

An Integrated View of Chemistry and Physics

The structure of Chemistry

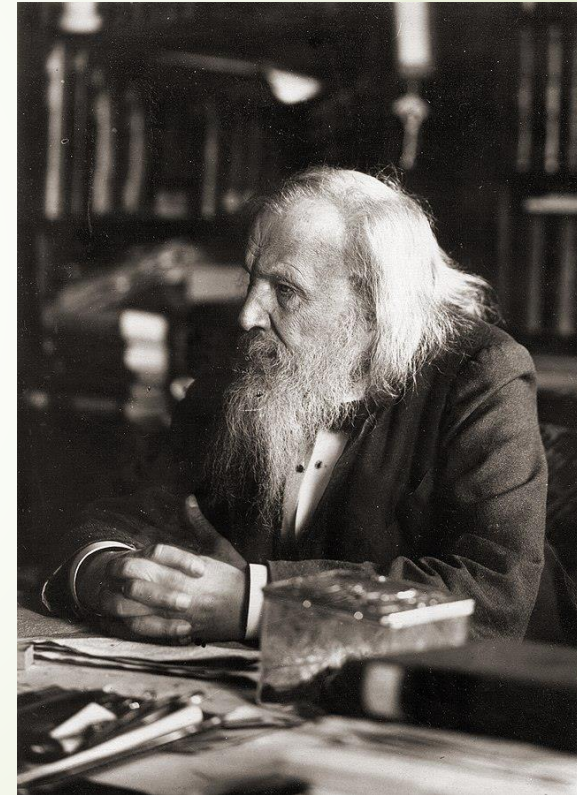
From electrons around a nucleus to the wonders of technology and life itself

Outline of this talk

- ▶ 1 The periodic table
- ▶ 2 The electrons around a nucleus shape what atoms can do
 - ▶ The outermost shell structure of the electrons in orbitals around a nucleus
- ▶ 3 Some selected elements
- ▶ **4 Molecules**
 - ▶ Geology, inorganic chemistry
 - ▶ Technology. The metals, radioactivity
 - ▶ Life, organic chemistry including, as a finale, DNA and proteins

1 The periodic table

- ▶ Dmitri Mendeleev (1834-1907)
- ▶ The table is in numerical order based on the atomic number
- ▶ The elements are arranged in groups according to their properties



Periodic Table of the Elements

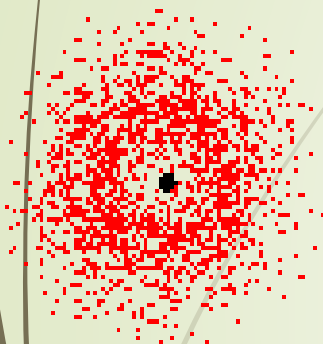
1 H Hydrogen 1.008	2 He Helium 4.003																															
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180															
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948															
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.972	35 Br Bromine 79.904	36 Kr Krypton 84.798															
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.294															
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018															
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Nh Nihonium unknown	114 Fl Flerovium [289]	115 Mc Moscovium unknown	116 Lv Livermorium [298]	117 Ts Tennessine unknown	118 Og Oganesson unknown															
																		57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.242	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.055	71 Lu Lutetium 174.967
																		89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

- Alkali Metal
- Alkaline Earth
- Transition Metal
- Basic Metal
- Semimetal
- Nonmetal
- Halogen
- Noble Gas
- Lanthanide
- Actinide

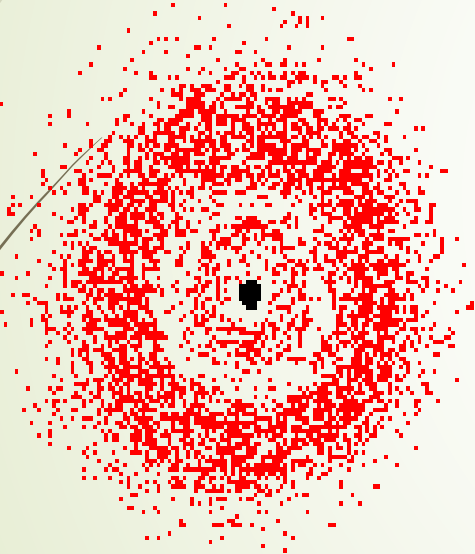
2 The electrons around a nucleus shape what atoms can do.

- ▶ **The electrons are distributed around the nucleus in quantum shells**
- ▶ **Valence electrons:-** Valence electrons are the electrons of an atom situated in an outermost shell surrounding an atomic nucleus.
- ▶ They can participate in the formation of chemical bonds.

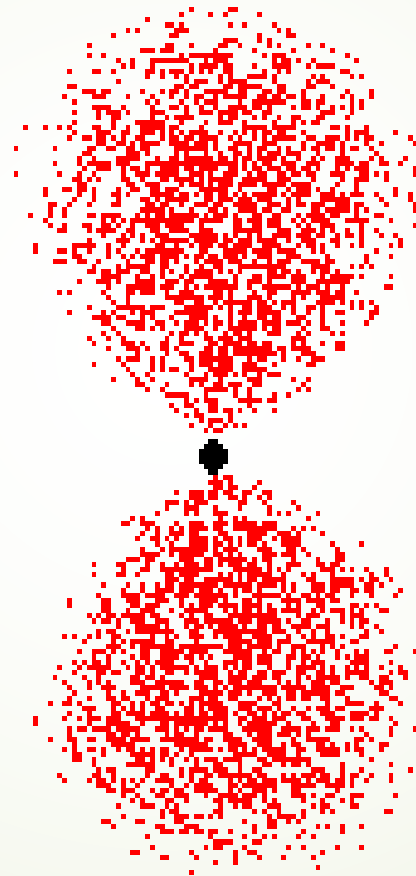
There are several shapes of orbitals around the nucleus



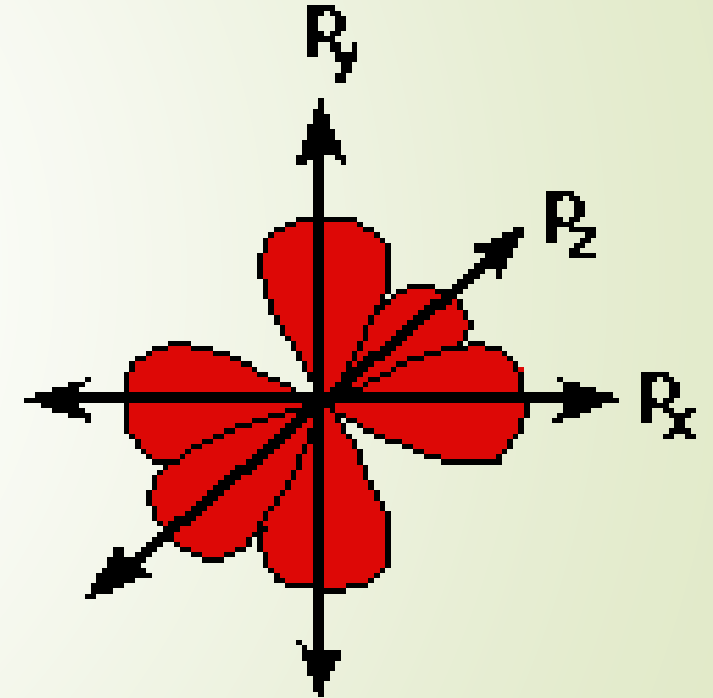
a 1s orbital



a 2s orbital



a p orbital



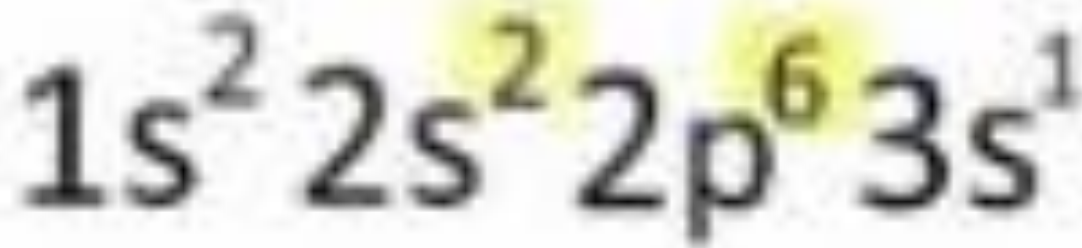
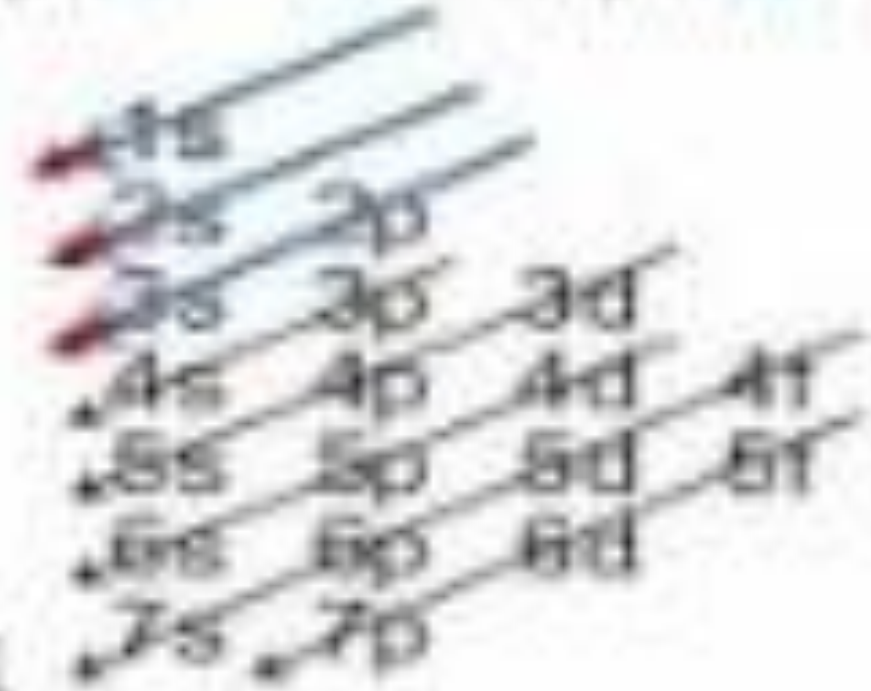
Electron Configuration Chart

s holds up to 2

p holds up to 6

d holds up to 10

11
Na
Sodium
22.99



3. The chemistry of some significant elements (demonstrating the rationale of the structure of the periodic table)

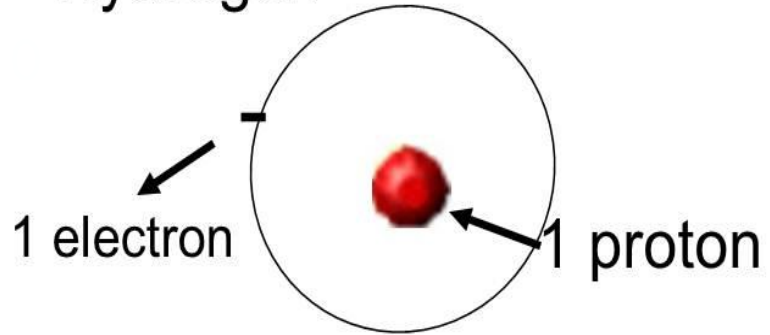
- a Hydrogen
- b Helium and the noble gases
- c Carbon and its relative, silicon
- d Oxygen
- e Sodium
- f Chlorine
- f Phosphorus
- g Iron and the multivalent metal elements
- h Uranium and its unstable cohort (radioactivity)

The Noble Gases – The stability of full shells

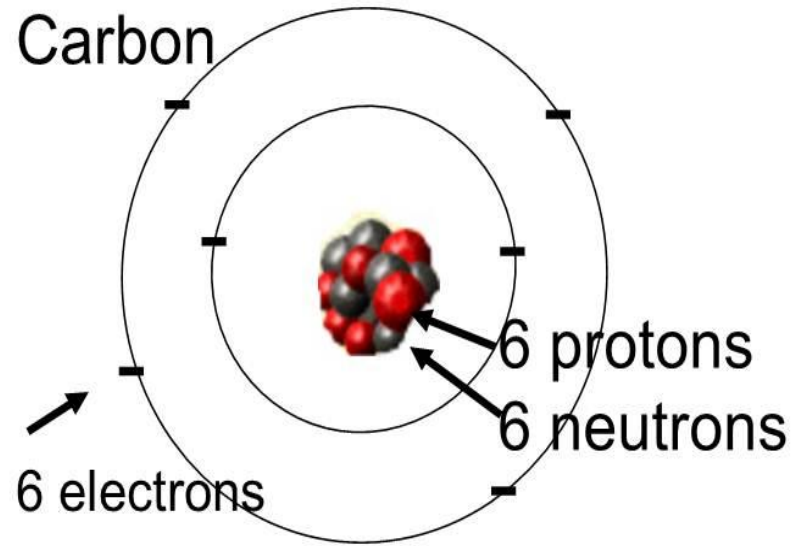
Element	Electron Configuration
He	$1s^2$
Ne	$[\text{He}] 2s^2 2p^6$
Ar	$[\text{Ne}] 3s^2 3p^6$
Kr	$[\text{Ar}] 4s^2 4p^6$
Xe	$[\text{Kr}] 5s^2 5p^6$

- All the noble gases have full valence shells
- Thus they are very stable
- Reactions between elements usually creates a shared stability

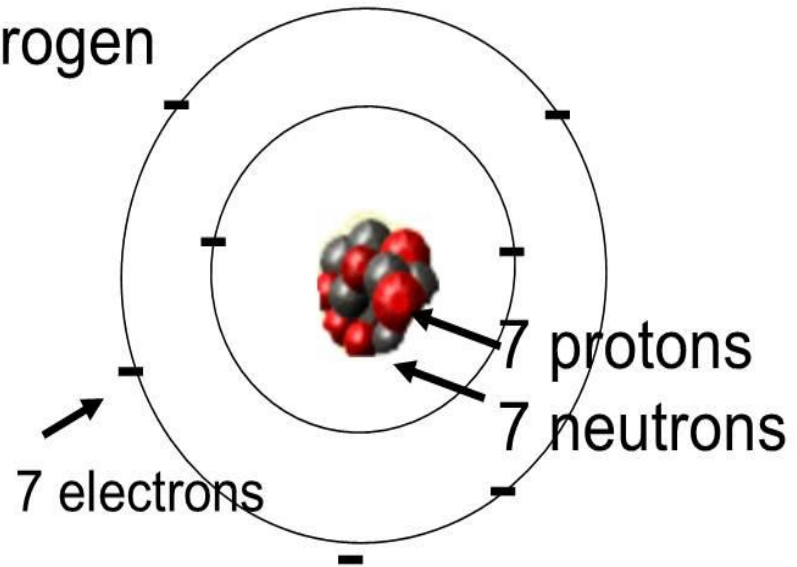
Hydrogen



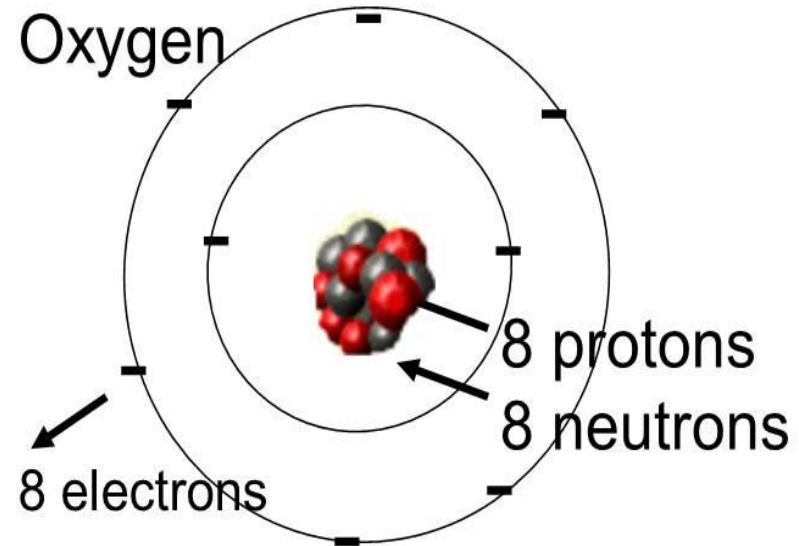
Carbon



Nitrogen



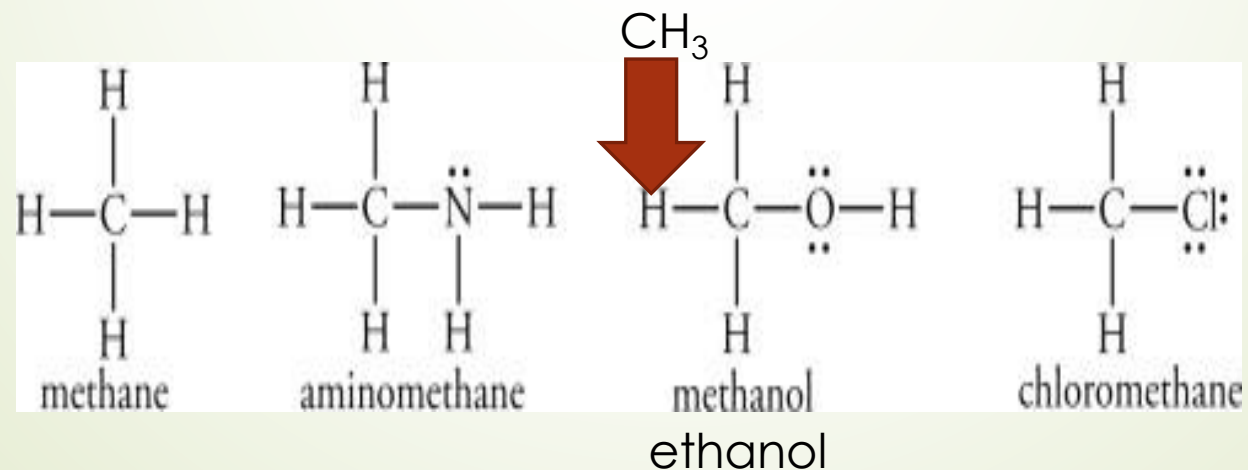
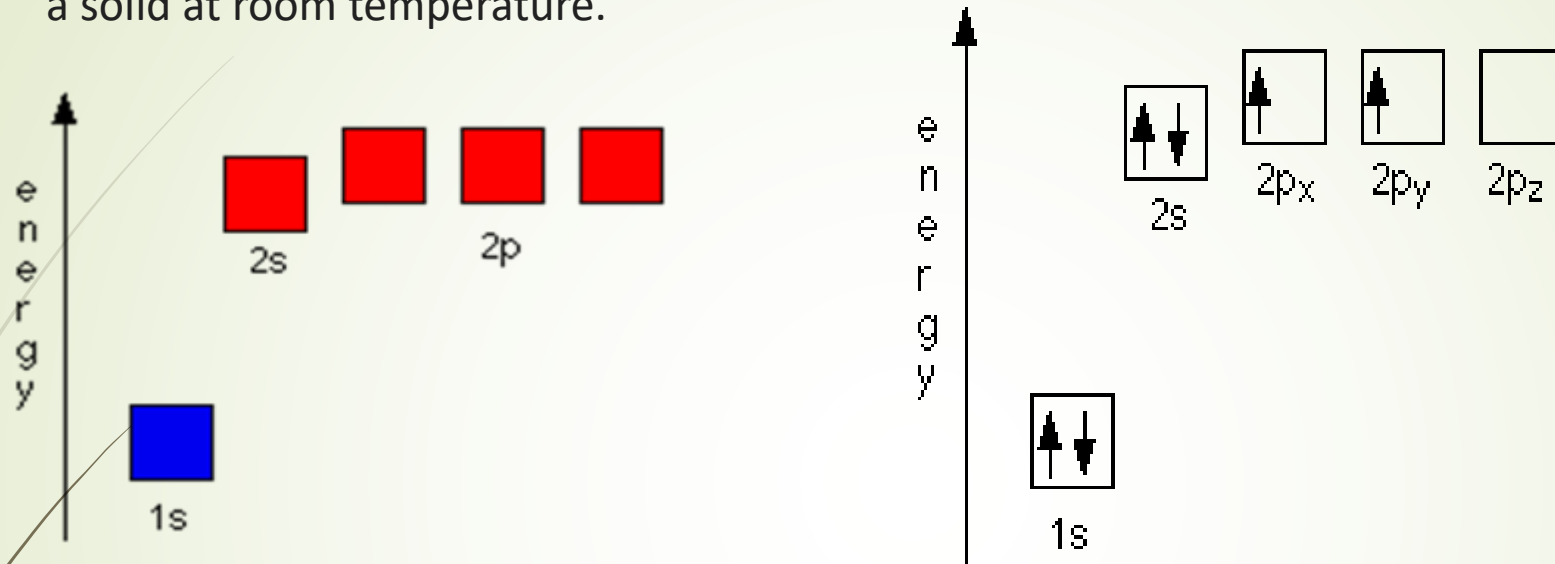
Oxygen



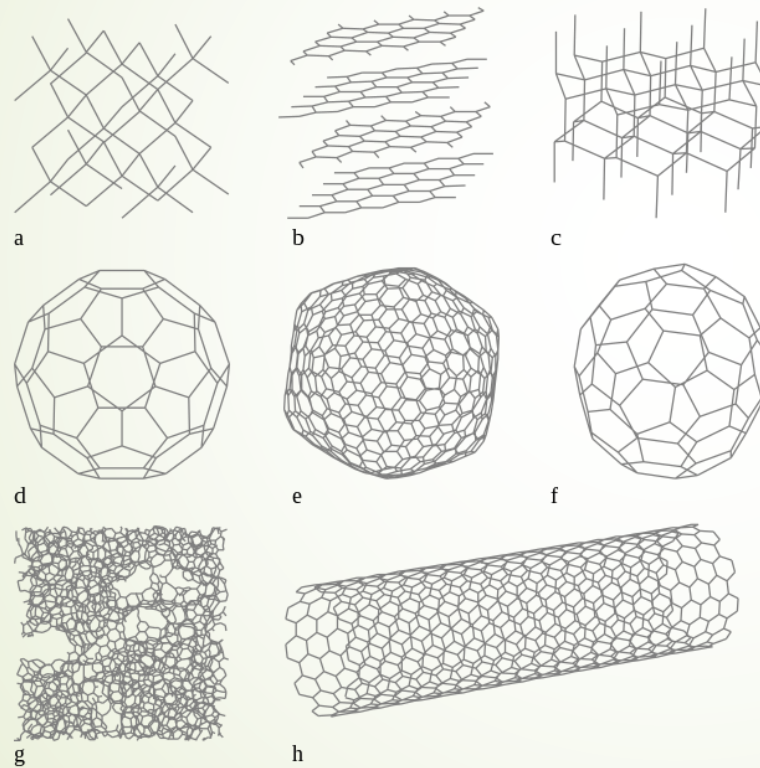
Carbon

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Carbon is a chemical element with symbol C and atomic number 6. Classified as a nonmetal, carbon is a solid at room temperature.



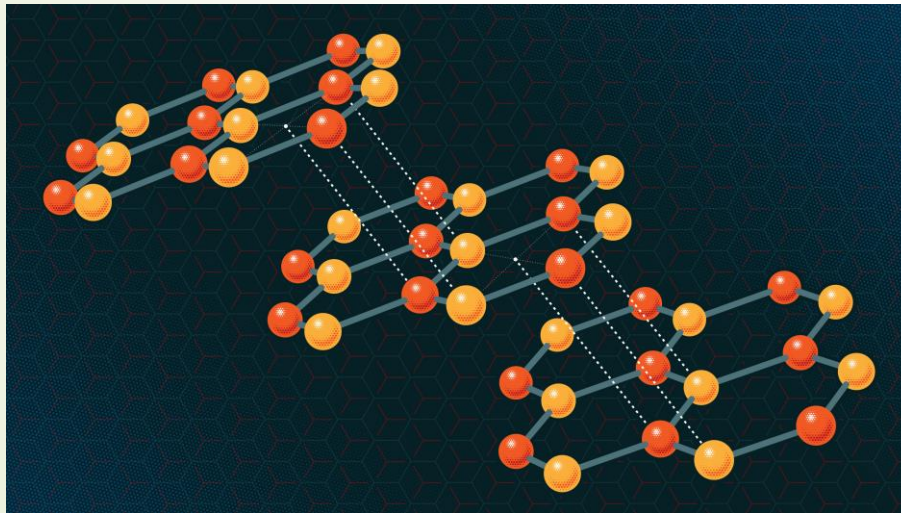
This illustration depicts eight of the allotropes (different molecular configurations) that pure carbon can take:



- a) Diamond
- b) Graphite
- c) Lonsdaleite
- d) C60 (Buckminsterfullerene)
- e) C540
- f) C70
- g) Amorphous carbon
- h) single-walled carbon nanotube

Graphene Superconductors May Be Less Exotic Than Physicists Hoped

- ▶ ABC trilayer graphene, with layers that are shifted rather than twisted, showed flickers of superconductivity when cooled to near absolute zero.



4. Molecules

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Geology, inorganic chemistry

Technology. The metals, Radioactivity

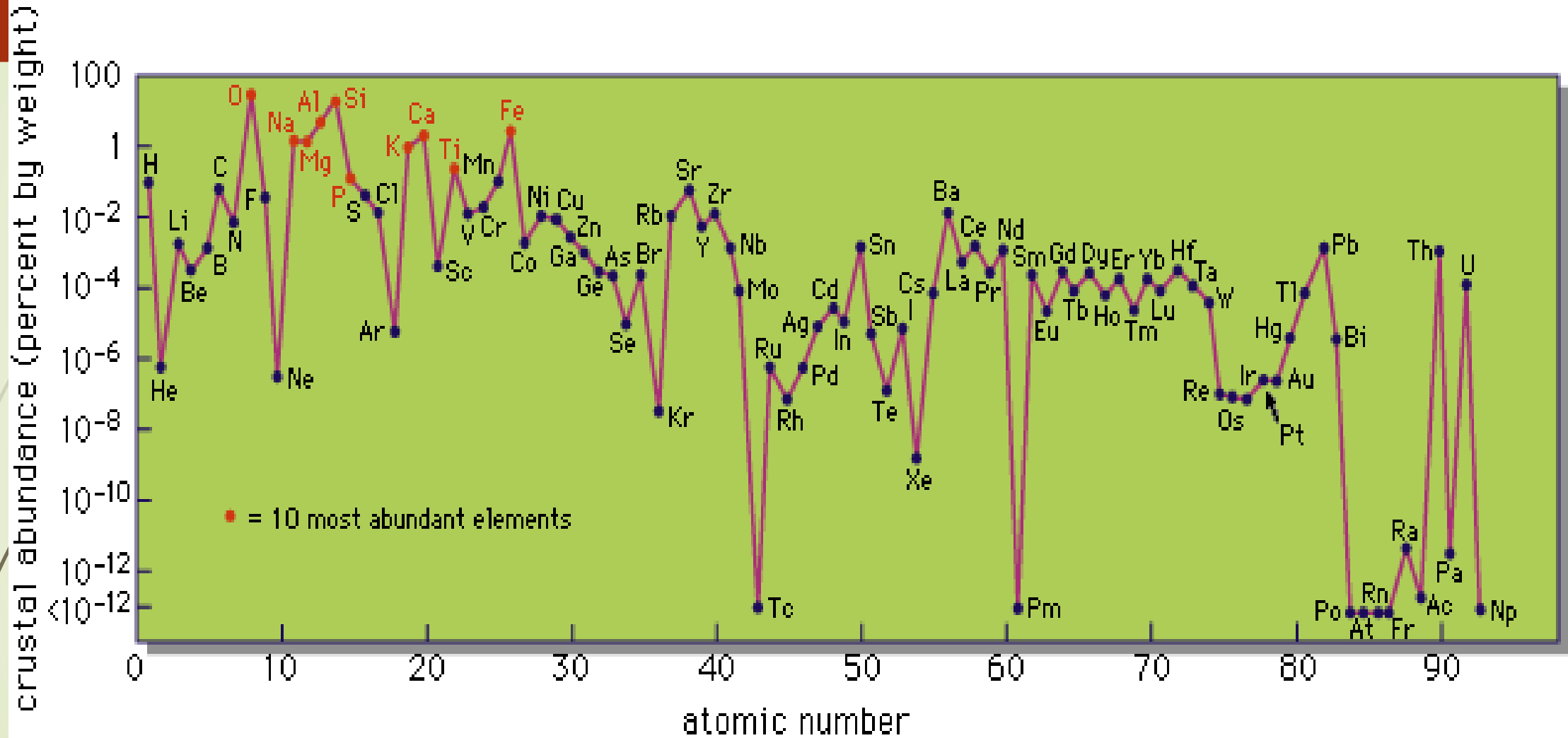
Life, organic chemistry including, as a finale,
DNA and proteins

Geology, inorganic chemistry

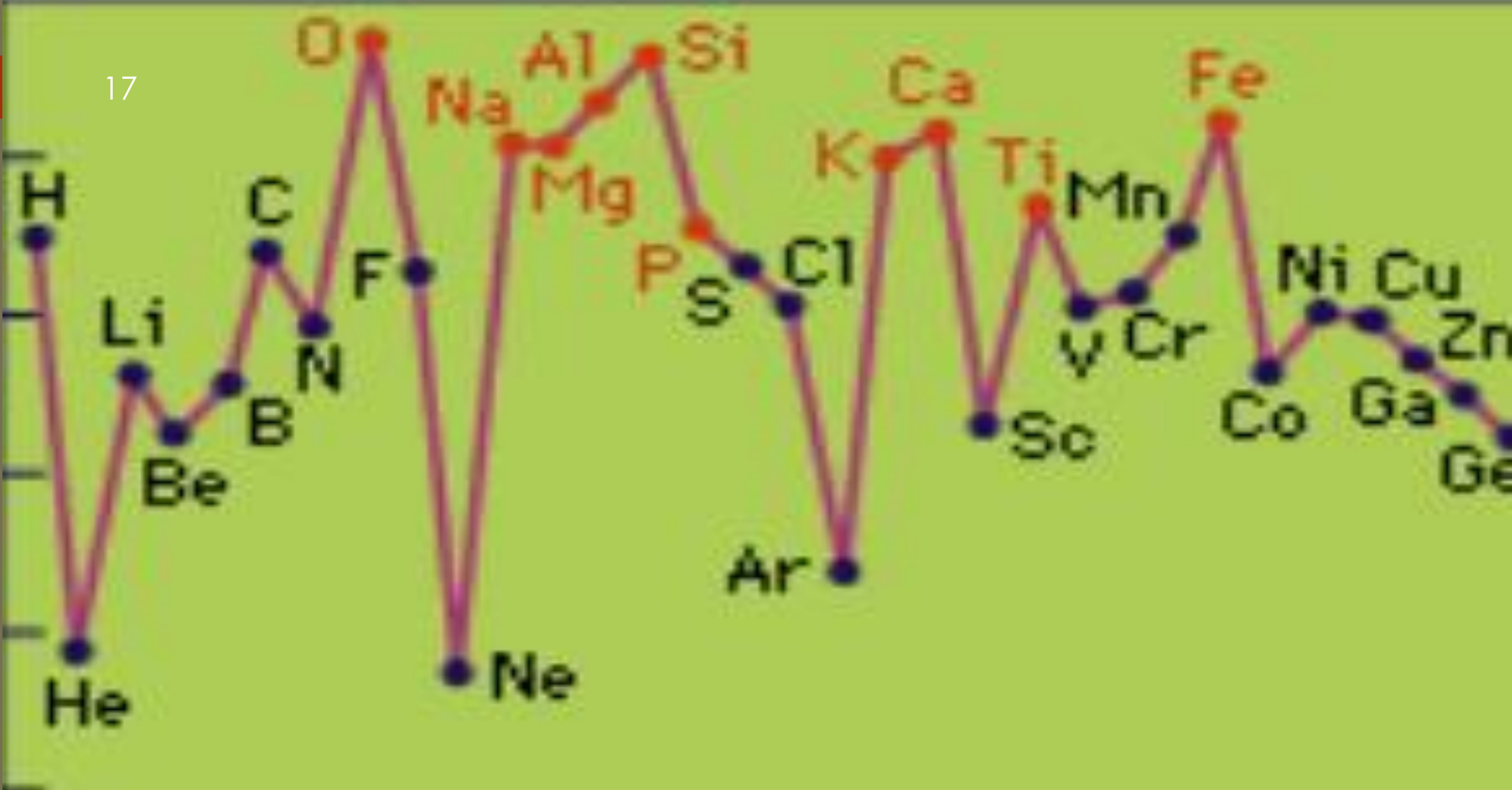
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Crustal abundances of elements of atomic numbers 1 to 93.

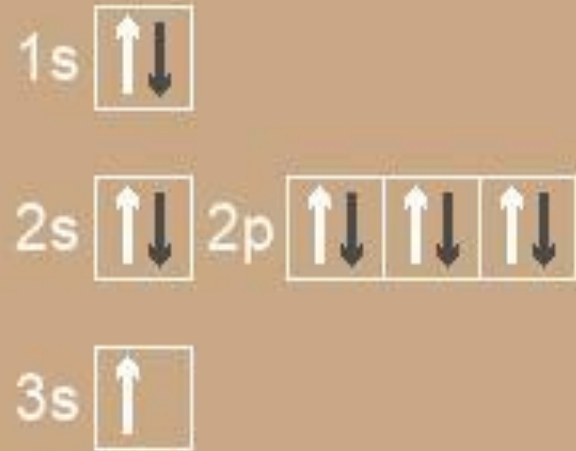
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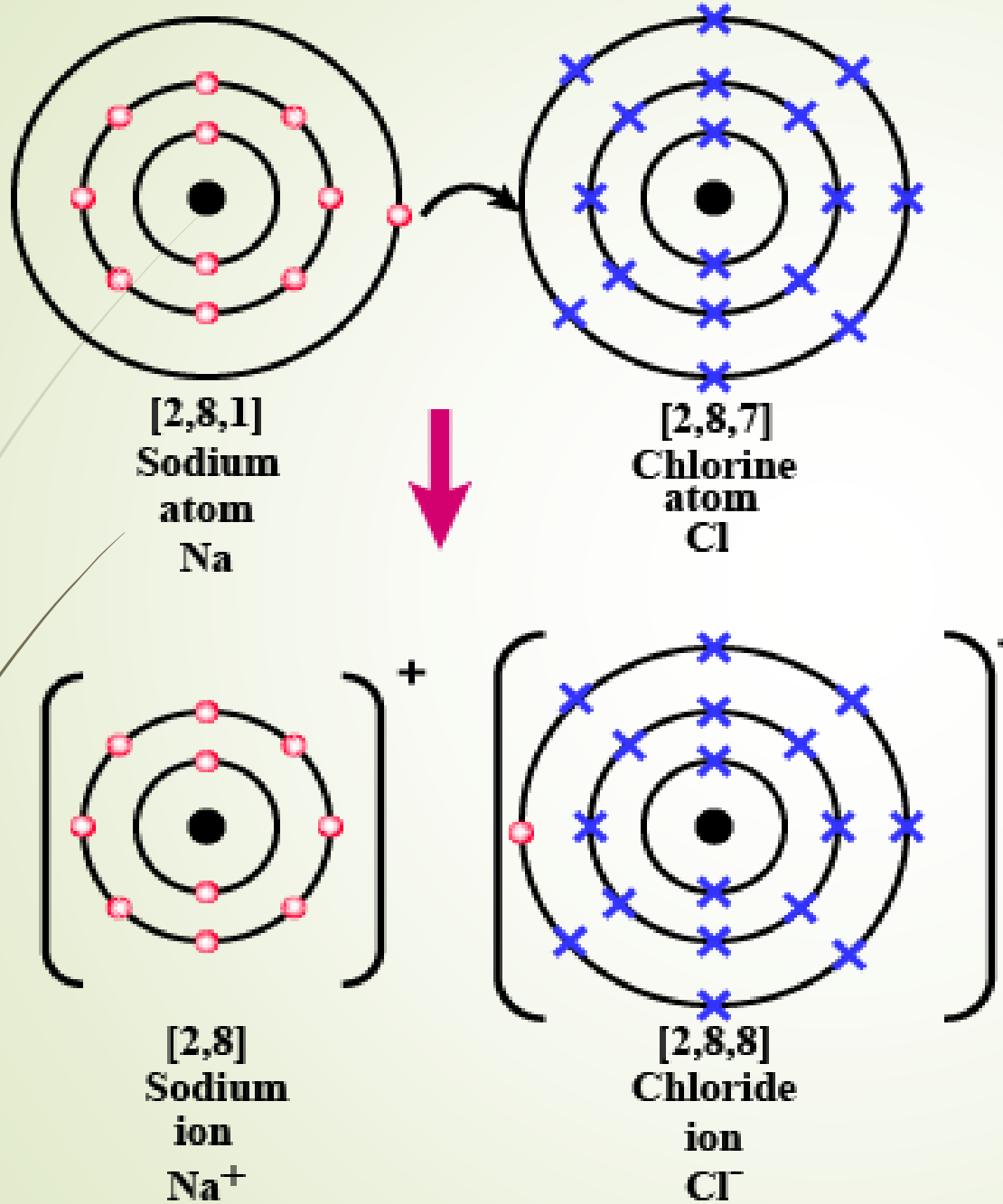


Orbital diagram of the Sodium (Na) atom



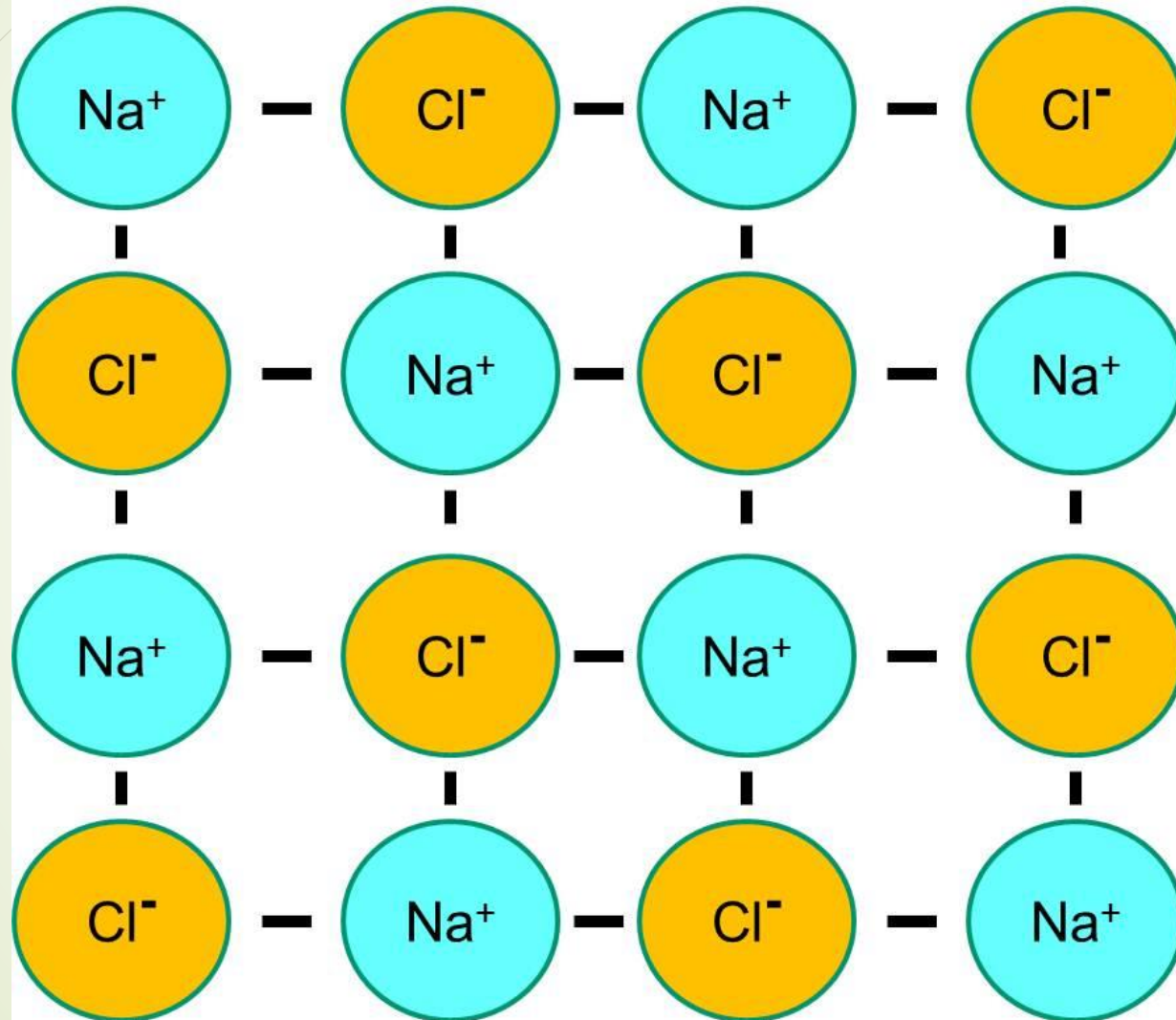
Orbital diagram of the Chlorine (Cl) atom



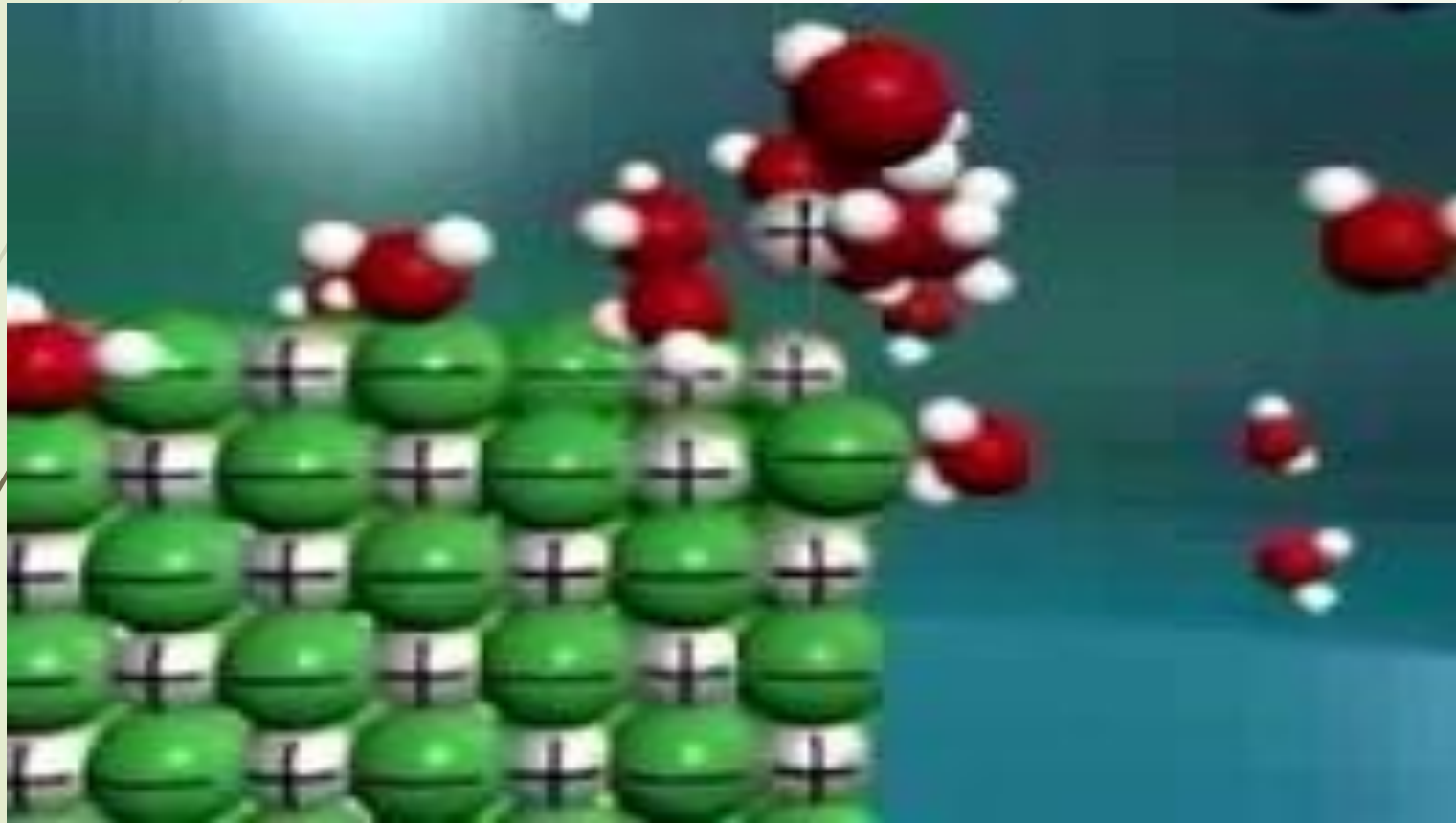


Ionic Bonding giving stability to each ion

Crystal Lattice of NaCl (table salt)

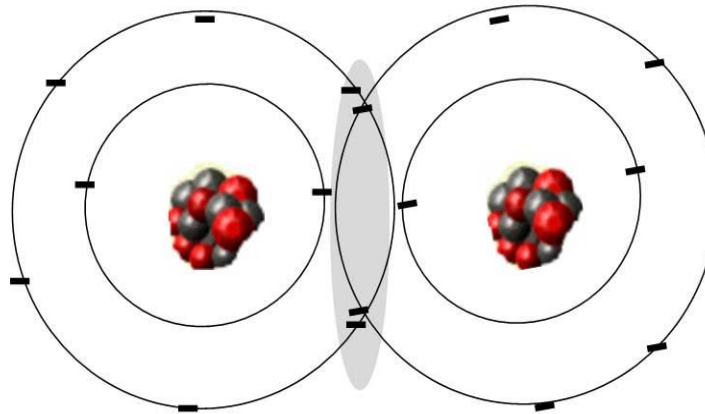


2 Ionic reactions; Dissolving salt in water



Covalent Bonds

- ▶ A covalent bond is one in which one or more pairs of electrons are shared by two atoms.
- ▶ two atoms of oxygen that are covalently bonded by the sharing of two pairs of electrons as illustrated in the shaded area.



Oxygen gas (O_2)

$O=O$

A double covalent bond
(sharing 2 pairs of electrons)

Phosphorus

- Phosphorus has 5 valence shell electrons available for bonding.
- Its valence shell configuration is $3s^23p^3$.
- Phosphorus forms mostly covalent bonds.

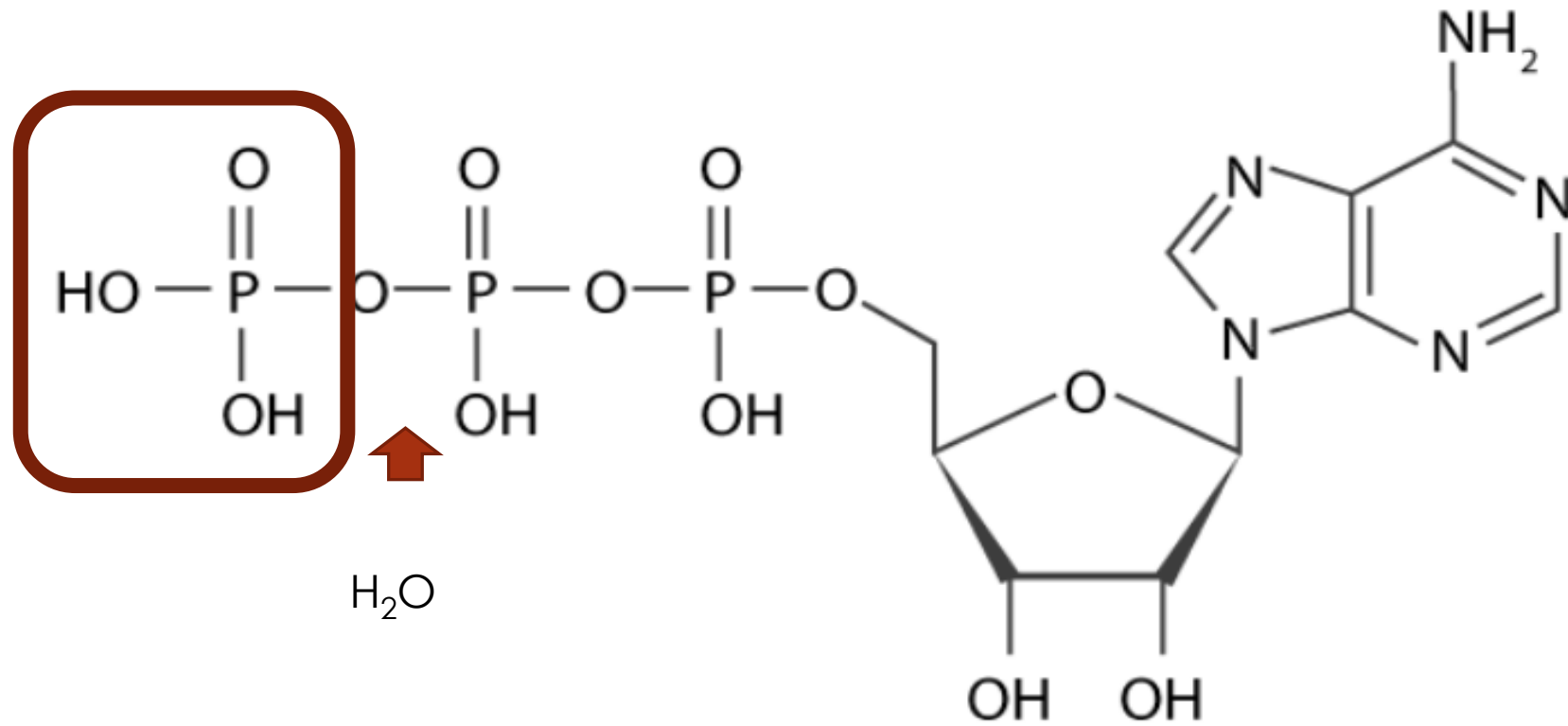
Many industrial uses as well as being very important in physiology

A salt, prepared by the action of phosphoric acid on phosphate rock, is calcium dihydrogen phosphate, or superphosphate, $\text{Ca}(\text{H}_2\text{PO}_4)_2$, the most widely used phosphate fertilizer.

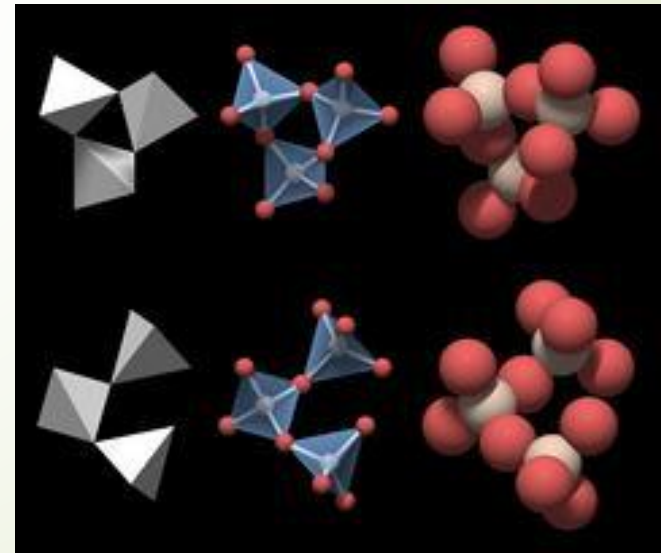
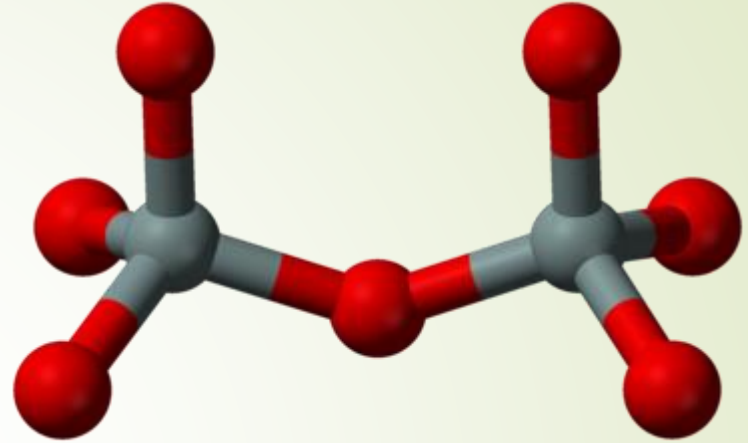
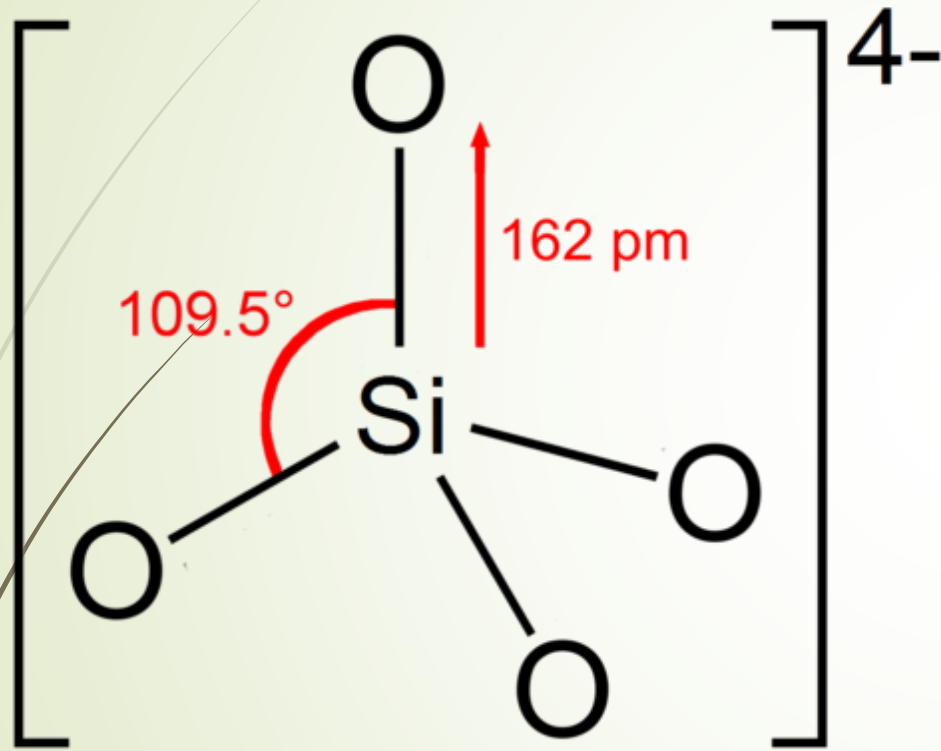
ATP, Adenosine tri phosphate

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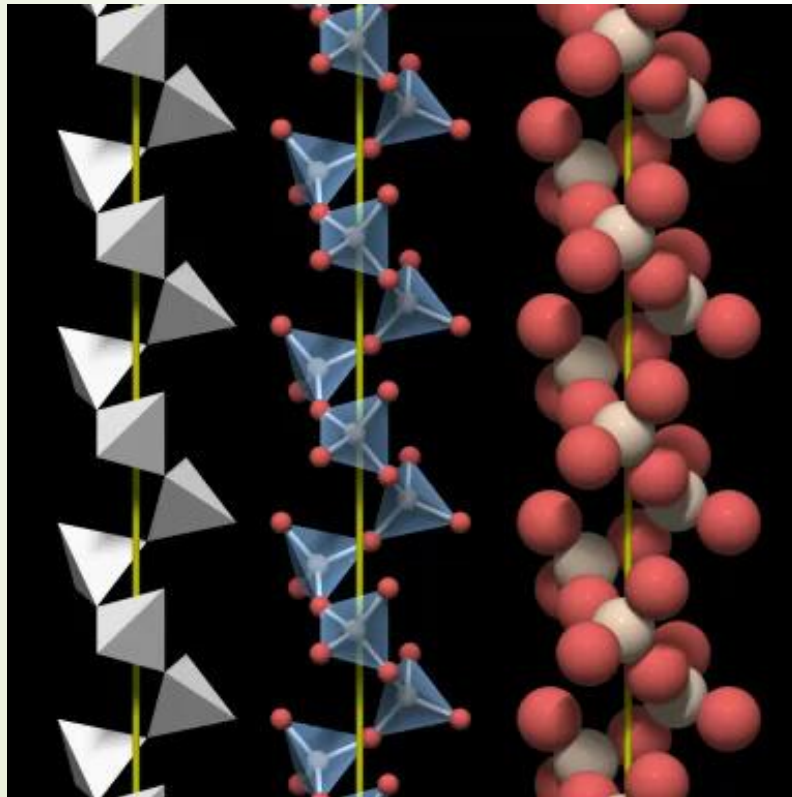
Structure of ATP Molecule



Silicon



Silicon



**In quartz
SiO₄ tetrahedra
are arranged in
virtual threefold
helices**

Amethyst (purple quartz)

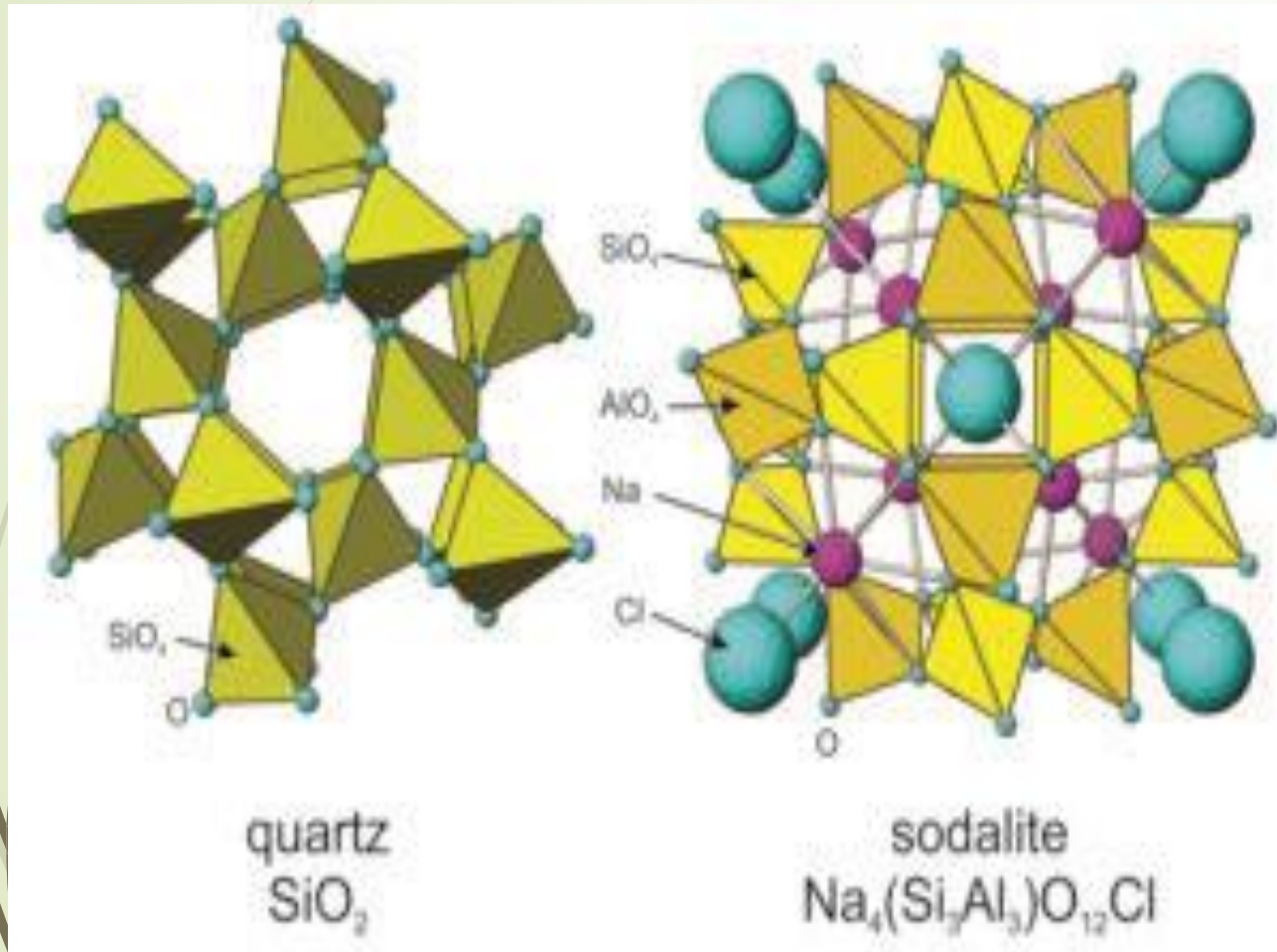
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Smoky quartz



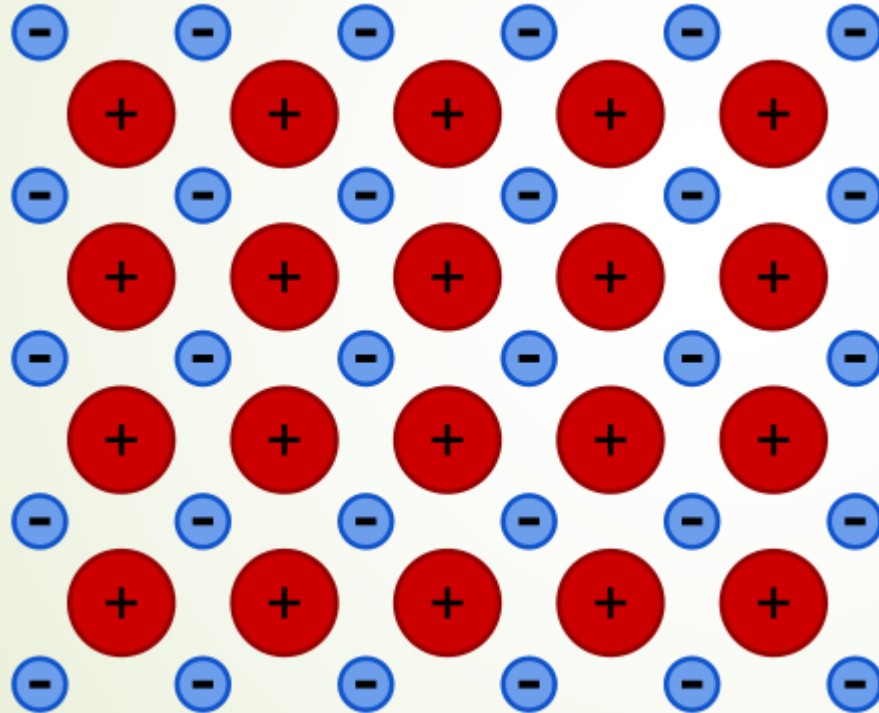
- ▶ Quartz has a formula unit composition of SiO_2 and is classified as a Tectosilicate..
- ▶ All four oxygens in quartz are polymerized to additional silica groups; all silica tetrahedra are polymerized to four other tetrahedra.
- ▶ In its characteristic crystal form, quartz has a hexagonal structure.

The atomic arrangements in quartz and sodalite

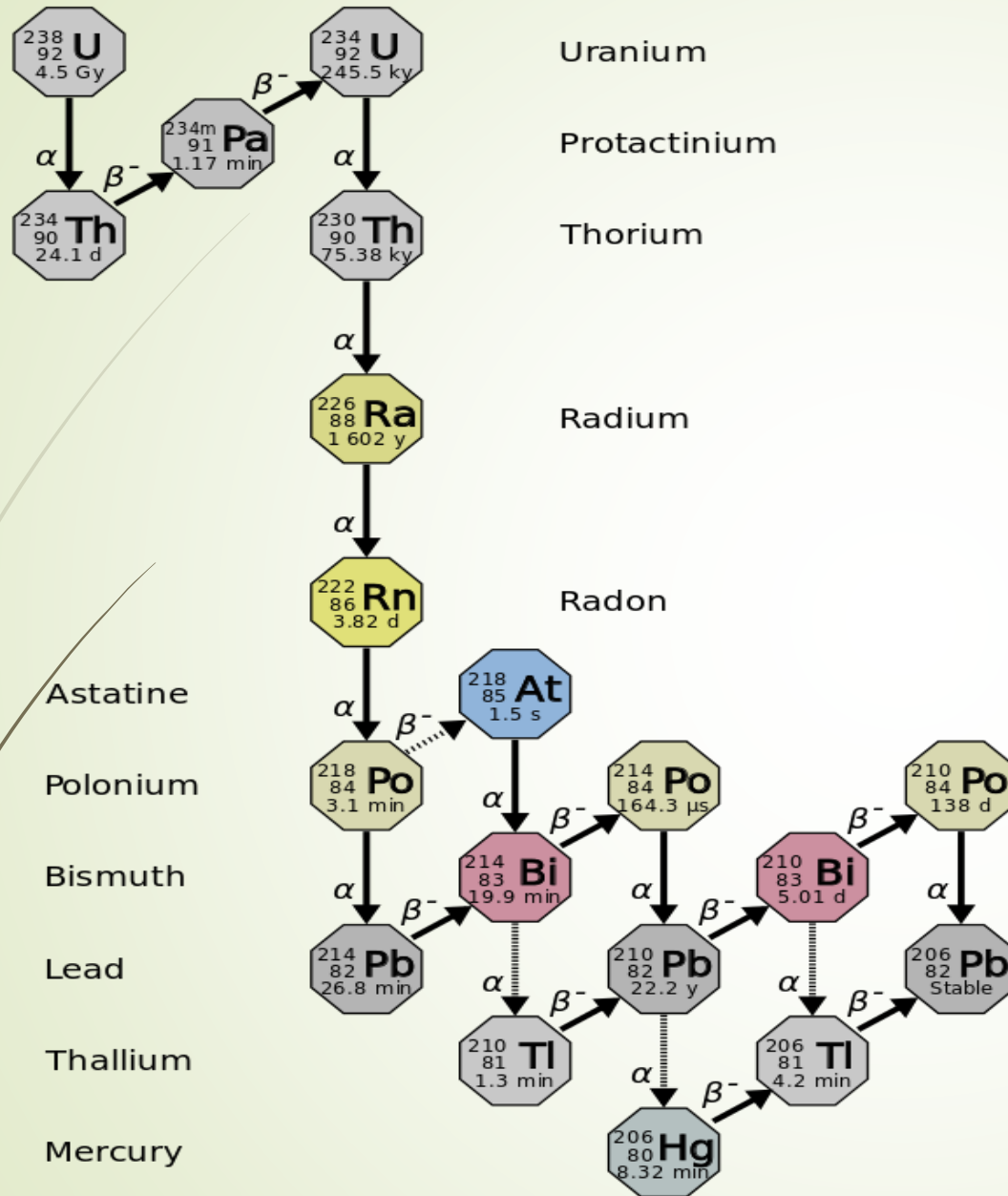


Technology. The metals, Radioactivity

Iron and metallic bonding



- Metallic bonding accounts for many physical properties of metals,
- strength,
- ductility,
- thermal and electrical resistivity and conductivity,
- opacity and luster.



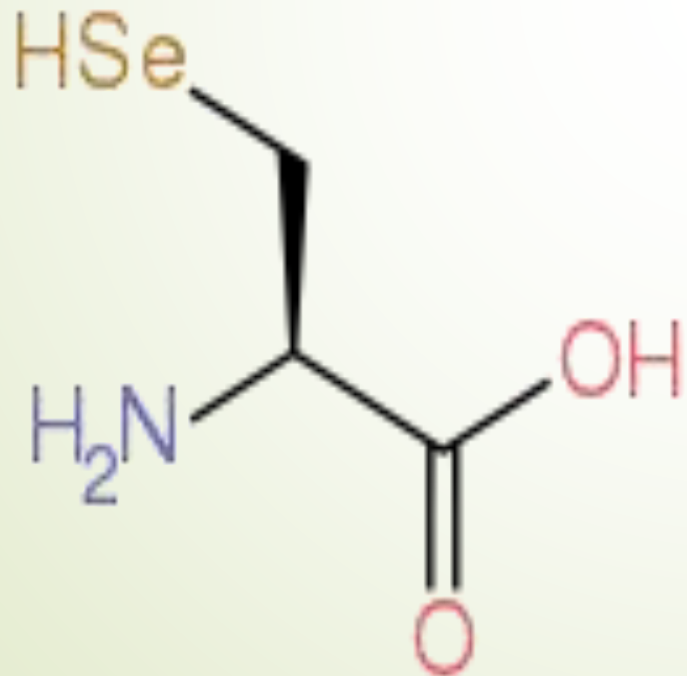
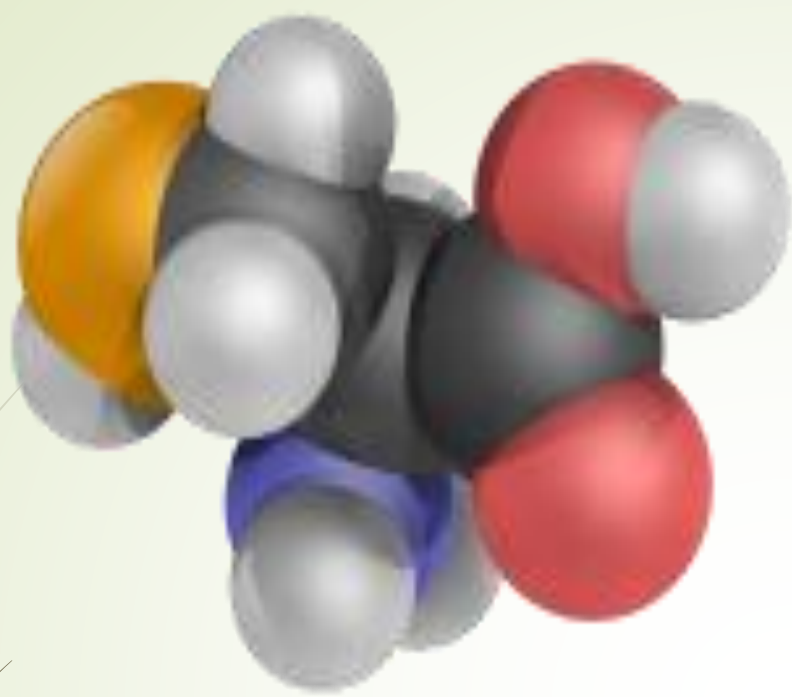
Uranium and its radioactive decay chain

Atoms are not indivisible!!

Many of the very large elements such as Uranium are unstable and radioactive.

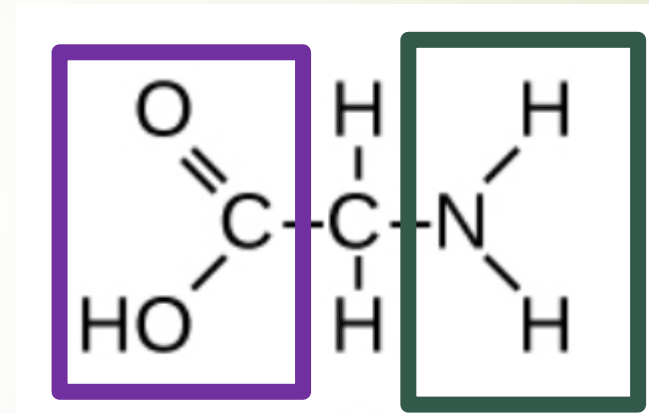
- They undergo **nuclear** reactions releasing at various stages, an **alpha particle**, which is a helium nucleus or a **beta particle** (an electron or a positron) and a neutrino and gamma radiation
- Ultimately the stable element is **lead**

Life, organic chemistry including, as a finale, DNA and proteins



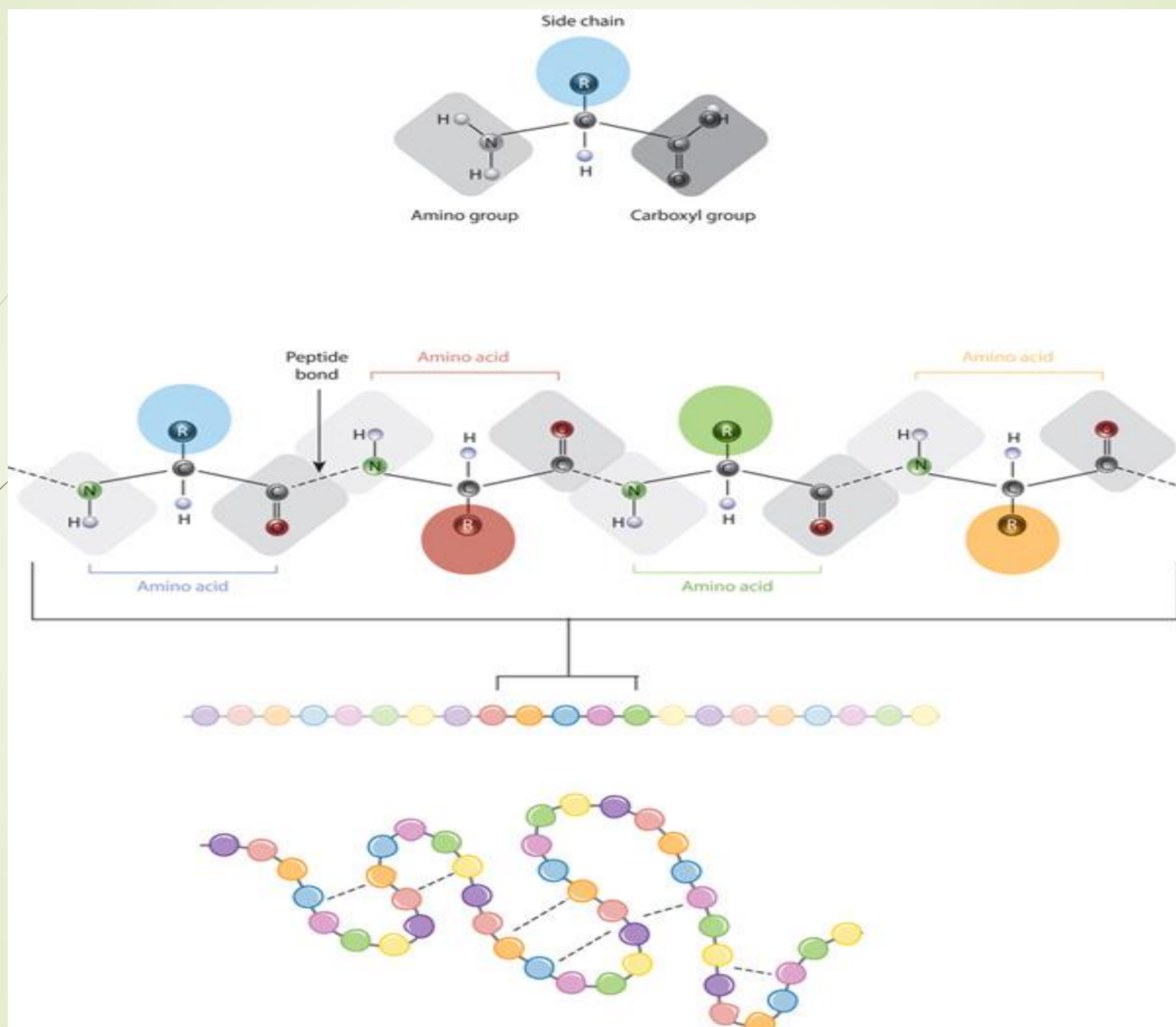
Amino Acids

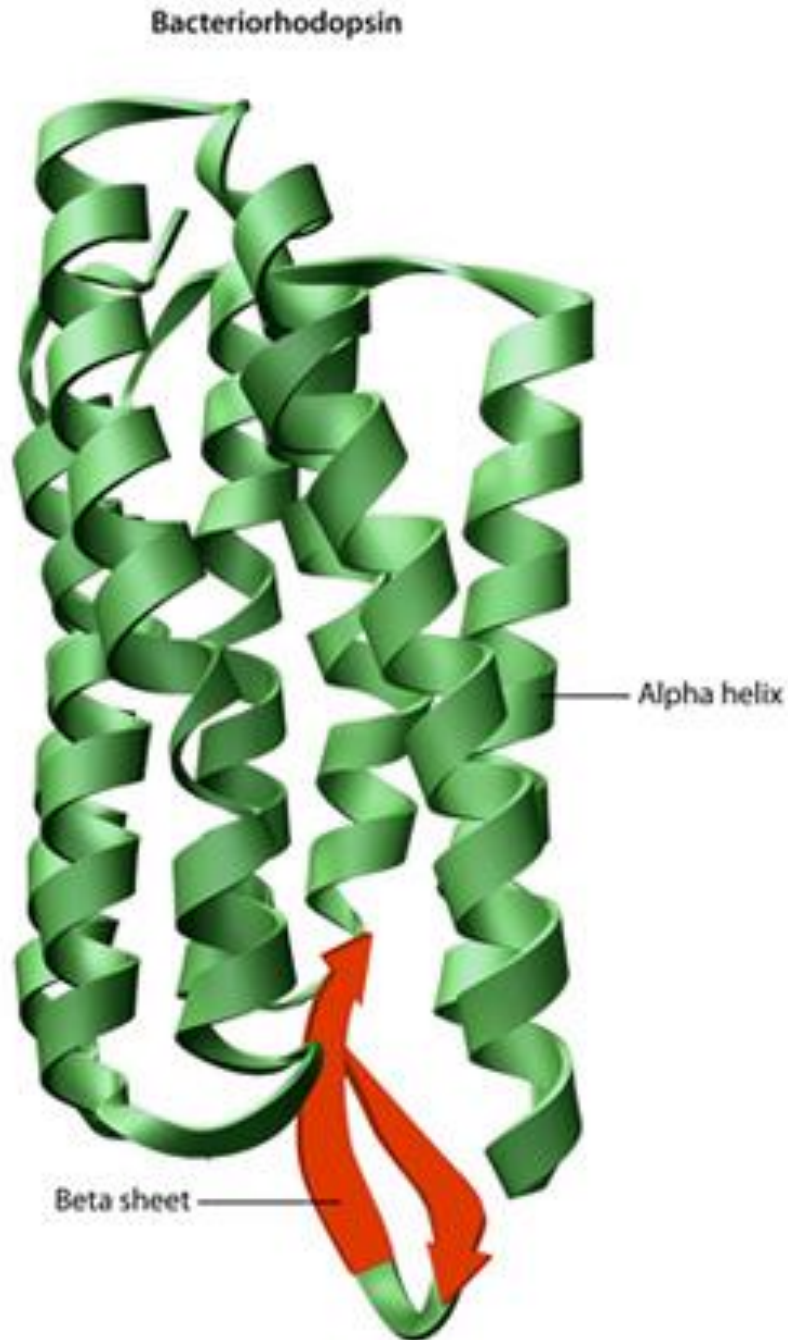
➤ glycine



Proteins

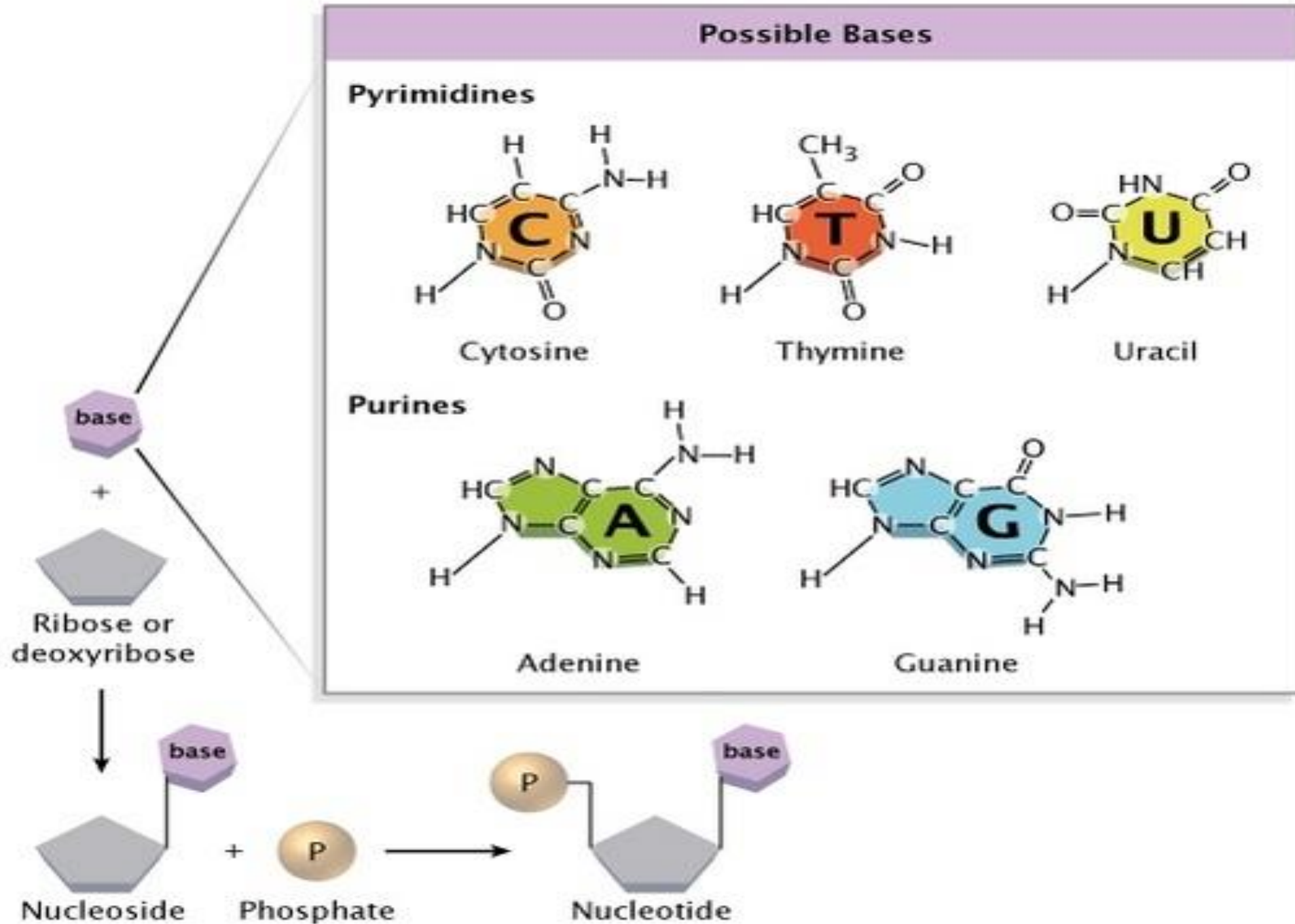
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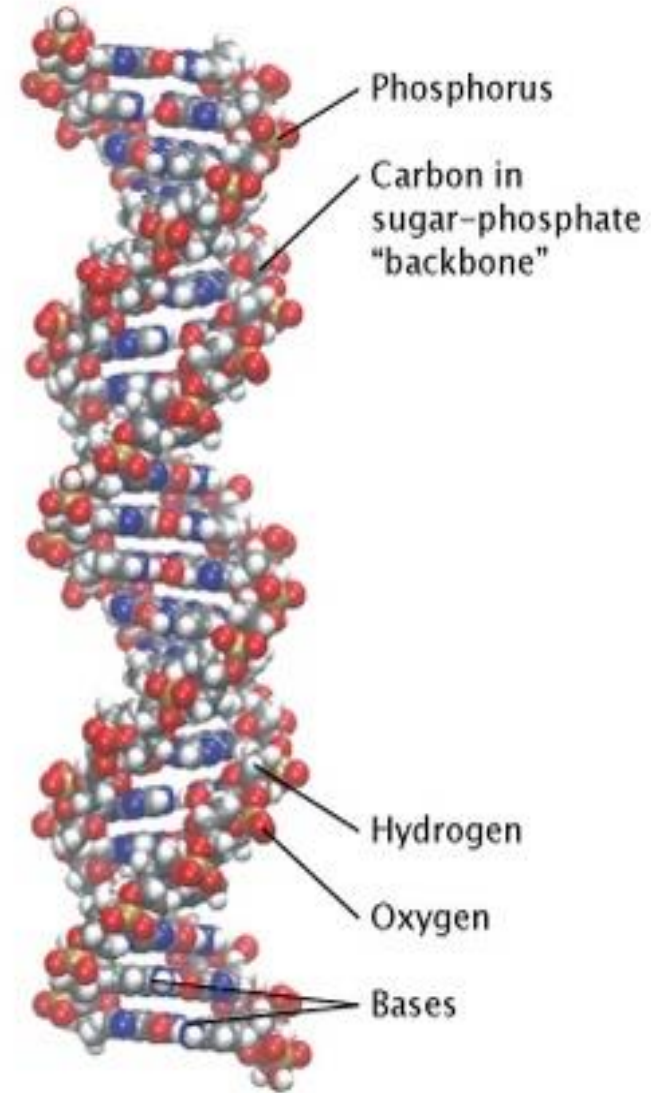
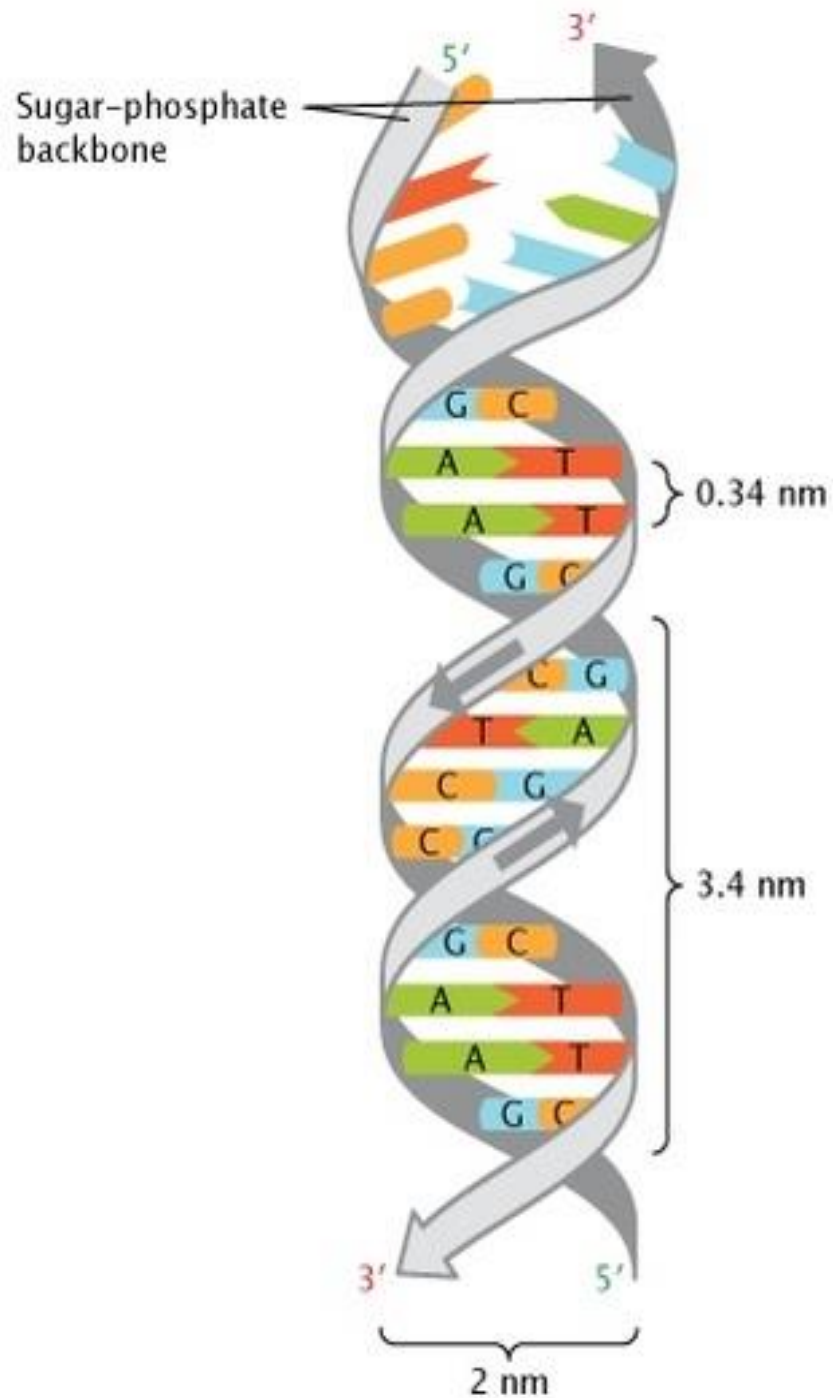


The structure of the protein bacteriorhodopsin

- ▶ Bacteriorhodopsin is a membrane protein in bacteria that acts as a proton pump.
- ▶ Its conformation is essential to its function.
- ▶ The overall structure of the protein includes both alpha helices (green) and beta sheets (red).

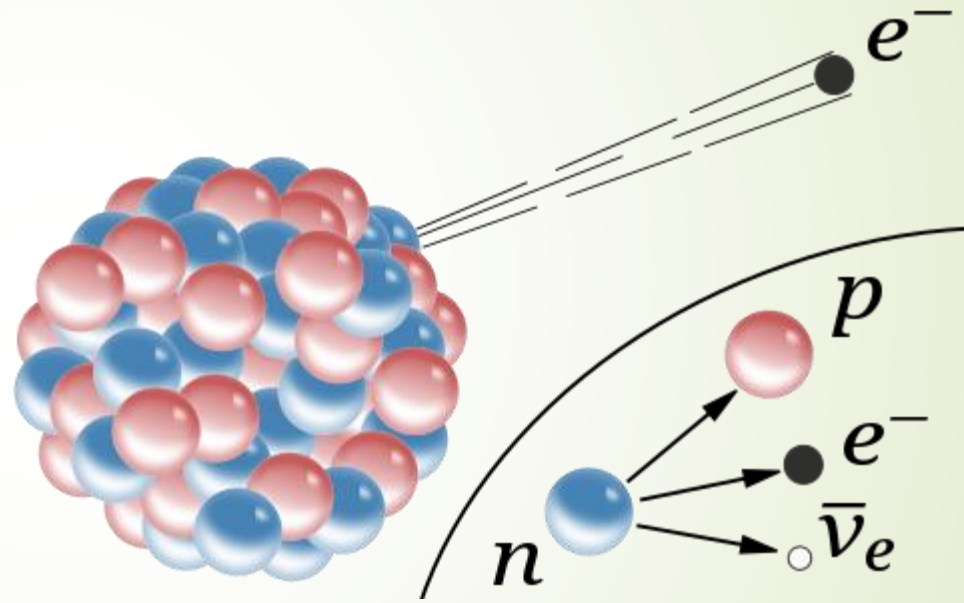
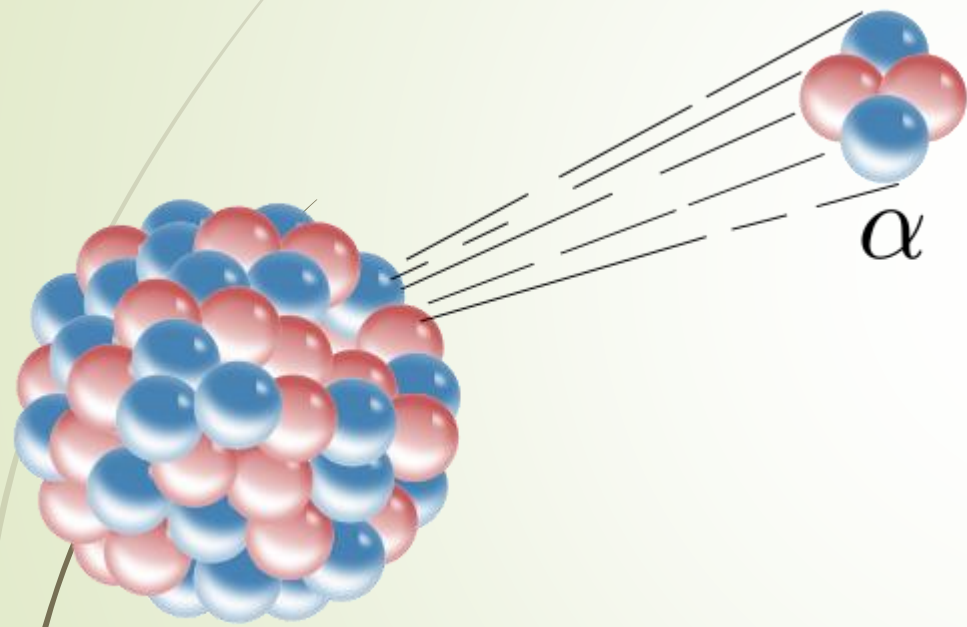
DNA
or RNA

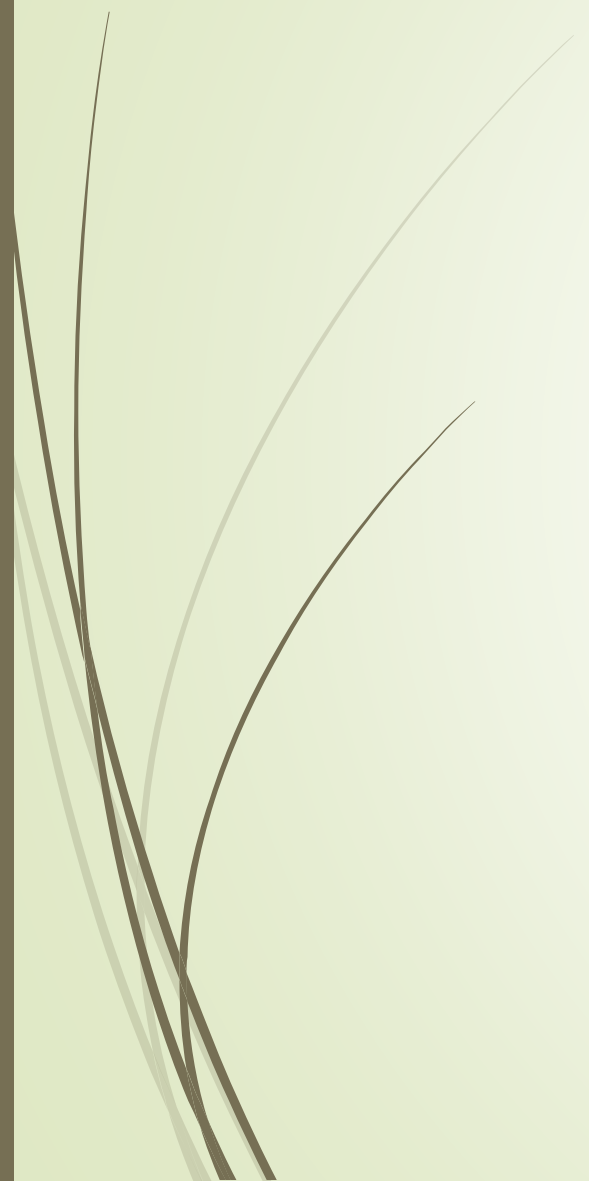
The DNA double helix

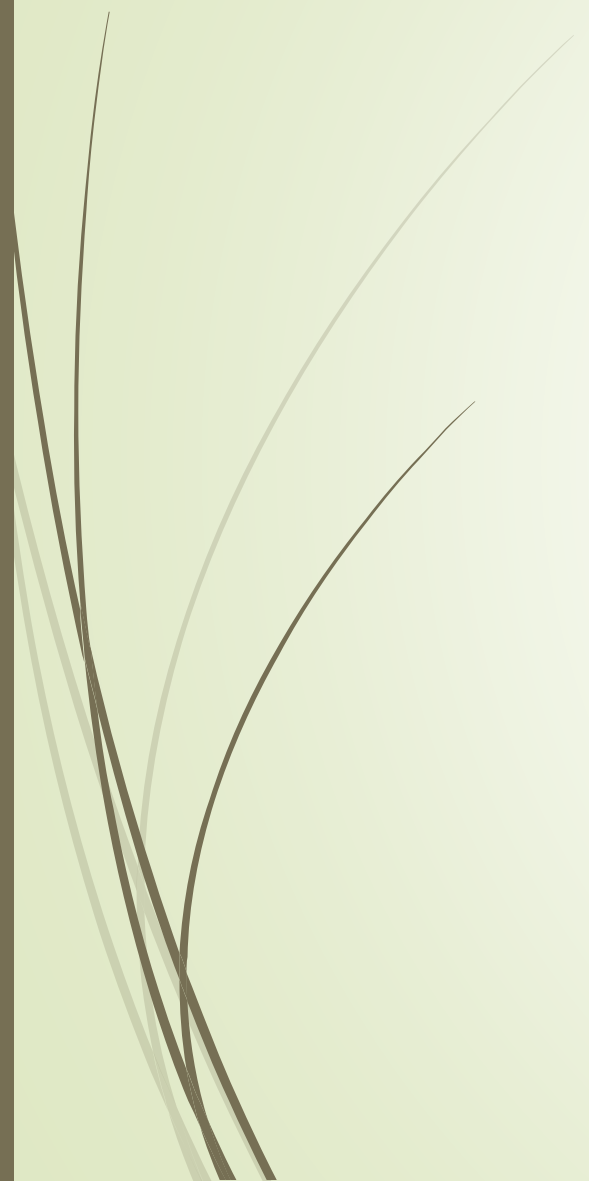


Thankyou for your attention

➤ Any questions?







2 The outermost shell structure of the electrons in orbitals around a nucleus (2,8,8... etc

