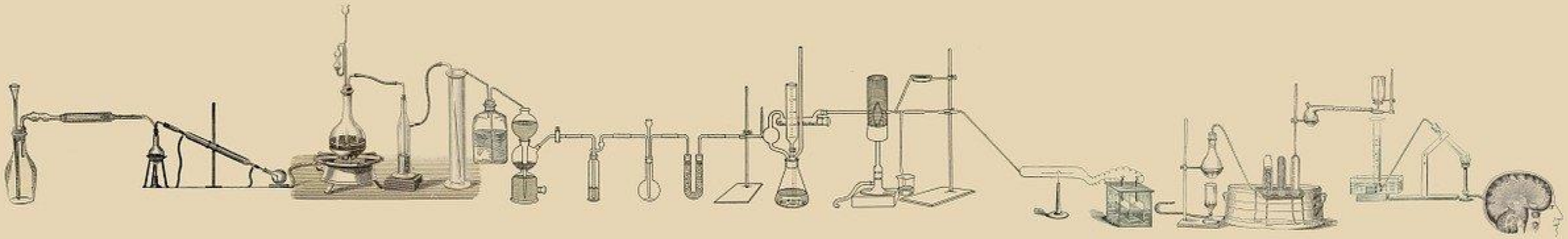
Organic chemistry and biochemistry

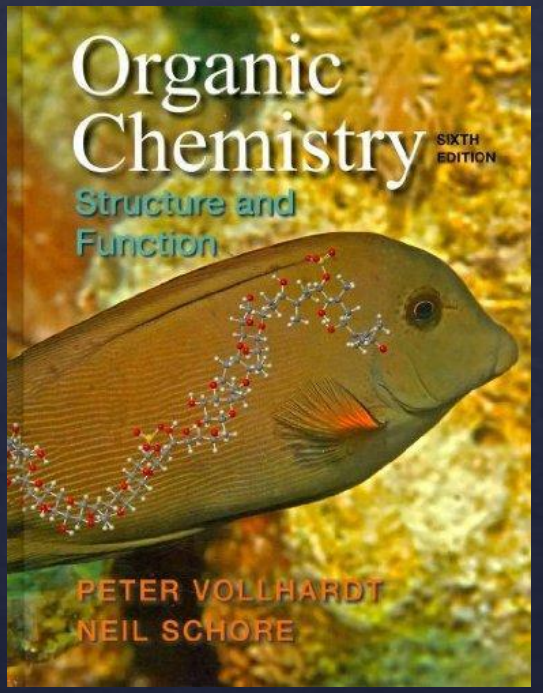


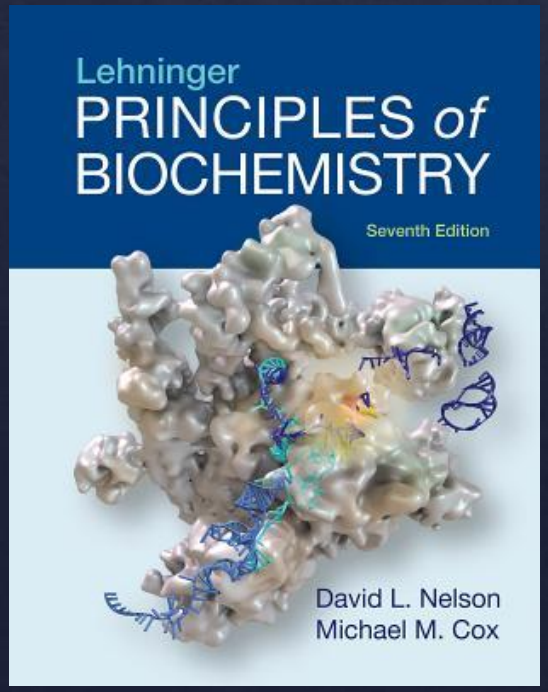
Assis. Prof. Dr. Laura Iacolina

laura.iacolina@famnit.upr.si

Readings

Peter K. Vollhardt, C. Neil, E. Schore. 2011. Organic chemistry: structure and function, 6th ed., W. H. Freeman, New York

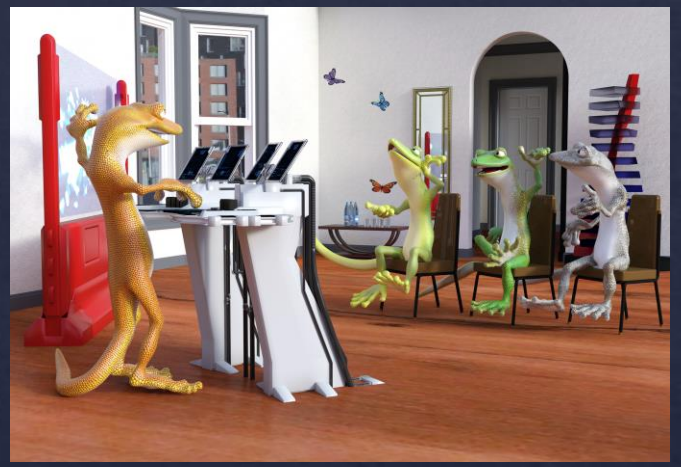




Lehninger, A. L., Nelson, D. L., Cox, M.M. 2017. Principles of biochemistry, W. H. Freeman, New York

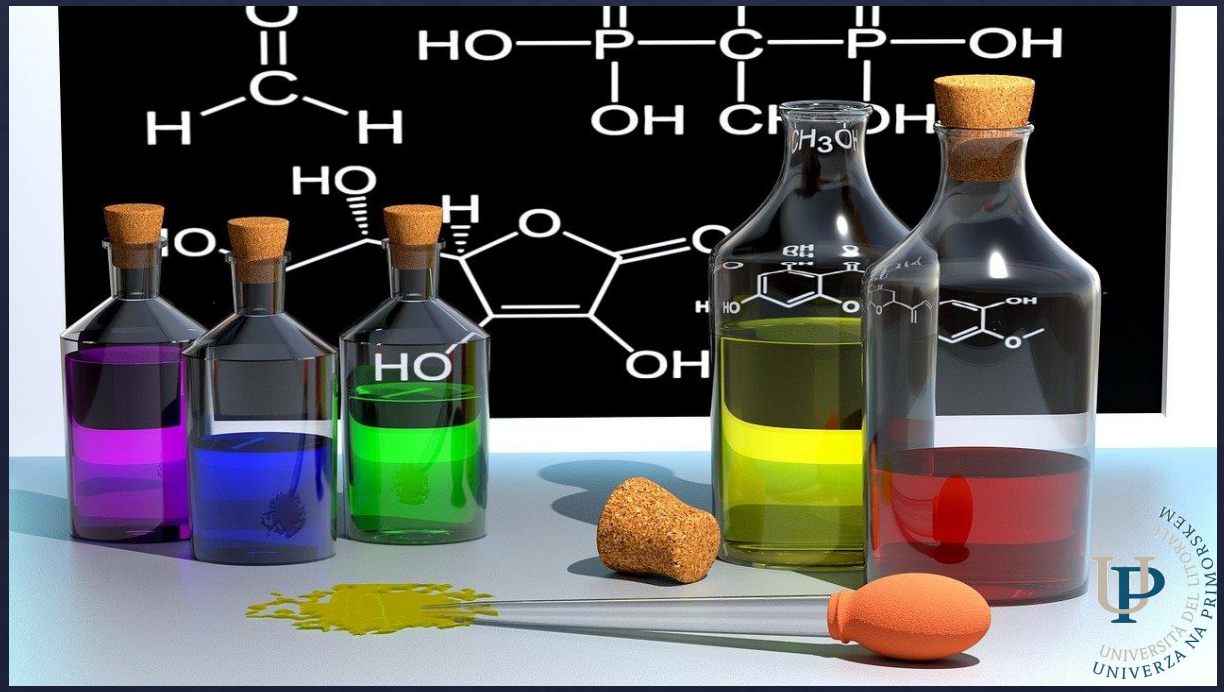
Structure of the Course

- Lectures – 45 hours, combination of synchronous and asynchronous
- Exercises – 45 hours
- At home work of students
  - Mandatory readings
  - Homework assignments



Syllabus – organic chemistry

- Importance and role of organic chemistry
- Structural characteristics of organic compounds
- Nucleophilic reactions
- Radical reaction
- Oxidations
- Reductions
- Carbohydrates
- Amino acids, peptides and proteins
- Isolation of organic compounds



Syllabus – Biochemistry

- Principles of biochemistry
- Structure and function of biomolecules and catalysis: amino acids, proteins, enzymes, carbohydrates, DNA structure, lipids
- Bioenergetics and metabolism (catabolism and anabolism): glycolysis, krebs cycle, glyoxylate cycle, phosphogluconate pathway, oxidative phosphorylation, beta-oxidation, urea-cycle, gluconeogenesis, fatty acid biosynthesis, amino acid biosynthesis
- Integration, coordination and specificities of metabolism of organs

Responsibilities

My responsibilities:

- Regularly carrying out of lectures and labs
- Being at disposal to students for questions
- Provide students with the necessary knowledge for the understanding of chemical phenomena and their importance in biology

Your responsibilities:

- Lecture attendance (recommended)
- Attendance on labs and seminars: mandatory (you can miss one lab, but only with *official excuse*, e.g. confirmation from a physician)
- Fulfilling of course activities
- Passing the exam

Grading system

Exam:

- Reports of the exercises: 30%
- Mid-term: 35%
  2/4/2021
- Final exam: 35%

Oral exam:

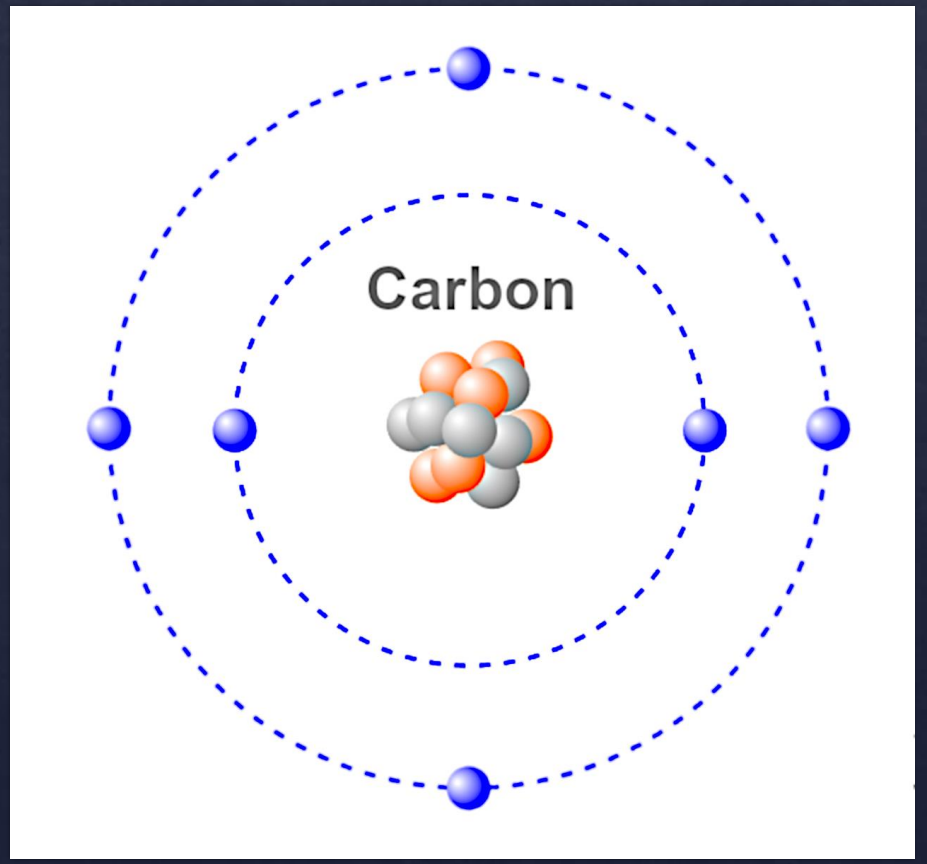
- If needed, lecturer's decision

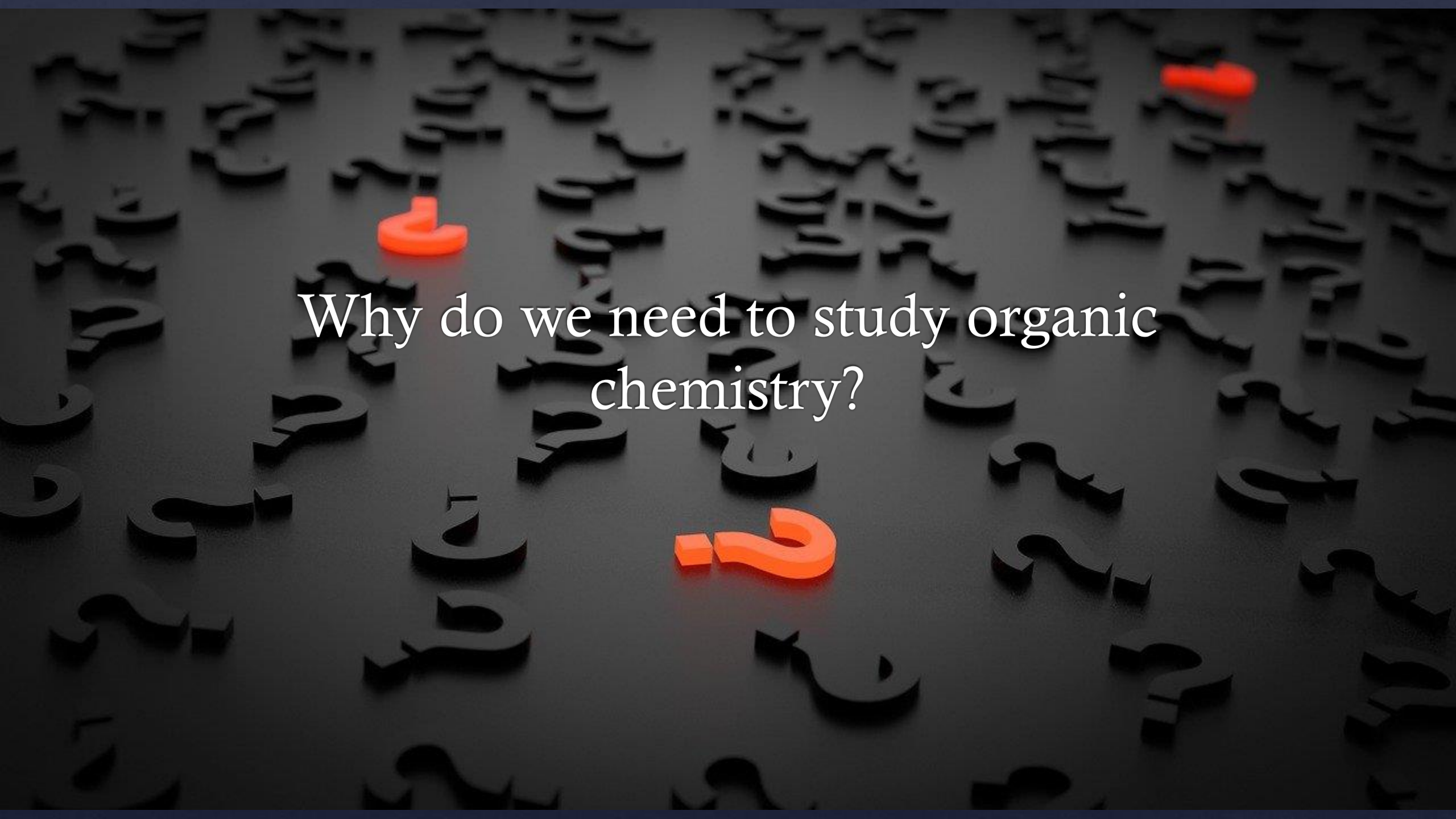
Grading system:

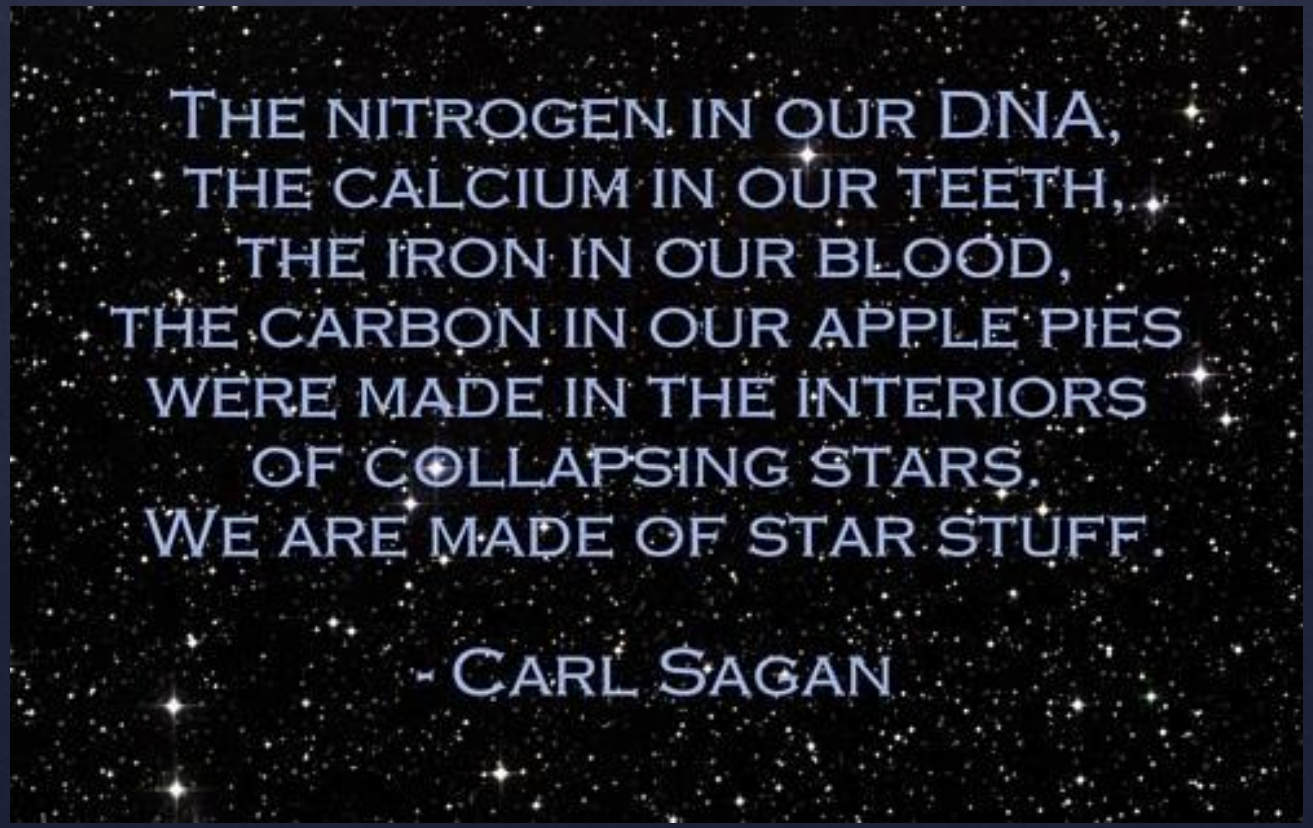
- 60-67%: sufficient 6
- 68-75%: good 7
- 76-83%: very good 8
- 84-90%: very good 9
- 91-100%: excellent 10

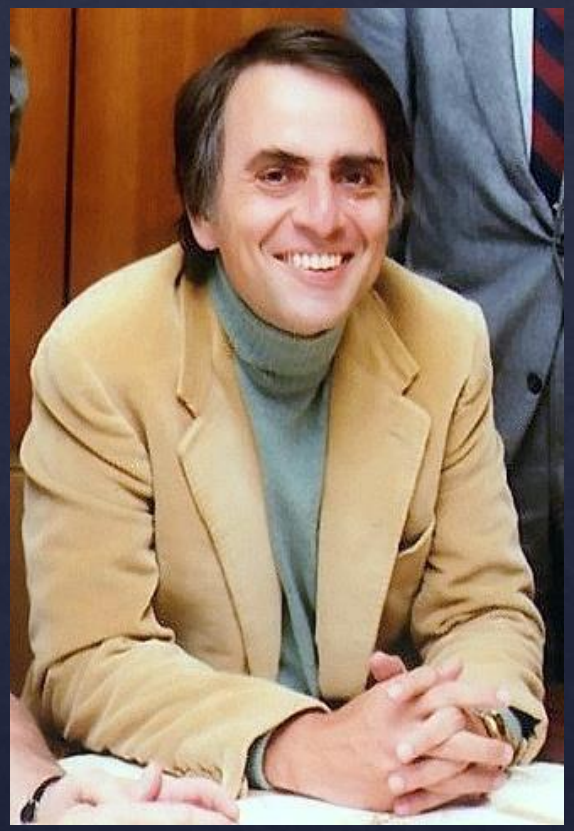
What is organic chemistry

Organic chemistry is the chemistry of carbon and its compounds (**organic molecules**). These molecules are the basis of life, and of our lifestyles




Why do we need to study organic chemistry?





Carl Edward Sagan
9. november 1934
- 20. december 1996


PRÉVOIR
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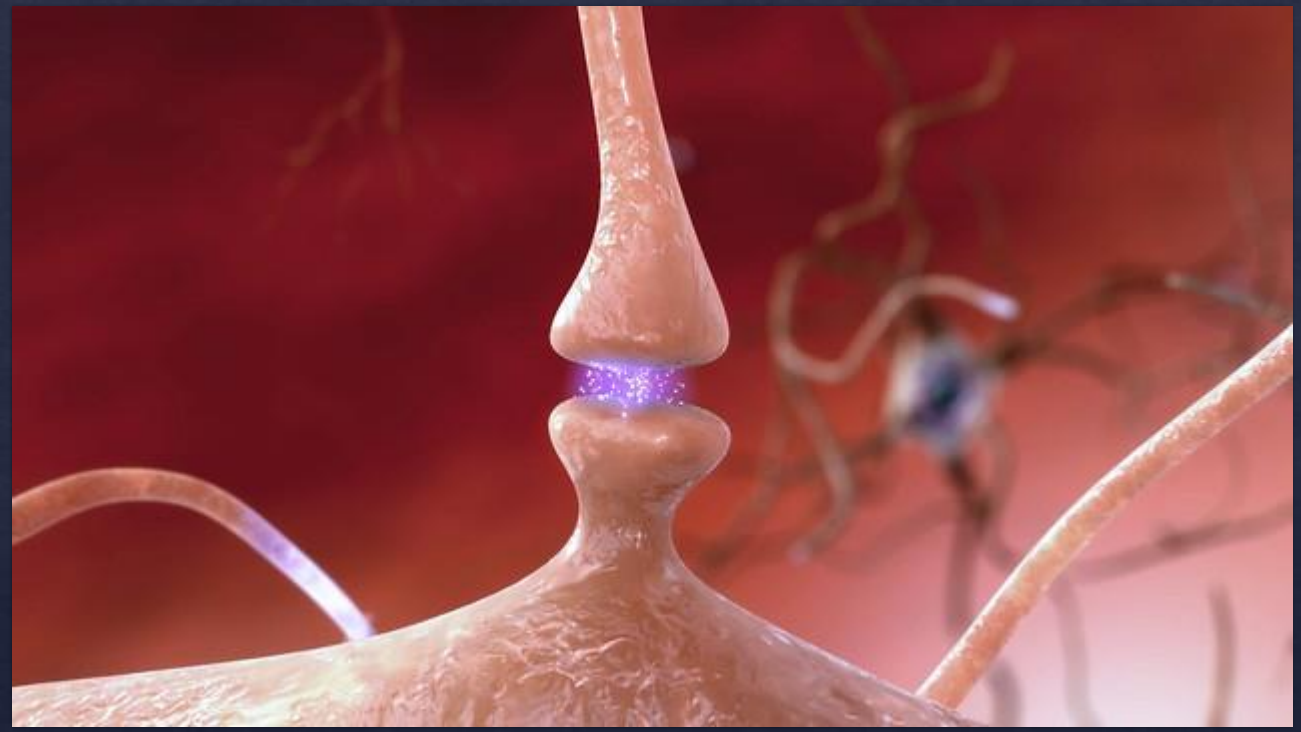
Downsides

But in the end…



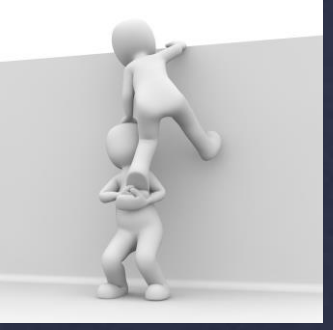
What is organic chemistry?

It is often called the chemistry of **carbon** but the elements essential to life are 17. Of those, just **four** constitute most of the organism.

Table 1-1. **Elemental Composition of the Human Body**[a]

Element	*Dry Weight (%)*	*Elements Present in Trace Amounts*
C	61.7	B
N	11.0	F
O	9.3	Si
H	5.7	V
Ca	5.0	Cr
P	3.3	Mn
K	1.3	Fe
S	1.0	Co
Cl	0.7	Cu
Na	0.7	Zn
Mg	0.3	Se
		Mo
		Sn
		I

[a]Calculated from Frieden, E., *Sci. Am.* 227(1), 54–55 (1972).



Your friend, the periodic table

Atomic number

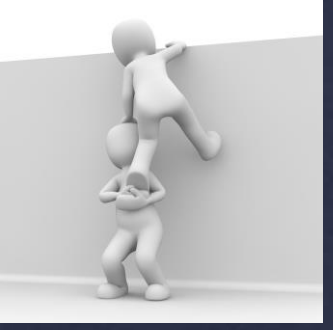
Atomic weight

Symbol

Name

	I	II	III	IV	V	VI	VII	VIII			I	II	III	IV	V	VI	VII	VIII
1	1 H 1																	4 He 2
2	7 Li 3	9 Be 4											11 B 5	12 C 6	14 N 7	16 O 8	19 F 9	20 Ne 10
3	23 Na 11	24 Mg 12											27 Al 13	28 Si 14	31 P 15	32 S 16	36 Cl 17	39 Ar 18
4	39 K 19	40 Ca 20	45 Sc 21	48 Ti 22	51 V 23	52 Cr 24	55 Mn 25	57 Fe 26	59 Co 27	59 Ni 28	64 Cu 29	65 Zn 30	70 Ga 31	73 Ge 32	75 As 33	79 Se 34	80 Br 35	84 Kr 36
5	86 Rb 37	88 Sr 38	89 Y 39	91 Zr 40	93 Nb 41	96 Mo 42	99 Tc 43	101 Ru 44	103 Rh 45	106 Pd 46	108 Ag 47	112 Cd 48	115 In 48	119 Sn 50	122 Sb 51	128 Te 52	127 I 53	131 Xe 54
6	133 Cs 55	137 Ba 56	139 La 57	178 Hf 72	181 Ta 73	184 W 74	186 Re 75	190 Os 76	192 Ir 77	195 Pt 78	197 Au 79	201 Hg 80	204 Tl 81	207 Pb 82	209 Bi 83	209 Po 84	210 At 85	222 Rn 86
7	223 Fr 87	226 Ra 88	227 Ac 89	261 Ku 104	262 Ha 105	263 Rf 106												

LANTANOIDI	140 Ce 58	141 Pr 58	144 Nd 60	145 Pm 61	150 Sm 62	152 Eu 63	157 Gd 64	159 Tb 65	163 Dy 66	165 Ho 67	167 Er 68	169 Tm 69	173 Yb 70	175 Lu 71
AKTINOIDI	232 Th 90	231 Pa 91	238 U 92	237 Np 93	244 Pš 94	243 Am 95	247 Cm 96	247 Bk 97	251 Cf 98	254 Es 99	257 Fm 100	258 Md 101	255 No 102	260 Lr 103



Your friend, the periodic table

Groups

Similar properties

Periods

Growing atomic number

	I	II	III	IV	V	VI	VII	VIII			I	II	III	IV	V	VI	VII	VIII
1	1 H 1																	4 He 2
2	7 Li 3	9 Be 4											11 B 5	12 C 6	14 N 7	16 O 8	19 F 9	20 Ne 10
3	23 Na 11	24 Mg 12											27 Al 13	28 Si 14	31 P 15	32 S 16	36 Cl 17	39 Ar 18
4	39 K 19	40 Ca 20	45 Sc 21	48 Ti 22	51 V 23	52 Cr 24	55 Mn 25	57 Fe 26	59 Co 27	59 Ni 28	64 Cu 29	65 Zn 30	70 Ga 31	73 Ge 32	75 As 33	79 Se 34	80 Br 35	84 Kr 36
5	86 Rb 37	88 Sr 38	89 Y 39	91 Zr 40	93 Nb 41	96 Mo 42	99 Tc 43	101 Ru 44	103 Rh 45	106 Pd 46	108 Ag 47	112 Cd 48	115 In 48	119 Sn 50	122 Sb 51	128 Te 52	127 I 53	131 Xe 54
6	133 Cs 55	137 Ba 56	139 La 57	178 Hf 72	181 Ta 73	184 W 74	186 Re 75	190 Os 76	192 Ir 77	195 Pt 78	197 Au 79	201 Hg 80	204 Tl 81	207 Pb 82	209 Bi 83	209 Po 84	210 At 85	222 Rn 86
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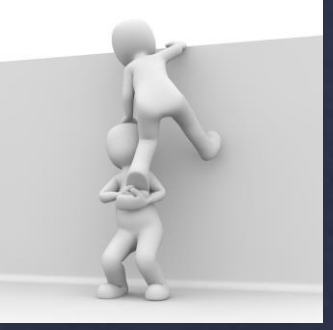


Your friend, the periodic table

Periodic Table of the Elements

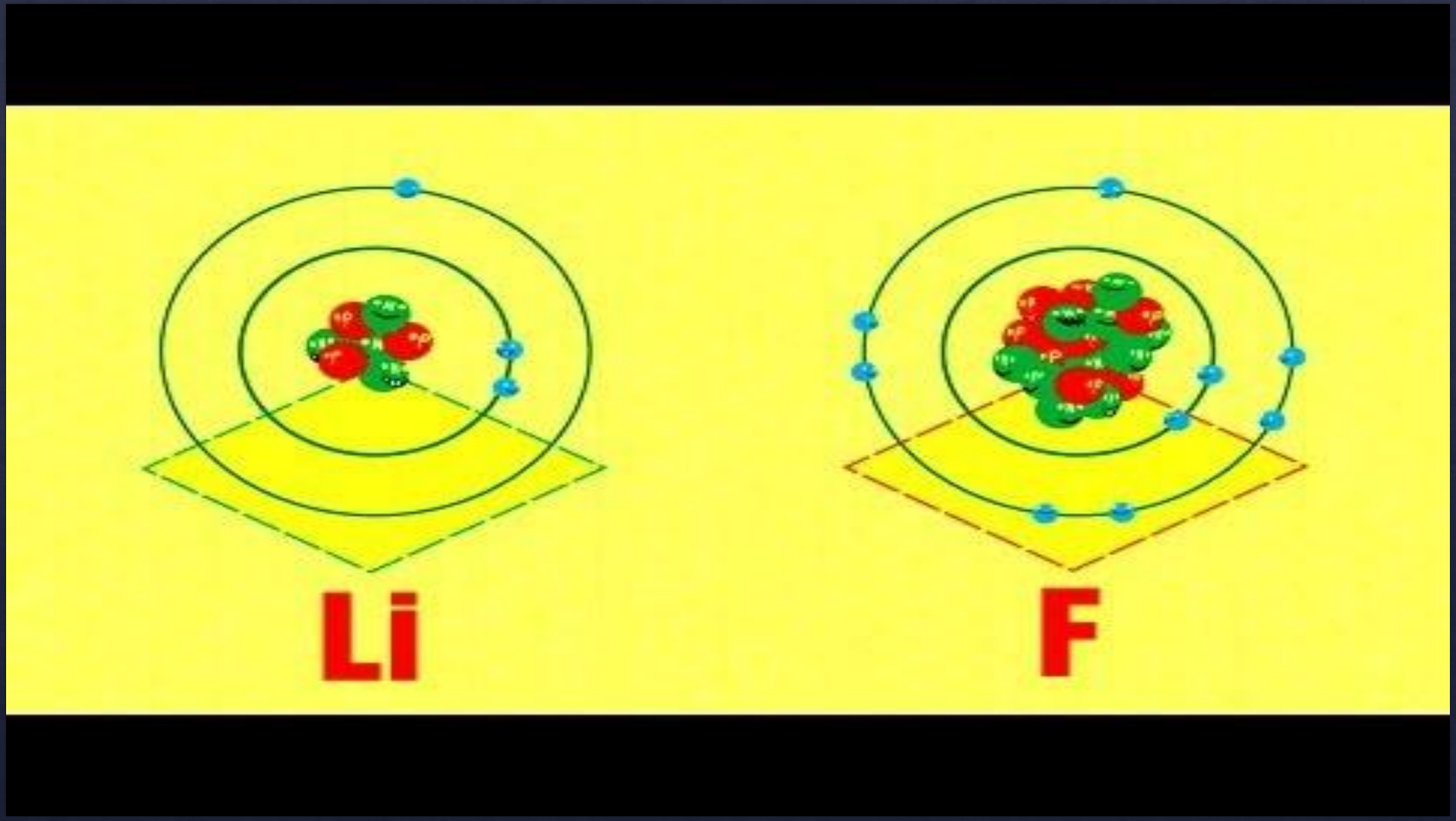
1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N 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 47.88	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 78.971	35 Br Bromine 79.904	36 Kr Krypton 84.798
37 Rb Rubidium 84.468	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 112.414	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 131.249
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 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

Lanthanide Series	57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.243	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
Actinide Series	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

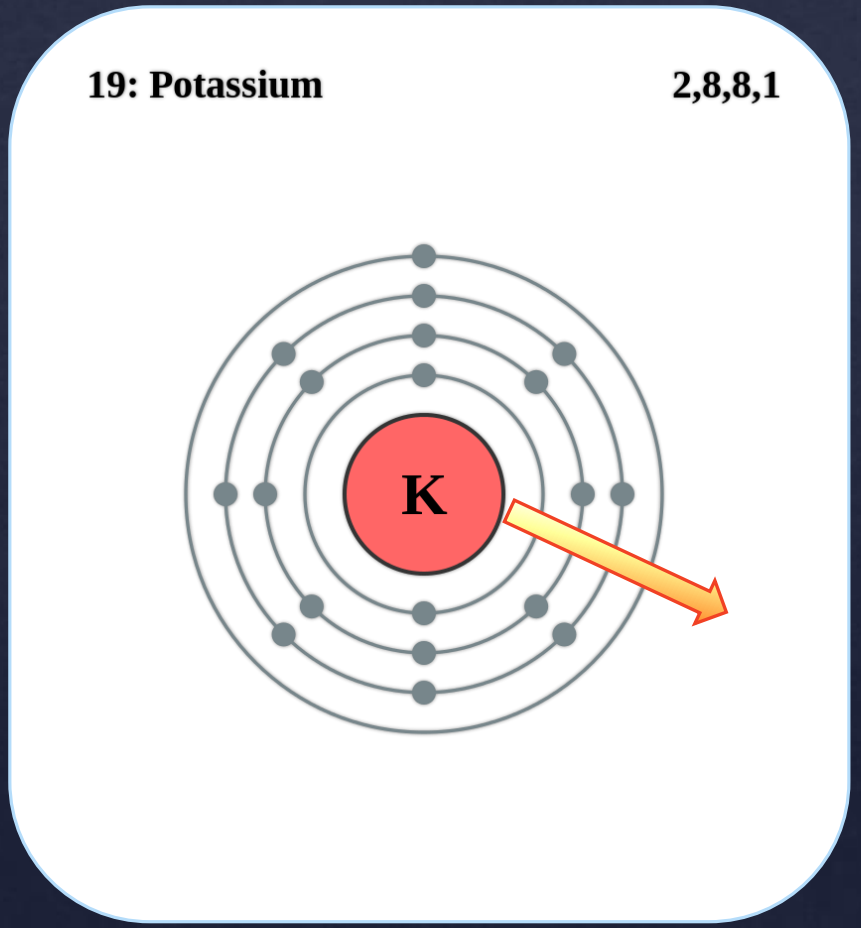
Before we continue…

…The atom



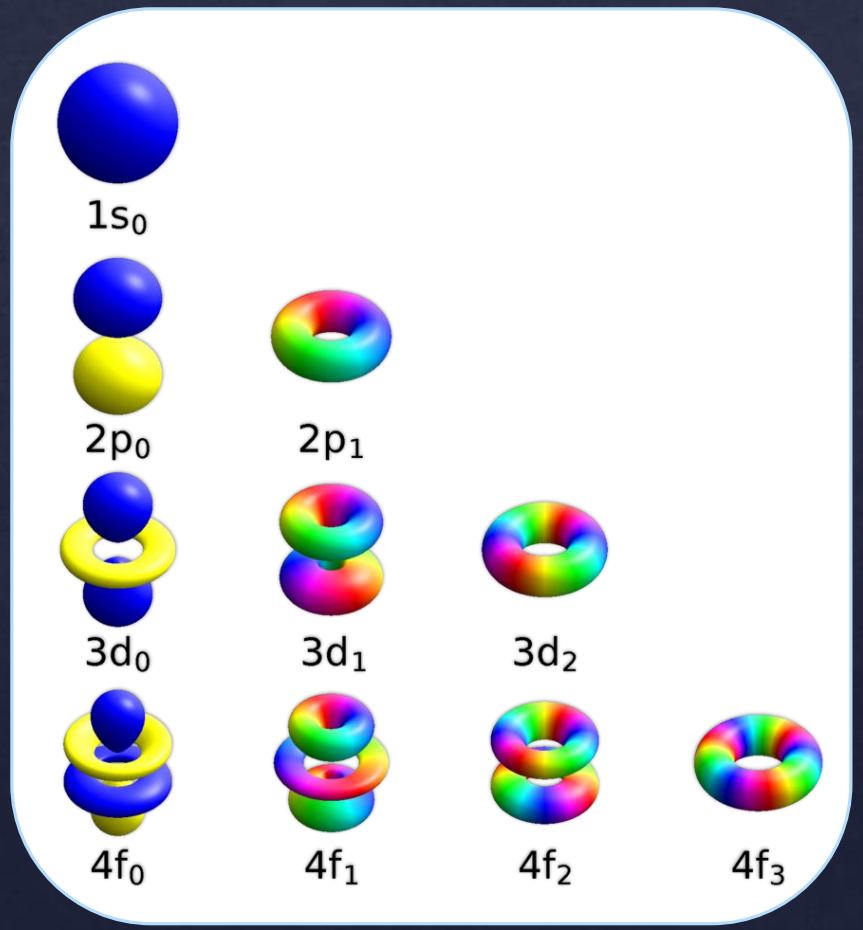
Shells & subshells

- Electrons orbit the nucleus of an atom at different ranges, called shells.
- Each shell has a different energy level, increasing the further it is from the nucleus
- There are 4 subshells, s, p, d, and f. Each subshell can hold a different number of electrons (s=2, p=6, d=10, f=14)

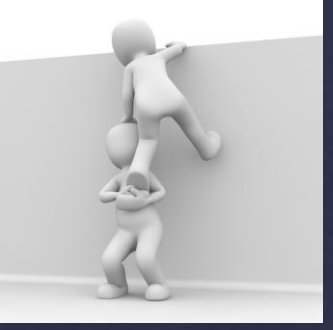


Orbitals

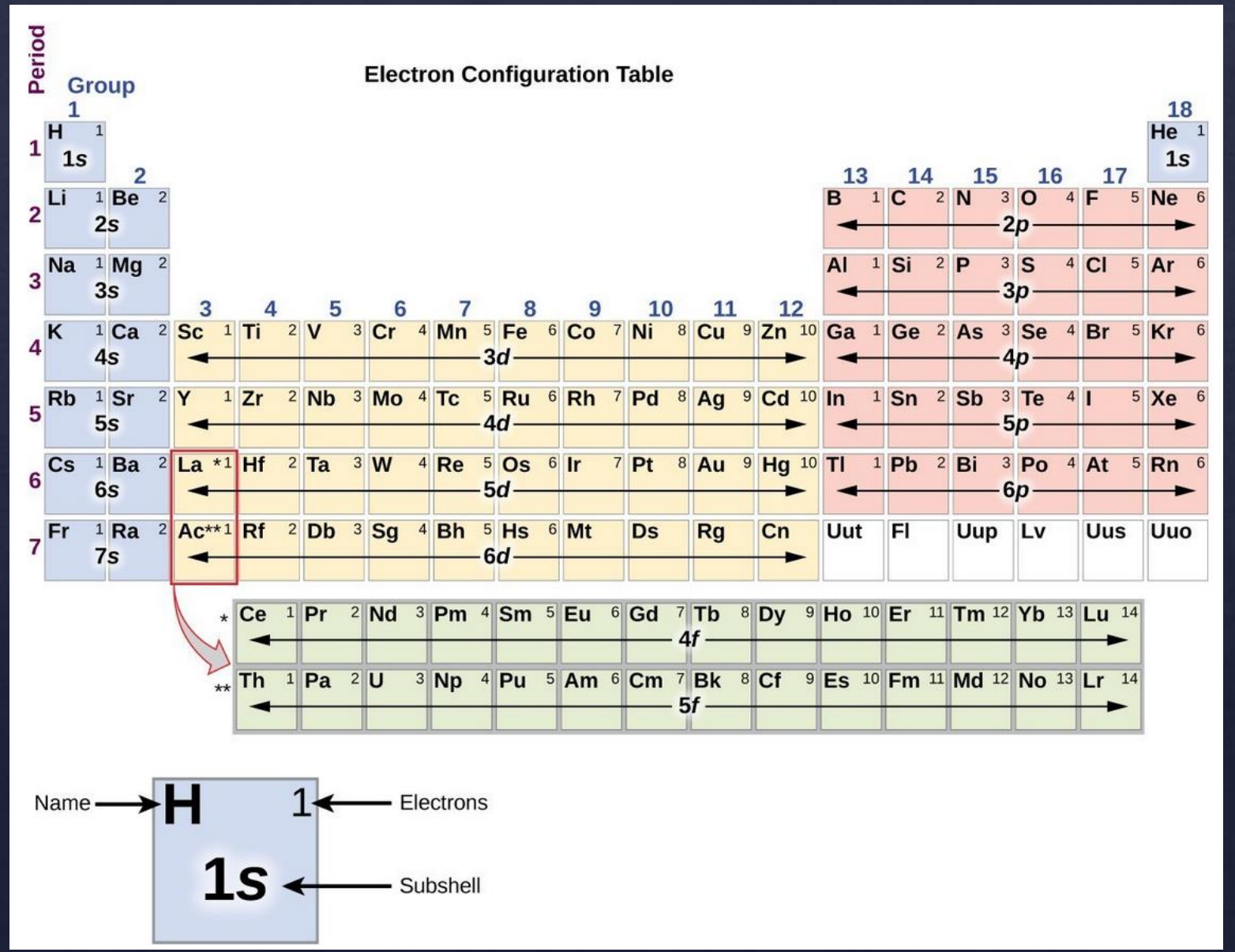
- Subshells have different distances from the nucleus and different n° of electrons, thus different shapes (orbitals)
- How do you know which subshell you have? You look at the periodic table!
- Warning!! They can hybridise!!



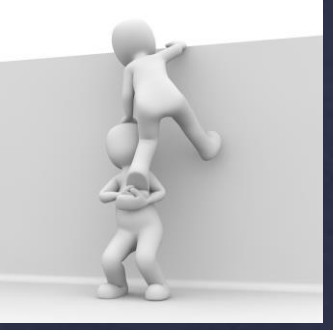
Picture from Wikipedia



Your friend, the periodic table



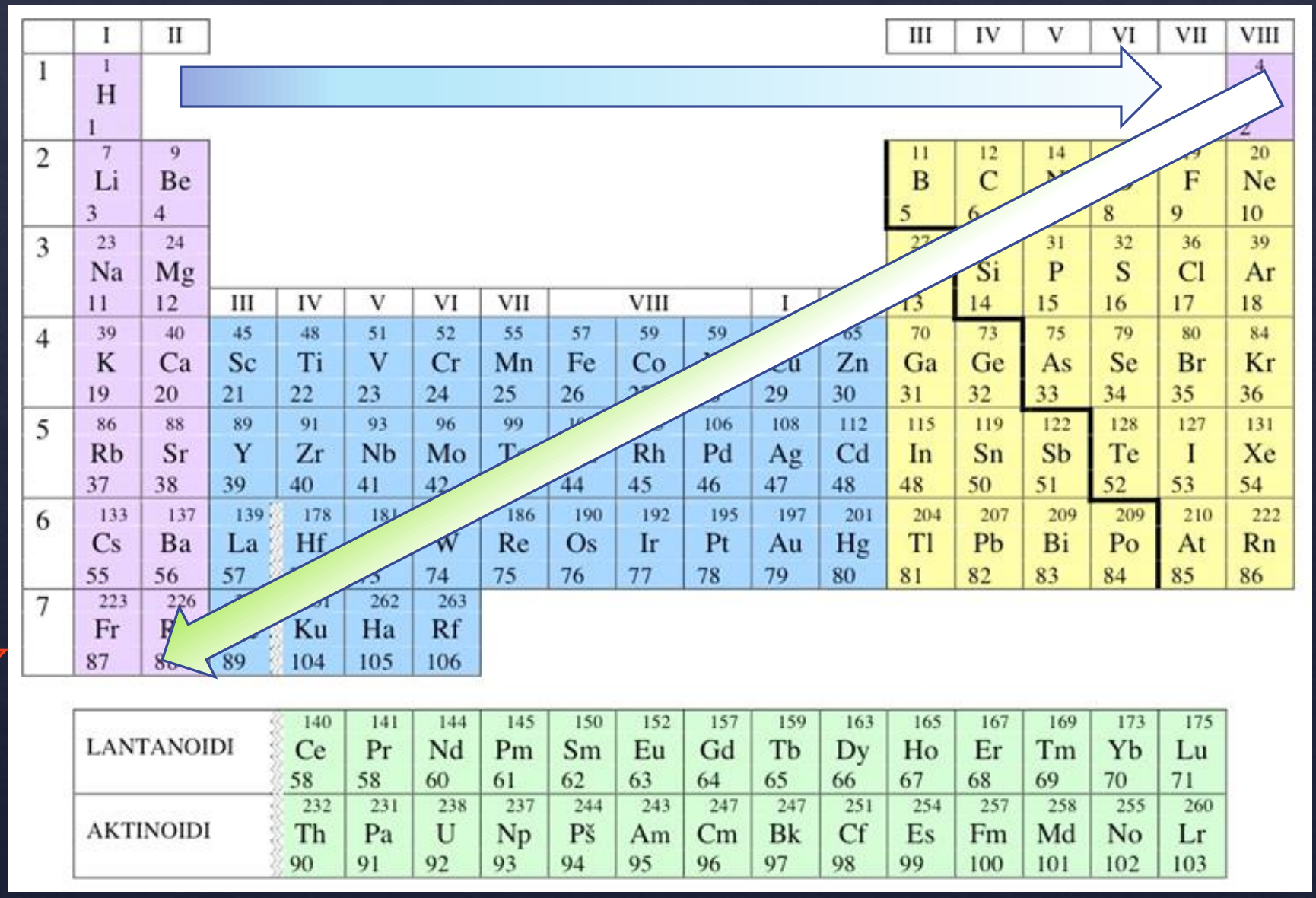
Picture from
lumenlearning.com

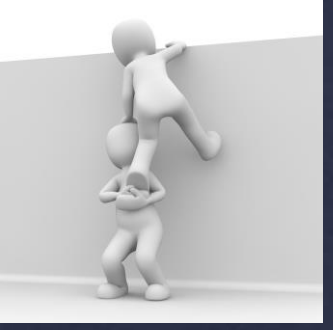


Your friend, the periodic table

Atomic radius

Increases top-down across periods
Decreases left to right across groups

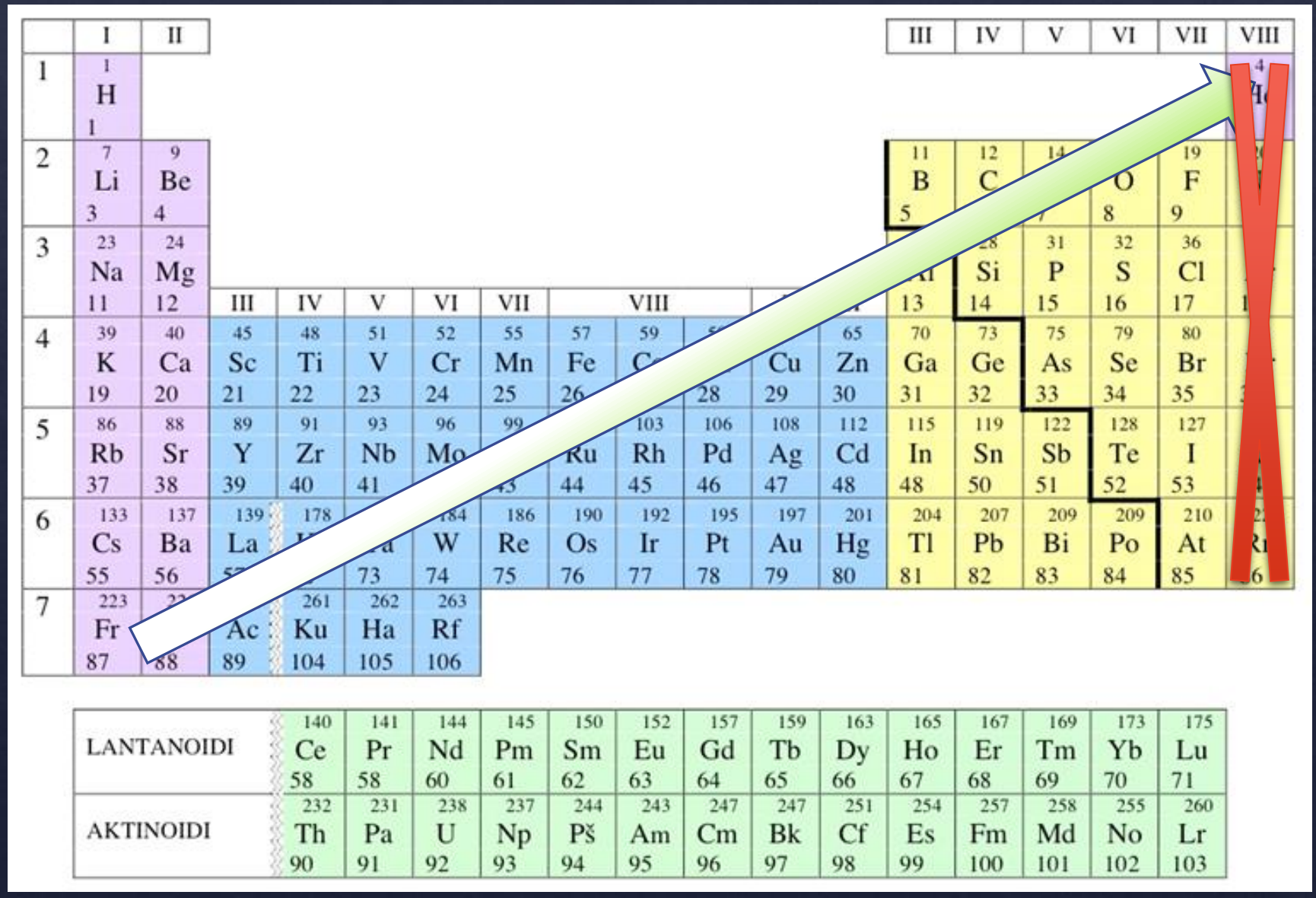


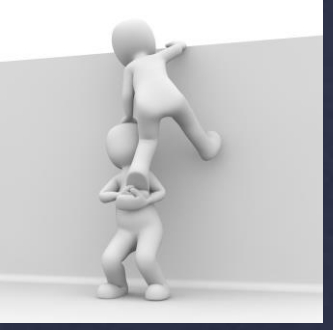


Your friend, the periodic table

Ionization energy is the energy required to remove an electron from the outer layer

Electron affinity is how eager the atom is to accept an electron





Your friend, the periodic table

Electronegativity is the ability of an atom to retain its electrons

	I	II	III	IV	V	VI	VII	VIII			III	IV	V	VI	VII	VIII
1	1 H 1															4
2	7 Li 3	9 Be 4									11 B 5	12 C	14		19 F 9	
3	23 Na 11	24 Mg 12										28 Si 14	31 P 15	32 S 16	36 Cl 17	
4	39 K 19	40 Ca 20	45 Sc 21	48 Ti 22	51 V 23	52 Cr 24	55 Mn 25	57 Fe 26	59	28	29 Cu	65 Zn 30	70 Ga 31	73 Ge 32	75 As 33	79 Se 34	80 Br 35	
5	86 Rb 37	88 Sr 38	89 Y 39	91 Zr 40	93 Nb 41	96 Mo	99	44 Ru	103 Rh 45	106 Pd 46	108 Ag 47	112 Cd 48	115 In 48	119 Sn 50	122 Sb 51	128 Te 52	127 I 53	
6	133 Cs 55	137 Ba 56	139 La	178	73	184 W 74	186 Re 75	190 Os 76	192 Ir 77	195 Pt 78	197 Au 79	201 Hg 80	204 Tl 81	207 Pb 82	209 Bi 83	209 Po 84	210 At 85	
7	223 Fr 87		89 Ac	261 Ku 104	262 Ha 105	263 Rf 106												

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AKTINOIDI	232 Th 90	231 Pa 91	238 U 92	237 Np 93	244 Pš 94	243 Am 95	247 Cm 96	247 Bk 97	251 Cf 98	254 Es 99	257 Fm 100	258 Md 101	255 No 102	260 Lr 103

Kahoot time!!

Connect to https://play.kahoot.it/

Number of bonds per atom

H	1
C	4
N	3
O	2
S	2
F	1
Cl	1
Br	1
I	1

	I	II										III	IV	V	VI	VII	VIII
1	1 H 1																4 He 2
2	7 Li 3	9 Be 4										11 B 5	12 C 6	14 N 7	16 O 8	19 F 9	20 Ne 10
3	23 Na 11	24 Mg 12	III	IV	V	VI	VII	VIII			I	II	27 Al 13	28 Si 14	31 P 15	32 S 16	36 Cl 17	39 Ar 18
4	39 K 19	40 Ca 20	45 Sc 21	48 Ti 22	51 V 23	52 Cr 24	55 Mn 25	57 Fe 26	59 Co 27	59 Ni 28	64 Cu 29	65 Zn 30	70 Ga 31	73 Ge 32	75 As 33	79 Se 34	80 Br 35	84 Kr 36
5	86 Rb 37	88 Sr 38	89 Y 39	91 Zr 40	93 Nb 41	96 Mo 42	99 Tc 43	101 Ru 44	103 Rh 45	106 Pd 46	108 Ag 47	112 Cd 48	115 In 48	119 Sn 50	122 Sb 51	128 Te 52	127 I 53	131 Xe 54
6	133 Cs 55	137 Ba 56	139 La 57	178 Hf 72	181 Ta 73	184 W 74	186 Re 75	190 Os 76	192 Ir 77	195 Pt 78	197 Au 79	201 Hg 80	204 Tl 81	207 Pb 82	209 Bi 83	209 Po 84	210 At 85	222 Rn 86
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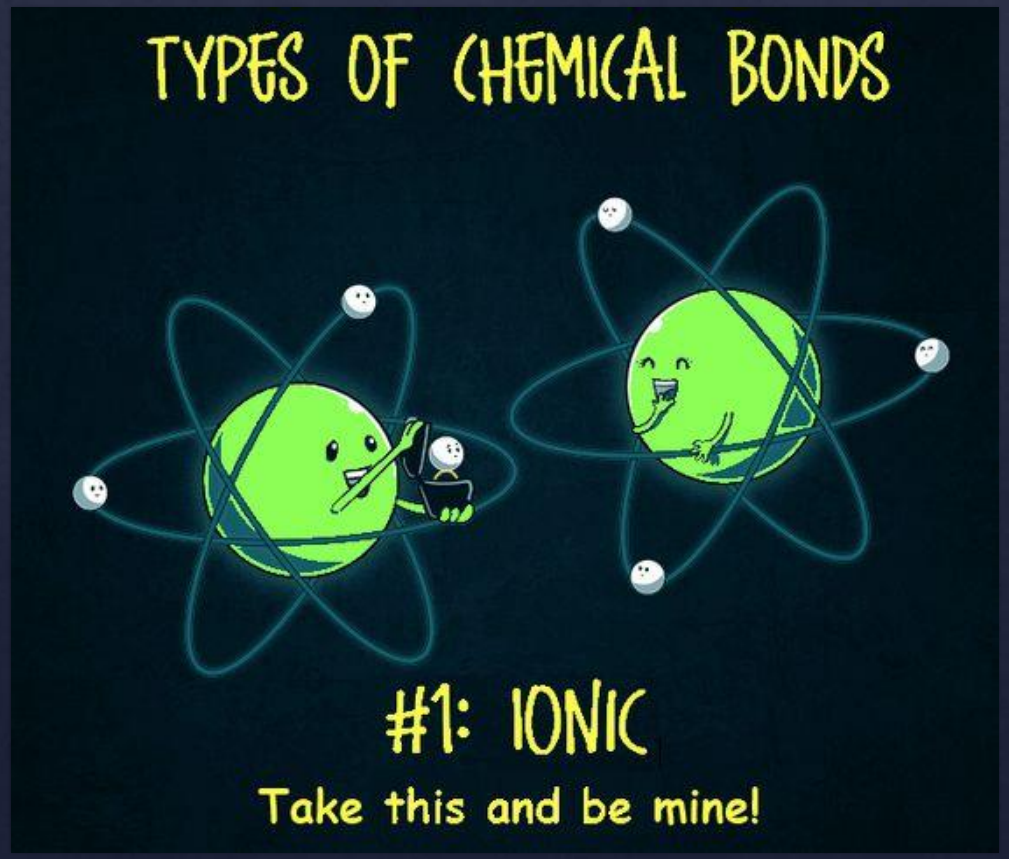
Any other difference with inorganic chemistry?

Organic chemistry	Inorganic chemistry
Covalent bonds	Ionic bonds
Low melting point (<360°C)	
(mostly) insoluble in water	(mostly) soluble in water
(mainly) soluble in organic solvents	Almost completely insoluble in organic solvents
Does not conduct electricity	Conducts electricity
(mostly) flammable	Rarely burns
Reactions are (mostly) slow	Reactions are (mostly) fast

Ionic bond

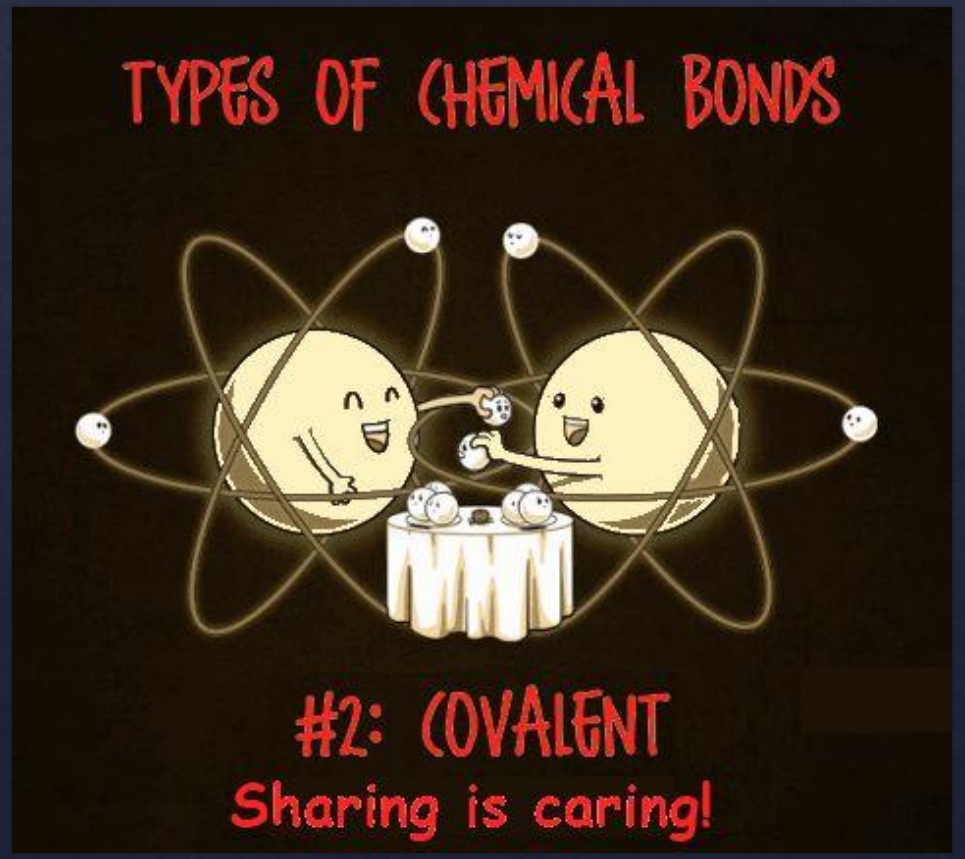


Electrons are given (or taken) and not given back. The molecules are thus charged and kept together though electrostatic attraction

Picture by Pablo Bustos

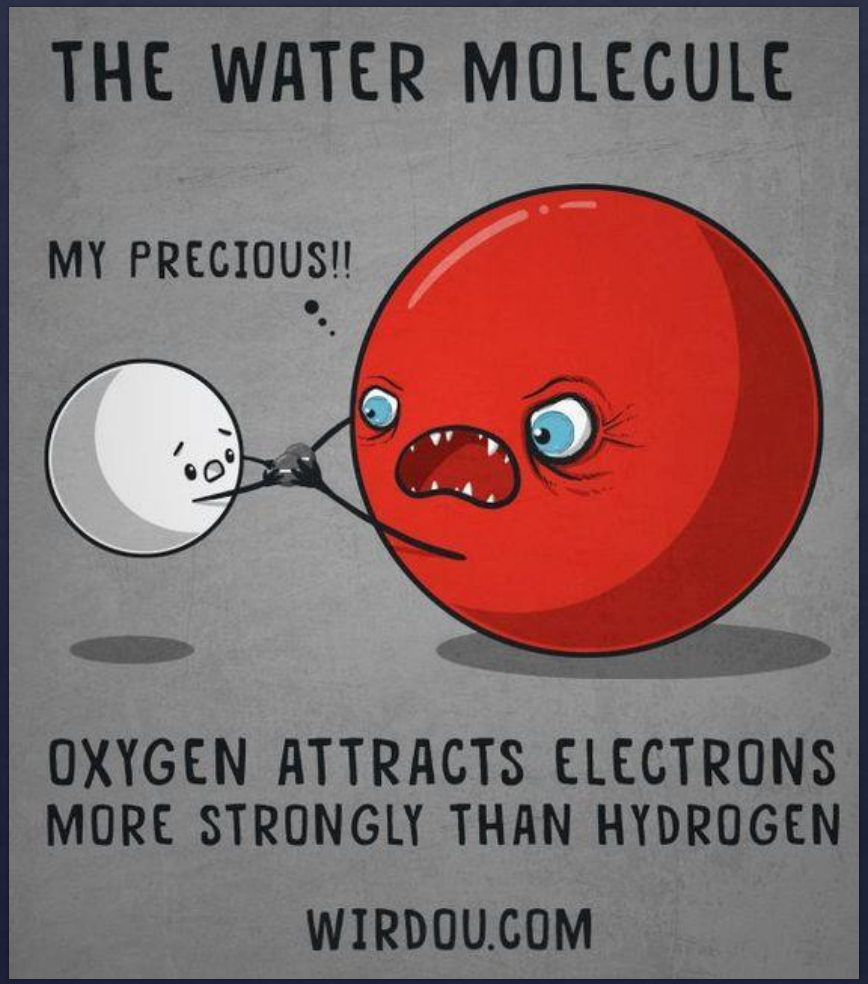
Covalent bond

Electrons are shared between molecules.



Picture by Pablo Bustos

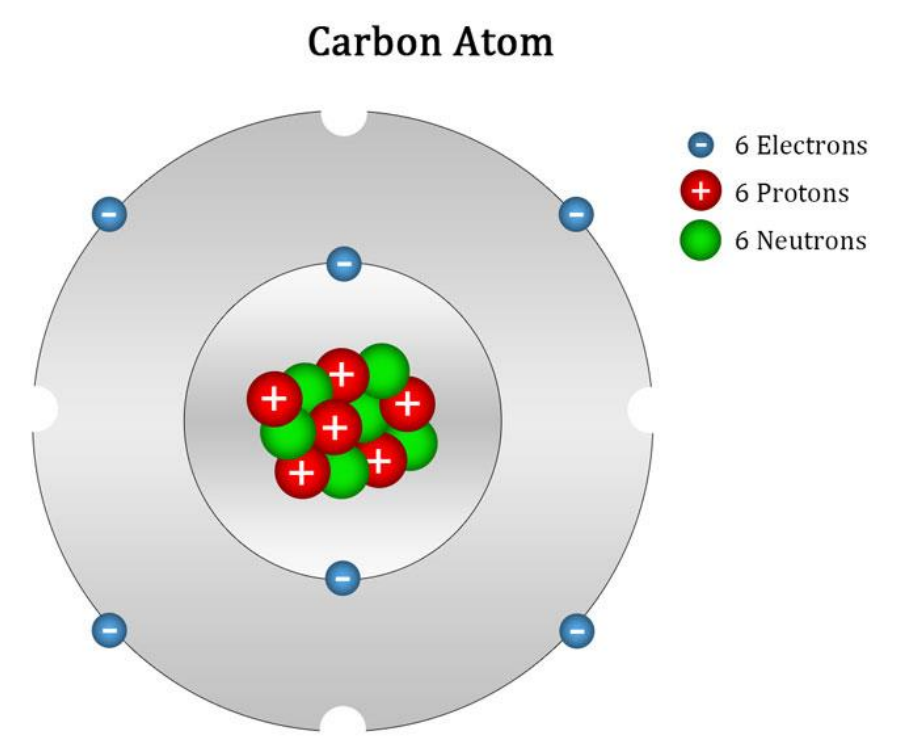
Polar covalent bond



Picture by Pablo Bustos

If electrons are not shared equally among molecules, they become partially charged. The larger the difference in electronegativity, the bigger is the charge separation

So many compounds with so few elements, why?



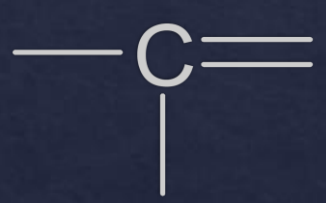
- The ability of C atoms to form multiple bonds
- The high bond energy between two C atoms (347 kJ/mol)
- The relatively small difference in electronegativity between H (2,20) and C (2,50). C-H bonds are basically non-polar and thus harder to break

Picture by ascensionglossary.com

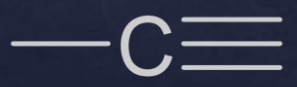
The 4 bonds of Carbon

- 4 single

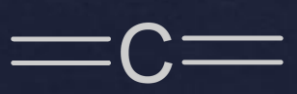
- 2 single and 1 double



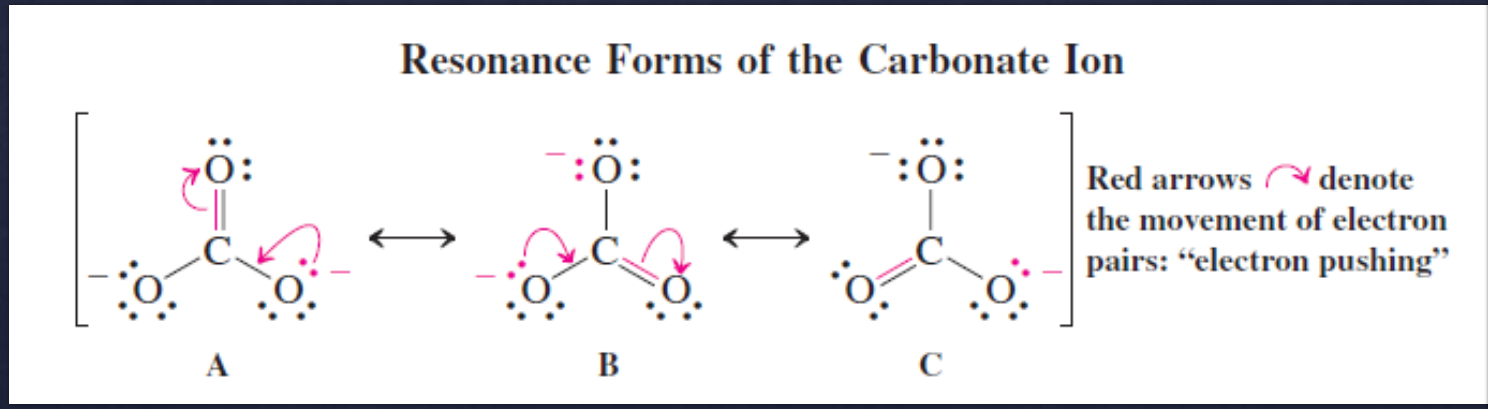
- 1 single and 1 triple

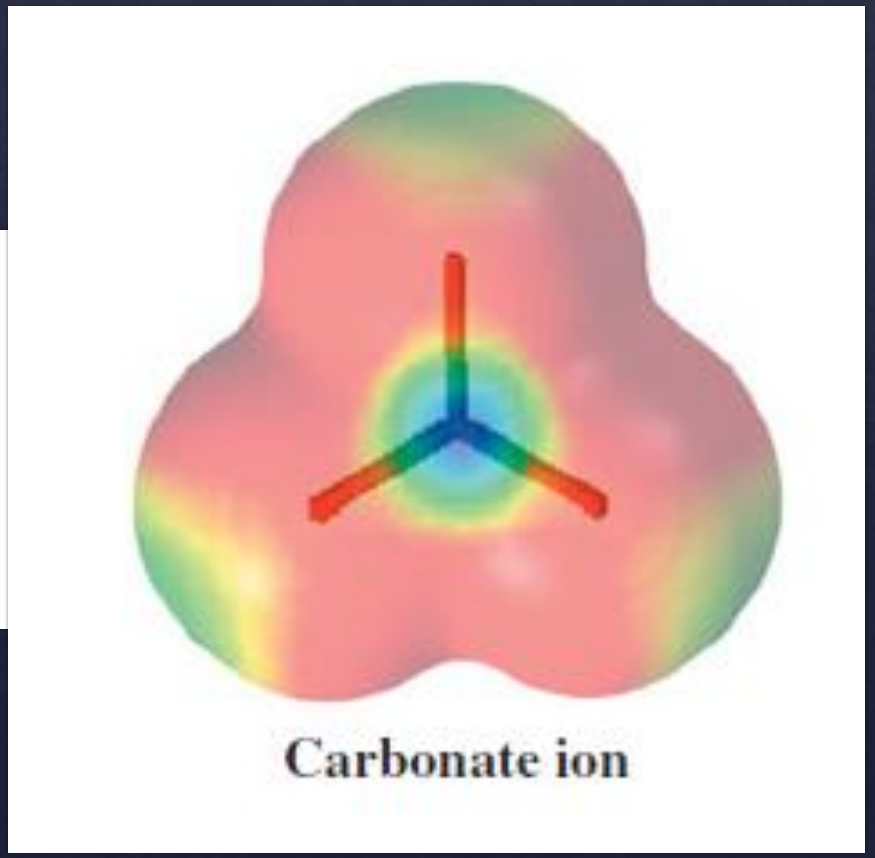


- 2 double



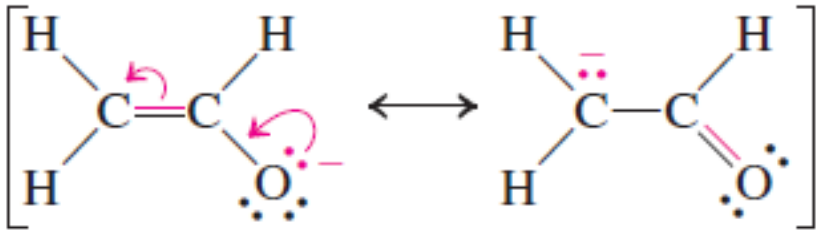
Resonance forms



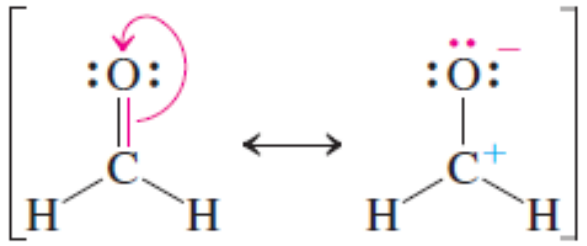


Resonance forms

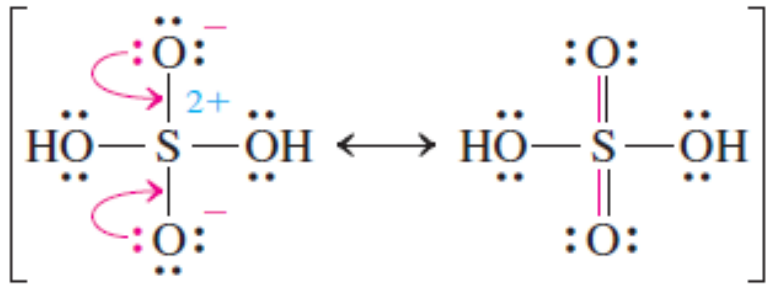
The Two Nonequivalent Resonance Forms of the Enolate Ion



[Octet ⟷ Nonoctet] Resonance Forms



Formaldehyde



Sulfuric acid