

Chemical Basis of Life

A knowledge of chemistry is essential for understanding organisms

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There are 118 different elements currently on the periodic table.

Periodic Table of Elements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18													
1	1 H Hydrogen (1.008)	Atomic # Symbol Name Atomic Mass C Solid Hg Liquid H Gas Rf Unknown Metals Alkali metals Alkaline earth metals Lanthanoids Actinoids Transition metals Poor metals Other nonmetals Noble gases																2 He Helium (4.0026)													
2	3 Li Lithium (6.941)	4 Be Beryllium (9.012182)															5 B Boron (10.81)	6 C Carbon (12.0107)	7 N Nitrogen (14.0067)	8 O Oxygen (15.9994)	9 F Fluorine (18.9984032)	10 Ne Neon (20.1797)									
3	11 Na Sodium (22.98976928)	12 Mg Magnesium (24.304)															13 Al Aluminum (26.9815386)	14 Si Silicon (28.0855)	15 P Phosphorus (30.973762)	16 S Sulfur (32.06)	17 Cl Chlorine (35.45)	18 Ar Argon (39.948)									
4	19 K Potassium (39.0983)	20 Ca Calcium (40.078)	21 Sc Scandium (44.955912)	22 Ti Titanium (47.88)	23 V Vanadium (50.9415)	24 Cr Chromium (51.9961)	25 Mn Manganese (54.938045)	26 Fe Iron (55.845)	27 Co Cobalt (58.933195)	28 Ni Nickel (58.6934)	29 Cu Copper (63.546)	30 Zn Zinc (65.38)	31 Ga Gallium (69.723)	32 Ge Germanium (72.64)	33 As Arsenic (74.9216)	34 Se Selenium (78.96)	35 Br Bromine (79.904)	36 Kr Krypton (83.798)													
5	37 Rb Rubidium (85.4678)	38 Sr Strontium (87.62)	39 Y Yttrium (88.90584)	40 Zr Zirconium (91.224)	41 Nb Niobium (92.90638)	42 Mo Molybdenum (95.94)	43 Tc Technetium (98.90625)	44 Ru Ruthenium (101.07)	45 Rh Rhodium (102.9055)	46 Pd Palladium (106.42)	47 Ag Silver (107.8682)	48 Cd Cadmium (112.411)	49 In Indium (114.818)	50 Sn Tin (118.710)	51 Sb Antimony (121.757)	52 Te Tellurium (127.6)	53 I Iodine (126.90545)	54 Xe Xenon (131.29)													
6	55 Cs Cesium (132.90545196)	56 Ba Barium (137.327)	57–71														72 Hf Hafnium (178.49)	73 Ta Tantalum (180.94788)	74 W Tungsten (183.84)	75 Re Rhenium (186.207)	76 Os Osmium (190.23)	77 Ir Iridium (192.222)	78 Pt Platinum (195.084)	79 Au Gold (196.966569)	80 Hg Mercury (200.59)	81 Tl Thallium (204.3833)	82 Pb Lead (207.2)	83 Bi Bismuth (208.9804)	84 Po Polonium ([209])	85 At Astatine ([210])	86 Rn Radon ([222])
7	87 Fr Francium ([223])	88 Ra Radium ([226])	89–103														104 Rf Rutherfordium ([261])	105 Db Dubnium ([262])	106 Sg Seaborgium ([266])	107 Bh Bohrium ([264])	108 Hs Hassium ([277])	109 Mt Meitnerium ([268])	110 Ds Darmstadtium ([271])	111 Rg Roentgenium ([272])	112 Uub Ununbium ([285])	113 Uut Ununtrium ([284])	114 Uuq Ununquadium ([289])	115 Uup Ununpentium ([288])	116 Uuh Ununhexium ([292])	117 Uus Ununseptium ([294])	118 Uuo Ununoctium ([294])

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

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57 La Lanthanum (138.9047)	58 Ce Cerium (140.12)	59 Pr Praseodymium (140.90766)	60 Nd Neodymium (144.242)	61 Pm Promethium ([145])	62 Sm Samarium (150.36)	63 Eu Europium (151.964)	64 Gd Gadolinium (157.25)	65 Tb Terbium (158.92535)	66 Dy Dysprosium (162.500)	67 Ho Holmium (164.93032)	68 Er Erbium (167.259)	69 Tm Thulium (168.93421)	70 Yb Ytterbium (173.054)	71 Lu Lutetium (174.967)
89 Ac Actinium ([227])	90 Th Thorium (232.0377)	91 Pa Protactinium (231.036889)	92 U Uranium (238.02891)	93 Np Neptunium ([237])	94 Pu Plutonium ([244])	95 Am Americium ([243])	96 Cm Curium ([247])	97 Bk Berkelium ([247])	98 Cf Californium ([251])	99 Es Einsteinium ([252])	100 Fm Fermium ([257])	101 Md Mendelevium ([258])	102 No Nobelium ([259])	103 Lr Lawrencium ([262])

Do life has any chemistry?

Plant tissue, animal tissue or a microbial biomass –
Elemental analysis

Life/living matter is composed of lifeless
chemical molecules

Carbon, Hydrogen, Oxygen and several others content per unit mass of a
living tissue

? any differences between the two in term of elemental lists

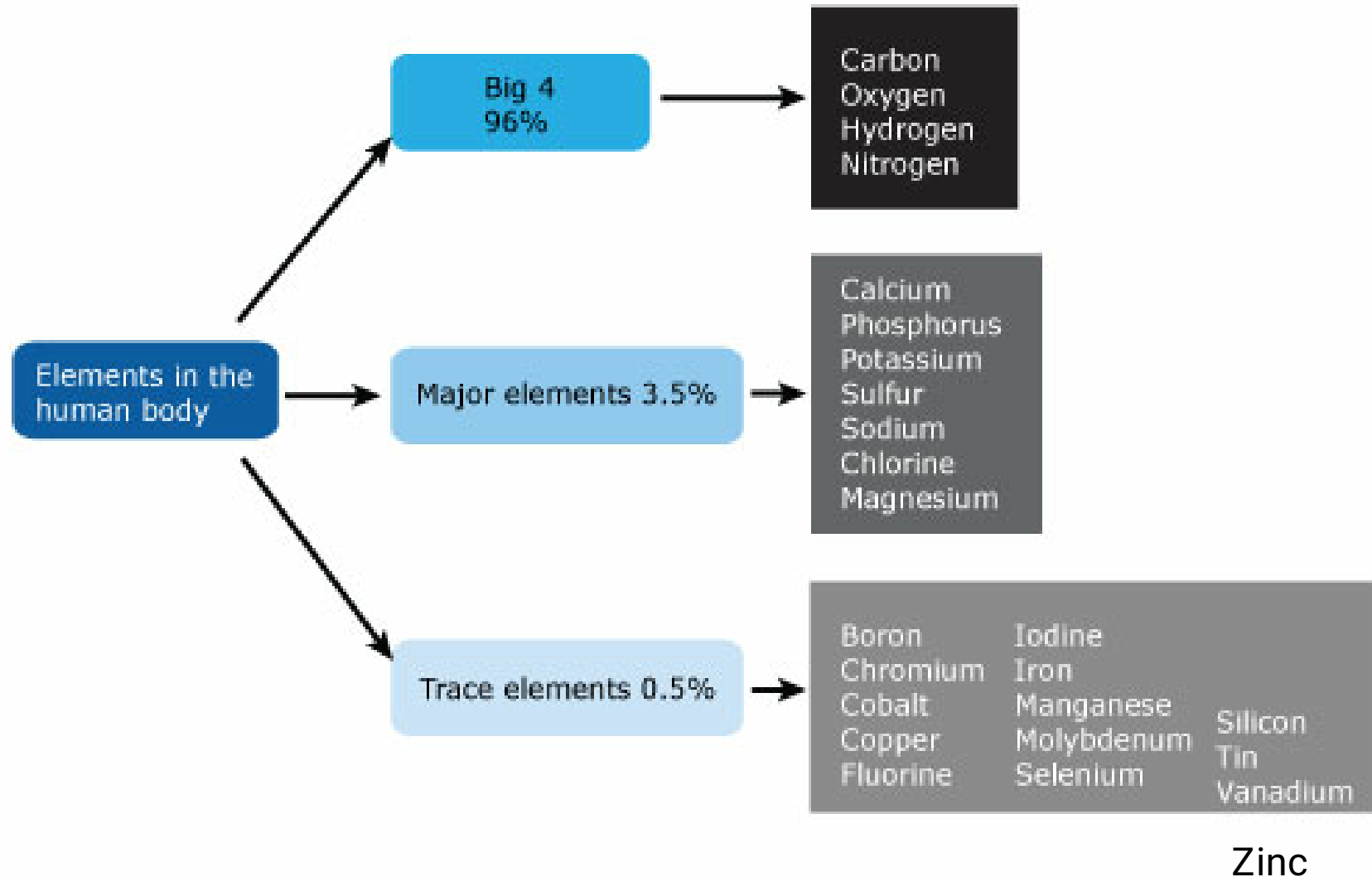
Earth's crust Vs Living matter

Relative abundance of carbon and hydrogen with respect to other elements is higher in any living organism than in earth's crust

**. A Comparison of Elements Present
in Non-living and Living Matter***

Element	% Weight of	
	Earth's crust	Human body
Hydrogen (H)	0.14	0.5
Carbon (C)	0.03	18.5
Oxygen (O)	46.6	65.0
Nitrogen (N)	very little	3.3
Sulphur (S)	0.03	0.3
Sodium (Na)	2.8	0.2
Calcium (Ca)	3.6	1.5
Magnesium (Mg)	2.1	0.1
Silicon (Si)	27.7	negligible
* Adapted from CNR Rao, <i>Understanding Chemistry</i> , Universities Press, Hyderabad.		

Living organisms are composed of about 25 chemical elements -Life requires 25 essential elements



Carbon, hydrogen, oxygen, and nitrogen make up the bulk of living matter, but there are other elements necessary for life

NATURALLY OCCURRING ELEMENTS IN THE HUMAN BODY

Symbol	Element	Wet Weight Percentage*
O	Oxygen	65.0
C	Carbon	18.5
H	Hydrogen	9.5
N	Nitrogen	3.3
Ca	Calcium	1.5
P	Phosphorus	1.0
K	Potassium	0.4
S	Sulfur	0.3
Na	Sodium	0.2
Cl	Chlorine	0.2
Mg	Magnesium	0.1

96.3

Trace elements (less than 0.01%): boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), and zinc (Zn).

*Includes water.

Some trace elements are required to prevent disease

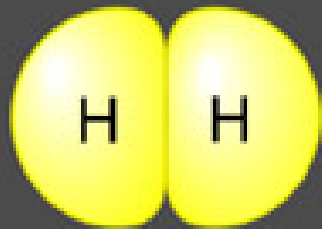
Without iron, your body cannot transport oxygen – Iron deficiency Anemia;

An iodine deficiency prevents production of thyroid hormones, resulting in goiter

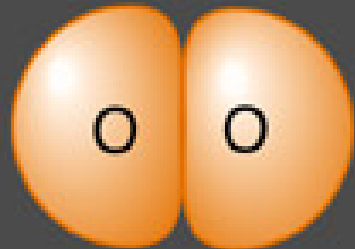


Elem
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Comp
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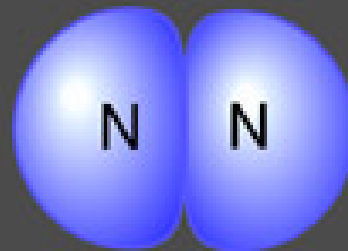
Elements – composed of the same types of atoms



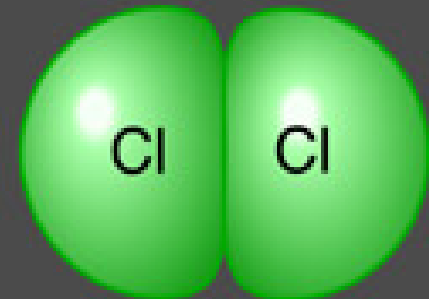
H_2
hydrogen



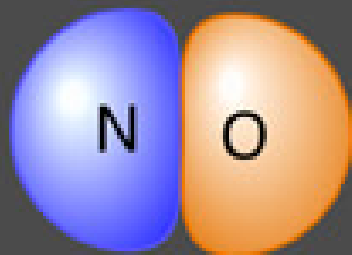
O_2
oxygen



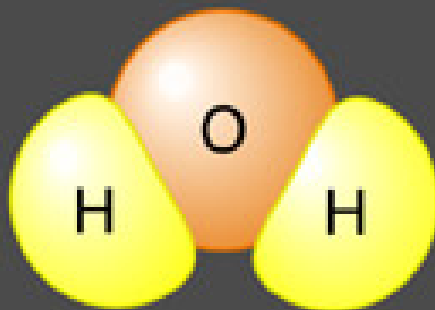
N_2
nitrogen



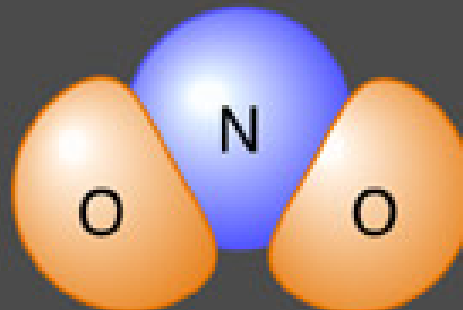
Cl_2
chlorine



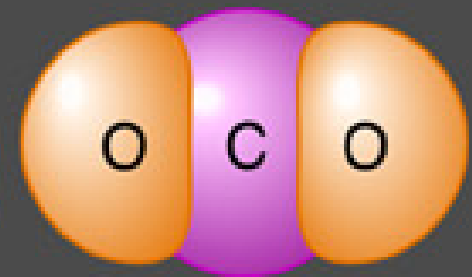
NO
nitrogen oxide



H_2O
water



NO_2
nitrogen dioxide



CO_2
carbon dioxide

Compounds – composed of two or more types of atoms

Element

- a substance that cannot be broken down to other substances
- If broken then they lose the property of that element
 - Ex) a bar of pure gold, nitrogen gas (N_2), oxygen gas (O_2)
 - Any substance composed of only ONE elem

COMPOUND

-Any substance composed of two or more elements

Types of Chemical Compounds

1. Molecular Compound/Molecules
2. Ionic Compounds

Types of Chemical Compounds

1. Organic Compounds
2. Inorganic Compounds

Molecular Compound/Molecules

When two or more atoms (non-metal atoms) of elements (same type of atom) or (different types of atoms) held together by covalent bonds -molecules

Even some elements exist as molecules rather than as atoms.

Hydrogen, nitrogen, oxygen, fluorine, chlorine, bromine, iodine, sulfur and phosphorus all exist as molecules whose atoms held together by covalent bond.

Therefore, we have to write them as H_2 , N_2 , O_2 , F_2 , Cl_2 , Br_2 , I_2 , S_8 and P_4 when using any of these elements in a chemical equation.

All compounds are molecules, but not all molecules are compounds

The Chemical Basis of Life

Using the terms element,
compound and/or
molecule, characterize
the following:

C_6H_6

This is certainly a molecule because there will be covalent bonds. It is also a compound because there is more than one type of element.

The Chemical Basis of Life

Using the terms element, compound and/or molecule, characterize the following:



This is not a molecule since there are no covalent bonds present. It is a compound since there is more than one type of atom present.

The Chemical Basis of Life

Using the terms element,
compound and/or
molecule, characterize
the following:

O_2

This is a molecule because there is a covalent bond (a double covalent bond in this case). It is not a compound since there is only oxygen, which would make it an element.

Number of bonds formed by each element:

	Element	Number of Covalent Bonds it will form to be "happy" (stable)
Flurine	Hydrogen	1
Sulphur	Oxygen	2
Phosphorus	Nitrogen	3
Sulphur	Carbon	4

The element will form as many bonds as it needs electrons in its valence shell.

For example, carbon needs four electrons and therefore it will make four covalent bonds (it will share 4 electrons) with other

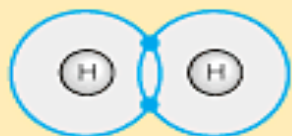
ALTERNATIVE WAYS TO REPRESENT MOLECULES

**Molecular
Formula**

Electron Configuration

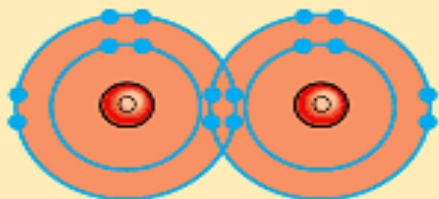
**Structural
Formula**

H₂



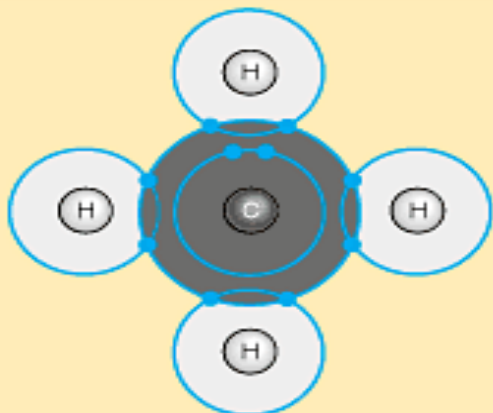
H—H
Single bond

O₂



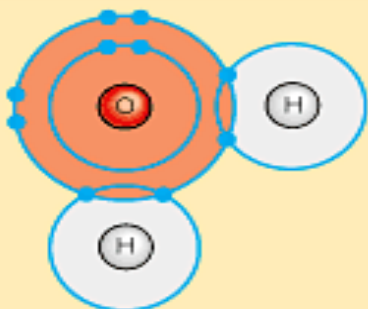
O=O
Double bond

CH₄
Methane



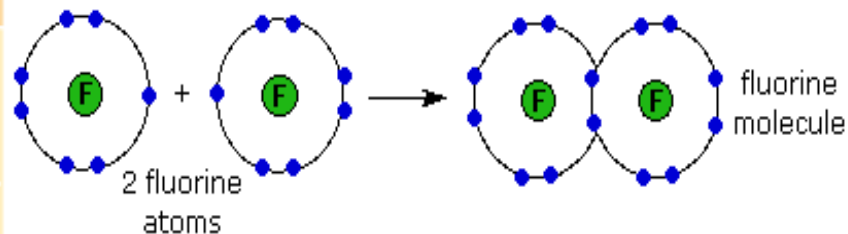
$\begin{array}{c} \text{H} \\ | \\ \text{H}-\text{C}-\text{H} \\ | \\ \text{H} \end{array}$

H₂O
Water



$\begin{array}{c} \text{O}-\text{H} \\ | \\ \text{H} \end{array}$

Covalent bond strengths:



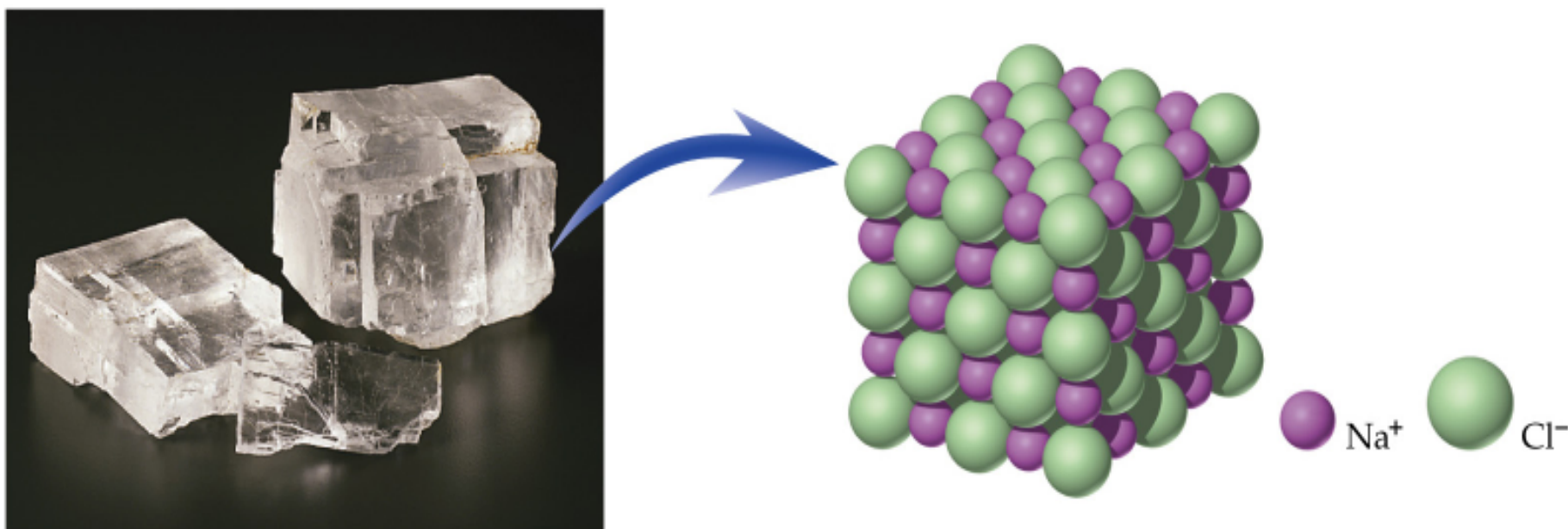
Triple > Double > Single bond

Ionic Compounds

A ionic compound is made up of positive and negative ions (cation and anion) joined together by ionic bonds.

A **ionic bond** result from a transfer of one or more electrons from one atom to another then joint together by electrostatic forces of attraction.

Ionic compounds conduct electricity when dissolved in water or when molten. Eg **NaCl (Sodium Chloride)**, **CaBr₂ (Calcium Bromide)**



the arrangement of Na⁺ions and Cl⁻ions in a crystal of sodium chloride. Each Na⁺ion is surrounded by six neighboring Cl⁻ ions, and each Cl⁻ ion is surrounded by six neighboring Na⁺ ions

Organic Compounds

Formed by carbon and hydrogen (hydrocarbon) or carbon and hydrogen together with oxygen, nitrogen, and a few other elements.

An **organic compound** is any member of a large class of gaseous, liquid, or solid chemical **compounds** whose molecules contain carbon.

Inorganic compounds

Compounds composed of elements other than carbon.

Except a few simple compounds of carbon, including **carbon monoxide, carbon dioxide, carbonates** and **cyanides** are generally considered to be inorganic.

Compounds in Living Organism

Many of the compounds in living organisms contain -

Carbon, hydrogen, oxygen, and nitrogen



1. Carbohydrates (CHO)
2. Proteins (CHONS)
3. Lipids (CHO)
4. Nucleic acids (CHONP)

Organic Compounds

As all these carbon containing compounds are in living organisms - can be called **'Biomolecules'**.

Inorganic constituents present in living tissues

Components	Chemical Formula
Sodium	Na^+
Potassium	K^+
Calcium	Ca^{2+}
Magnesium	Mg^{2+}
Water	H_2O
Compounds	NaCl , CaCO_3 , PO_4^{3-} , SO_4^{2-}

Average Composition of Cells

Components	Percentage (%) of the total cellular mass
Water	70 -90 (forms the intracellular, extracellular fluid & interstitial fluid)
Proteins	10 – 15 (Forms the building blocks of the body)
Carbohydrates	3
Nucleic Acids	5-7 (Genetic Material)
Ions	1

Water is the most abundant chemical in living organisms

Macromolecules

Conventional biopolymers created by **polymerization of smaller subunits**

Process in which repeating subunits termed monomers bound in to chains of different lengths

(Nucleic acids, proteins, and carbohydrates)

Non-polymeric molecules – not created by polymerization of smaller subunits
(Lipids)

