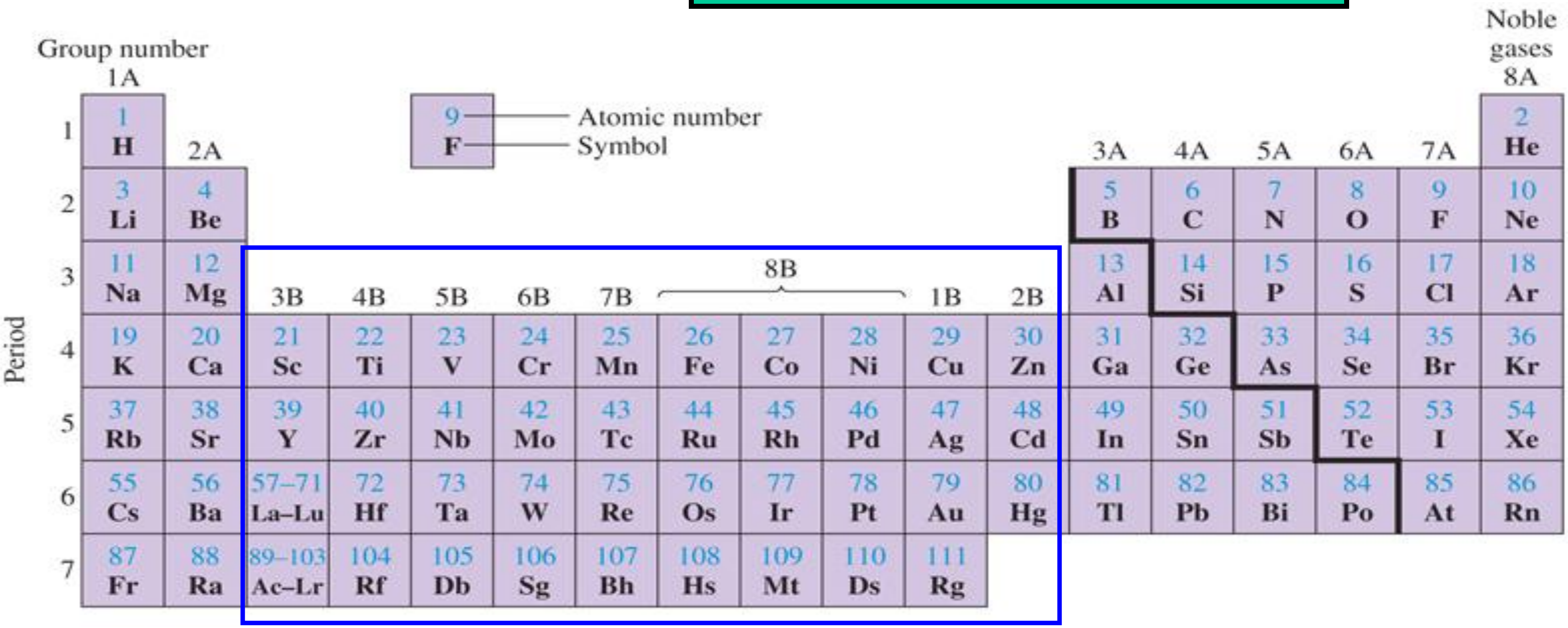
Elements in the A groups are designated **representative elements**

Group number

Atomic number: 9; Symbol: F

Period	1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A	8A (Noble gases)
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57–71 La–Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89–103 Ac–Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg							

Elements in the B groups are designated **transition elements**



1A	2A	3A	4A	5A	6A	7A	Noble gases
1 **H** $1s^1$							2 **He** $1s^2$
3 **Li** $2s^1$	4 **Be** $2s^2$	5 **B** $2s^22p^1$	6 **C** $2s^22p^2$	7 **N** $2s^22p^3$	8 **O** $2s^22p^4$	9 **F** $2s^22p^5$	10 **Ne** $2s^22p^6$
11 **Na** $3s^1$	12 **Mg** $3s^2$	13 **Al** $3s^23p^1$	14 **Si** $3s^23p^2$	15 **P** $3s^23p^3$	16 **S** $3s^23p^4$	17 **Cl** $3s^23p^5$	18 **Ar** $3s^23p^6$

The chemical behavior and properties of elements in a family are associated with the electron configuration of its elements.

1A	2A	3A	4A	5A	6A	7A	Noble gases
1 **H** $1s^1$							2 **He** $1s^2$
3 **Li** $2s^1$	4 **Be** $2s^2$	5 **B** $2s^22p^1$	6 **C** $2s^22p^2$	7 **N** $2s^22p^3$	8 **O** $2s^22p^4$	9 **F** $2s^22p^5$	10 **Ne** $2s^22p^6$
11 **Na** $3s^1$	12 **Mg** $3s^2$	13 **Al** $3s^23p^1$	14 **Si** $3s^23p^2$	15 **P** $3s^23p^3$	16 **S** $3s^23p^4$	17 **Cl** $3s^23p^5$	18 **Ar** $3s^23p^6$

With the exception of helium which has a filled s orbital, the noble gases have filled p orbitals.

The electron configuration of any of the noble gas elements can be represented by the symbol of the element enclosed in square brackets (noble gas configuration).

B	$1s^2 2s^2 2p^1$	$[He]2s^2 2p^1$
Na	$1s^2 2s^2 2p^6 3s^1$	$[Ne]3s^1$
Cl	$1s^2 2s^2 2p^6 3s^2 3p^5$	$[Ne]3s^2 3p^5$

The electron configuration of argon is

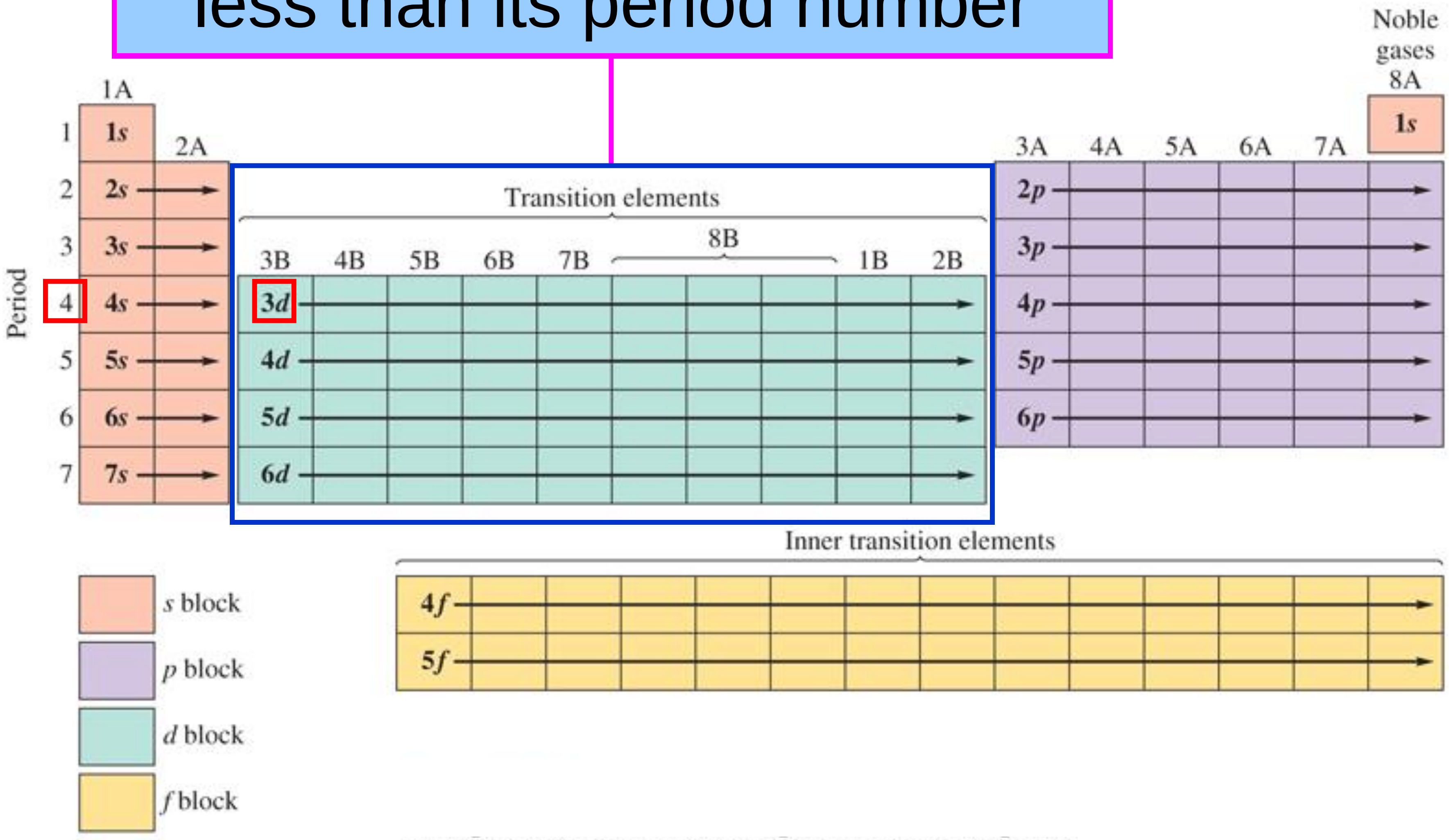
Ar $1s^2 2s^2 2p^6 3s^2 3p^6$

The elements after argon are potassium and calcium. Instead of entering a 3d orbital, the valence electrons of these elements enter the 4s orbital.

K $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$ $[Ar] 4s^1$

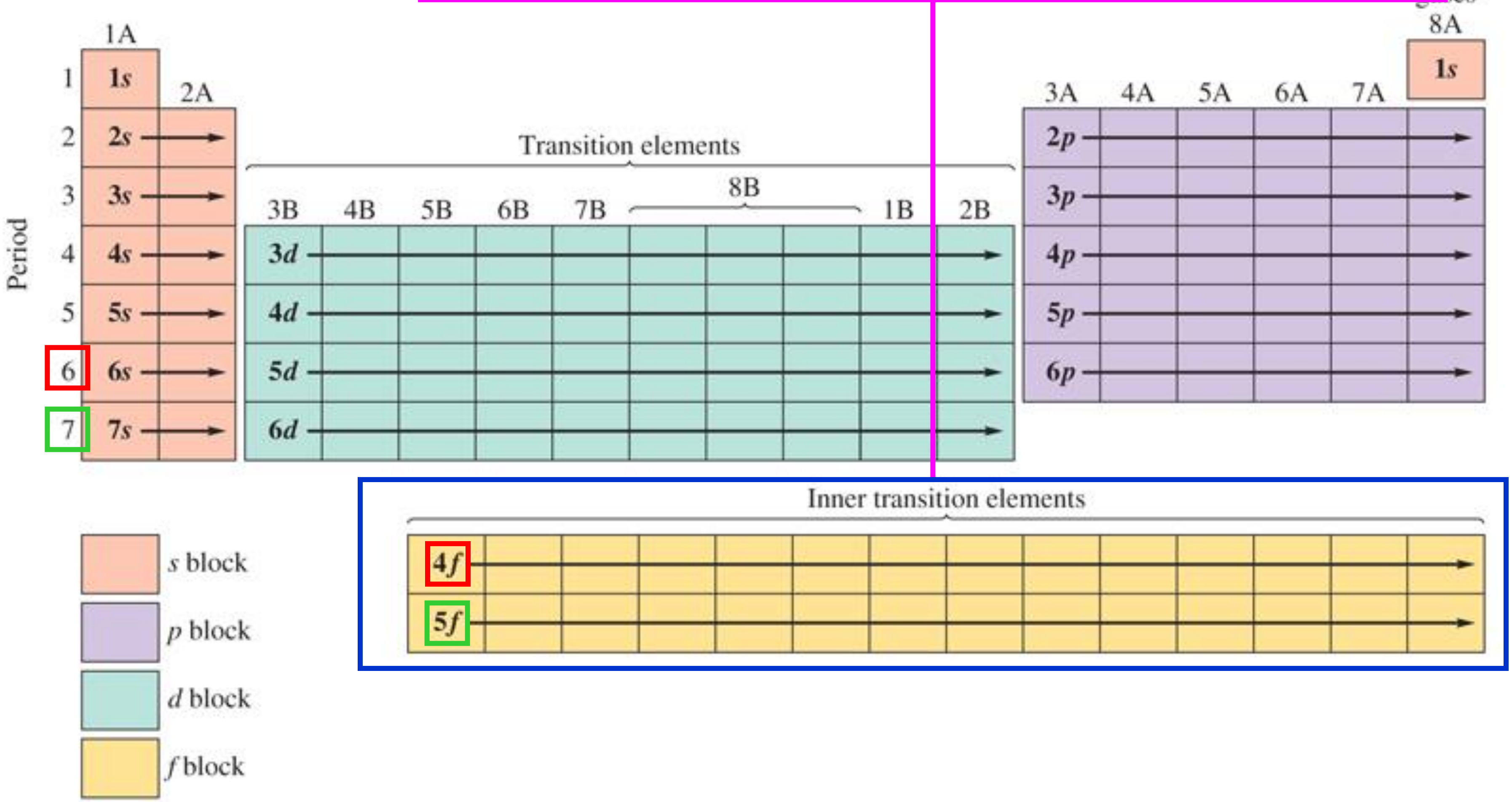
Ca $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ $[Ar] 4s^2$

The number of a *d* orbital is 1 less than its period number



Arrangement of electrons according to sublevel being filled.

The number of an *f* orbital is 2 less than its period number



Arrangement of electrons according to sublevel being filled.

Group number

Period	1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A	8A (Noble gases)
1	1 **H** $1s^1$																	2 **He** $1s^2$
2	3 **Li** $2s^1$	4 **Be** $2s^2$											5 **B** $2s^22p^1$	6 **C** $2s^22p^2$	7 **N** $2s^22p^3$	8 **O** $2s^22p^4$	9 **F** $2s^22p^5$	10 **Ne** $2s^22p^6$
3	11 **Na** $3s^1$	12 **Mg** $3s^2$											13 **Al** $3s^23p^1$	14 **Si** $3s^23p^2$	15 **P** $3s^23p^3$	16 **S** $3s^23p^4$	17 **Cl** $3s^23p^5$	18 **Ar** $3s^23p^6$
4	19 **K** $4s^1$	20 **Ca** $4s^2$	21 **Sc** $4s^23d^1$	22 **Ti** $4s^23d^2$	23 **V** $4s^23d^3$	24 **Cr** $4s^13d^5$	25 **Mn** $4s^23d^5$	26 **Fe** $4s^23d^6$	27 **Co** $4s^23d^7$	28 **Ni** $4s^23d^8$	29 **Cu** $4s^13d^{10}$	30 **Zn** $4s^23d^{10}$	31 **Ga** $4s^24p^1$	32 **Ge** $4s^24p^2$	33 **As** $4s^24p^3$	34 **Se** $4s^24p^4$	35 **Br** $4s^24p^5$	36 **Kr** $4s^24p^6$
5	37 **Rb** $5s^1$	38 **Sr** $5s^2$	39 **Y** $5s^24d^1$	40 **Zr** $5s^24d^2$	41 **Nb** $5s^14d^4$	42 **Mo** $5s^14d^5$	43 **Tc** $5s^14d^6$	44 **Ru** $5s^14d^7$	45 **Rh** $5s^14d^8$	46 **Pd** $5s^04d^{10}$	47 **Ag** $5s^14d^{10}$	48 **Cd** $5s^24d^{10}$	49 **In** $5s^25p^1$	50 **Sn** $5s^25p^2$	51 **Sb** $5s^25p^3$	52 **Te** $5s^25p^4$	53 **I** $5s^25p^5$	54 **Xe** $5s^25p^6$
6	55 **Cs** $6s^1$	56 **Ba** $6s^2$	57 **La** $6s^25d^1$	72 **Hf** $6s^25d^2$	73 **Ta** $6s^25d^3$	74 **W** $6s^25d^4$	75 **Re** $6s^25d^5$	76 **Os** $6s^25d^6$	77 **Ir** $6s^25d^7$	78 **Pt** $6s^15d^9$	79 **Au** $6s^15d^{10}$	80 **Hg** $6s^25d^{10}$	81 **Tl** $6s^26p^1$	82 **Pb** $6s^26p^2$	83 **Bi** $6s^26p^3$	84 **Po** $6s^26p^4$	85 **At** $6s^26p^5$	86 **Rn** $6s^26p^6$
7	87 **Fr** $7s^1$	88 **Ra** $7s^2$	89 **Ac** $7s^26d^1$	104 **Rf** $7s^26d^2$	105 **Db** $7s^26d^3$	106 **Sg** $7s^26d^4$	107 **Bh** $7s^26d^5$	108 **Hs** $7s^26d^6$	109 **Mt** $7s^26d^7$	110 **Ds** $7s^16d^9$	111 **Rg** $7s^16d^{10}$							

A period number corresponds to the highest energy level occupied by electrons in the period.

Group number

Period	1A	2A	3B	4B	5B	6B	7B	8B	8B	8B	1B	2B	3A	4A	5A	6A	7A	Noble gases 8A
1	1 **H** $1s^1$																	2 **He** $1s^2$
2	3 **Li** $2s^1$	4 **Be** $2s^2$											5 **B** $2s^22p^1$	6 **C** $2s^22p^2$	7 **N** $2s^22p^3$	8 **O** $2s^22p^4$	9 **F** $2s^22p^5$	10 **Ne** $2s^22p^6$
3	11 **Na** $3s^1$	12 **Mg** $3s^2$											13 **Al** $3s^23p^1$	14 **Si** $3s^23p^2$	15 **P** $3s^23p^3$	16 **S** $3s^23p^4$	17 **Cl** $3s^23p^5$	18 **Ar** $3s^23p^6$
4	19 **K** $4s^1$	20 **Ca** $4s^2$	21 **Sc** $4s^23d^1$	22 **Ti** $4s^23d^2$	23 **V** $4s^23d^3$	24 **Cr** $4s^13d^5$	25 **Mn** $4s^23d^5$	26 **Fe** $4s^23d^6$	27 **Co** $4s^23d^7$	28 **Ni** $4s^23d^8$	29 **Cu** $4s^13d^{10}$	30 **Zn** $4s^23d^{10}$	31 **Ga** $4s^24p^1$	32 **Ge** $4s^24p^2$	33 **As** $4s^24p^3$	34 **Se** $4s^24p^4$	35 **Br** $4s^24p^5$	36 **Kr** $4s^24p^6$
5	37 **Rb** $5s^1$	38 **Sr** $5s^2$	39 **Y** $5s^24d^1$	40 **Zr** $5s^24d^2$	41 **Nb** $5s^14d^4$	42 **Mo** $5s^14d^5$	43 **Tc** $5s^14d^6$	44 **Ru** $5s^14d^7$	45 **Rh** $5s^14d^8$	46 **Pd** $5s^04d^{10}$	47 **Ag** $5s^14d^{10}$	48 **Cd** $5s^24d^{10}$	49 **In** $5s^25p^1$	50 **Sn** $5s^25p^2$	51 **Sb** $5s^25p^3$	52 **Te** $5s^25p^4$	53 **I** $5s^25p^5$	54 **Xe** $5s^25p^6$
6	55 **Cs** $6s^1$	56 **Ba** $6s^2$	57 **La** $6s^25d^1$	72 **Hf** $6s^25d^2$	73 **Ta** $6s^25d^3$	74 **W** $6s^25d^4$	75 **Re** $6s^25d^5$	76 **Os** $6s^25d^6$	77 **Ir** $6s^25d^7$	78 **Pt** $6s^15d^9$	79 **Au** $6s^15d^{10}$	80 **Hg** $6s^25d^{10}$	81 **Tl** $6s^26p^1$	82 **Pb** $6s^26p^2$	83 **Bi** $6s^26p^3$	84 **Po** $6s^26p^4$	85 **At** $6s^26p^5$	86 **Rn** $6s^26p^6$
7	87 **Fr** $7s^1$	88 **Ra** $7s^2$	89 **Ac** $7s^26d^1$	104 **Rf** $7s^26d^2$	105 **Db** $7s^26d^3$	106 **Sg** $7s^26d^4$	107 **Bh** $7s^26d^5$	108 **Hs** $7s^26d^6$	109 **Mt** $7s^26d^7$	110 **Ds** $7s^16d^9$	111 **Rg** $7s^16d^{10}$							

The elements of a family have the same outermost electron configuration except that the electrons are in different energy levels.

The End