

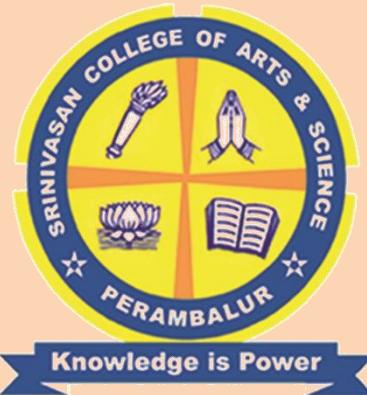
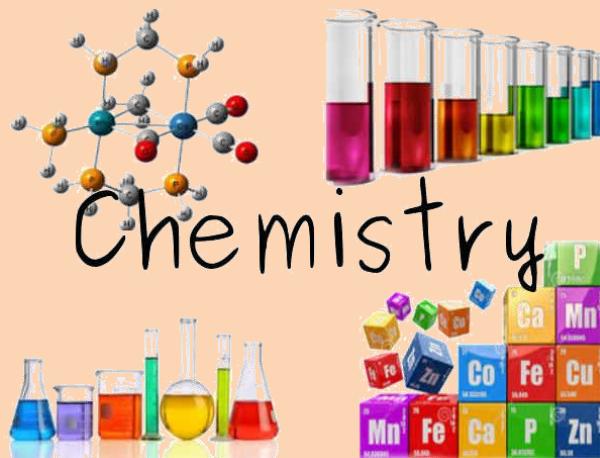
CHEMISTRY

(Allied)

Second ALLIED COURSE I

For II B.Sc Forensic Science Students

Subject Code: 19SACFS3



Dr. N. PRABU

Assistant Professor
Department of Chemistry

Srinivasan College of Arts and Science
Perambalur 621 212

Syllabus

UNIT: I

Introduction to inorganic chemistry: Atomic structure -de Broglie matter wave, Heisenberg uncertainty Principle, atomic orbitals, quantum numbers, Aufbau and Pauli Exclusion Principle, Hund's multiplicity rule. Study of periodic table: Modern periodic table and periodic properties, electronic configuration, atomic and ionic radii, ionization potential, electron affinity, electronegativity, metallic, non-metallic characters and magnetic properties. Comparative study of S and P block elements. Introduction to Noble gases, Lanthanide and Actinide series.

UNIT: II

Introduction to organic chemistry: Empirical and Molecular formula, Classification of Aliphatic and Aromatic compounds, IUPAC Nomenclature of alkanes, alkenes, haloalkanes, alcohols, aldehydes, ketones, ethers, carboxylic acids and nitro compounds.

Introduction to chemical compounds: Aromatic hydrocarbons, Amines, Diazonium salts, Phenyl hydrazine, Sulphonic acids, Aromatic Alcohols, Phenols, quinones and also aromatic cyclic compounds - Naphthalene, Anthracene, Phenanthracene and its carcinogenicity.

UNIT: III

Dyes: Introduction and classification synthesis and use of Congo red malachite green alizarin and indigo

Food Chemistry: Organic food preservatives and food additive. Detection of food adulterants.

Textile Chemistry: Manufacture of synthetic fibers - Viscos rayon, acetate silk or rayon – properties and uses.

Petrochemicals: Raw materials, production of petrochemicals from olefin and acetylene, alkanes and cycloalkanes, aromatic hydrocarbons. Synthetic petrol – Bergius process, petroleum products – ISS of Gasoline and kerosene.

Pharmaceutical chemistry: Organic Pharmaceutical aids – preservatives, antioxidant, emulsifiers, stabilizing and suspending agents, ointments bases and related agents. Relationship between chemical structure and pharmacological activity – effect of unsaturation, chain length, isomerism, halogens, amine group, aldehydes and ketones group on structure property relations.

UNIT: IV

Spectroscopic Techniques: Introduction: Properties of light, Interaction of Electromagnetic radiation with Matter, application in forensic science, Spectroscopy and its application in Forensic science: UV/ Visible

Spectrophotometry, Molecular Fluorescence, IR spectroscopy, Raman Spectroscopy , Atomic Absorption Spectroscopy

Chromatographic Techniques: General Principles, Paper, Column, TLC, Adsorption chromatography, Partition Chromatography, gas -liquid and gas chromatography, ion -exchange chromatography, HPLC and HPTLC techniques.

Physical methods of analysis: X-ray spectroscopy: X-ray absorption and fluorescence methods, X-ray diffraction, EDX, AES (Auger Emission Spectroscopy) ESCA (electron spectroscopy for chemical analysis)

UNIT: V

Radioactivity. Fission, Fusion reactions. Half-Life Period. Alpha, Beta and Gamma emissions. Penetration of Matter. Nuclear reactors. Applications. Geiger counters. Scintillation detectors. Hazards of radioactivity.

Text Books:

- 1) R.D. Madan, "Modern Inorganic Chemistry", 2nd edition, S. Chand & Company Ltd., 200
- 2) J. E. Huheey, Inorganic Chemistry; 4th Ed., Harper and Row Publishers, Singapore, 2006.
- 3) Bahl, B.S. and Bahl, A., Advanced Organic Chemistry, (12th edition), New Delhi, Sultan Chand & Co., (2010).
- 4) Finar I.L., Organic Chemistry, Vol 1&2, (6th edition) England, addison Wesley Longman Ltd. (1996).
- 5) C. N. Banwell, Fundamentals of Molecular Spectroscopy; 4th Ed., McGraw Hill Education, Noida, 1994.
- 6) V. K. Srivastava and K. K. Srivastava, Introduction to Chromatography; 2nd Ed., Holden Day, New York, 1985.
- 7) Gurdeep. R. Chatwal and Sham K. Anand , Instrumental Methods of Chemical Analysis, Himalaya publish house
- 8) D. A. Skoog, D. M. West and F.J. Holler, Fundamentals of Analytical Chemistry, 6th Edition, Saunders College Publishing, Fort Worth (1992).
- 9) Max Houck Forensic Chemistry, 1st edition Academic press 2015, Elesvier.
- 10) Tewari.S.N: Liquor and Narcotic drugs.
- 11) Egon Stahl, Thin Layer Chromatography-A Laboratory Manual.

Chemistry (Allied)

Course Material

Unit-1

Introduction to Inorganic Chemistry

CHEMISTRY: Chemistry is the scientific discipline involved with the elements and compounds composed of atoms, molecules and ions.

Study of their composition, structure, properties, behaviour and the changes they undergo during a reaction with other substances.

Chemistry: central science because it provides a foundation for understanding both basic and applied scientific disciplines at a fundamental level.

Organic Chemistry: The word organic refers to the compounds which contain the carbon atoms in it, the study of carbon-hydrogen and its compounds.

Ex. Hydrocarbons, polymers, etc.

Inorganic Chemistry: The study of compounds, which does not consist of carbon-hydrogen atoms in it. In simple words, it is opposite to that of Organic Chemistry. The substances which do not have carbon-hydrogen bonding are the metals, salts, chemical substances, etc.

Ex. Metals, non-metals, noble gases, etc.

Many of the elements are technologically important: titanium, iron, nickel and copper, for example, are used structurally and electrically.

Physical chemistry: Branch of chemistry concerned with interactions and transformations of materials. Unlike other branches, it deals with the principles of physics underlying all chemical interactions seeking to measure, correlate, and explain the quantitative aspects of reactions.

Ex. gas laws, concepts and principles for instruments

Atomic structure -de Broglie matter wave, Heisenberg uncertainty Principle.

Atom: It is the smallest unit of ordinary matter that forms a chemical element. Every solid, liquid, gas, and plasma is composed of neutral or ionized atoms. Atoms are extremely small, typically around 100 picometers ($1 \times 10^{-12} \text{ m}$).

Matter is any substance that has mass and takes up space by having volume.

Atomic structure: It refers to the structure of atom comprising a nucleus (center) in which the protons (positively charged) and neutrons (neutral) are present.

The negatively charged particles called electrons revolve around the center of the nucleus.

The study about the structure of atom gives a great insight into the entire class of chemical reactions, bonds and their physical properties to produce new chemicals.

Structure of the atom:

The first scientific theory of atomic structure was proposed by John Dalton in 1800s.

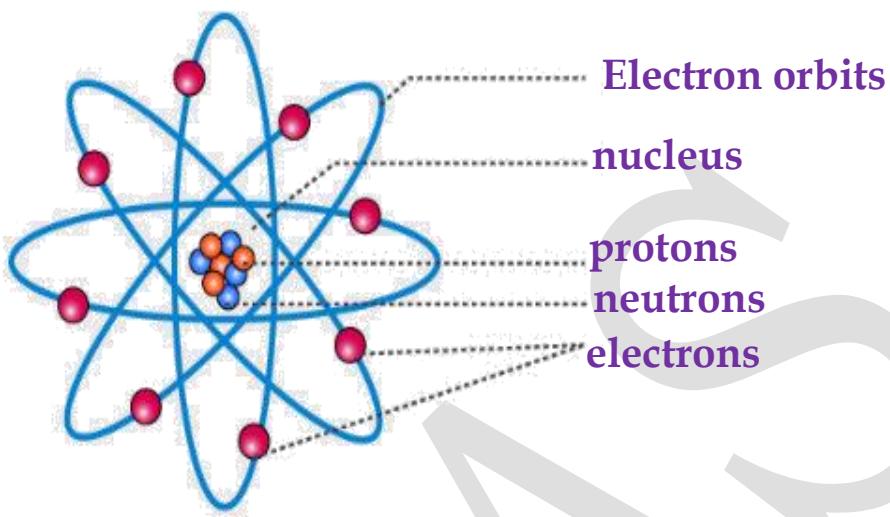


Figure 1: Structure of the atom

The atomic structure of an element refers to the constitution of its nucleus and the arrangement of the electrons around it. Primarily, the atomic structure of matter is made up of protons, electrons and neutrons.

To study or understand about the elements, structure of the atom is must.

What is Element?

- A substance that cannot be broken down into simpler substances by chemical means.
- An element is composed of atoms that have the same atomic number, that is, each atom has the same number of protons in its nucleus as all other atoms of that element.
- Today 117 elements are known, of which 92 are known to occur in nature, while the remainder have only been made with particle accelerators.
- Eighty-one of the elements have isotopes that are stable.
- The others, including technetium, promethium, and those with atomic numbers higher than 83, are radioactive.

The most notable contributions to the structure of the atom were by the following scientists.,

John Dalton, J.J. Thomson, Ernest Rutherford and Niels Bohr.

Their ideas and the contributions on the structure of the atom were remarkable.

Dalton's Atomic Theory

According to Dalton's atomic theory, involve a rearrangement of atoms to form products.

The following are the postulates of his theory:

- Every matter is made up of atoms.
- Atoms are indivisible.
- Specific elements have only one type of atoms in them.
- Each atom has its own constant mass that varies from element to element.
- Atoms undergo rearrangement during a chemical reaction.
- Atoms can neither be created nor be destroyed but can be transformed from one form to another

Demerits of Dalton's Atomic Theory

- The theory was unable to explain the existence of isotopes
- Nothing about the structure of atom was appropriately explained
- Later, the scientists discovered particles inside the atom that proved, the atoms are divisible
- Didn't explain the subatomic particles.

JJ Thomson's Atomic model

The concept of the electrons around the nucleus. He was later awarded the Nobel prize for the **discovery of “electrons”**. His work is based on an experiment called cathode ray experiment.

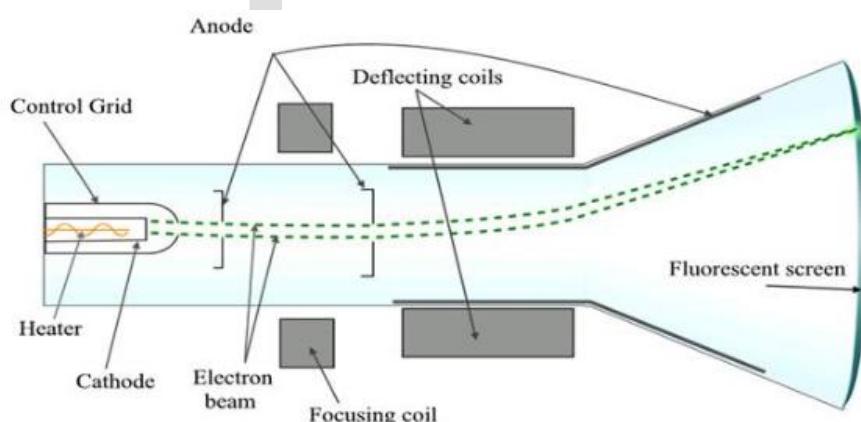


Figure 2: Cathode ray experiment setup

- Based on conclusions from his cathode ray experiment, Thomson described the atomic structure as a positively charged sphere into which negatively charged electrons were embedded.
- Thomson's atomic structure described atoms as electrically neutral, i.e. the positive and the negative charges were of equal magnitude.

Limitations of Thomson's Atomic Structure:

- ✓ Thomson's atomic model does not clearly explain the stability of an atom.
- ✓ Also, further discoveries of other subatomic particles, couldn't be placed inside his atomic model.

Rutherford's atomic theory

Modified the atomic structure with the discovery of another **subatomic particle called "Nucleus"**. His atomic model is based on the Alpha ray scattering experiment.

- The nucleus is at the centre of an atom, where most of the charge and mass are concentrated.
- Atomic structure is spherical.
- Electrons revolve around the nucleus in a circular orbit, similar to the way planets orbit the sun.

Limitations of Rutherford Atomic Model:

- If electrons have to revolve around the nucleus, they will spend energy and that too against the strong force of attraction from the nucleus, they will lose all their energy and will fall into the nucleus so the stability of atom is not explained.
- If electrons continuously revolve around the 'nucleus, the type of spectrum expected is a continuous spectrum. But in reality, what we see is a line spectrum.

Subatomic Particles

Protons

Protons are positively charged subatomic particles. The charge of a proton is $1e$, which corresponds to approximately 1.602×10^{-19}

The mass of a proton is approximately 1.672×10^{-24}

Protons are over 1800 times heavier than electrons.

The total number of protons in the atoms of an element is always equal to the atomic number of the element.

Neutrons

The mass of a neutron is almost the same as that of a proton i.e. 1.674×10^{-24}

Neutrons are electrically neutral particles and carry no charge.

Different isotopes of an element have the same number of protons but vary in the number of neutrons present in their respective nuclei.

Electrons

The charge of an electron is $-1e$, which approximates to -1.602×10^{-19}

The mass of an electron is approximately 9.1×10^{-31} .

Due to the relatively negligible mass of electrons, they are ignored when calculating the mass of an atom.

Bohr's Atomic Theory

Neils Bohr put forth his model of the atom in the year 1915. This is the most widely used atomic model to describe the atomic structure of an element which is based on Planck's theory of quantization.

Postulates:

- ✓ The electrons inside atoms are placed in discrete orbits called “stationery orbits”.
- ✓ The energy levels of these shells can be represented via quantum numbers.
- ✓ Electrons can jump to higher levels by absorbing energy and move to lower energy levels by losing or emitting its energy.
- ✓ As longs as, an electron stays in its own stationery, there will be no absorption or emission of energy.
- ✓ Electrons revolve around the nucleus in these stationery orbits only.
- ✓ The energy of the stationary orbits is quantized.

Limitations of Bohr's Atomic Theory:

- Bohr's atomic structure works only for single electron species such as H, He^+ , Li^{2+} , Be^{3+} ,
- When the emission spectrum of hydrogen was observed under a more accurate spectrometer, each line spectrum was seen to be a combination of no of smaller discrete lines.
- Both Stark and Zeeman effects couldn't be explain using Bohr's theory.

Dual Nature of Matter

The electrons which were treated to be particles, the evidence of photoelectric effect show they also have wave nature. This was proved by “Thomas young” with the help of his double slit experiment.

De-Broglie concluded that since nature is symmetrical, so should be light or any other matter wave.

Matter has both particle and wave nature, which was clearly explained by the De-Broglie experiments, for the measurement of the wavelength of the particles.

De Broglie's hypothesis stated that there is symmetry in nature and that if light and radiation behave as both particles and waves, matter too will have both the particle and wave nature.

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

The 'Lambda' here represents the wavelength of the particle and 'p' represents the momentum of the particle.

The significance of the de Broglie relationship is that it proves mathematically that matter can behave as a wave. In layman terms, de Broglie equation says that every moving particle – microscopic or macroscopic – has its own wavelength.

For macroscopic objects, the wave nature of matter is observable.

Heisenberg's Uncertainty principle

Quantum mechanics is the discipline of measurements on the minuscule scale. Those measurements are in macro and microphysics can lead to very diverse consequences.

Heisenberg uncertainty principle or basically uncertainty principle is a vital concept in Quantum mechanics.

The uncertainty principle says that both the position and momentum of a particle cannot be determined at the same time and accurately.

The result of position and momentum is at all times greater than $h/4\pi$. The formula for Heisenberg Uncertainty principle is articulated as,

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$

Where

h is the Planck's constant ($6.62607004 \times 10^{-34} \text{ m}^2 \text{ kg/s}$)

Δp is the uncertainty in momentum

Δx is the uncertainty in position

Problem – 1:

The uncertainty in the momentum Δp of a ball travelling at 20m/s is 1×10^{-6} of its momentum. Calculate the uncertainty in position Δx ? Mass of the ball is given as 0.5kg.

Known numerics are,

$$v = 20 \text{ m/s},$$

$$m = 0.5\text{kg},$$

$$h = 6.62607004 \times 10^{-34} \text{ m}^2 \text{ kg / s}$$

$$\Delta p = p \times 1 \times 10^{-6}$$

As we know that,

$$P = m \times v = 0.5 \times 20 = 10 \text{kgm/s}$$

$$\Delta p = 10 \times 1 \times 10^{-6}$$

$$\Delta p = 10^{-5}$$

Heisenberg Uncertainty principle formula is given as,

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$

$$\Delta x \geq \frac{h}{4\pi \Delta p}$$

$$\Delta x \geq \frac{6.626 \times 10^{-34}}{4 \times 3.14 \times 10^{-5}} = 0.527 \times 10^{-29} \text{m}$$

Atomic Orbitals:

- ❖ It is a mathematical tool derived from quantum mechanics, to locate the position of the electrons in an atom.
- ❖ It is a representation of the three-dimensional volume in which an electron is most likely to be found.
- ❖ It cannot be observed experimentally (*electron density* can, however, be observed experimentally).

In atomic theory and quantum mechanics:

An **atomic orbital** is a mathematical function describing the location and wave-like behaviour of an electron in an atom.

Each orbital in an atom is characterized by a unique set of values of the three quantum numbers n , ℓ , and m , which respectively correspond to the electron's energy, angular momentum, and an angular momentum vector component (the magnetic quantum number).

Quantum numbers:

- Atomic orbitals can be uniquely defined by a set of integers known as quantum numbers.
- These quantum numbers only occur in certain combinations of values, and their physical interpretation changes depending on whether real or complex versions of the atomic orbitals are employed.

The quantum numbers can be defined as "the sets of numerical values which give acceptable solutions to the Schrödinger wave equation for the hydrogen atom".

Four quantum numbers can describe an electron in an atom completely:

- 1. Principal quantum number (n)**
- 2. Azimuthal quantum number (ℓ)**
- 3. Magnetic quantum number (m_ℓ)**
- 4. Spin quantum number (s)**

The spin-orbital interaction, however, relates these numbers.

Principal quantum number:

This describes the electron shell, or energy level, of an electron. The value of ' n ' ranges from 1 to the shell containing the outermost electron of that atom, that is

$$n = 1, 2, \dots$$

For example, in caesium (Cs), the outermost valence electron is in the shell with energy level 6, so an electron in caesium can have an n value from 1 to 6.

Azimuthal quantum number:

Also known as the (angular quantum number or orbital quantum number), this describes the subshell, and gives the magnitude of the orbital angular momentum through the relation.

$$L^2 = \hbar^2 \ell (\ell + 1)$$

In chemistry and spectroscopy, $\ell = 0$ is called an s orbital, $\ell = 1$ a p orbital, $\ell = 2$ a d orbital, and $\ell = 3$ an f orbital.

The value of ℓ ranges from 0 to $n - 1$, so the first p orbital ($\ell = 1$) appears in the second electron shell ($n = 2$), the first d orbital ($\ell = 2$) appears in the third shell ($n = 3$), and so on: $\ell = 0, 1, 2, \dots, n - 1$

Uses of Azimuthal quantum number

- A quantum number beginning in $n = 3$, $\ell = 0$, describes an electron in the s orbital of the third electron shell of an atom.
- In chemistry, this quantum number is very important, since it specifies the shape of an atomic orbital and strongly influences chemical bonds and bond angles.
- The azimuthal quantum number can also denote the number of angular nodes present in an orbital.
- For example, for p orbitals, $\ell = 1$ and thus the amount of angular nodes in a p orbital is 1.
- Shape of orbital is also given by azimuthal quantum number.

Magnetic quantum number:

This describes the specific orbital (or "cloud") within that subshell, and yields the *projection* of the orbital angular momentum *along a specified axis*:

$$L_z = m_\ell \hbar$$

The values of m_l range from $-l$ to l , with integer intervals,

The s subshell ($l = 0$) contains only one orbital, and therefore the m_l of an electron in an s orbital will always be 0.

The p subshell ($l = 1$) contains three orbitals (in some systems, depicted as three "dumbbell-shaped" clouds), so the m_l of an electron in a p orbital will be -1, 0, or 1. The d subshell ($l = 2$) contains five orbitals, with m_l values of -2, -1, 0, 1, and 2.

Spin quantum number:

This describes the spin (intrinsic angular momentum) of the electron within that orbital, and gives the projection of the spin angular momentum S along the specified axis:

$$S_z = m_s \hbar$$

In general, the values of m_s range from $-s$ to s , where s is the spin quantum number, an intrinsic property of particles:

$$m_s = -s, -s+1, -s+2, \dots, s-2, s-1, s$$

An electron has spin number $s = 1/2$, consequently m_s will be $\pm 1/2$, referring to "spin up" and "spin down" states. Each electron in any individual orbital must have different quantum numbers because of the Pauli exclusion principle; therefore an orbital never contains more than two electrons.

Table 1: Overview of quantum numbers

Name	Symbol	Orbital meaning	Range of values	Value examples
Principal quantum number	n	shell	$1 \leq n$	$n = 1, 2, 3, \dots$
Azimuthal quantum number (angular momentum)	l	subshell (s orbital is listed as 0, p orbital as 1 etc.)	$0 \leq l \leq n - 1$	for $n = 3$: $l = 0, 1, 2$ (s, p, d)
Magnetic quantum number (projection of angular momentum)	m_l	energy shift (orientation of the subshell's shape)	$-l \leq m_l \leq l$	for $l = 2$: $m_l = -2, -1, 0, 1, 2$
Spin quantum number	m_s	spin of the electron ($-1/2$ = "spin down", $1/2$ = "spin up")	$-s \leq m_s \leq s$	for an electron $s = 1/2$, so $m_s = -1/2, +1/2$

Example: The quantum numbers used to refer to the outermost valence electrons of a carbon (C) atom, which are located in the 2p atomic orbital, are; $n = 2$ (2nd electron shell), $l = 1$ (p orbital subshell), $m_l = 1, 0, -1$, $m_s = 1/2$ (parallel spins).

Aufbau Principle

The word ‘Aufbau’ has German roots with the meaning of ‘construct’ or ‘build up’.

A diagram illustrating the order in which atomic orbitals are filled is provided below.

The Aufbau principle states in which electrons are filled in the atomic orbitals of an atom in its ground state.

It states that electrons are filled into atomic orbitals in the increasing order of orbital energy level.

The available atomic orbitals with the lowest energy levels are occupied before those with higher energy levels.

Here,

‘n’ refers to the principal quantum number
and ‘l’ is the azimuthal quantum number.

The Aufbau principle can be used to understand the location of electrons in an atom and their corresponding energy levels.

For example, carbon has 6 electrons and its electronic configuration is $1s^2 2s^2 2p^2$.

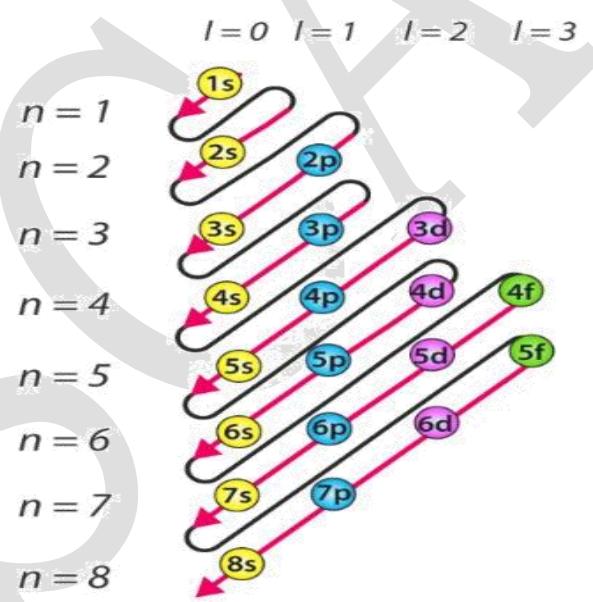


Figure 3: Arrangement of electrons in the orbitals

Salient features of Aufbau Principle:

- ❖ Electrons first occupy those orbitals whose energy is the lowest. This implies that the electrons enter the orbitals having higher energies only when orbitals with lower energies have been completely filled.
- ❖ The order in which the energy of orbitals increases can be determined with the help of the $(n+l)$ rule, where the sum of the principal and azimuthal quantum numbers determines the energy level of the orbital.

- ❖ Lower ($n+l$) values correspond to lower orbital energies. If two orbitals share equal ($n+l$) values, the orbital with the lower n value is said to have lower energy associated with it.
- ❖ The order in which the orbitals are filled with electrons is: 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d, 7p, and so on.

Exception:

- ❖ The electron configuration of chromium (at. No:24) is $[Ar]3d^54s^1$ or $[Ar]3d^44s^2$ (as suggested by the Aufbau principle). [Ar] is $18 = 1s^22s^22p^63s^23p^6$
- ❖ Answer: $[Ar]3d^54s^1$
- ❖ $[Ar]$ is $18 = 1s^22s^22p^63s^23p^6$
- ❖ This exception is attributed to several factors such as the increased stability provided by half-filled subshells and the relatively low energy gap between the 3d and the 4s subshells.

Pauli exclusion Principle

An Austrian physicist named Wolfgang Pauli formulated the principle in the year 1925. With this principle, he basically described the behaviour of the electrons.

Each electron should have or be in its own unique state (singlet state).

There are two salient rules that the Pauli Exclusion Principle follows:

- Only two electrons can occupy the same orbital.
- The two electrons that are present in the same orbital must have opposite spins or it should be antiparallel.

Wolfgang Pauli was also awarded the Nobel prize in the year 1945 for the discovery of the ‘Pauli exclusion principle’ and his overall contribution in the field of quantum mechanics.

We can take a neutral helium atom as a common example.

The atom has 2 bound electrons and they occupy the outermost shell with opposite spins.

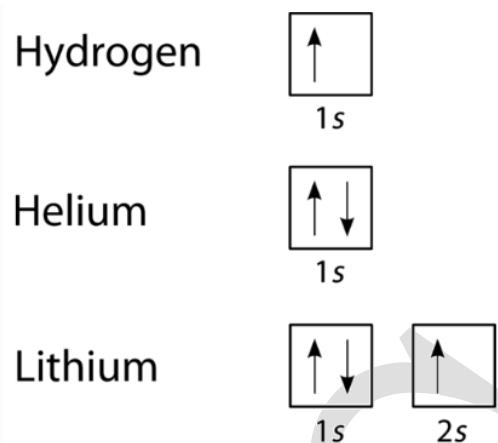
Here, we will find that the two electrons are in the 1s subshell where $n = 1$, $l = 0$, and $m_l = 0$. Their spin moments will also be different. One will be $m_s = -1/2$ and the other will be $+1/2$.

If we draw a diagram then the subshell of the helium atom will be represented with 1 “up” electron and 1 “down” electron.

Formulation of the pauli exclusion principle

- The number of electrons in the outermost shell is also directly related to the different chemical properties that elements possess.

- Elements with the same number of electrons in the outermost shell will have similar properties.



Key Points

- i. Electrons are part of subatomic particles called fermions.
- ii. Fermions are particles with half-integer spin.
- iii. All fermions including neutrons and protons (derived particles) obey the Pauli exclusion principle.
- iv. Pauli exclusion principle states that no two identical electrons (fermions) can have the same quantum state.
- v. Bosons, which have integer values of spin do not obey the Pauli exclusion principle. Photons, gravitons, gluons are an example of bosons.

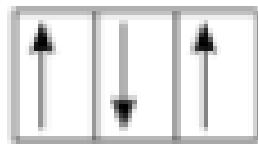
Hund's Rule for periodicity

The problem with pauli's rule is that it does not tell about the three 2p orbitals and the order that they will be filled/pair in.

German physicist Friedrich Hund formulated around 1927, rule of arrangement of electrons in subshell and its spin values.

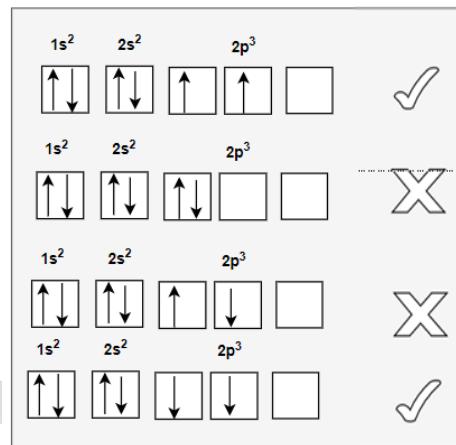
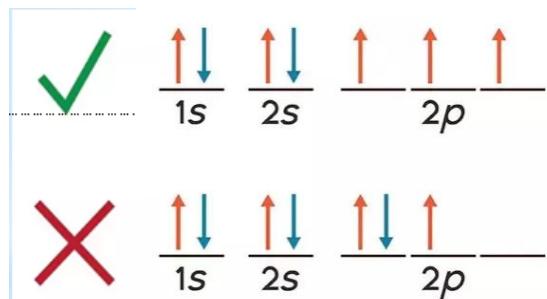
It states that:

1. In a sublevel, each orbital is singly occupied before it is doubly occupied.
 2. The electrons present in singly occupied orbitals possess identical spin.
- The electron pairing in p, d and f orbitals cannot occur until each orbital of a given subshell contains one electron each or is singly occupied.
 - It says if two or more than two orbitals having the same amount of energy are unoccupied then the electrons will start occupying them individually before they fill them in pairs.
 - When all the orbitals of an atom are full it is most stable. The orbitals that have full energy level are the most stable, for example, noble gases. These types of elements do not react with other elements.



2p

Examples:



PERIODIC TABLE

Study of Periodic table:

Periodic Table: It is a table that was created to study the properties and understanding of the elements.

- ❖ Dmitri Mendeleev was the first scientist to create a periodic table of the elements in 1869.
- ❖ This table showed that when the elements were ordered by increasing atomic weight, a pattern appeared where properties of the elements repeated periodically.
- ❖ This periodic table is a chart that groups the elements according to their similar properties.

Why was the Periodic Table Created?

- ❖ Why Mendeleev made a periodic table?
- ❖ Many elements remained to be discovered in Mendeleev's time.
- ❖ The periodic table helped predict the properties of new elements.

Main-Group Elements s Subshell fills

1 IA	1 H $1s^1$	2 IIA
3	4 Be $2s^2$	
2	5	6
3	7	8
4	9	10
5	11	12
6	13 IIIB	14 IVB
7	15 VIB	16 VIIB
8	17 VIIIB	
9	18 VIIIIA	

Transition Metals d Subshell fills

19 K $4s^1$	20 Ca $4s^2$	21 Sc $3d^1 4s^2$	22 Ti $3d^2 4s^2$	23 V $3d^3 4s^2$	24 Cr $3d^4 4s^1$	25 Mn $3d^5 4s^2$	26 Fe $3d^6 4s^2$	27 Co $3d^7 4s^2$	28 Ni $3d^8 4s^2$	29 Cu $3d^{10} 4s^2$	30 Zn $3d^{10} 4s^2$	31 Ga $3d^1 4s^2$	32 Ge $3d^2 4s^2$	33 As $3d^3 4s^2$	34 Se $3d^4 4s^2$	35 Br $3d^5 4s^2$	36 Kr
37 Rb $5s^1$	38 Sr $5s^2$	39 Y $4d^1 5s^2$	40 Zr $4d^2 5s^2$	41 Nb $4d^3 5s^2$	42 Mo $4d^4 5s^2$	43 Tc $4d^5 5s^1$	44 Ru $4d^6 5s^1$	45 Rh $4d^7 5s^1$	46 Pd $4d^8 5s^1$	47 Ag $4d^9 5s^1$	48 Cd $4d^{10} 5s^1$	49 In $4d^1 5s^2$	50 Sn $4d^2 5s^2$	51 Te $4d^3 5s^2$	52 I $4d^4 5s^2$	53 Xe $4d^5 5s^2$	
55 Cs $6s^1$	56 Ba $6s^2$	57 La* $5d^1 6s^2$	58 Hf $5d^2 6s^2$	59 Ta $5d^3 6s^2$	60 W $5d^4 6s^2$	61 Re $5d^5 6s^2$	62 Os $5d^6 6s^2$	63 Ir $5d^7 6s^2$	64 Pt $5d^{10} 6s^1$	65 Au $5d^1 6s^2$	66 Hg $5d^2 6s^2$	67 Tl $5d^3 6s^2$	68 Pb $5d^4 6s^2$	69 Bi $5d^5 6s^2$	70 Po $5d^6 6s^2$	71 At $5d^7 6s^2$	72 Rn $6s^2 6p^6$
87 Fr $7s^1$	88 Ra $7s^2$	89 Ac** $6d^1 7s^2$	104 Db $6d^2 7s^2$	105 JI $6d^3 7s^2$	106 Rf $6d^4 7s^2$	107 Bh $6d^5 7s^2$	108 Hn $6d^6 7s^2$	109 Mt $6d^7 7s^2$									

Main-Group Elements p Subshell fills

13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIIA
5 B $2s^2 2p^1$	6 C $2s^2 2p^2$	7 N $2s^2 2p^3$	8 O $2s^2 2p^4$	9 F $2s^2 2p^5$	2 He $1s^2$

Inner-Transition Metals f Subshell fills

58 Ce $4f^1 5d^6 6s^2$	59 Pr $4f^1 5d^6 6s^2$	60 Nd $4f^1 5d^6 6s^2$	61 Pm $4f^1 5d^6 6s^2$	62 Sm $4f^1 5d^6 6s^2$	63 Eu $4f^1 5d^6 6s^2$	64 Gd $4f^1 5d^6 6s^2$	65 Tb $4f^1 5d^6 6s^2$	66 Dy $4f^1 5d^6 6s^2$	67 Ho $4f^1 5d^6 6s^2$	68 Er $4f^1 5d^6 6s^2$	69 Tm $4f^1 5d^6 6s^2$	70 Yb $4f^1 5d^6 6s^2$	71 Lu $4f^1 5d^6 6s^2$
90 Th $5f^1 6d^1 7s^2$	91 Pa $5f^1 6d^1 7s^2$	92 U $5f^2 6d^1 7s^2$	93 Np $5f^2 6d^1 7s^2$	94 Pu $5f^2 6d^1 7s^2$	95 Am $5f^2 6d^1 7s^2$	96 Cm $5f^2 6d^1 7s^2$	97 Bk $5f^2 6d^1 7s^2$	98 Cf $5f^2 6d^1 7s^2$	99 Es $5f^2 6d^1 7s^2$	100 Fm $5f^2 6d^1 7s^2$	101 Md $5f^2 6d^1 7s^2$	102 No $5f^2 6d^1 7s^2$	103 Lr $5f^2 6d^1 7s^2$

***Lanthanides**

****Actinides**

Figure 4: Periodic Table

Introduction

- The periodic table is made up of rows of elements and columns.
- An element is identified by its chemical symbol.
- The number above the symbol is the atomic number
- The number below the symbol is the rounded atomic weight of the element.
- A row is called a **period**
- A column is called a **group**

Chemists used the properties of elements to sort them into groups.

J.W. Dobreiner grouped elements into triads.

A triad is a set of three elements with similar properties.



Chlorine Bromine Iodine
35.453 amu 79.904 amu 126.90 amu

Figure 5. Dobreiner triads

Mendeleev's Periodic Table

- In 1869, a Russian chemist and teacher published a table of the elements.
- Mendeleev arranged the elements in the periodic table in order of increasing atomic mass.

Ti = 50	Zr = 90	? = 180.
V = 51	Nb = 94	Ta = 182.
Cr = 52	Mo = 96	W = 186.
Mn = 55	Rh = 104, ⁴	Pt = 197, ¹
Fe = 56	Ru = 104, ⁴	Ir = 198.
Ni = 59	Os = 106, ⁸	O = 199.
Cu = 63, ⁴	Pl = 106, ⁸	Hg = 200.
Be = 9, ⁴	Zn = 65, ²	Cd = 112
B = 11	Al = 27, ¹	? = 68
C = 12	Si = 28	? = 70
N = 14	P = 31	As = 75
O = 16	S = 32	Se = 79, ⁴
F = 19	Cl = 35, ⁶	Br = 80
Li = 7	Na = 23	K = 39
		Rb = 85, ⁴
		Ca = 40
		Sr = 87, ⁶
		? = 45
		Ce = 92
		?Er = 56
		?Y = 60
		?In = 75, ⁶
		Th = 118?

Д. Менделеев

Figure 6: Mendeleev's Periodic Table

Henry Moseley's Prediction:

In 1913, through his work with X-rays, he determined the actual nuclear charge (atomic number) of the elements. He rearranged the elements in order of increasing atomic number.

"There is in the atom a fundamental quantity which increases by regular steps as we pass from each element to the next. This quantity can only be the charge on the central positive nucleus."

The Periodic Law:

In the modern periodic table elements are arranged in order of **increasing atomic number**.

Periodic Law states: *When elements are arranged in order of increasing atomic number, there is a periodic repetition of their physical and chemical properties.*

Study of Periodic table:

Elements in the periodic table are arranged in periods (rows) and groups (columns). Atomic number increases as you move across a row or period.

The periodic table has 7 periods and 18 groups.

PERIODS:

Rows of elements are called periods. The period number of an element signifies the highest unexcited energy level for an electron in that element.

The number of elements in a period increases as you move down the periodic table because there are more sublevels per level as the energy level of the atom increases.

GROUPS:

Columns of elements help define element groups. Elements within a group share several common properties.

Groups are elements have the same outer electron (valence electrons) arrangement. Elements in a group share similar chemical properties.

The Roman numerals listed above each group are the usual number of valence electrons. For example, a group VA element will have 5 valence electrons.

Table: 2 Comparisons of Groups and Periods:

GROUP	PERIOD
Columns of elements are called groups or families.	Each horizontal row of elements is called a period.
Elements in each group have similar but not identical properties.	The elements in a period are not alike in properties.
For example, lithium (Li), sodium (Na), potassium (K), and other members of group IA are all soft, white, shiny metals.	In fact, the properties change greatly across even given row.
All elements in a group have the same number of valence electrons.	The first element in a period is always an extremely active solid. The last element in a period, is always an inactive gas.

Broad Classification of Periodic Table

- The elements can be grouped into three broad classes based on their general properties.
- Three classes of elements are Metals, Nonmetals, and Metalloids.
- Across a period, the properties of elements become less metallic and more nonmetallic.

Figure 7: Broad classification of periodic table

Metals:

- Metals are good conductors of heat and electricity.
- Metals are shiny.
- Metals are ductile (can be stretched into thin wires).
- Metals are malleable (can be pounded into thin sheets).
- A chemical property of metal is its reaction with water which results in corrosion.
- Solid at room temperature except Hg.



Non-Metals:

- Non-metals are poor conductors of heat and electricity.
- Non-metals are not ductile or malleable.
- Solid non-metals are brittle and break easily.
- They are dull.



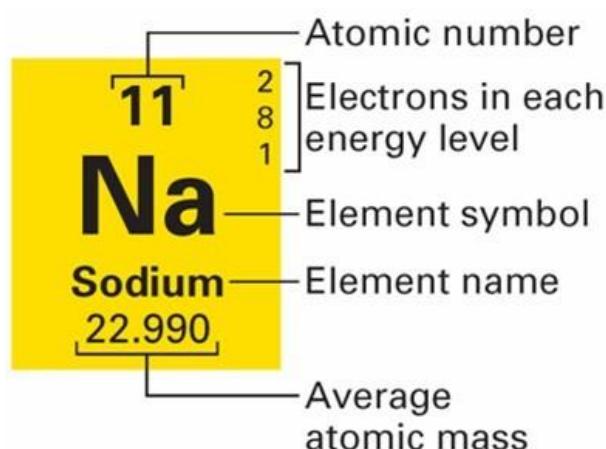
- Many non-metals are gases. Ex: Sulfur

Metalloids:

- Metalloids (metal-like) have properties of both metals and non-metals.
- They are solids that can be shiny or dull.
- They conduct heat and electricity better than non-metals but not as well as metals.
- They are ductile and malleable. Ex: Silicon

Identification of the elements and its properties:

The periodic table displays the symbols and names of the elements along with information about the structure of their atoms.



		Alkali metals (IA)
H	Be	Alkaline earth metals (IIA)
Li	Mg	
Na	Ca	
K	Sr	
Rb	Ba	
Cs		Halogens (VIIA)
Fr		Noble gases (VIIIA)
		He
		F Ne
		Cl Ar
		Br Kr
		I Xe
		At Rn

Figure 8: Identification of elements in periodic table

Four chemical groups of the periodic table:

- Alkali metals (IA)
- Alkaline earth metals (IIA)
- Halogens (VIIA)
- Noble gases (VIIIA)

11	Na
	$3s^1$
19	K
	$4s^1$
37	Rb
	$5s^1$
55	Cs
	$6s^1$
87	Fr
	$7s^1$

Alkali Metals:

- The alkali family is found in the first column of the periodic table.
- Atoms of the alkali metals have a single electron in their outermost level, in other words, 1 valence electron.
- They are shiny, have the consistency of clay, and are easily cut with a knife.
- They are the most reactive metals.
- They react violently with water.

- Alkali metals are never found as free elements in nature. They are always bonded with another element.

Alkaline Earth Metals:

- They are never found uncombined in nature.
- They have two valence electrons.
- Alkaline earth metals include magnesium and calcium, among others.

4 Be 2S²	12 Mg 3S²	20 Ca 4S²	38 Sr 5S²	56 Ba 6S²	88 Ra 7S²
--	---	---	---	---	---

Transition Metals:

- Transition Elements include those elements in the B groups.
- These are the metals you are probably most familiar: copper, tin, zinc, iron, nickel, gold, and silver.
- They are good conductors of heat and electricity.
- The compounds of transition metals are usually brightly colored and are often used to color paints.
- Transition elements have 1 or 2 valence electrons, which they lose when they form bonds with other atoms. Some transition elements can lose electrons in their next-to- outermost level.
- Transition elements have properties similar to one another and to other metals, but their properties do not fit in with those of any other group.
- Many transition metals combine chemically with oxygen to form compounds called oxides.

3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9	10	11 IB	12 IIB
21 Sc 3d ¹ 4s ²	22 Ti 3d ² 4s ²	23 V 3d ³ 4s ²	24 Cr 3d ⁴ 4s ¹	25 Mn 3d ⁵ 4s ²	26 Fe 3d ⁶ 4s ²	27 Co 3d ⁷ 4s ²	28 Ni 3d ⁸ 4s ²	29 Cu 3d ¹⁰ 4s ¹	30 Zn 3d ¹⁰ 4s ²
39 Y 4d ¹ 5s ²	40 Zr 4d ² 5s ²	41 Nb 4d ³ 5s ¹	42 Mo 4d ⁴ 5s ¹	43 Tc 4d ⁵ 5s ²	44 Ru 4d ⁶ 5s ¹	45 Rh 4d ⁷ 5s ¹	46 Pd 4d ⁸	47 Ag 4d ¹⁰ 5s ¹	48 Cd 4d ¹⁰ 5s ²
57 La* 5d ¹ 6s ²	72 Hf 5d ² 6s ²	73 Ta 5d ³ 6s ²	74 W 5d ⁴ 6s ²	75 Re 5d ⁵ 6s ²	76 Os 5d ⁶ 6s ²	77 Ir 5d ⁷ 6s ²	78 Pt 5d ⁸ 6s ¹	79 Au 5d ¹⁰ 6s ¹	80 Hg 5d ¹⁰ 6s ²
89 Ac** 6d ¹ 7s ²	104 Db 6d ² 7s ²	105 Jl 6d ³ 7s ²	106 Rf 6d ⁴ 7s ²	107 Bh 6d ⁵ 7s ²	108 Hn 6d ⁶ 7s ²	109 Mt 6d ⁷ 7s ²	Inner-Transition (Subshell f)		

Trends in the periodic table:

Study of the properties of the elements and its periodic behaviour was studied to locate the elements for various applications.

These are some of the properties,

- i. Ionization Energy
- ii. Atomic Radius
- iii. Electron Affinity
- iv. Electronegativity

Size of Atoms:

Atomic radii: The bonding atomic radius is defined as one-half of the distance between covalently bonded nuclei.

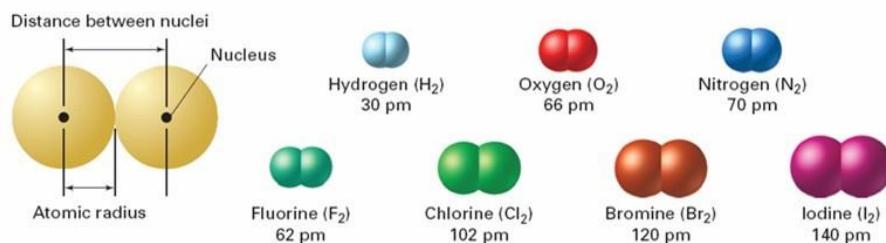


Figure 9: Atomic radius trend in the periodic elements

Atomic Radius Trend:

- Group Trend – As you go down a column, atomic radius increases.
As you go down, e⁻ are filled into orbitals that are farther away from the nucleus (attraction not as strong).
- Period Trend – As you go across a period (L to R), atomic radius decreases.
As you go L to R, e⁻ are put into the same orbital, but more p⁺ and e⁻ total (more attraction = smaller size).

Ionic Radius Trend:

- Metals – lose e⁻, which means more p⁺ than e⁻ (more attraction) SO...
Ionic Radius < Neutral Atomic Radius
- Nonmetals – gain e⁻, which means more e⁻ than p⁺ (not as much attraction) SO...
Ionic Radius > Neutral Atomic Radius

Sizes of Ions:

Ionic size depends upon:

- Nuclear charge.
- Number of electrons.
- Orbitals in which electrons reside.

Sizes of Cations:

- Cations are smaller than their parent atoms.

- The outermost electron is removed and repulsions are reduced.

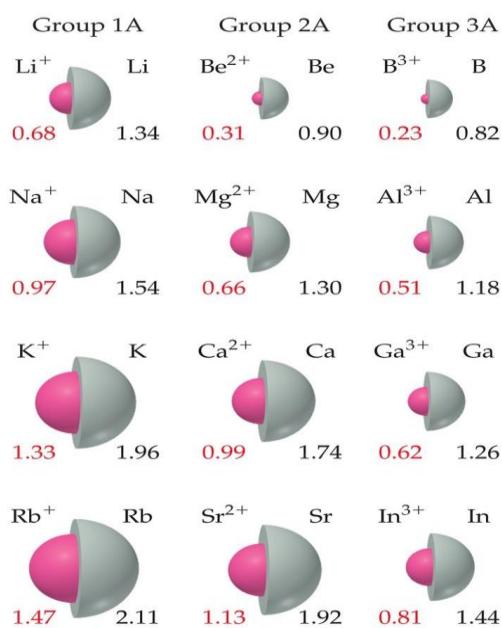


Figure 10: Size of the cations

Sizes of Anions:

- Anions are larger than their parent atoms.
 - Electrons are added and repulsions are increased.

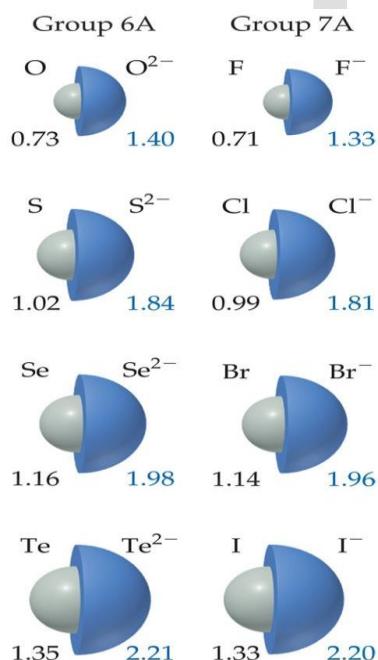


Figure 11: Size of the anions

Metals versus Nonmetals act of ions:

- Metals tend to form cations.

- Nonmetals tend to form anions.

		1A								7A	8A
	H ⁺	2A								H ⁻	
	Li ⁺									N ³⁻	O ²⁻
	Na ⁺	Mg ²⁺								P ³⁻	S ²⁻
	K ⁺	Ca ²⁺			Cr ³⁺	Mn ²⁺	Fe ²⁺	Fe ³⁺	Co ²⁺	Ni ²⁺	Cu ⁺
	Rb ⁺	Sr ²⁺								Cu ²⁺	Zn ²⁺
	Cs ⁺	Ba ²⁺								Ag ⁺	Cd ²⁺
										Sn ²⁺	
											Te ²⁻
											I ⁻

Figure 12: Ion formation in metals and non metals

- Electrons can jump between shells (Bohr's model supported by line spectra)
- The electrons can be pushed so far that they escape the attraction of the nucleus
- Losing an electron is called ionization
- An ion is an atom that has either a net positive or net negative charge
- Q: what would the charge be on an atom that lost an electron? Gained two electrons?
- A: +1 (because you are losing an e⁻ -ve electron)
- A: -2 (because you gain 2e⁻ -ve electrons)

Ionization Energy:

- Amount of energy required to remove an electron from the ground state of a gaseous atom or ion.
 - First ionization energy is that energy required to remove first electron.
 - Second ionization energy is that energy required to remove second electron, etc.

Periodic trend of ionization energy: Group Trend – As you go down a column, ionization energy decreases.

- As you go down, atomic size is increasing (less attraction), so easier to remove an e⁻.
- Periodic Trend – As you go across a period (L to R), ionization energy increases.

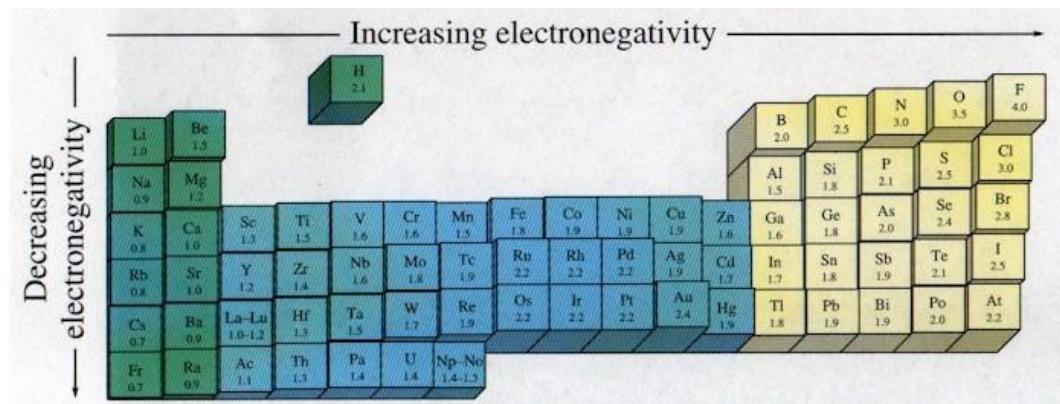
As you go L to R, atomic size is decreasing (more attraction), so more difficult to remove an e⁻ (also, metals want to lose e⁻, but nonmetals do not).

Trends in First Ionization Energies: As one goes down a column, less energy is required to remove the first electron.

For atoms in the same group, Z_{eff} is essentially the same, but the valence electrons are farther from the nucleus.

Electronegativity:

Electronegativity- tendency of an atom to attract e^- .



Electronegativity Trend:

- Group Trend – As you go down a column, electronegativity decreases.

As you go down, atomic size is increasing, so less attraction to its own e^- and other atom's e^- .

- Periodic Trend – As you go across a period (L to R), electronegativity increases.

As you go L to R, atomic size is decreasing, so there is more attraction to its own e^- and other atom's e^- .

Electron Affinity:

Electron Affinity is the energy associated with the addition of an electron to a gaseous atom. Example:



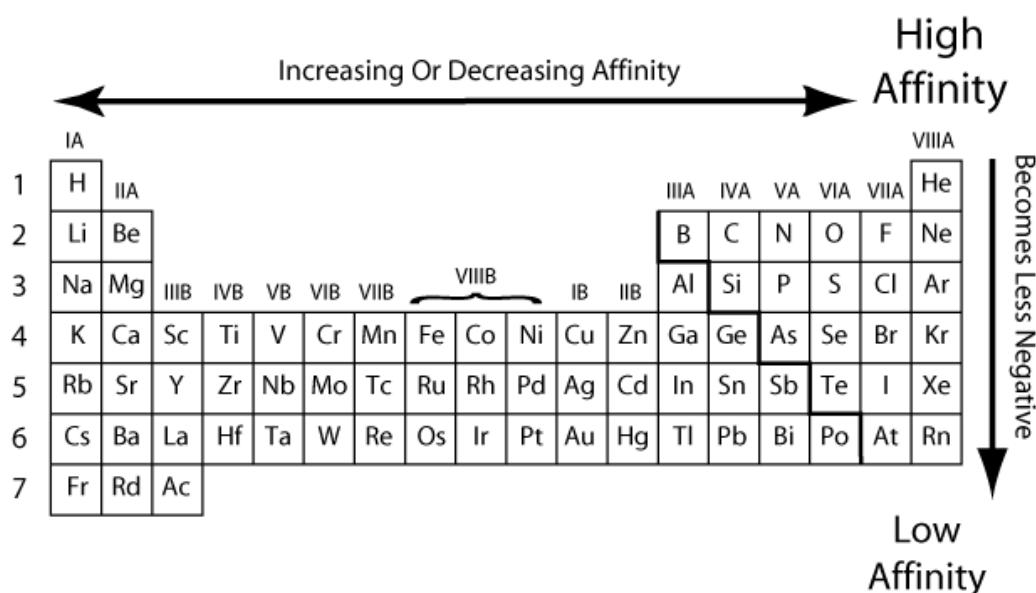
$$\text{E.A.} = -349 \text{ kJ/mol}$$

Notice the sign on the energy is negative. This is because energy is usually **released** in this process, as opposed to ionization energy, which **requires** energy. A **more negative** electron affinity corresponds to a **greater** attraction for an electron. (An unbound electron has an energy of zero.)

Periodic trend of Electronaffinity: As with ionization energy, there are two rules that govern the periodic trends of electron affinities:

Electron affinity becomes less negative down a group.

Electron affinity decreases or increases across a period depending on electronic configuration.



Affinity of Elements:

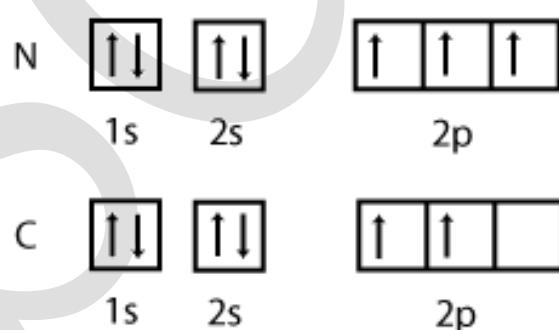
Electron affinity becomes less negative down a group.

As the principal quantum number increases, the size of the orbital increases and the affinity for the electron is less. The change is small and there are many exceptions.

Electron affinity decreases or increases across a period depending on electronic configuration.

This occurs because of the same subshell rule that governs ionization energies.

Example:



Since a half-filled "p" subshell is more stable, carbon has a **greater** affinity for an electron than nitrogen.

Obviously, the halogens, which are one electron away from a noble gas electron configuration, have high affinities for electrons:

(More negative energy = greater affinity)

*Fluorine's electron affinity is smaller than chlorine's because of the higher electron - electron repulsions in the smaller 2p orbital compared to the larger 3p orbital of chlorine.

Element	Electron affinity
I	-295.2 kJ/mole
Br	-324.5 kJ/mole
Cl	-348.7 kJ/mole
F*	-327.8 kJ/mole

Magnetic properties

Magnetism: Magnetism is a property of materials that respond to an applied magnetic field. Permanent magnets have persistent magnetic fields caused by ferromagnetism, the strongest and most familiar type of magnetism.

However, all materials are influenced differently by the presence of a magnetic field. Some are attracted to a magnetic field (paramagnetism); others are repulsed by it (diamagnetism); still others have a much more complex relationship with an applied magnetic field (e.g., spin-glass behaviour and antiferromagnetism).

Substances that are negligibly affected by magnetic fields are considered non-magnetic, these are: copper, aluminum, gases, and plastic. Pure oxygen exhibits magnetic properties when cooled to a liquid state.

The magnetic properties of a given element depend on the electron configuration of that element, which will change when the element loses or gains an electron to form an ion.

The ionization of an element yields an ion with unpaired electrons; these electrons may align the sign of their spins in the presence of a magnetic field, making the material paramagnetic. If the spins tend to align spontaneously in the absence of a magnetic field, the resulting species is termed ferromagnetic.

- Molecular oxygen (O_2) is paramagnetic and is attracted to a magnet.
- In contrast, molecular nitrogen, N_2 , has no unpaired electrons and is diamagnetic; it is therefore unaffected by the magnet.
- Diamagnetic substances are characterized by paired electrons, e.g., no unpaired electrons.

- According to the Pauli Exclusion Principle which states that no two electrons may occupy the same quantum state at the same time, the electron spins are oriented in opposite directions. This causes the magnetic fields of the electrons to cancel out; thus there is no net magnetic moment, and the atom cannot be attracted into a magnetic field.

The magnetic moment of a system measures the strength and the direction of its magnetism. The term itself usually refers to the magnetic dipole moment. Anything that is magnetic, like a bar magnet or a loop of electric current, has a magnetic moment. A magnetic moment is a vector quantity, with a magnitude and a direction. An electron has an electron magnetic dipole moment, generated by the electron's intrinsic spin property, making it an electric charge in motion. There are many different magnetic behaviour including paramagnetism, diamagnetism, and ferromagnetism.

Ferromagnetism (Permanent Magnet)

Ferromagnetism is the basic mechanism by which certain materials (such as iron) form permanent magnets. This means the compound shows permanent magnetic properties rather than exhibiting them only in the presence of an external magnetic field (Figure 8). In a ferromagnetic element, electrons of atoms are grouped into domains in which each domain has the same charge. In the presence of a magnetic field, these domains line up so that charges are parallel throughout the entire compound. Whether a compound can be ferromagnetic or not depends on its number of unpaired electrons and on its atomic size.

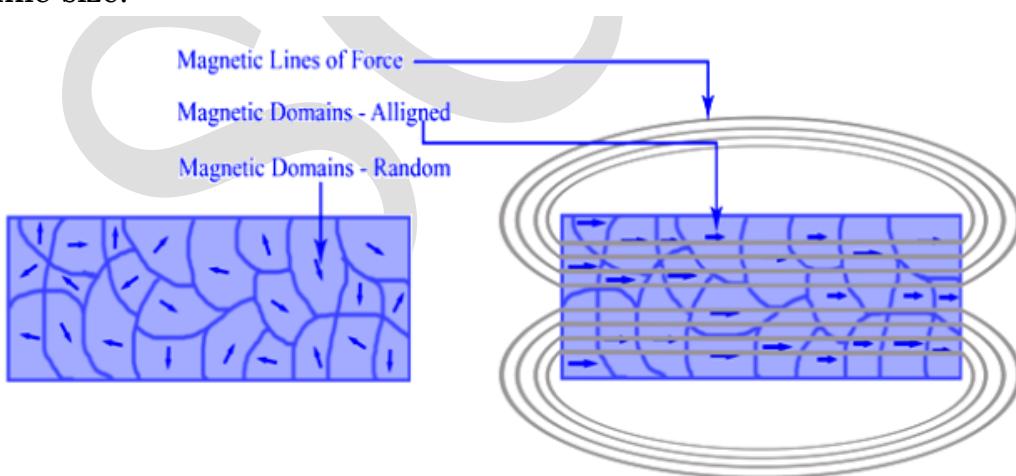


Figure 13: Ferromagnetism (L) nonmagnatized material and (R) Magnetized material with corresponding magnetic fields shown.

Ferromagnetism, the permanent magnetism associated with nickel, cobalt, and iron, is a common occurrence in everyday life. Examples of the knowledge and application of ferromagnetism include Aristotle's discussion in 625 BC, the

use of the compass in 1187, and the modern-day refrigerator. Einstein demonstrated that electricity and magnetism are inextricably linked in his theory of special relativity.

Paramagnetism (Attracted to Magnetic Field)

Paramagnetism refers to the magnetic state of an atom with one or more unpaired electrons. The unpaired electrons are attracted by a magnetic field due to the electrons' magnetic dipole moments. Hund's Rule states that electrons must occupy every orbital singly before any orbital is doubly occupied. This may leave the atom with many unpaired electrons. Because unpaired electrons can spin in either direction, they display magnetic moments in any direction. This capability allows paramagnetic atoms to be attracted to magnetic fields. Diatomic oxygen, O₂ is a good example of paramagnetism (described via molecular orbital theory). The following video shows liquid oxygen attracted into a magnetic field created by a strong magnet:

Diamagnetism (Repelled by Magnetic Field)

As shown in the video, molecular oxygen (O₂) is paramagnetic and is attracted to be paramagnetic and is attracted to the magnet. In contrast, molecular nitrogen, N₂, has no unpaired electrons and is diamagnetic; it is therefore unaffected by the magnet. Diamagnetic substances are characterized by paired electrons, e.g., no unpaired electrons. According to the Pauli Exclusion Principle which states that no two electrons may occupy the same quantum state at the same time, the electron spins are oriented in opposite directions. This causes the magnetic fields of the electrons to cancel out; thus there is no net magnetic moment, and the atom cannot be attracted into a magnetic field. In fact, diamagnetic substances are weakly repelled by a magnetic field as demonstrated with the pyrolytic carbon sheet in Figure 9.

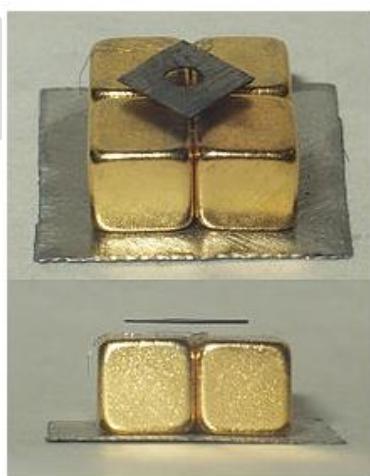


Figure 14: Levitating pyrolytic carbon: A small (~6 mm) piece of pyrolytic graphite levitating over a permanent neodymium magnet array.

How to tell if a Substance is Paramagnetic or Diamagnetic

The magnetic properties of a substance can be determined by examining its electron configuration: If it has unpaired electrons, then the substance is paramagnetic and if all electrons are paired, the substance is then diamagnetic. This process can be broken into three steps:

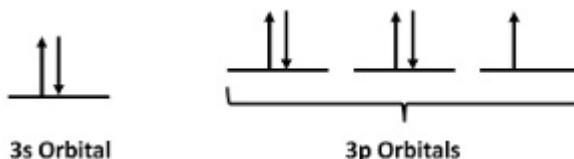
1. Write down the electron configuration
2. Draw the valence orbitals
3. Identify if unpaired electrons exist
4. Determine whether the substance is paramagnetic or diamagnetic

Example: Chlorine atoms

Step 1: Find the electron configuration

For Cl atoms, the electron configuration is $3s^23p^5$

Step 2: Draw the valence orbitals



Ignore the core electrons and focus on the valence electrons only.

Step 3: Look for unpaired electrons

There is one unpaired electron.

Step 4: Determine whether the substance is paramagnetic or diamagnetic

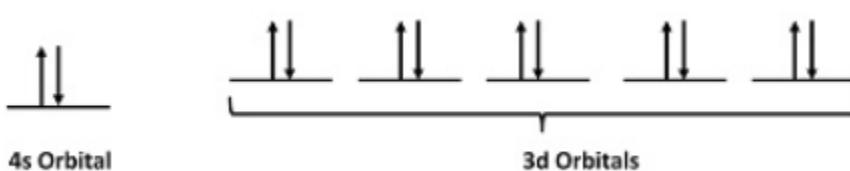
Since there is an unpaired electron, Cl atoms are paramagnetic (weakly).

Example 2: Zinc atoms

Step 1: Find the electron configuration

For Zn atoms, the electron configuration is $4s^23d^{10}$

Step 2: Draw the valence orbitals



Step 3: Look for unpaired electrons

There are no unpaired electrons.

Step 4: Determine whether the substance is paramagnetic or diamagnetic

Because there are no unpaired electrons, Zn atoms are diamagnetic.

Periodic trend of Magnetic property:

The element/material has unpaired e^- have a magnetic moment, but paired electrons cancel out the opposing magnetic fields. Atoms with unpaired e^- are attracted into a magnetic field: "paramagnetic".

Atoms with all e^- paired do not interact strongly with a magnetic field: "diamagnetic".

Most matter is diamagnetic, with all paired electrons, but most single atoms are paramagnetic, due to unpaired electrons in the electronic configuration.

		LONG FORM OF PERIODIC TABLE																				
		s-block or Light Metals		IA - Alkali metal IIA - Alkaline earth metal --- - Metalloids												p-block or Non-Metals		VIIA or 0				
		1	2	Heavy Metals or d-block (Transition Metals)												14	15	16	17	18	2	
Period 1		H	Li	Be	Na	Mg	Al	Si	P	S	Cl	Ar									He	
Period 2	3	4					Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Period 3	11	12	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18				
Period 4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36				
Period 5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54				
Period 6	55	56	57 to 71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86				
Period 7	87	88	89 to 103	104	105	106	107	108	109												Rn	
		La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu						
		Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr						
		Lanthanide series →																		}		
		Actinide series →																		}		

Figure 15: Overview of the periodic table

Comparative study of s and p block elements:

Main Difference – S vs P Block Elements:

The periodic table of elements contains all elements that have been discovered so far. These elements are grouped into 4 major groups as s block, p block, d block and f block. They are categorized according to the orbital where their valence electrons are present. Furthermore, these elements can also be categorized as metals, nonmetals, and metalloids according to their physical properties. All s block elements except hydrogen are metals. Most p block elements are nonmetals. Rest of the elements in the p block are metalloids. The main difference between s and p block elements is that the valence electrons of the s block elements are in the s orbital whereas the valence electrons of the p block elements are in the p orbital.

S BLOCK ELEMENTS V E R S U S P BLOCK ELEMENTS	
S block elements are elements having their valence electrons in their outermost s orbital	P block elements are elements having their valence electrons in their outermost p orbital
Can have 0, +1 or +2 oxidation states	Show a number of oxidation states varying from -3, 0 to +5
Form metallic bonds and ionic bonds	Form covalent bonds or ionic bonds
Most elements are metals	Most are nonmetals, others are metalloids
Electronegativity is comparatively less	Electronegativity is comparatively more

Visit www.Pediaa.com

Table 3: Comparison of s and p block elements

S Block Elements

S block elements are the elements that have their valence electrons in their outermost s orbital. Since s orbital can keep a maximum of only 2 electrons, all s block elements are composed of either 1 or 2 electrons in their outermost s orbital. Their electron configuration always ends with s orbital (ns).

Except for hydrogen, all other members of s block are metals. Hydrogen is a nonmetal. But since it has only an s orbital, it is also categorized as an s block element. The groups 1 and 2 includes block elements. Elements in group 1A are composed of one valence electron in the outermost s orbital whereas group 2 elements are composed of two valence electrons. Group 1 elements are named as alkali metals, and group 2 elements are alkali earth metals.

Helium is also an s block element since it has only an s orbital that is composed of 2 electrons. Therefore, Helium also has its valence electrons in s orbital and is categorized as an s block element. Helium is also a non-metal.

The oxidation states of s block elements can be either +1 or +2 (hydrogen sometimes have -1 oxidation state). This is because these elements can become

stable by removing one electron (in group 1 elements) or two electrons (in group 2 elements).

The atomic radius of s block elements increases down the group due to the addition of a new electron shell after each period. The ionization energy decreases down the group since the atomic radius increases. This is because electrons in the outermost orbital are weakly attracted by the nucleus

Both melting point and boiling point decrease down the group as well. This is because the strength of the metallic bond decreases with the increase of atomic radius. Thus, metal atoms can easily be separated.

P Block Elements:

P block elements are elements having their valence electrons in their outermost p orbital. P subshell can hold up to 6 electrons. Therefore, the number of electrons in the outermost p orbital of p block elements can be 1, 2, 3, 4, 5, or 6. Their electron configuration always ends with p orbital (np).

5 B	6 C	7 N	8 O	9 F
13 Al	14 Si	15 P	16 S	17 Cl
31 Ga	32 Ge	33 As	34 Se	35 Br
49 In	50 Sn	51 Sb	52 Te	53 I
81 Tl	82 Pb	83 Bi	84 Po	85 At

Figure 16: P block elements

Most p block elements are nonmetals whereas few others are metalloids. From group 3 to group 8 includes p block elements except for Helium (Helium belongs to the s block as described above). The atomic radii of p block elements increase down a group and decrease along a period. The ionization energy decreases down the group and increases along the period. Electronegativity is also increased along the period. The most electronegative element is Fluorine which belongs to the p block.

Most p block elements show allotropy. Allotropy refers to different forms of molecular structures of the same element. The oxidation states of p block elements may vary depending on the number of valence electrons present in their atoms. Some elements may have only one oxidation state whereas other elements have several oxidation states.

Group 8 of the p block is composed of noble gases. These elements are inert gases and cannot undergo chemical reactions unless in extreme conditions. Noble gases

have the most stable electron configuration and their p orbitals are completely filled with electrons. Group 7 elements are called halogens. Almost all elements in the p block form covalent compounds and can also take part in ionic bonds.

Metalloids				
	13	14	15	16
2	B Boron	C Carbon	N Nitrogen	O Oxygen
3	Al Aluminium	Si Silicon	P Phosphorus	S Sulfur
4	Ga Gallium	Ge Germanium	As Arsenic	Se Selenium
5	In Indium	Sn Tin	Sb Antimony	Te Tellurium
6	Tl Thallium	Pb Lead	Bi Bismuth	Po Polonium
				At Astatine

Figure 17: Metalloids p block elements

A metalloid is a chemical element that exhibits some properties of metals and some of nonmetals. In the periodic table metalloids form a jagged zone dividing elements that have clear metallic properties from elements that have clear non-metallic properties.

Definition for metalloids: elements with properties intermediate between metals and nonmetals.

Boron, silicon, germanium, arsenic, antimony, tellurium, and polonium are metalloids. In some cases, authors may also class selenium, astatine, aluminum, and carbon as metalloids, but this is less common.

The reason for differences in classification is that no clear, unambiguous definition exists for metalloids. In the periodic table, the farther you look to the left or right of the metalloid dividing zone, the clearer the metallic or non-metallic properties become. The closer you get to the zone, the more blurred the properties become.

Table 4: Property wise comparison of S & P block elements:

S.no:	Properties	s block elements	p block elements
1	Valence electrons	Elements having their valence electrons in their outermost 's' orbital.	Elements having their valence electrons in their outermost 'p' orbital.
2	Oxidation states	elements can have 0, +1 or +2	elements show a number of oxidation states varying from -3, 0 to +5
3	Chemical bonding	form metallic bonds and ionic bonds.	form covalent bonds or ionic bonds
4	Metallic	elements are metals.	elements are nonmetals, others are metalloids.

	character		
5	Ionization energy	is comparatively less	decreases down the group and increases along the period.
6	Electronegativity	is comparatively less.	is comparatively high.

The most electronegative element is Fluorine which belongs to the p block.

Most of p block elements show allotropy. Allotropy refers to different forms of molecular structures of the same element.

HALOGENS: Group 7 elements are called halogens. Almost all elements in the p block form covalent compounds and can also take part in ionic bonds.

Noble gases:

Group 8 of the p block is composed of noble gases. These elements are inert gases and cannot undergo chemical reactions unless in extreme conditions. Noble gases have the most stable electron configuration and their p orbitals are completely filled with electrons.

The noble gases (Group 18) are located in the far right of the periodic table and were previously referred to as the "inert gases" due to the fact that their filled valence shells (octets) make them extremely nonreactive. The noble gases were characterized relatively late compared to other element groups. This family has the happiest elements of all.

Nitrogen (N_2) might be considered an inert gas, but it is not a noble gas. So noble gas is nothing but the non-reactivity.

Using the Bohr description of **electron shells**, happy atoms have full shells. All of the noble gases have full outer shells with eight electrons, other than helium.

All of the elements in Group Zero are noble gases. The list includes helium, neon (Ne), argon (Ar), krypton (Kr), xenon (Xe), and radon (Rn).

Don't think that, because these elements don't like to react, we don't use them. You will find noble gases all over our world.

The Electron Configurations for Noble Gases

- **Helium –** 2 ----- $1s^2$
- **Neon -** 10 ----- [He] $2s^2 2p^6$
- **Argon –** 18 ----- [Ne] $3s^2 3p^6$
- **Krypton –** 36 ----- [Ar] $3d^{10} 4s^2 4p^6$
- **Xenon –** 54 ----- [Kr] $4d^{10} 5s^2 5p^6$
- **Radon –** 86 ----- [Xe] $4f^{14} 5d^{10} 6s^2 6p^6$

Uses/ Applications of noble gases:

- Neon is used in advertising signs.

- Argon is used in light bulbs.
- Helium is used in balloons and to cool things.
- Xenon is used in headlights for new cars.

Because of their chemical properties, these gases are also used in the laboratory to help stabilize reactions that would usually proceed too quickly.

When you move down the periodic table, as the atomic numbers increase, the elements become rarer. They are not just rare in nature, but rare as useful elements, too.

Lanthanides and Actinides

We see some hidden "layers" in chemistry. As we look at the periodic table below, we see two pink boxes - one between Ba (element 56) and Hf (element 72) and the other between Ra (88) and Rf (104). These elements all have unfilled f-sublevels. Because of the uniqueness of the electron configurations, these elements fit into the two boxes in the larger periodic table.

As the number of electrons in an atom increases, we begin to see some strange behaviour. Due to the way the electron energy levels work, some inner levels fill after one or more outer layers do. We see this in two similar groups of elements - the **lanthanides** and the **actinides**.

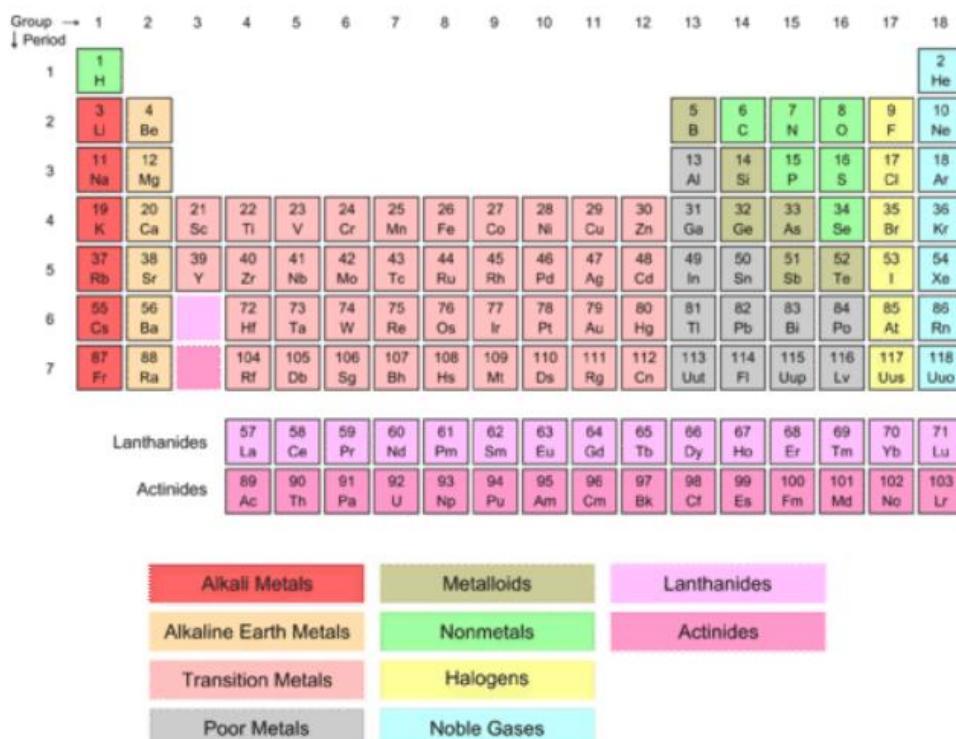


Figure 18: The lanthanides and actinides are displayed below the rest of the periodic table, but in reality belong in the middle of periods 6 and 7, respectively.

The first of the f sublevels to begin filling is the 4f sublevel. It fills after the 6s sublevel, meaning that f sublevels are two principal energy levels behind. The general electron configuration for elements in the **f-block** is $(n-2)f^{1-14}ns^2$. The seven orbitals of the f sublevel accommodate 14 electrons, so the f block is 14 elements in length. It is pulled out of the main body of the periodic table and is shown at the very bottom. Because of that, the elements of the f block do not belong to a group, being wedged in between Groups 3 and 4. The lanthanides are the 14 elements from cerium (atomic number 58) to lutetium (atomic number 71). The word comes from the Greek meaning "to be hidden". The name probably arose because these elements all hide behind one another in the periodic table. The 4f4f sublevel is in the process of being filled for the lanthanides. They are all metals and are similar in reactivity to the Group 2 alkaline earth metals.

The actinides are the 14 elements from thorium (atomic number 90) to lawrencium (atomic number 103). The 5f5f sublevel is in the process of being filled. The actinides are all radioactive elements and only the first four have been found naturally on Earth. All of the others have only been artificially made in the laboratory. The lanthanides and actinides together are sometimes called the inner transition elements.

Properties of Lanthanides and Actinides:

- Lanthanides have different chemistry from transition metals because their 4f orbitals are shielded from the atom's environment.
- Lanthanide contraction: The progressive decrease in the radii of atoms of the lanthanide elements as the atomic number increases; evident in various physical properties of the elements and their compounds.
- Lanthanide: Any of the 14 rare earth elements from lanthanum to lutetium in the periodic table. Because their outermost orbitals are empty, they have very similar chemistry. Below them are the actinides.
- Actinides are typical metals and have properties of both the d-block and the f-block elements, but they are also radioactive.
- Actinide: Any of the 14 radioactive elements of the periodic table that are positioned under the lanthanides, with which they share similar chemistry.

Elemental Properties

1. The chemistry of the lanthanides differs from main group elements and transition metals because of the nature of the 4f orbitals. These orbitals are "buried" inside the atom and are shielded from the atom's environment by the 4d and 5p electrons. As a consequence, the chemistry of the elements is largely

determined by their size, which decreases gradually with increasing atomic number. This phenomenon is known as the lanthanide contraction.

2. All the lanthanide elements exhibit the oxidation state +3.
3. Actinides are typical metals. All of them are soft, have a silvery color (but tarnish in air), and have relatively high density and plasticity. Some of them can be cut with a knife.
4. The hardness of thorium is similar to that of soft steel, so heated pure thorium can be rolled in sheets and pulled into wire. Thorium is nearly half as dense as uranium and plutonium but is harder than both of them.
5. Lanthanides, most elements of the actinide series have the same properties as the d block.
6. Members of the actinide series can lose multiple electrons to form a variety of different ions. All actinides are radioactive, paramagnetic, and with the exception of actinium, have several crystalline phases.
7. All actinides are pyrophoric, especially when finely divided (i.e., they spontaneously ignite upon exposure to air).
8. Like the lanthanides, all actinides are highly reactive with halogens and chalcogens; however, the actinides react more easily.

Uses of Lanthanides and Actinides:

- i. Lanthanides have been widely used as alloys to impart strength and hardness to metals. The main lanthanide used for this purpose is cerium, mixed with small amounts of lanthanum, neodymium, and praseodymium. These metals are also widely used in the petroleum industry for refining crude oil into gasoline products.
- ii. Oxides of Erbium and other lanthanides are widely used in some optical devices, such as night vision goggles, laser beams, and phosphorescent materials.
- iii. The actinides are valuable primarily because they are radioactive.
- iv. These elements can be used as energy sources for applications as varied as cardiac pacemakers and generation of electrical energy for instruments on the moon.
- v. Uranium and plutonium have been employed in nuclear weapons and in nuclear power plants.

Differences and Similarities between Lanthanides and Actinides

Lanthanides	Actinides
Rare-earth elements	Not rare-earth elements
Reasonably abundant in the surface of the earth	Synthesized in the laboratory (except uranium, thorium)
4f shell filled progressively	5f shell filled progressively.
Non-radioactive (except promethium)	Radioactive
Do not form oxocations	Form oxocation
Form compounds that are low in basicity	Form compounds that are high in basicity
Have a low tendency to form complexes with ligands	Have a high tendency to form complexes with ligands
Colorless	Most ions are colored
Display maximum oxidation state of +4	Display maximum oxidation states of +6

UNIT: II Introduction to organic chemistry:

Empirical and Molecular formula:

Empirical formula: A formula that gives the simplest whole-number ratio of atoms in a compound.

Steps for Determining an Empirical Formula:

Start with the number of grams of each element, given in the problem.

If percentages are given, assume that the total mass is 100 grams so that

the mass of each element = the percent given.

- Convert the mass of each element to moles using the molar mass from the periodic table.
- Divide each mole value by the smallest number of moles calculated.
- Round to the nearest whole number. This is the mole ratio of the elements and is represented by subscripts in the empirical formula.
- If the number is too far to round (x.1 ~ x.9), then multiply each solution by the same factor to get the lowest whole number multiple.
 - e.g. If one solution is 1.5, then multiply each solution in the problem by 2 to get 3.
 - e.g. If one solution is 1.25, then multiply each solution in the problem by 4 to get 5.
- Once the empirical formula is found, the molecular formula for a compound can be determined if the molar mass of the compound is known.
- Simply calculate the mass of the empirical formula and divide the molar mass of the compound by the mass of the empirical formula to find the ratio between the molecular formula and the empirical formula.
- Multiply all the atoms (subscripts) by this ratio to find the molecular formula.

Example Problem #1 A compound was analyzed and found to contain 13.5 g Ca, 10.8 g O, and 0.675 g H. What is the empirical formula of the compound?

Start with the number of grams of each element, given in the problem.

Given ↓
13.5 g Ca
10.8 g O
0.675 g H

Convert the mass of each element to moles using the molar mass from the periodic table.

Given ↓ P.T. ↓

$$13.5 \text{ g Ca} \times \frac{1 \text{ mol Ca}}{40.1 \text{ g Ca}} = 0.337 \text{ mol Ca}$$

$$10.8 \text{ g O} \times \frac{1 \text{ mol O}}{16.0 \text{ g O}} = 0.675 \text{ mol O}$$

$$0.675 \text{ g H} \times \frac{1 \text{ mol Ca}}{1.01 \text{ g H}} = 0.668 \text{ mol H}$$

Divide each mole value by the smallest number of moles calculated. Round to the nearest whole number.

Given ↓ P.T. ↓

$$13.5 \text{ g Ca} \times \frac{1 \text{ mol Ca}}{40.1 \text{ g Ca}} = \frac{0.337}{0.337} \text{ mol Ca} \Rightarrow 1.00$$

$$10.8 \text{ g O} \times \frac{1 \text{ mol O}}{16.0 \text{ g O}} = \frac{0.675}{0.337} \text{ mol O} \Rightarrow 2.00$$

$$0.675 \text{ g H} \times \frac{1 \text{ mol Ca}}{1.01 \text{ g H}} = \frac{0.668}{0.337} \text{ mol H} \Rightarrow 1.98 \approx 2.00$$

This is the mole ratio of the elements and is represented by subscripts in the empirical formula.

From the mole ration, the empirical formula is



Example Problem #2

NutraSweet is 57.14% C, 6.16% H, 9.52% N, and 27.18% O. Calculate the empirical formula of NutraSweet and find the molecular formula. (The molar mass of NutraSweet is 294.30 g/mol)

Start with the number of grams of each element, given in the problem.

If percentages are given, assume that the total mass is 100 grams so that the mass of each element = the percent given.

Given ↓

57.14 g C

6.16 g H

9.52 g N

27.18 g O

Convert the mass of each element to moles using the molar mass from the periodic table.

Given ↓ P.T. ↓

$$57.14 \text{ g C} \times \frac{1 \text{ mol C}}{12.0 \text{ g C}} = 4.76 \text{ mol C}$$

$$6.16 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 6.10 \text{ mol H}$$

$$9.52 \text{ g N} \times \frac{1 \text{ mol N}}{14.0 \text{ g N}} = 0.68 \text{ mol N}$$

$$27.18 \text{ g O} \times \frac{1 \text{ mol O}}{16.0 \text{ g O}} = 1.70 \text{ mol O}$$

Divide each mole value by the smallest number of moles calculated. Round to the nearest whole number.

Given ↓ P.T. ↓

$$57.14 \text{ g C} \times \frac{1 \text{ mol C}}{12.0 \text{ g C}} = \frac{4.76}{0.68} \text{ mol C} \Rightarrow 7$$

$$6.16 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = \frac{6.10}{0.68} \text{ mol H} \Rightarrow 8.97 \approx 9$$

$$9.52 \text{ g N} \times \frac{1 \text{ mol N}}{14.0 \text{ g N}} = \frac{0.68}{0.68} \text{ mol N} \Rightarrow 1$$

$$27.18 \text{ g O} \times \frac{1 \text{ mol O}}{16.0 \text{ g O}} = \frac{1.70}{0.68} \text{ mol O} \Rightarrow 2.5$$

This is the mole ratio of the elements and is represented by subscripts in the empirical formula.

If the number is too far to round (x.1 ~ x.9), then multiply each solution by the same factor to get the lowest whole number multiple.

Given ↓ P.T. ↓

$$57.14 \text{ g C} \times \frac{1 \text{ mol C}}{12.0 \text{ g C}} = \frac{4.76}{0.68} \text{ mol C} \Rightarrow 7(2) = 14$$

$$6.16 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = \frac{6.10}{0.68} \text{ mol H} \Rightarrow 8.97 \approx 9(2) = 18$$

$$9.52 \text{ g N} \times \frac{1 \text{ mol N}}{14.0 \text{ g N}} = \frac{0.68}{0.68} \text{ mol N} \Rightarrow 1(2) = 2$$

$$27.18 \text{ g O} \times \frac{1 \text{ mol O}}{16.0 \text{ g O}} = \frac{1.70}{0.68} \text{ mol O} \Rightarrow 2.5(2) = 5$$

Too far to round, multiply to get a whole number

Empirical Formula is : $C_{14}H_{18}N_2O_5$

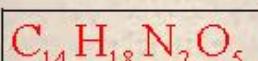
Now, we can find the molecular formula by finding the mass of the empirical formula and setting up a ratio:

$$C_{14}H_{18}N_2O_5 = 14(12.0\text{g}) + 18(1.01\text{g}) + 2(14.0\text{g}) + 5(16.0\text{g}) = 294 \text{ g/mol}$$

from P.T. → C H N O

$$\frac{\text{molar mass}}{\text{empirical formula}} = \frac{294.30 \text{ g/mol}}{294 \text{ g/mol}} \approx 1$$

So the empirical formula is the molecular formula



Problem: 3 Calculate the empirical formula of a compound that contains 36.8% nitrogen and 63.25% oxygen

Solution:

1. Assume that you have 100 g of the compound, which will contain 36.8 g nitrogen and 63.25 g oxygen.

2. Convert these weights to moles.

$$? \text{ mol N} = 36.8 \text{ g N} \times \frac{1 \text{ mol N}}{14.0 \text{ g N}} = 2.63 \text{ mol N}$$

$$? \text{ mol O} = 63.25 \text{ g O} \times \frac{1 \text{ mol O}}{16.0 \text{ g O}} = 3.95 \text{ mol O}$$

This calculation gives the formula: $N_{2.63}O_{3.95}$

3. Change this ratio to whole numbers:

$$N_{2.63}O_{3.95}^{2.63} = NO_{1.5}$$

But the ratio is not yet whole numbers as wanted. If each subscript is multiplied by 2, the subscripts then become whole numbers giving N_2O_3 , this is the correct empirical formula for the compound.

Problem 4: Analysis of 3.23 g of a compound shows that it contains 0.728 g of phosphorus and 2.50 g chlorine. What is the empirical formula of the compound?

Solution:

1. Calculate the number of moles of each element in 3.23 g of the compound.

2. Convert these weights to moles.

phosphorus $0.728 \text{ g P} \times \frac{1 \text{ mol P}}{30.97 \text{ g P}} = 0.0235 \text{ mol P}$

chlorine $2.50 \text{ g Cl} \times \frac{1 \text{ mol Cl}}{35.45 \text{ g Cl}} = 0.0705 \text{ mol Cl}$

This calculation gives the formula: $\text{P}_{0.0235}\text{Cl}_{0.0705}$

3. Change this ratio to whole numbers:

$$\text{P}_{0.0235}/0.0235 \text{ O}_{0.0705}/0.0235 = \text{PCl}_3$$

The percentage composition of chloroform is 10.06% carbon, 0.85% hydrogen, and 89.09% chlorine. We know then that 100 g chloroform contain 10.06 g carbon, 0.85 g hydrogen, and 89.09 g chlorine. This weight relationship can be converted to a mole ratio by the following calculations:

<p>carbon $10.06 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 0.8376 \text{ mol C}$</p> <p>hydrogen $0.85 \text{ g H} \times \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 0.84 \text{ mol H}$</p> <p>chlorine $89.09 \text{ g Cl} \times \frac{1 \text{ mol Cl}}{35.45 \text{ g Cl}} = 2.513 \text{ mol Cl}$</p>

These calculations show that the mole ratio between the elements in chloroform is 0.84 mol C to 0.84 mol H to 2.51 mol Cl. This ratio can be expressed by the formula:

$$\text{C}_{0.8376}\text{H}_{0.84}\text{Cl}_{2.513}$$

However, formulas by definition can contain only whole numbers of atoms. The ratio can be changed to whole numbers by dividing each subscript by the smallest subscript, giving the formula of chloroform as:

$$\text{C}_{0.8376/0.8376}\text{H}_{0.84/0.8376}\text{Cl}_{2.513/0.8376} \text{ or } \text{CHCl}_3$$

PRACTICE:

- In chemistry, the empirical formula of a chemical is a simple expression of the relative number of each type of atom or ratio of the elements in the compound.
- Empirical formulae are the standard for ionic compounds, such as CaCl_2 , and for macromolecules, such as SiO_2 .

- An empirical formula makes no reference to isomerism, structure, or absolute number of atoms.
- The term *empirical* refers to the process of elemental analysis, a technique of analytical chemistry used to determine the relative percent composition of a pure chemical substance by element.

For example,

- ❖ Hexane has a molecular formula of C_6H_{14} , or structurally $CH_3CH_2CH_2CH_2CH_2CH_3$, implying that it has a chain structure of 6 carbon atoms, and 14 hydrogen atoms. However, the empirical formula for hexane is C_3H_7 .
- ❖ Likewise the empirical formula for hydrogen peroxide, H_2O_2 , is simply HO expressing the 1:1 ratio of component elements.
- ❖ Formaldehyde and acetic acid have the same empirical formula, CH_2O . This is the actual chemical formula for formaldehyde, but acetic acid has double the number of atoms.

Molecular Formula:

Molecular formulae indicate the simple numbers of each type of atom in a molecule of a molecular substance.

They are the same as empirical formulae for molecules that only have one atom of a particular type, but otherwise may have larger numbers.

An example of the difference is the empirical formula for glucose, which is CH_2O (*ratio* 1:2:1), while its molecular formula is $C_6H_{12}O_6$ (*number of atoms* 6:12:6).

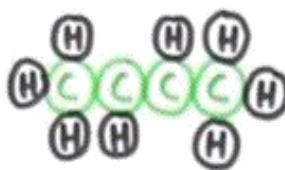
For water, both formulae are H_2O .

A molecular formula provides more information about a molecule than its empirical formula, but is more difficult to establish.

A molecular formula shows the number of elements in a molecule, and determines whether it is a **binary compound**, **ternary compound**, **quaternary compound**, or has even more elements.

molecular formula
"regular formula"

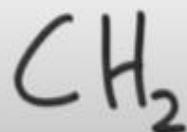
How many atoms of each element are in a compound.



empirical formula

The simplest or most reduced ratio of atoms in a compound.

$$\frac{4 \text{ Carbon}}{8 \text{ Hydrogen}} \div 4 = \frac{1 \text{ Carbon}}{2 \text{ Hydrogen}}$$



Classification of Aliphatic and Aromatic compounds:

In organic chemistry, compounds are composed of carbon and hydrogen. These compounds are called hydrocarbons. These are divided into two classes: aromatic compounds and aliphatic compounds. Aliphatic compounds are also known as non-aromatic compounds. Aliphatic compound can be cyclic or not, but only aromatic compounds contain a stable ring of atoms, such as benzene. Open-chain compounds are either straight or branched. They contain no rings of any type, and are thus called aliphatic.

Open-chain compounds are either straight or branched. They contain no rings of any type, and are thus called aliphatic.

Aliphatic compounds can be saturated or unsaturated.

Saturated compounds are made up of single bond only while unsaturated compounds are with double bonds (alkenes) or triple bonds (alkynes).

Besides hydrogen, other elements can be bound to the carbon chain are oxygen, nitrogen, sulphur, and chlorine.

An aliphatic compound alkane is primarily characterized by the fact that all of the carbon carbon bonds that make up the skeleton of the molecule are single bonds.

Compounds with double bonds and triple bonds between carbon atoms are alkenes and alkynes respectively. Ring system is also possible in aliphatic compounds, e.g. cyclohexane, but no double bonds in cyclic aliphatic compounds.

Naming of aliphatic compounds:

- Basic units of the aliphatic compounds are alkanes,
- The presence of carbon atoms the naming was mentioned.
- The names of all alkanes end with *-ane*.
- Whether or not the carbons are linked together end-to-end in a ring (called *cyclic alkanes* or *cycloalkanes*)
- whether they contain side chains and branches, the name of every carbon-hydrogen chain that lacks any double bonds or functional groups will end with the suffix *-ane*.
- Alkanes with unbranched carbon chains are simply named by the number of carbons in the chain.
- The first four members of the series (in terms of number of carbon atoms) are named as follows:

CH_4 = **methane** = one hydrogen-saturated carbon

C_2H_6 = **ethane** = two hydrogen-saturated carbons

C_3H_8 = **propane** = three hydrogen-saturated carbons

C_4H_{10} = **butane** = four hydrogen-saturated carbons

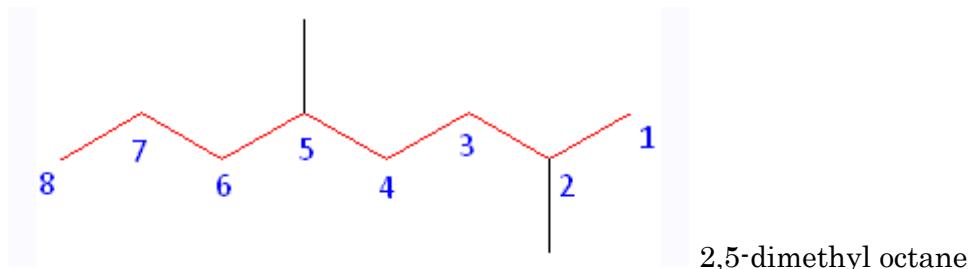
C_5H_{12} - pentane; C_6H_{14} – hexane; C_7H_{16} – heptane; C_8H_{18} – octane;

C_9H_{20} – nonane; $\text{C}_{10}\text{H}_{22}$ – decane

$\text{C}_{11}\text{H}_{24}$ – Undecane; $\text{C}_{12}\text{H}_{26}$ – Dodecane $\text{C}_{20}\text{H}_{42}$ - Eicosane

Three Principles of Naming

1. Choose the longest, most substituted carbon chain containing a functional group.
2. A carbon bonded to a functional group must have the lowest possible carbon number. If there are no functional groups, then any substitute present must have the lowest possible number.
3. Take the alphabetical order into consideration; that is, after applying the first two rules given above, make sure that your substitutes and/or functional groups are written in alphabetical order.



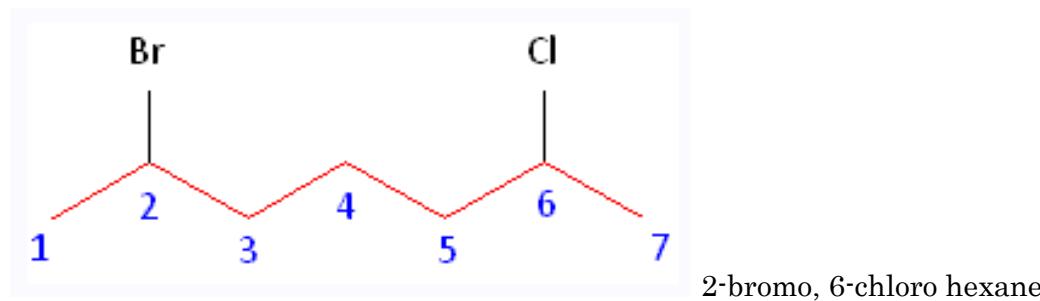


Figure 19: Hexane is an example of saturated aliphatic compound since it only contains carbon–carbon single bonds

Aliphatic compounds don't have to be made of only carbon and hydrogen like hexane. They can also contain atoms like oxygen, nitrogen etc. Isopropanol is an example of compound which contains an alcoholic (OH) group bonded to an aliphatic carbon chain.



Figure 20: Isopropanol is an example of an aliphatic alcohol

The least complex aliphatic compound is methane (CH_4). In organic chemistry, aromaticity is used to describe a cyclic (ring-shaped), planar (flat) molecule with a ring of resonance bonds that exhibits more stability than other geometric or connective arrangements with the same set of atoms. Aromatic molecules are very stable, and do not break apart easily to react with other substances. Organic compounds that are not aromatic are classified as aliphatic compounds—they might be cyclic, but only aromatic rings have special stability (low reactivity).

Aromatic compounds are similar to aliphatic compounds because they both are made of carbon. However, they are also very different from one another in other ways. An aromatic organic compound is characterized by the fact that they contain both a ring structure and a network of alternating double-single-double-single bonds all around the ring. The most common example of an aromatic compound is benzene.

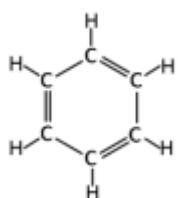


Figure 21: Benzene is an example of an aromatic compound because of its ring and alternating double and single bonds.

The most common aromatic compounds are derivatives of benzene (an aromatic hydrocarbon common in petroleum and its distillates), so very first it was considered that the word aromatic means the benzene derivatives. Many

non-benzene aromatic compounds also exist. For example, in living organisms, the most common aromatic rings are the double-ringed bases in RNA and DNA. An aromatic functional group or other substituent is called an aryl group.

Properties of Aliphatic Compounds:

Most aliphatic compounds are flammable. They allow the use of hydrocarbons as fuel, such as methane in Bunsen burners and as liquefied natural gas (LNG), and acetylene in welding.

Properties of Aromatic Hydrocarbons:

The major sources of Aromatic Hydrocarbons are Petroleum and coal. They are well known for their exceptional physical and chemical properties.

- Polyaromatic hydrocarbons are defined as aromatic compounds composed of more than one benzene ring. When they include in atmospheric pollution then it is known as carcinogenic in nature.
- Aromatic compounds also include amino acids and precursors to nucleotides. Compounds which are soluble in water they are known as non-polar hydrocarbons. These hydrocarbons cannot form ions or Hydrogen bonds with water molecules. They are usually unreactive because of extra stability and for many organic and inorganic reactions it is widely used as an inert solvent.
- The ratio for carbon-hydrogen is high. They are born with sooty yellow flame because of the presence of high carbon content.
- They go through electrophilic substitution reactions and nucleophile aromatic substitution.
- Hydrocarbons which have multiple bonds are unsaturated in nature like alkenes and alkynes. They tend to give addition reactions due to this unsaturation.
- Due to resonance and give characteristic electrophilic substitution reactions aromatic hydrocarbons are stable. The carbon ring acts as a nucleophile in these reactions and to form a substituted product an electrophile attack on benzene.
- With the coming electrophile, one of the H-atom of a ring is substituted because of this the product also holds its stability and aromatic in nature. • In the addition reactions, aromatic compound may lose their aromaticity so they do not prefer to give such reactions.

Types: Aromatic compounds are always cyclic as it contains the benzene ring as part of its structure while aliphatic compounds can be linear as well as cyclic. The majority of aromatic compounds are compounds of carbon, but they need not be hydrocarbons.

IUPAC Nomenclature of organic compounds:

How to name organic compounds using the IUPAC rules:

In order to name organic compounds you must first memorize a few basic names. These names are listed within the discussion of naming alkanes. In general, the base part of the name reflects the number of carbons in what you have assigned to be the parent chain. The suffix of the name reflects the type(s) of functional group(s) present on (or within) the parent chain. Other groups which are attached to the parent chain are called substituents.

Alkanes - saturated hydrocarbons: The names of the straight chain saturated hydrocarbons for up to a 12 carbon chain are shown below. The names of the substituents formed by the removal of one hydrogen from the end of the chain are obtained by changing the suffix **-ane** to **-yl**.

Table 5. Numerical naming of hydrocarbon

Number of Carbons	Name
1	methane
2	ethane
3	propane
4	butane
5	pentane
6	hexane
7	heptane
8	octane
9	nonane
10	decane
11	undecane
12	dodecane

There are a few common branched substituents which you should memorize. These are shown below.

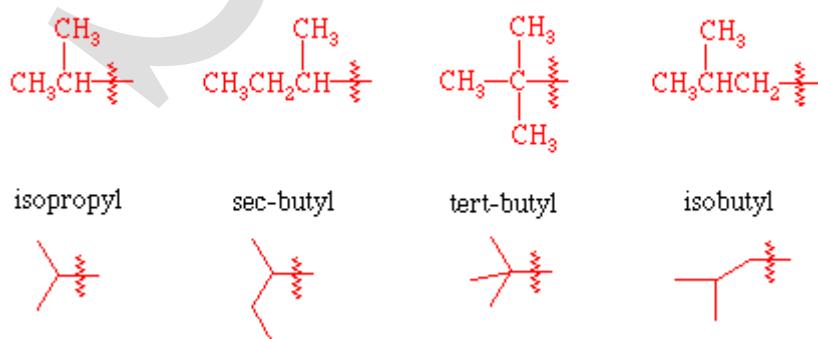
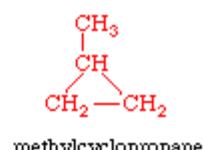
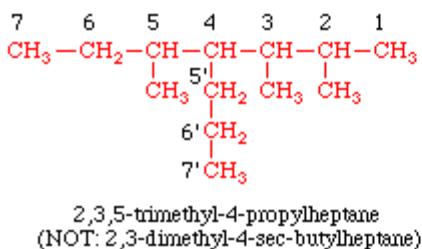
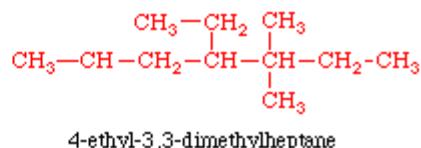
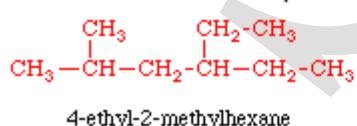


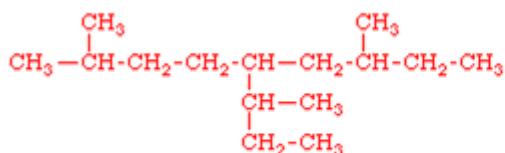
Figure 22. Naming of branched Chains

Here is a simple list of rules to follow. Some examples are given at the end of the list.

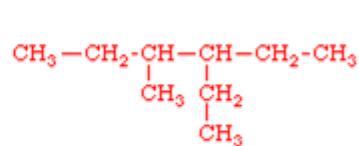
1. Identify the longest carbon chain. This chain is called the parent chain.
2. Identify all of the substituents (groups appending from the parent chain).
3. Number the carbons of the parent chain from the end that gives the substituents the lowest numbers. When comparing a series of numbers, the series that is the "lowest" is the one which contains the lowest number at the occasion of the first difference. If two or more side chains are in equivalent positions, assign the lowest number to the one which will come first in the name.
4. If the same substituent occurs more than once, the location of each point on which the substituent occurs is given. In addition, the number of times the substituent group occurs is indicated by a prefix (di, tri, tetra, etc.).
5. If there are two or more different substituents they are listed in alphabetical order using the base name (ignore the prefixes). The only prefix which **is** used when putting the substituents in alphabetical order is **iso** as in isopropyl or isobutyl. The prefixes sec- and tert- are not used in determining alphabetical order except when compared with each other.
6. If chains of equal length are competing for selection as the parent chain, then the choice goes in series to: a) the chain which has the greatest number of side chains. b) the chain whose substituents have the lowest-numbers. c) the chain having the greatest number of carbon atoms in the smaller side chain. d) the chain having the least branched side chains.
7. A cyclic (ring) hydrocarbon is designated by the prefix **cyclo-** which appears directly in front of the base name.

Here are some examples:





5-sec-butyl-2,7-dimethylnonane



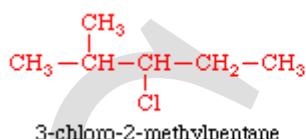
3-ethyl-4-methylhexane

Alkyl halides

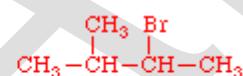
The halogen is treated as a substituent on an alkane chain. The halo-substituent is considered of equal rank with an alkyl substituent in the numbering of the parent chain. The halogens are represented as follows:

F	fluoro-
Cl	chloro-
Br	bromo-
I	iodo-

Here are some examples:



3-chloro-2-methylpentane



2-bromo-3-methylbutane

Alkenes and Alkynes - unsaturated hydrocarbons Double bonds in hydrocarbons are indicated by replacing the suffix **-ane** with **-ene**. If there is more than one double bond, the suffix is expanded to include a prefix that indicates the number of double bonds present (**-adiene**, **-atriene**, etc.). Triple bonds are named in a similar way using the suffix **-yne**. The position of the multiple bond(s) within the parent chain is (are) indicated by placing the number(s) of the first carbon of the multiple bond(s) directly in front of the base name.

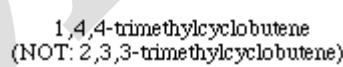
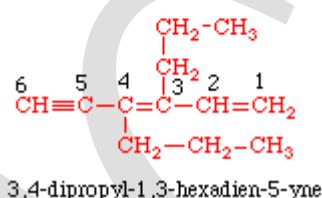
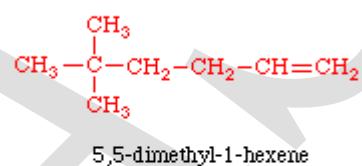
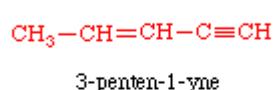
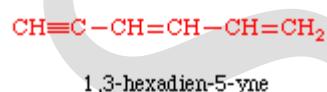
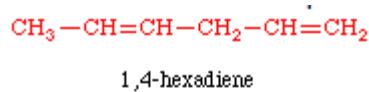
Here is an important list of rules to follow:

1. The parent chain is numbered so that the multiple bonds have the lowest numbers (double and triple bonds have priority over alkyl and halo substituents).
2. When both double and triple bonds are present, numbers as low as possible are given to double and triple bonds even though this may at times give "**-yne**" a lower number than "**-ene**". When there is a choice in numbering, the double bonds are given the lowest numbers.
3. When both double and triple bonds are present, the **-en** suffix follows the parent chain directly and the **-yne** suffix follows the **-en** suffix (notice that the **e** is left off, **-en** instead of **-ene**). The location of the double bond(s) is(are) indicated before the parent name as before, and the

location of the triple bond(s) is(are) indicated between the -en and -yne suffixes. See below for examples.

4. For a branched unsaturated acyclic hydrocarbon, the parent chain is the longest carbon chain that contains the **maximum number of double and triple bonds**. If there are two or more chains competing for selection as the parent chain (chain with the most multiple bonds), the choice goes to (1) the chain with the greatest number of carbon atoms, (2) the # of carbon atoms being equal, the chain containing the maximum number of double bonds.
5. If there is a choice in numbering not previously covered, the parent chain is numbered to give the substituents the **lowest number at the first point of difference**.

Here are some examples:



Alcohols:

Alcohols are named by replacing the suffix -ane with -anol. If there is more than one hydroxyl group (-OH), the suffix is expanded to include a prefix that indicates the number of hydroxyl groups present (-anediol, -anetriol, etc.). The position of the hydroxyl group(s) on the parent chain is(are) indicated by placing the number(s) corresponding to the location(s) on the parent chain directly in front of the base name (same as alkenes).

Here is an important list of rules to follow:

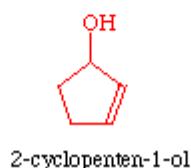
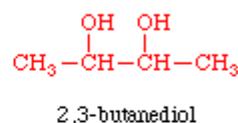
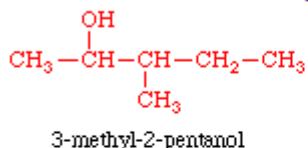
- 1 The hydroxyl group takes precedence over alkyl groups and halogen substituents, as well as double bonds, in the numbering of the parent chain.
- 2 When both double bonds and hydroxyl groups are present, the -en suffix follows the parent chain directly and the -ol suffix follows the -en suffix (notice that the e is left off, -en instead of -ene). The location of the double bond(s) is(are) indicated before the parent name as before, and the location of the hydroxyl group(s) is(are) indicated between the -en

and -ol suffixes. See below for examples. Again, the hydroxyl gets priority in the numbering of the parent chain.

- If there is a choice in numbering not previously covered, the parent chain is numbered to give the substituents the lowest number at the first point of difference.

Here are some examples:

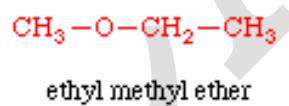
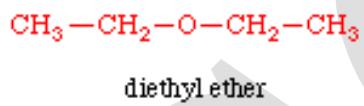
Here are some examples:



Ethers:

You are only expected to know how to name ethers by their common names. The two alkyl groups attached to the oxygen are put in alphabetical order with spaces between the names and they are followed by the word ether. The prefix di- is used if both alkyl groups are the same.

Here are some examples:



Aldehydes

Aldehydes are named by replacing the suffix **-ane** with **-anal**. If there is more than one -CHO group, the suffix is expanded to include a prefix that indicates the number of -CHO groups present (**-anedral** - there should not be more than 2 of these groups on the parent chain as they must occur at the ends). It is not necessary to indicate the position of the -CHO group because this group will be at the end of the parent chain and its carbon is automatically assigned as C-1.

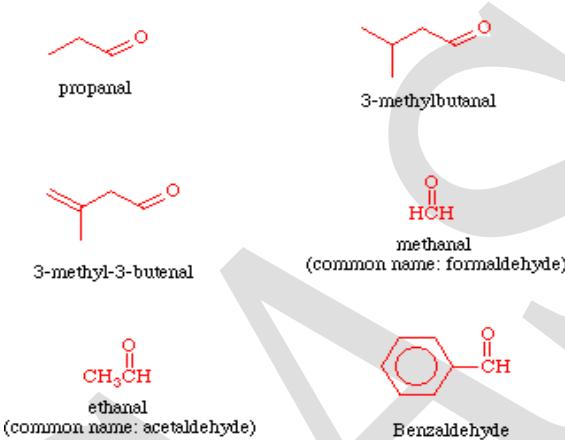
Here is an important list of rules to follow:

- The carbonyl group takes precedence over alkyl groups and halogen substituents, as well as double bonds, in the numbering of the parent chain.
- When both double bonds and carbonyl groups are present, the -en suffix follows the parent chain directly and the -al suffix follows the -en suffix (notice that the e is left off, **-en** instead of **-ene**). The location of the double bond(s) is(are) indicated before the parent name as before, and the -al suffix follows the -en suffix directly. Remember it is not necessary to specify the location of the carbonyl group because it will automatically be carbon #1.

See below for examples. Again, the carbonyl gets priority in the numbering of the parent chain.

3. There are a couple of common names which are acceptable as IUPAC names. They are shown in the examples at the end of this list but at this point these names will not be accepted by the computer. Eventually they will be accepted.
4. If there is a choice in numbering not previously covered, the parent chain is numbered to give the substituents the **lowest** number at the **first point of difference**.

Here are some examples:



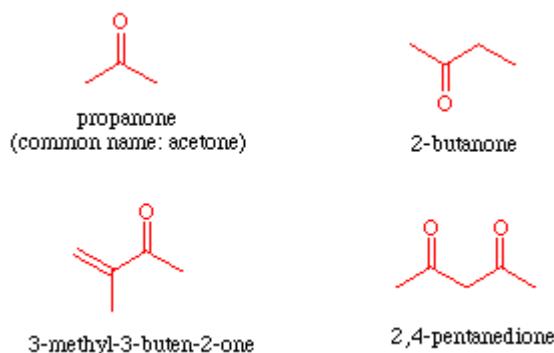
Ketones:

Ketones are named by replacing the suffix **-ane** with **-anone**. If there is more than one carbonyl group ($\text{C}=\text{O}$), the suffix is expanded to include a prefix that indicates the number of carbonyl groups present (**-anedione**, **-anetrione**, etc.). The position of the carbonyl group(s) on the parent chain is (are) indicated by placing the number(s) corresponding to the location(s) on the parent chain directly in front of the base name (same as alkenes).

Here is an important list of rules to follow:

1. The carbonyl group takes precedence over alkyl groups and halogen substituents, as well as double bonds, in the numbering of the parent chain.
2. When both double bonds and carbonyl groups are present, the **-en** suffix follows the parent chain directly and the **-one** suffix follows the **-en** suffix (notice that the **e** is left off, **-en** instead of **-ene**). The location of the double bond(s) is(are) indicated before the parent name as before, and the location of the carbonyl group(s) is(are) indicated between the **-en** and **-one** suffixes. See below for examples. Again, the carbonyl gets priority in the numbering of the parent chain.
3. If there is a choice in numbering not previously covered, the parent chain is numbered to give the substituents the **lowest** number at the **first point of difference**.

Here are some examples:



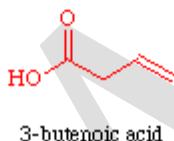
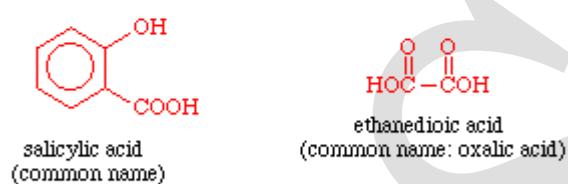
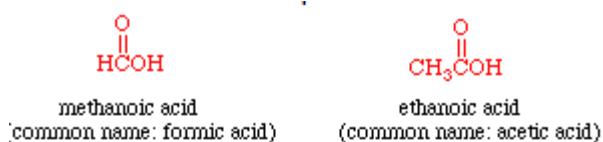
Carboxylic Acids:

Carboxylic acids are named by counting the number of carbons in the longest continuous chain including the carboxyl group and by replacing the suffix **-ane** of the corresponding alkane with **-anoic acid**. If there are two -COOH groups, the suffix is expanded to include a prefix that indicates the number of -COOH groups present (**-anedioic acid** - there should not be more than 2 of these groups on the parent chain as they must occur at the ends). It is not necessary to indicate the position of the -COOH group because this group will be at the end of the parent chain and its carbon is automatically assigned as C-1.

Here is an important list of rules to follow:

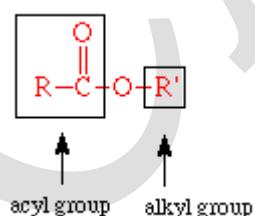
1. The carboxyl group takes precedence over alkyl groups and halogen substituents, as well as double bonds, in the numbering of the parent chain.
2. If the carboxyl group is attached to a ring the parent ring is named and the suffix -carboxylic acid is added.
3. When both double bonds and carboxyl groups are present, the -en suffix follows the parent chain directly and the -oic acid suffix follows the -en suffix (notice that the e is left off, **-en** instead of -ene). The location of the double bond(s) is(are) indicated before the parent name as before, and the -oic acid suffix follows the -en suffix directly. Remember it is not necessary to specify the location of the carboxyl group because it will automatically be carbon #1. See below for examples. Again, the carboxyl gets priority in the numbering of the parent chain.
4. There are several common names which are acceptable as IUPAC names. They are shown in the examples at the end of this list **but** at this point these names will **not** be accepted by the computer. Eventually they will be accepted.
5. If there is a choice in numbering not previously covered, the parent chain is numbered to give the substituents the **lowest** number at the **first point of difference**.

Here are some examples:



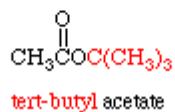
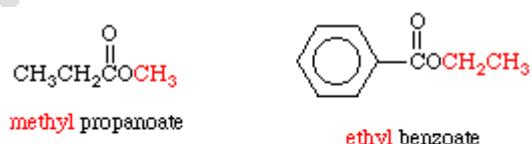
Esters:

Systematic names of esters are based on the name of the corresponding carboxylic acid. Remember esters look like this:



The alkyl group is named like a substituent using the **-yl** ending. This is followed by a space. The acyl portion of the name (what is left over) is named by replacing the **-ic acid** suffix of the corresponding carboxylic acid with **-ate**.

Here are some examples:

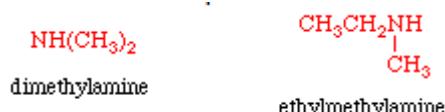


Nitro Compounds:

Amines:

You are only expected to know how to name amines by their common names . They are named like ethers, the alkyl (R) groups attached to the nitrogen are put in alphabetical order with no spaces between the names and these are followed by the word amine. The prefixes di- and tri- are used if two or three of the alkyl groups are the same.
NOTE: Some books put spaces between the parts of the name, but we will not. Follow the examples.

Here are some examples:



Summary of functional groups:

Functional group	Prefix	Suffix
carboxylic acids	none	-oic acid
aldehydes	none	-al
ketones	none	-one
alcohols	hydroxy-	-ol
amines	amino-	-amine
ethers	alkoxy-	-ether
fluorine	fluoro-	none
chlorine	chloro-	none
bromine	bromo-	none
iodine	iodo-	none

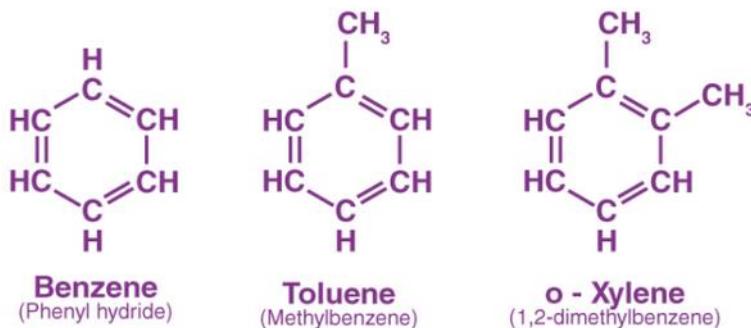
What are Aromatic Hydrocarbons?

Aromatic Hydrocarbons are circularly structured organic compounds that contain sigma bonds along with delocalized pi electrons. They are also referred to as arenes or aryl hydrocarbons.

Aromatic Hydrocarbons Explanation

The aromatic hydrocarbons are “*unsaturated hydrocarbons which have one or more planar six-carbon rings called benzene rings, to which hydrogen atoms are attached*”. Many aromatic hydrocarbons contain a benzene ring (also referred to as an aromatic ring). The benzene ring is stabilized by resonance and the pi electrons are delocalized in the ring structure.

A few examples of aromatic hydrocarbons are provided below. It can be observed that all these compounds contain a benzene ring.



Examples of aromatic hydrocarbons

The aromatic hydrocarbons which do not contain a benzene ring are commonly referred to as heteroarenes. All of these heteroarenes obey Huckel's rule (total number of pi electrons in a monocyclic ring = $4n + 2$ where n is any positive integer or zero).

In these types of compounds, a minimum of one carbon is replaced by either nitrogen, oxygen, or sulphur. Common examples of heteroarenes include furan (contains oxygen) and pyridine (contains nitrogen).

Properties of Aromatic Hydrocarbons

"The first compound that was categorized as an aromatic hydrocarbon was benzene".

It is also the most complex aryl hydrocarbon. Each carbon atom belonging to the benzene ring has two carbon-carbon sigma bonds, one carbon-hydrogen sigma bond, and one double bond with a neighbouring carbon in which the pi electron is delocalized.

This delocalization of pi electrons in the benzene molecule is represented by a circle inside the hexagon. The bond order of all carbon-carbon bonds in this molecule is considered to be 1.5 and this equivalency can be explained with the help of the resonance structures of benzene.

Some general properties of aromatic hydrocarbons have been listed below.

- These compounds exhibit **aromaticity** (additional stability granted by resonance)
- The ratio of carbon atoms to hydrogen atoms is relatively high in these types of molecules.
- When burnt, the aromatic hydrocarbons display a strong and sooty flame which is yellow.
- These compounds generally **undergo electrophilic substitutions and nucleophilic aromatic substitution reactions**.

It can be noted that these compounds can be either monocyclic or polycyclic.

Uses of Aromatic Hydrocarbons

The use of aromatic hydrocarbons is common in both biological and synthetic processes. Some numerous uses of aromatic hydrocarbons are listed below.

- The **green pigment found in plants, more commonly known as chlorophyll, consists of aromatic hydrocarbons** and is very important in the process of food production in plants.

- The nucleic acids and amino acids in the human body also consist of these aromatic hydrocarbons.
- Methylbenzene which is an aromatic hydrocarbon is used as a solvent in model glues
- Naphthalene is an important item in the production of mothballs
- For the synthesis of drugs, dyes, and explosives, an aryl hydrocarbon known as Phenanthrene is used
- Trinitrotoluene or TNT** is a very important aromatic hydrocarbon which is widely used for **explosive purposes**.
- Plastic industry and petrochemical industries make use of aromatic hydrocarbons extensively.

Aromatic Amines

An **aromatic amine** is an organic compound consisting of an aromatic ring attached to an amine. It is a broad class of compounds that encompasses anilines, but also many more complex aromatic rings and many amine substituents beyond NH₂. Such compounds occur widely

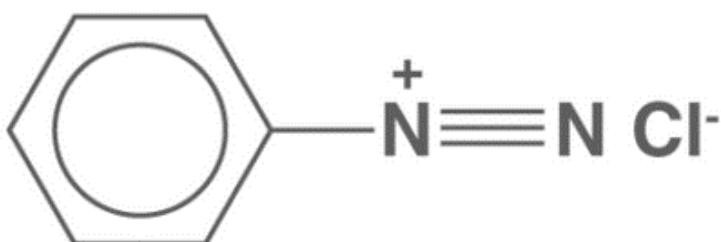
Representative aromatic amines		
Aromatic ring	Name of parent amines	Example
benzene	aniline	substituted anilines
benzene	phenylenediamines	the antioxidant p-phenylenediamine
toluene	toluidines	the pharmaceutical prilocain
toluene	diaminotoluenes	the hair dye ingredient 2,5-diaminotoluene
naphthalene	naphthylamines	the dyes Congo red and Prodan
pyridine	aminopyridines	the drug tenoxicam

Aromatic amines are widely used as precursor to pesticides, pharmaceuticals, and dyes.

Diazonium Salts

The diazonium salts (**di** refers to ‘two’, **azo** is indicative of ‘nitrogen’ and **ium** implies that it is **cationic** in nature), or diazonium compounds.

The class of organic compounds with general formula R—N₂⁺X[−] where X is an organic or inorganic anion (for example, Cl[−], Br[−], BF₄[−], etc.) and R is an alkyl or aryl group.



Benzenediazonium Chloride – A Diazonium Salt

Hence, they have two nitrogen atoms with one being charged. Benzenediazonium chloride ($C_6H_5N_2^+Cl^-$), benzene diazonium hydrogen sulfate ($C_6H_5N_2^+HSO_4^-$), etc. are some examples of the diazonium salt.

- Diazonium salts are one of the most versatile combinations of organic and inorganic components. Its general way of representation is $R-N_2^+X^-$. The R is an organic group, generally an aryl group while X represents ion.
- Generally, diazonium salts have Cl^- , Br^- , BF_4^- , as X. The name of these salts is based on the presence of the N_2^+ group or the diazonium group.
- The naming of these salts is done by adding the suffix diazonium to the parent hydrocarbon from which they are derived and then it is followed by the anion X such as bromide.

The importance of these compounds lies in their application and uses.

- They find application in the dye and pigment industries and are used to produce dyed fabrics.
- Due to their property of breaking down near the ultraviolet light, they are used in document reproduction
- They are useful in the synthesis of a large variety of organic compounds, especially aryl derivatives.

Phenyl Hydrazine:

Phenylhydrazine is the chemical compound with the formula $C_6H_5NHNH_2$. It is often abbreviated as $PhNHNH_2$. It is also found in edible mushrooms.

Phenylhydrazine forms monoclinic prisms that melt to an oil around room temperature which may turn yellow to dark red upon exposure to air. Phenylhydrazine is miscible with ethanol, diethyl ether, chloroform and benzene. It is sparingly soluble in water.

Sulfonic Acid

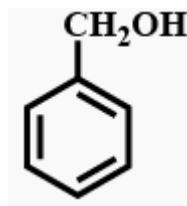
Sulfonic acid, sulfonic also spelled sulphonic, any of a class of organic acids containing sulfur and having the general formula RSO_3H , in which R is an organic combining group. The sulfonic acids are among the most important of the organosulfur compounds; the free acids are widely used as catalysts in organic syntheses, while the salts and other derivatives form the basis of the manufacture of detergents, water-soluble dyes and catalysts, sulfonamide pharmaceuticals, and ion-exchange resins.

Aromatic sulfonic acids are particularly useful as intermediates or starting materials in synthesis—for example, in the preparation of phenols. Sulfonic acid groups can greatly enhance the water solubility of compounds, as seen with the sulfonic acid derivative of triphenyl phosphine (TPPTS), $P(C_6H_4-m-SO_3Na)_3$. Metal complexes of this compound are used as

homogeneous catalysts for the syntheses of organic compounds in two-phase systems (e.g., in a mixture of water and an organic solvent) in industry and in the laboratory.

Aromatic Alcohol

In organic chemistry, the **aromatic alcohols or aryl-alcohols** are a class of chemical compounds containing a hydroxyl group ($-\text{OH}$) bonded carbon attached directly to an aromatic ring.



Phenols

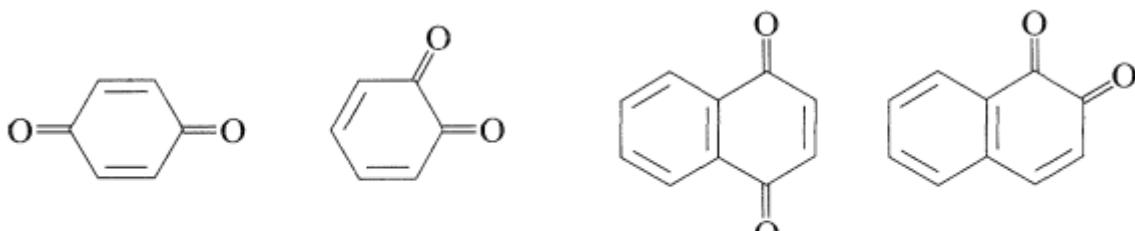
Phenol, any of a family of organic compounds characterized by a hydroxyl ($-\text{OH}$) group attached to a carbon atom that is part of an aromatic ring. Besides serving as the generic name for the entire family, the term phenol is also the specific name for its simplest member, monohydroxybenzene ($\text{C}_6\text{H}_5\text{OH}$), also known as benzenol, or carbolic acid.

Phenols are similar to alcohols but form stronger hydrogen bonds. Thus, they are more soluble in water than are alcohols and have higher boiling points. Phenols occur either as colourless liquids or white solids at room temperature and may be highly toxic and caustic.

Quinones

Quinones are not aromatic compounds but are conjugated cyclic diketones. Yet it is convenient to discuss their chemistry at this point because quinones and the related aromatic arenols are readily interconverted, and their chemistry is largely interdependent.

A variety of quinone like structures have been prepared, the most common of which are the 1,2 - and 1,4-quinones as exemplified by 1,2- and 1,4-benzenediones. Usually the 1,2-quinones are more difficult to make and are more reactive than the 1,4-quinones.



1,4-benzenedione
(*para*-benzoquinone)

1,2-benzenedione
(*ortho*-benzoquinone)

1,4-naphthalenedione
(1,4-naphthoquinone)

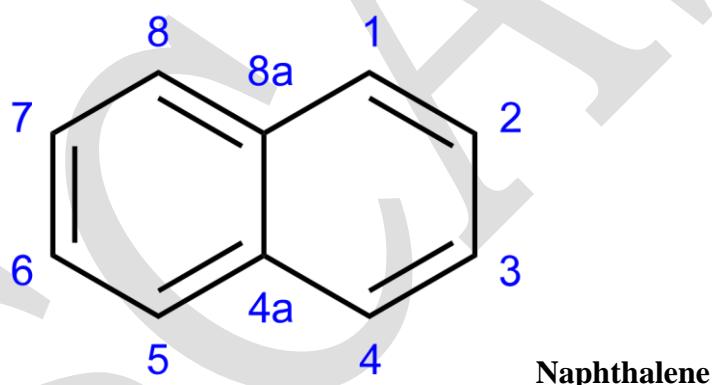
1,2-naphthalenedione
(1,2-naphthoquinone)

Naphthalene

Naphthalene is an organic compound with formula C₁₀H₈. It is the simplest polycyclic aromatic hydrocarbon, and is a white crystalline solid with a characteristic odor that is detectable at concentrations as low as 0.08 ppm by mass. As an aromatic hydrocarbon, naphthalene's structure consists of a fused pair of benzene rings. It is best known as the main ingredient of traditional mothballs.

A naphthalene molecule can be viewed as the fusion of a pair of benzene rings. (In organic chemistry, rings are fused if they share two or more atoms.) As such, naphthalene is classified as a benzenoid polycyclic aromatic hydrocarbon (PAH).

The eight carbons that are not shared by the two rings carry one hydrogen atom each. For purpose of the standard IUPAC nomenclature of derived compounds, those eight atoms are numbered 1 through 8 in sequence around the perimeter of the molecule, starting with a carbon adjacent to a shared one. The shared carbons are labeled 4a (between 4 and 5) and 8a (between 8 and 1).

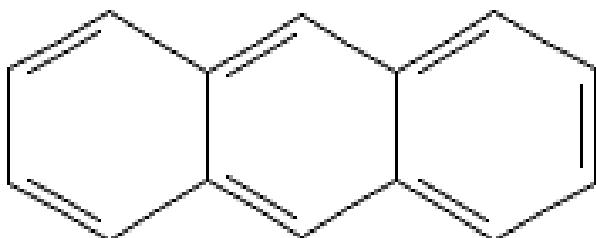


The International Agency for Research on Cancer (IARC) classifies naphthalene as possibly carcinogenic to humans and animals (Group 2B).

Anthracene

Anthracene is anthracene, also called paranaphthalene or green oil, a solid polycyclic aromatic hydrocarbon (PAH) consisting of three benzene rings derived from coal-tar, is the simplest tricyclic aromatic hydrocarbon. It is on the EPA's priority pollutant list. It is ubiquitous in the environment as a product of incomplete combustion of fossil fuels. It has been identified in surface and drinking water, ambient air, exhaust emissions, smoke of cigarettes and cigars, and in smoked foods and edible aquatic organisms.

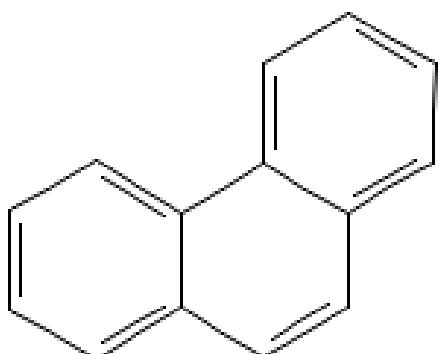
It is primarily used as an intermediate in the production of dyes, smoke screens, scintillation counter crystals, and in organic semiconductor research. Although a large body of literature exists on the toxicity of PAHs, data for anthracene are limited. Prolonged exposure causes variety of topical and systemic adverse reactions. Carcinogenicity bioassays with anthracene generally gave negative results.



ANTHRACENE

Phenanthracene

Phenanthracene or Phenanthrene is a polycyclic aromatic hydrocarbon composed of three fused benzene rings which takes its name from the two terms 'phenyl' and 'anthracene.' It has a role as an environmental contaminant and a mouse metabolite. It is an ortho-fused polycyclic arene, an ortho-fused tricyclic hydrocarbon and a member of phenanthrenes.



Phenanthrene

Phenanthrene is used to make dyes, plastics and pesticides, explosives and drugs. It has also been used to make bile acids, cholesterol and steroids.

DYE CHEMISTRY

DYES

A dye is a colored substance that chemically bonds to the substrate to which it is being applied. This distinguishes dyes from pigments which do not chemically bind to the material they color. Dye is generally applied in an aqueous solution, and may require a mordant to improve the fastness of the dye on the fiber.

Natural and synthetic dyes

The majority of natural dyes are derived from plant sources: roots, berries, bark, leaves, wood, fungi and lichens. In the 21st century, most dyes are synthetic, i.e., are man-made from petrochemicals. Other than pigmentation, they have a range of applications including organic dye lasers, optical media (CD-R) and camera sensors.

Congo red Dye:

Congo red is an organic compound, the sodium salt of 3,3'-([1,1'-biphenyl]-4,4'-diyl)bis(4-aminonaphthalene-1-sulfonic acid). It is an azo dye. Congo red is water-soluble, yielding a red colloidal solution; its solubility is greater in organic solvents. However, the use of Congo red has long been abandoned, primarily because of its carcinogenic properties.

It is prepared by azo coupling of the bis(diazonium) derivative of benzidine with naphthionic acid.

Due to a color change from blue to red at pH 3.0–5.2, Congo red can be used as a pH indicator.

USES:

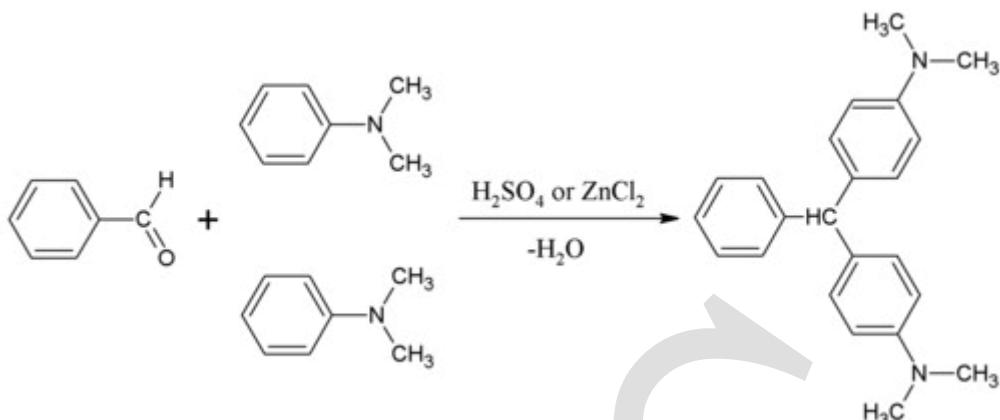
- ✓ Congo red is used for staining in amyloidosis, and for the cell walls of plants and fungi, and for the outer membrane of Gram-negative bacteria.
- ✓ Apple-green birefringence of Congo red stained preparations under polarized light is indicative of the presence of amyloid fibrils.
- ✓ Congo red is used for the diagnostics of the *Shigella flexneri* serotype 2a, where the dye binds the bacterium's unique lipopolysaccharide structure.
- ✓ Congo red may also be used to induce expression of the type III secretion system of *Shigella flexneri*, bringing about the secretion of IpaB and IpaC, which form translocation pores within host cell membrane, allowing effector proteins to pass through and alter the host cell's biochemistry.
- ✓ The dye can also be used in flow cytometry experiments for the detection of Acanthamoeba, Naegleria and other amoebal cysts.

Malachite green dye:

Malachite green is an organic compound that is used as a dyestuff and controversially as an antimicrobial in aquaculture. Malachite green is traditionally used as a dye for materials such as silk, leather, and paper. Despite its name the dye is not prepared from the mineral malachite; the name just comes from the similarity of color.

Preparation:

The leuco form of malachite green was first prepared by Hermann Fischer in 1877 by condensing benzaldehyde and dimethylaniline in the molecular ratio 1:2 in the presence of sulfuric acid.



USES:

Malachite green is traditionally used as a dye. Kilotonnes of MG and related triarylmethane dyes are produced annually for this purpose.

MG is active against the oomycete *Saprolegnia*, which infects fish eggs in commercial aquaculture.

MG has been used to treat *Saprolegnia* and is used as an antibacterial. It is a very popular treatment against *Ichthyophthirius multifiliis* in freshwater aquaria.

The principal metabolite, LMG, is found in fish treated with malachite green, and this finding is the basis of controversy and government regulation.

MG has frequently been used to catch thieves and pilferers. The bait, usually money, is sprinkled with the anhydrous powder. Anyone handling the contaminated money will find that on upon washing the hands, a green stain on the skin that lasts for several days will result.

Alizarin Red dye:

Alizarin, also spelled Alizarine, a red dye originally obtained from the root of the common madder plant, *Rubia tinctorum*, in which it occurs combined with the sugars xylose and glucose. The cultivation of madder and the use of its ground root for dyeing by the complicated Turkey red process were known in ancient India, Persia, and Egypt; the use spread to Asia Minor about the 10th century and was introduced into Europe in the 13th.

Laboratory methods of preparing alizarin from anthraquinone were discovered in 1868, and, upon commercial introduction of the synthetic dye in 1871, the natural product disappeared from the market for textile dyes, though natural rose madder is still occasionally used, as a lake, for artists' colours. The application of alizarin to cotton, wool, or silk requires prior impregnation of the fibre with a metal oxide, or mordant. The shade produced depends on the metal present: aluminum yields a red; iron, a violet; and chromium, a brownish red.

Indigo dye:

Indigo dye is an organic compound with a distinctive blue color. Historically, indigo was a natural dye extracted from the leaves of some plants of the *Indigofera* genus, in particular *Indigofera tinctoria*; dye-bearing *Indigofera* plants were commonly grown and used throughout the world, in Asia in particular, as an important crop, with the production of indigo dyestuff economically important due to the previous rarity of some blue dyestuffs historically.

Most indigo dye produced today is synthetic, constituting several thousand tons each year. It is most commonly associated with the production of denim cloth and blue jeans, where its properties allow for effects such as stone washing and acid washing to be applied quickly.

USES:

The primary use for indigo is as a dye for cotton yarn, mainly used in the production of denim cloth suitable for blue jeans; on average, a pair of blue jeans requires just 3 grams (0.11 oz) to 12 grams (0.42 oz) of dye. Smaller quantities are used in the dyeing of wool and silk.

Indigo carmine, also known as indigo, is an indigo derivative which is also used as a colorant. About 20 thousand tons are produced annually, again mainly for the production of blue jeans. It is also used as a food colorant, and is listed in the United States as FD&C Blue No. 2.

FOOD CHEMISTRY

Food Preservatives:

A preservative is a substance or a chemical that is added to products such as food products, beverages, pharmaceutical drugs, paints, biological samples, cosmetics, wood, and many other products to prevent decomposition by microbial growth or by undesirable chemical changes. In general, preservation is implemented in two modes, chemical and physical. Chemical preservation entails adding chemical compounds to the product. Physical preservation entails processes such as refrigeration or drying.

Preservative food additives reduce the risk of foodborne infections, decrease microbial spoilage, and preserve fresh attributes and nutritional quality. Some physical techniques for food preservation include dehydration, UV-C radiation, freeze-drying, and refrigeration. Chemical preservation and physical preservation techniques are sometimes combined.

Food preservation

Preservatives have been used since prehistoric times. Smoked meat for example has phenols and other chemicals that delay spoilage. The preservation of foods has evolved greatly over the centuries and has been instrumental in increasing food security. The use of preservatives

other than traditional oils, salts, paints, etc. in food began in the late 19th century, but was not widespread until the 20th century.

The use of food preservatives varies greatly depending on the country. Many developing countries that do not have strong governments to regulate food additives face either harmful levels of preservatives in foods or a complete avoidance of foods that are considered unnatural or foreign. These countries have also proven useful in case studies surrounding chemical preservatives, as they have been only recently introduced. In urban slums of highly populated countries, the knowledge about contents of food tends to be extremely low, despite consumption of these imported foods.

Antioxidants

The oxidation process spoils most food, especially those with a high fat content. Fats quickly turn rancid when exposed to oxygen. Antioxidants prevent or inhibit the oxidation process. The most common antioxidant additives are ascorbic acid (vitamin C) and ascorbates. Thus, antioxidants are commonly added to oils, cheese, and chips. Other antioxidants include the phenol derivatives BHA, BHT, TBHQ and propyl gallate. These agents suppress the formation of hydroperoxides.[6] Other preservatives include ethanol and methylchloroisothiazolinone.

E number	chemical compound	comment
E300-304	ascorbic acid, sodium ascorbate	cheese, chips
E321	butylated hydroxytoluene, butylated hydroxyanisole	also used in food packaging
E310-312	gallic acid and sodium gallate	oxygen scavenger
E220 - E227	sulfur dioxide and sulfites	beverages, wine
E306 - E309	tocopherols	vitamin E activity
E number	chemical compound	comment

Nonsynthetic compounds for food preservation:

Citric and ascorbic acids target enzymes that degrade fruits and vegetables, e.g., mono/polyphenol oxidase which turns surfaces of cut apples and potatoes brown. Ascorbic acid and tocopherol, which are vitamins, are common preservatives. Smoking entails exposing food to a variety of phenols, which are antioxidants. Natural preservatives include rosemary and oregano extract, hops, salt, sugar, vinegar, alcohol, diatomaceous earth and castor oil.

Traditional preservatives, such as sodium benzoate have raised health concerns in the past. Benzoate was shown in a study to cause hypersensitivity in some asthma sufferers. This has caused reexamination of natural preservatives which occur in vegetables.

Food Additives:

Food additives are substances intentionally added to food products in order to perform specific functions, such as colouring, preservation or sweetening. This is the definition given by the EFSA, the **European Food Safety Authority**, which also explains how, in the European Union, additives should always be mentioned in the ingredients list, if present. Not only: **the label of food** must necessarily bring both the additive function and the substance used, indicating the appropriate acronym. Among the **food additives** most commonly listed on food labels are:

- Antioxidants

- Colorants
- Stabilizers
- Emulsifiers
- Thickeners
- Sweeteners
- Preservatives
- Gelling

Additives in organic food

As regards **organic food**, basically, they should undergo very few treatments and hence be more natural as possible. However, even in so-called **organic food some additives are allowed.**

Below, a quick overview on the **organic food additives**, classified as follows:

- **Colorants from E100 to E199**, including curcumin (E100), cochineal (E120), amaranth (E123), chlorophyll and chlorophyllin (E140), caramel (E150a), paprika extract (E160c), betanin (E162), tannin (E181)
- **Preservatives from E200 to E299**, including sorbic acid (E200), calcium sorbate (E203), nisin (E234), sodium nitrate (E251), boric acid (E284), malic acid (E296), carbon dioxide (E290)
- **Antioxidants and acidity regulators from E300 to E399**, including ascorbic acid, ie vitamin C (E300), dodecyl gallate (E312), calcium lactate (E327), citric acid (E330), sodium fumarate (E365), rosemary extract (E392)
- **Thickeners, emulsifiers and stabilizers from E400 to E499**, including agar-agar (E406), xanthan gum (E415), mannitol (E412), glycerol (E422), sorbitol (E420), guar gum (E412), sucroglycerides (E474)
- **Acidity regulator and anti-caking agents, from E500 to E599**, including potassium chloride (E508), calcium chloride (E509), sulfuric acid (E513), aluminum sulphate (E520), calcium oxide (E526), gluconic acid (E574)

Flavour enhancers, from E600 to E699, including glutamic acid (E620), inosinic acid (E630), maltol (E636), carnauba wax (E903), lanolin (E913), helium (E939), hydrogen (E949), sucralose (E955), xylitol (E967)

Detection of Adulterants in food:

S. No	Food Article	Adulterant	Method for Detection	Remarks
1	Milk	water	The presence of water can be by putting a drop of milk on a polished slanting surface. The drop of pure milk either or flows slowly leaving a white trail behind it, whereas milk adulterated water will flow immediately without leaving a mark	
2		Starch	Add a few drops of tincture of Iodine or Iodine solution. Formation of blue colour indicates the presence of starch.	Iodine solution is easily available in the medical stores.

3		Urea	Take a teaspoon of milk in a test tube. Add $\frac{1}{2}$ teaspoon of soybean or arhar powder. Mix up the contents thoroughly by shaking the test tube. After 5 minutes, dip a red litmus paper in it. Remove the paper after $\frac{1}{2}$ a minute. A change in colour from red to blue indicates the presence of urea in the milk.	
4		Vanaspati	Take 3 ml of milk in a test tube. Add 10 drops of hydrochloric acid. Mix up one teaspoonful of sugar. After 5 minutes, examine the mixture. The red colouration indicates the presence of vanaspati in the milk.	
5		Formalin	Take 10 ml of milk in a tests tube and add 5 ml of conc. sulphuric acid from the sides of the wall without shaking. If a violet or blue ring appears at the intersection of two layers then it shows presence of formalin.	Formalin enhances the life of milk and thus is added for preservation purpose.
6		Detergent	Shake 5-10 ml. of sample with an equal amount of water lather indicates the presence of detergent.	
7	Milk	Synthetic milk	Synthetic milk has a bitter after taste, gives a soapy feeling on rubbing between the fingers and turns yellowish on heating.	
8	Synthetic milk-test for protein		The milk can easily be tested by Urease strips (available in the Medical stores) because Synthetic milk is devoid of protein.	
9		Test for Glucose/inverted sugar	Milk does not contain glucose /invert sugar, if test for glucose with urease strip found positive. It means milk is adulterated.	If it is made synthetically by adding white colour water paint. Oils, alkali, urea and detergent etc. Glucose, inverted sugar syrup is added in milk to increase the consistency and test
10	Ghee, cottage cheese, condensed milk, khoa, milk	Coal Tar Dyes	Add 5 ml of dil. H_2SO_4 or conc. HCL to one teaspoon full of melted sample in a test tube. Shake well. Pink colour (in case of H_2SO_4) or crimson colour (in case of HCl) indicates coal tar dyes. If HCl does not give colour dilute it with water to get the colour.	

	powder etc,			
11	Sweet Curd	Vanaspati	Take 1 teaspoon full of curd in a test tube. Add 10 drops of hydrochloric acid. Mix up the contents shaking the test tube gently. After 5 minutes, examine the mixture. The red colouration indicates the presence of vanaspati in the curd.	
12	Rabri	Blotting paper	Take a teaspoon of rabri in a test tube. Add 3 ml of hydrochloric acid and 3 ml of distilled water. Stir the content with a glass rod. Remove the rod and examine. Presence of fine fibres to the glass rod will indicate the presence of blotting paper in rabri.	
13	Khoa and its products	Starch	Boil a small quantity of sample with some water, cool and add a few drops of Iodine solution. Formation of blue colour indicates the presence of starch.	
14	Chhana or Paneer	Starch	Boil a small quantity of sample with some water, cool and add a few drops of Iodine solution. Formation of blue colour indicates the presence of starch.	

Oil and Fats

S. No	Food Article	Adulterant	Method for Detection	Remarks
1	Ghee	Vanaspathy or Margarine	Take about one tea spoon full of melted sample of Ghee with equal quantity of concentrated Hydrochloric acid in a stoppered test tube and add to it a pinch of sugar. Shake for one minute and let it for five minutes. Appearance of crimson colour in lower (acid) of Vanaspati or Margarine.	The test is specific for sesame oil Which is compulsorily added to Vanaspati and Margarine. Some coal tar colours also give a positive test. If the test is positive i.e. red colour develops only by adding strong Hydrochloric acid (without adding crystals of sugar) then the sample is adulterated with coal tar dye. If the crimson or red colour develops after adding and shaking with sugar, then alone Vanaspati or Margarine is present

2		Mashed Potatoes, Sweet Potatoes and other starches.	The presence of mashed potatoes and sweet potatoes in a sample of ghee can easily be detected by adding a few drops of Iodine, which is brownish in colour turns to blue if mashed potatoes/sweet potatoes/other starches are present.	
3	Butter	Vanaspati or Margarine	Take about one teaspoon full of melted sample of butter with equal quantity of concentrated Hydrochloric acid in a stoppered test tube and add to it a pinch of sugar. Shake for one minute and let it for five minutes. Appearance of crimson colour in lower (acid) of Vanaspati or Margarine.	The test is specific for sesame oil which is compulsorily added to Vanaspati and Margarine. Some coal tar colours also give a positive test. If the test is positive i.e. red colour develops only by adding strong Hydrochloric acid (without adding crystals of sugar) then the sample is adulterated with coal tar dye. If the crimson or red colour develops after adding and shaking with sugar, then alone Vanaspati or Margarine is present
4		Mashed Potatoes and other starches	The presence of mashed potatoes and sweet potatoes in a sample of butter can easily be detected by adding a few drops of iodine (which is brownish in colour), turns to blue.	
5	Edible oil	Prohibited colour	Take 5 ml of sample in a test tube and add 5 ml of concentrated hydrochloric acid. Shake gently, let it stand for 5 minutes. Colour will separate in the upper layer of the solution.	
6	Coconut oil	Any other oil	Place a small bottle of oil in refrigerator. Coconut oil solidifies leaving the adulterant as a Separate layer.	

Food grains and their products:

S. No	Food Article	Adulterant	Method for Detection	Remarks
1	Wheat, Rice, Maize, Jawar, Bajra, Chana, Barley etc.	Dust, pebble, Stone, Straw, weed seeds, damaged grain, weevilled grain, insects, hair and excreta of rodent	These may be examined visually to see foreign matter, damaged grains, discoloured grains, insect, rodent contamination etc.	Damaged/discoloured grains should be as low as possible since they may be affected by fungal toxins, argemone seeds, Dhatura seeds etc. In moderately excessive amount can result in risk to health, Discard the damaged undesirable grains before use
2	Maida	Resultant atta or cheap flour	When dough is prepared from resultant or left out atta, more water has to be used. The normal taste of chapattis prepared out of wheat is somewhat sweetish whereas those prepared out of adulterated wheat will taste insipid.	
3	Maida/ Rice	Boric Acid	Take a small amount of sample in a test tube, add some water and shake. Add a few drops of HCl. Dip a turmeric paper strip if it turns red, boric acid is present.	
4	Wheat, bajra and other grains	Ergot (a fungus containing poisonous substance)	(i) Purple black longer sized grains in Bajra show the presence of Ergots. (ii) Put some grains in a glass tumbler containing 20 per cent salt solution (20 gm common salt to 100 ml water) purple black longer size grain Ergot floats over the surface while sound grains settle down.	
5	Wheat, bajra and other grain	Dhatura	Dhatura seeds are flat with edges with blackish brown colour which can be separated out by close examination.	
6	Wheat, bajra and other grain	Karnal Bunt	The affected wheat kernel have a dull appearance, blackish in colour and rotten fish smell,	
7	Sella Rice (Parboiled Rice)	Metanil yellow(a non-permitted coal tar colour)	Rub a few grains in the palms of two hands. Yellow would get reduced or disappear. Add a few drops of dilute Hydrochloric acid to a few rice grains mixed with little water, presence of pink colour indicates presence of Metanil yellow	

8		Turmeric (colouring for golden appearance)	Take a small amount of sample in a test tube, add some water and shake. Dip Boric acid paper (filter paper dipped in Boric acid solution) If it turns pink turmeric is present (ii) Take some rice and sprinkle on it a small amount of soaked lime for some time, grains will turn red if turmeric is present.	
9	Parched rice	Urea	Take 30 numbers of parched rice in a test tube. Add 5ml of distilled water in it. Mix up the contents thoroughly, by shaking the test tube. After 5 minutes, filter the water - contents, and add ½ teaspoon of powder of arhar or soybean in it. Leave it for 5 minutes, and then dip a red litmus paper in the mixture. Take out the litmus paper after 30 seconds and examine it. A blue colouration indicates the presence of urea in the parched rice.	
10	Wheat flour	Excess bran	Sprinkle on water surface. Bran will float on the surface.	
11	Wheat flour	Chalk powder	Shake sample with dil.HCl Effervescence indicates chalk	Chalk powder is used as an adulterant due to its weight.
12	Dal whole and spilt	Khesari Dal	(i) Khesari dal has edged type appearance showing a slant on one side and square in appearance in contrast to other daIs. (ii) Add 50 ml of dilute Hydrochloric acid to the sample and keep on simmering water for about 15minutes. The pink color developed indicates the presence of Khesari dal.	The test is only for Khesari dal.(Metanil yellow if present will give a similar colour immediately even without simmering).
13		Clay, stone, gravels, webs, insects, rodent hair and excreta	Visual examination will detect these adulterants	Reject if the number of Insects is large or if the odour is unpleasant and taste bitter or gritty
14		Metanil yellow (a non permitted coaltar colour)	Take 5 gms of the sample with 5ml. Of water in a test tube and add a few drops of concentrated Hydrochloric acid. A pink colour shows presence o Metanil yellow	
15	Atta, Maida Suji (Rawa)	Sand, soil, insects, webs, lumps. rodent hair and excrete	These can be identified by visual examination.	

16		Iron filings	By moving a magnet through the sample, iron filings can be separated.	
17	Bajra	Ergot infested Bajra.	Soak bajra in water, swollen and black Ergot infested grains will turn light in weight and will float in water	
18	Sago	Sand or talcum	Put a little quantity of sago in mouth, it will have a gritty feel, if adulterated. Burn the sago, if pure, it will swell and leave hardly any ash. Adulterated sago will leave behind appreciable quantity of ash.	
19	Besan	Metanil Yellow	Take $\frac{1}{2}$ teaspoon of the besan in a test tube. Pour 3 ml of alcohol in the test tube. Mix up the contents thoroughly by shaking the test tube. Add 10 drops of hydrochloric acid it. A pink colouration indicates presence of metanil yellow in the gram powder.	
20		Khesari Flour	Add 50 ml of dilute Hydrochloric acid to 10 gms of sample and keep on simmering water for about 15 minutes. The pink colour, if developed, indicates the presence of Khesari flour	The test is only for Khesari dal (Metanil yellow, if present will give a similar colour even without simmering).
21	Pulses	Lead Chromate	Shake 5 gm. Of pulse with 5 ml. Of water and add a few drops of HCl. Pink colour indicates Lead Chromate.	

SPICES:

S. No	Food Article	Adulterant	Method for Detection	Remarks
1	Whole spices	Dirt, dust, straw, insect, damaged seeds, other seeds, rodent hair and excrete	These can be examined visually	
2	Black pepper	Papaya seeds	Papaya seeds can be separated out from pepper as they are shrunken, oval in shape and greenish brown or brownish black in colour.	

3		Light black pepper	Float the sample of black pepper in alcohol (rectified spirit). The black pepper berries sink while the papaya seeds and light black pepper float. (ii) Press the berries with the help of fingers light peppers will break easily while black berries of pepper will not break.	
4		Coated with mineral oil	Black pepper coated with mineral oil gives Kerosene like smell.	
5	Cloves	Volatile oil extracted (exhausted cloves)	Exhausted cloves can be identified by its small size and shrunken appearance. The characteristic pungent of genuine cloves is less pronounced in exhausted cloves	
6	Cloves	Coated with mineral oil	Cloves coated with mineral oil gives kerosene like smell	
7	Mustard seed	Argemone seed	Mustard seeds have a smooth surface. The argemone seed have grainy and rough surface and are black and hence can be separated out by close examination. When Mustard seed is pressed inside it is yellow while for Argemone seed it is white	Use magnifying glass for identification.
8	Powdered spices	Added starch	Add a few drops of tincture of Iodine or Iodine solution. Indication of blue colour shows the presence of starch.	Iodine test for added starch is not applicable for Turmeric powder
9	Powdered spices	Common Salt	Taste for addition of common salt.	
10	Turmeric powder	Coloured saw dust	Take a tea spoon full of turmeric powder in a test tube. Add a few drops of concentrated Hydrochloric acid. Instant appearance of pink colour which disappears on dilution with water shows the presence of turmeric. If the colour persists, metanil yellow (an artificial colour) a not permitted coal tar colour is present.	This test is only for Metanil yellow
11	Turmeric whole	Lead chromate	Appears to be bright in colour which leaves colour immediately in water.	
12		Chalk powder or yellow soap stone powder	Take a small quantity of turmeric powder in a test tube containing small quantity of water. Add a few drops of concentrated Hydrochloric acid, effervescence (give off bubbles) will indicate the presence of chalk or yellow soap stone powder	

13	Chillies powder	Brick powder, salt powder or talc,powder.	<p>Take a teaspoon full of chillies powder in a glass of water. Coloured water extract will show the presence of artificial colour. Any grittiness that may be felt on rubbing the sediment at the bottom of glass confirms the presence of brick powder/sand, soapy and smooth touch of the white residue at the bottom indicates the presence of soap stone. To a little powder of chilli add small amount of conc HCl and mix to the consistency of paste,dip the rear end of the match stick into the paste and hold over the flame,brick red flame colour due to the presence of calcium slats in brick powder.</p>	This test is only for earthy material
14		Artificial colours	Sprinkle the chilli powder on a glass of water. Artificial colorants descend as coloured streaks.	
15		Water soluble coal tar colour	<p>Water soluble artificial color can be detected by sprinkling a small quantity of chillies or turmeric powder on the surface of water contained in a glass tumbler.</p> <p>The water soluble colour will immediately start descending in colour streaks</p>	
16	Asafoetida (Hing)	Soap stone or other earthy material	Shake little portion of the sample with water and allow to settle. Soap stone or other earthy mailer will settle down at the bottom.	In compounded asafoetida due to presence of starch, a slight turbid solution may be produced. However, this will settle down after keeping
17		Starch	Add tincture of iodine, appearance of blue colour shows the presence of starch.	Compound of asafoetida contains starch which is declared on the label. This test is not applicable for compound asafoetida.
18		Foreign resin	Burn on a spoon, if the sample burns like camphor, it indicates the sample is pure.	Pure hing burns like aromatic camphor
19	Spices	Powdered bran and saw dust	Sprinkle on water surface. Powdered bran and sawdust float on the surface.	
20	Cinnamon	Cassia bark	Cinnamon barks are very thin and can be rolled. It can be rolled around a pencil or pen. It has a distinct smell. Whereas cassia ark comprise of several layers in between the rough outer and inner most smooth layers. On examination of the ark loosely, a clear distinction can be made.	
21	Cumin seeds	Grass seeds coloured with charcoal dust	Rub the cumin seeds on palms. If palms turn black adulteration is indicated.	

22	Green chilli and green vegetables	Malachite green	Take a cotton piece soaked in liquid paraffin and rub the outer green surface of a small part of green vegetable. If the cotton turns green, we can say the vegetable is adulterated with malachite green.	
23	Green peas	Artificially coloured	Take a little amount of green peas in a 250 ml beaker add water to it and mix well. Let it stand for half an hour. Clear separation of colour in water indicates adulteration.	
24	Saffron	Dried tendrils of maize cob	Genuine saffron will not break easily like artificial. Artificial saffron is prepared by soaking maize cob in sugar and colouring it with coal tar colour. The colour dissolves in water if artificially coloured. A bit of pure saffron when allowed to dissolve in water will continue to give its saffron colour so long as it lasts	

TEXTILE CHEMISTRY

Synthetic fibres:

Synthetic fibres are man-made fibres, most of them are prepared from raw material petroleum called petrochemicals. All fabrics are obtained from fibres, while fibres are obtained from artificial or man-made sources. They consist of a small unit or a polymer which is made from many repeating units known as monomers. They include nylon, acrylics, polyurethane, and polypropylene. Millions of tons of these fibres are produced all over the world each year.

Following are some of the most commonly used synthetic fibres: Know more about Classifications of Fibres,

1. Rayon

- This is a type of synthetic fibre obtained from wood pulp.
- Rayon fabric is soft, absorbent and comfortable.
- It is easy to dye in a wide range of colours.
- Rayon is mixed with cotton to make bedsheets.
- Rayon is mixed with wool to make carpets.

2. Nylon

- This type of synthetic fibre is obtained from coal, water and air.
- Nylon is very lustrous, easy to wash and elastic.
- It dries quickly and retains its shape.
- Nylon finds its application in seat belts of car, sleeping bags, socks, ropes, etc.
- Nylon is also used in ropes for rock climbing, making parachutes and fishing nets.

3. Polyester

- This type of synthetic fibre is obtained from coal, water, air and petroleum.
- Polyester is made from repeating units of a chemical known as esters.
- Polyester is easy to wash and it remains wrinkle-free and it is quite suitable in making dress material.
- Polyester retains its shape and remains crisp.
- Polyester is used in making ropes, nets, raincoats, jackets, etc.

Synthetic Fibres Examples

The modern textile industry is unthinkable today without synthetic fibres. Man-made fibres like silk have always been greatly valued for its gloss and fineness. Man-made fibres are smooth. They can be distinguished by looking at a cross-section. Some synthetic fibres are listed below.

1. *rayon*
2. *nylon*
3. *Polyester*

This fibre finds its applications in household articles like ropes, bucket, furniture, etc.

Advantages of Synthetic Fibres

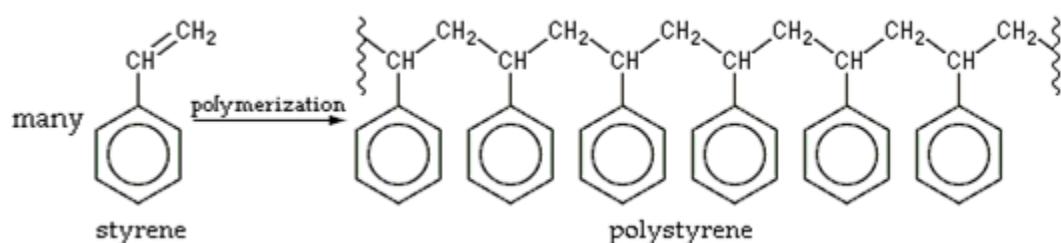
- Synthetic fibres are very durable and do not wrinkle easily
- They are elastic and can be easily stretched out
- They are strong and can sustain the heavy load.
- They are soft and hence used in clothing material.
- They are cheaper than compared to natural fibres.

Disadvantages of Synthetic Fibres

- Most synthetic fibres do not absorb moisture.
- Synthetic fibre can be affected if washed using hot water.
- They catch fire easily as compared to natural fibre.

Manufacture of Synthetic fibres:

Synthetic fibers can be manufactured in continuous filaments, which are infinite in length. A yarn can be made by assembling the filaments together continuously while producing threads.



An example of alkene polymerization, in which each styrene monomer's double bond reforms as a single bond plus a bond to another styrene monomer. The product is polystyrene.

1. Polymerization is the reacting of small molecules together in a chemical reaction to form polymer chains. There are two types of polymerization: Condensation polymers are formed by the gradual reaction of functional groups of monomers, usually containing heterogeneous substances such as oxygen or nitrogen. An addition polymer is a mechanism in which monomers react to form a polymer without forming by-products. In addition polymerization processes are performed in the presence of catalysts.

2. Pumping: The molten polymer is pumped through a filter bed and then through small deep holes. Both units will lead to high-pressure drops along the flow direction of viscous liquids. There are two main devices used to pump liquids: centrifugal pumps and gear pumps. Centrifugal pumps are used to transport low viscosity liquids around in a process while gear pumps are used to pump highly viscous liquids at a controlled flow rate.

3- Filtration: It is cleaning the spinneret plate. The filtration process must be completed to very strict standards.

4- Spinning: The fibers are formed by extruding molten polymer through small holes in the spinneret plate. A plate may contain 1,000 or more holes. The filament thickness is not determined in linear dimensions but in terms of mass per length. There are three methods of spinning:

- Melt spinning: In the spinning of molten polymers, such as polyester, nylon, and polypropylene. Once the molten polymer comes out of the spinneret hole, begins to cool down and also begins to stretch out. After application of finish, fibers are collected at high speed in a process known as spin drawing.
- Dry spinning: In the process of dry spinning, solvents are used in which the polymer dissolves where a solvent evaporates after the solution (spine dope) leaves the spinneret. This process is followed by stretching, applying the finish, and taking follow-up on the spindle or cutting into the staple. This process is more expensive than conventional melt spinning processes.
- Wet spinning: This method is used for polymers that do not melt easily. The polymer dissolved in a solvent which extracted into a liquid (water) after the solution (spin dope) leaves the spinneret. The fibres are dried on large hot cylinders. The fibers are then sent to a cutter to cut fibres in lengths of 2.5-15 cm. The fibers produced by wet yarn include rayon, Kevlar, and acrylic fibres.

5- Drawing: Stretching, or drawing the filament is the process of pulling the long polymer chains to align along the longitudinal axis of fibers, grouping together, and developing cohesion. During the drawing process, the polymer chains slide over each other as they are pulled to align along the longitudinal axis of the fibres.

Petrochemicals

Petrochemicals (sometimes abbreviated as petchems) are the chemical products obtained from petroleum by refining. Some chemical compounds made from petroleum are also obtained from other fossil fuels, such as coal or natural gas, or renewable sources such as maize, palm fruit or sugar cane.

The two most common petrochemical classes are olefins (including ethylene and propylene) and aromatics (including benzene, toluene and xylene isomers).

Oil refineries produce olefins and aromatics by fluid catalytic cracking of petroleum fractions. Chemical plants produce olefins by steam cracking of natural gas liquids like ethane and propane. Aromatics are produced by catalytic reforming of naphtha. Olefins and aromatics are the building-blocks for a wide range of materials such as solvents, detergents, and adhesives. Olefins are the basis for polymers and oligomers used in plastics, resins, fibers, elastomers, lubricants, and gels.

Synthetic petrol:

Synthetic fuel or synfuel is a liquid fuel, or sometimes gaseous fuel, obtained from either syngas, a mixture of carbon monoxide and hydrogen, or a mixture of carbon dioxide and hydrogen. The syngas could be derived from gasification of solid feedstocks such as coal or biomass or by reforming of natural gas. Alternatively a mixture of carbon dioxide from the atmosphere and green hydrogen could be used for an almost climate neutral production of synthetic fuels.

Common ways for refining synthetic fuels include the Fischer–Tropsch conversion, methanol to gasoline conversion, or direct coal liquefaction.

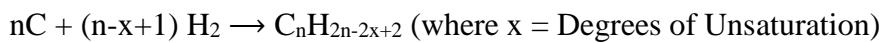
Synthetic fuels are fuels produced from coal, natural gas, or biomass feedstocks through chemical conversion into synthetic crude and/or synthetic liquid products. A number of synthetic fuel's definitions include fuels produced from biomass, and industrial and municipal waste. The definition of synthetic fuel also allows oil sands and oil shale as synthetic fuel sources, and in addition to liquid fuels, synthesized gaseous fuels are also considered to be synthetic fuels.

Bergius process:

The Bergius process is a method of production of liquid hydrocarbons for use as synthetic fuel by hydrogenation of high-volatile bituminous coal at high temperature and pressure. It was first developed by Friedrich Bergius in 1913. In 1931 Bergius was awarded the Nobel Prize in Chemistry for his development of high-pressure chemistry.

The coal is finely ground and dried in a stream of hot gas. The dry product is mixed with heavy oil recycled from the process. A catalyst is typically added to the mixture. A number of catalysts have been developed over the years, including tungsten or molybdenum sulfides, tin or nickel oleate, and others. Alternatively, iron sulphides present in the coal may have sufficient catalytic activity for the process, which was the original Bergius process.

The mixture is pumped into a reactor. The reaction occurs at between 400 and 500 °C and 20 to 70 MPa hydrogen pressure. The reaction produces heavy oils, middle oils, gasoline, and gases. The overall reaction can be summarized as follows:



The immediate product from the reactor must be stabilized by passing it over a conventional hydrotreating catalyst. The product stream is high in cycloalkanes and aromatics, low in alkanes (paraffins) and very low in alkenes (olefins). The different fractions can be passed to further processing (cracking, reforming) to output synthetic fuel of desirable quality. If passed through a process such as Platforming, most of the cycloalkanes are converted to aromatics and the recovered hydrogen recycled to the process. The liquid product from Platforming will contain over 75% aromatics and has a Research Octane Number (RON) of over 105.

Overall, about 97% of input carbon fed directly to the process can be converted into synthetic fuel. However, any carbon used in generating hydrogen will be lost as carbon dioxide, so reducing the overall carbon efficiency of the process.