Chemistry in Living Systems

SBI4U

Essential Elements of Life

Carbon (C), oxygen (O), hydrogen (H) and nitrogen (N) make up 96 % of living matter.

Elements	Symbol	% of human body weight
Oxygen	O	65
Carbon	C	18.5
Hydrogen	H	9.5
Nitrogen	N	3.3
Calcium	Ca	1.5
Phosphorus	P	1.0
Potassium	K	0.4
Sulfur	S	0.3

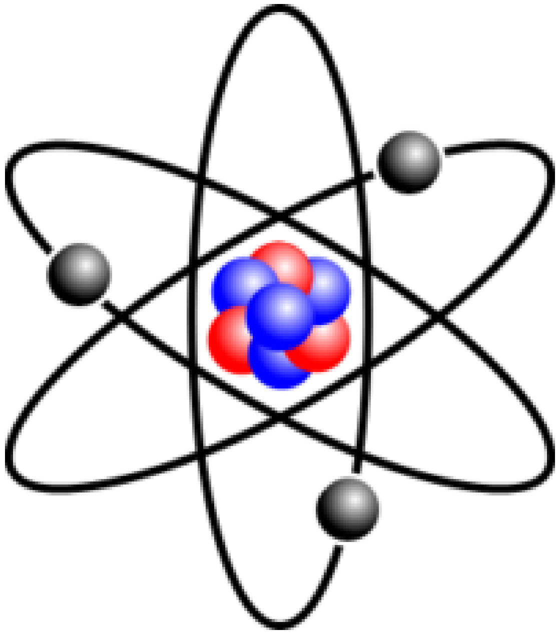
Atoms and Elements

All matter is composed of extremely small particles called ***atoms*** which is the smallest unit of any given element.

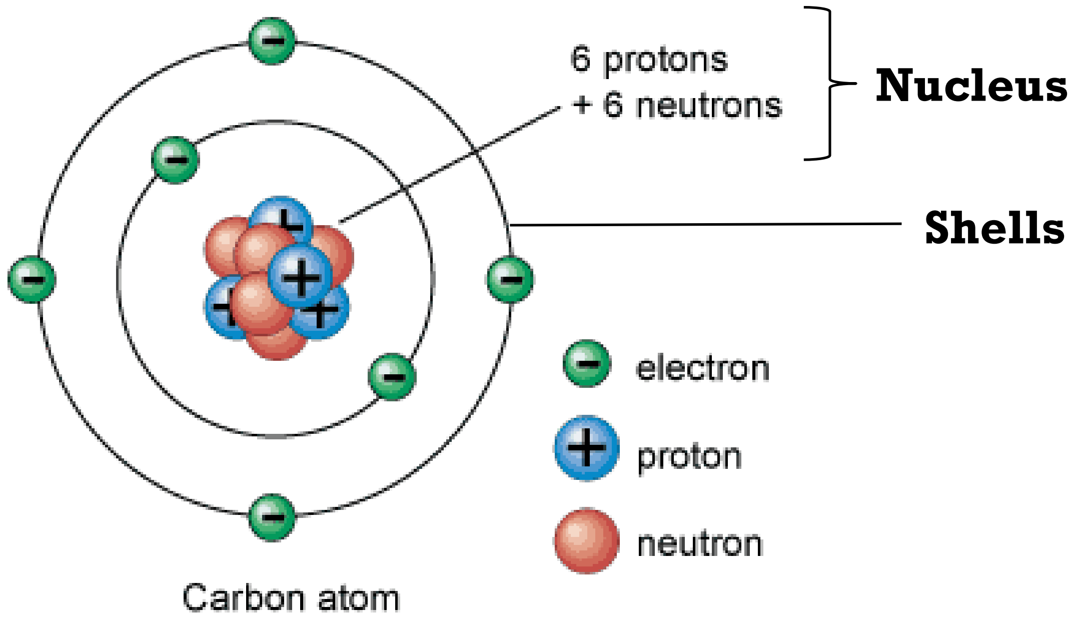
Every atom has the same basic structure:

Subatomic Particles:

- Core nucleus of *protons* and *neutrons*
- Orbiting cloud of *electrons*



Atoms and Elements

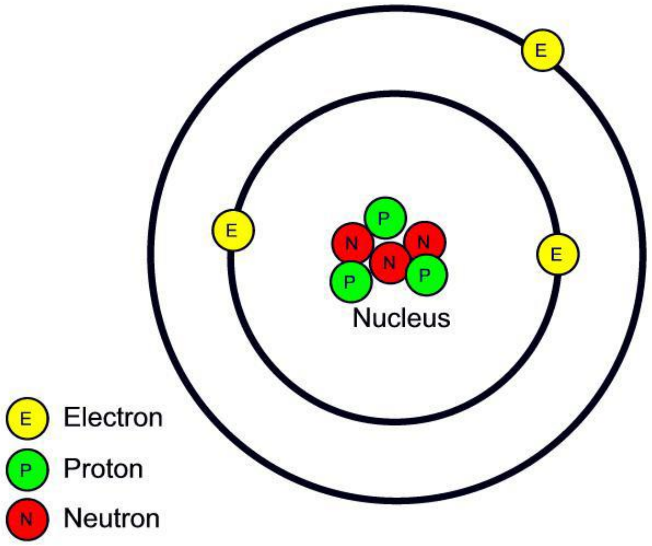


Subatomic Particles

Subatomic Particle	Charge	Weight
Neutron (n^o)	Neutral	1.7 x 10 $^{-24}$ g
Proton (p +)	Positive	1.7 x 10 $^{-24}$ g
Electron (e -)	Negative	0

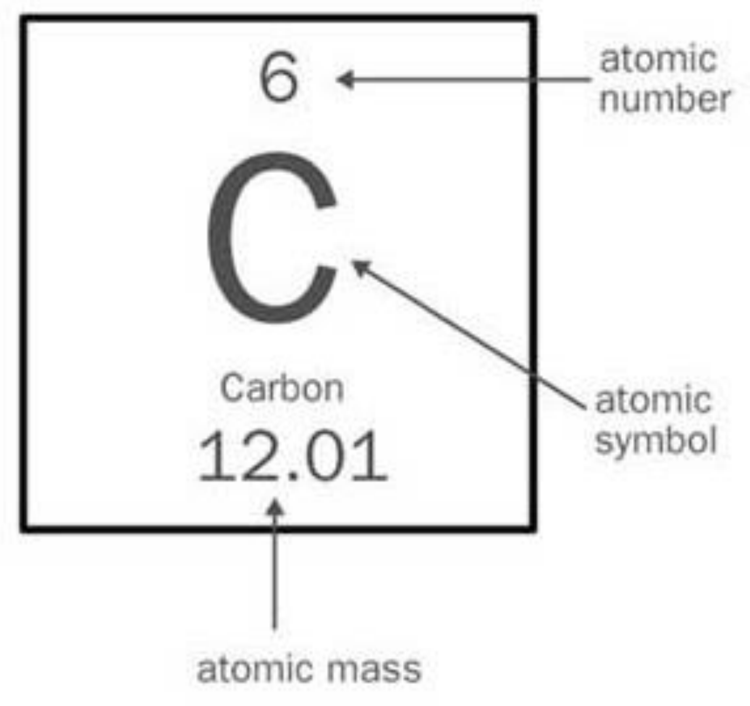
Subatomic Particles

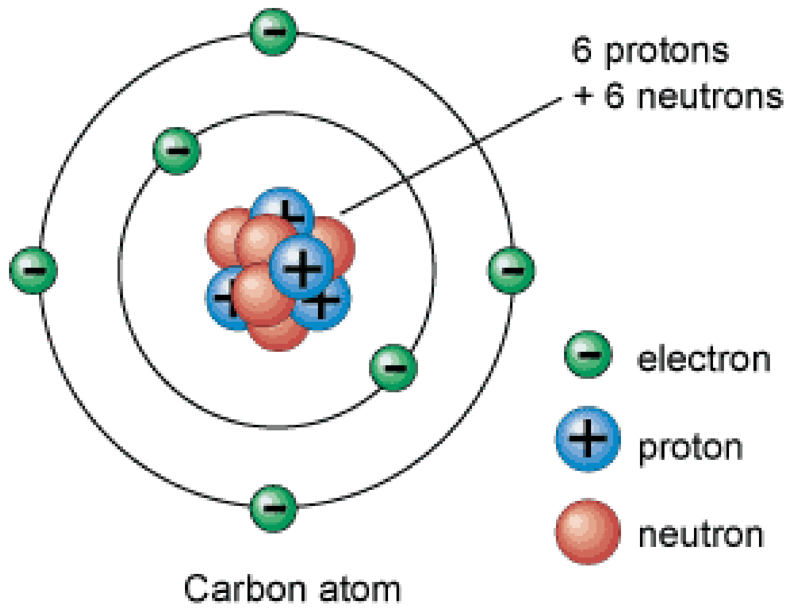
- Neutrons and protons are packed together to form a dense core known as the *'nucleus'*
- Electrons move at the speed of light around the nucleus in a different orbital.



Elements and Periodic Table

Each element has a symbol associated with it that is recognized worldwide.



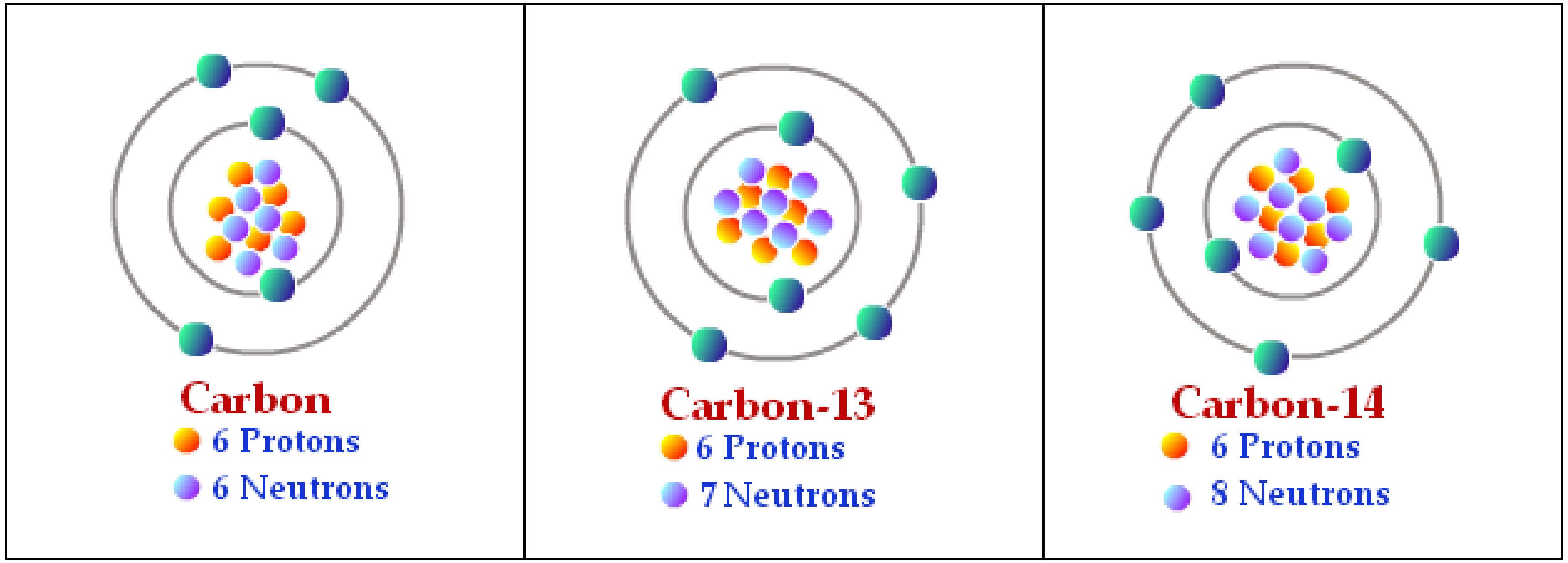


Elements and Periodic Table

hydrogen 1 H 1.0079																		helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122												boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305												aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
* *Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

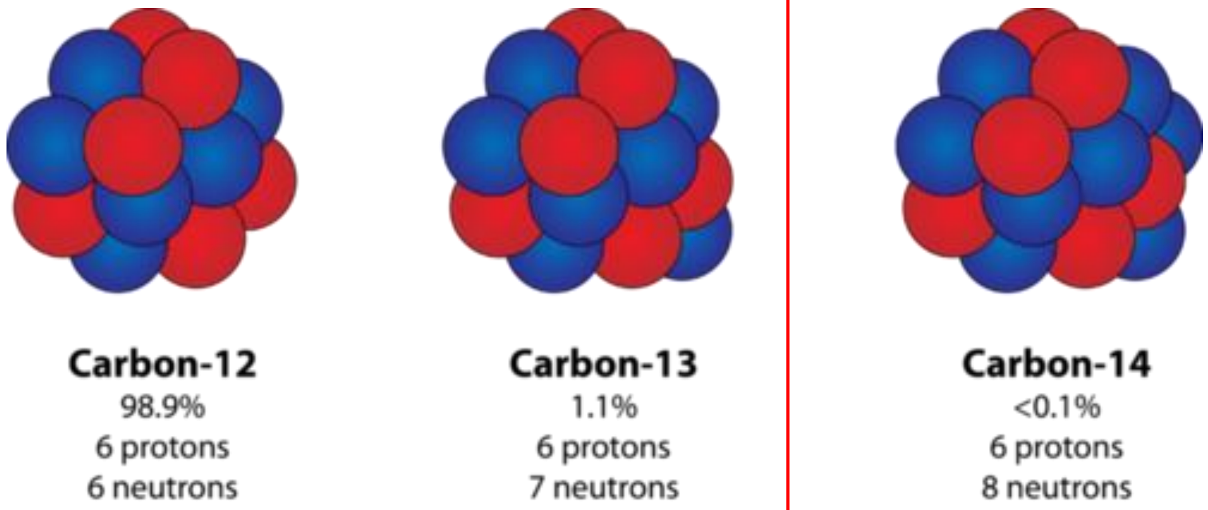
Isotopes



Because they have the same number of electrons and protons, all isotopes of an element have the ***same chemical properties.***

Radioactive Isotopes

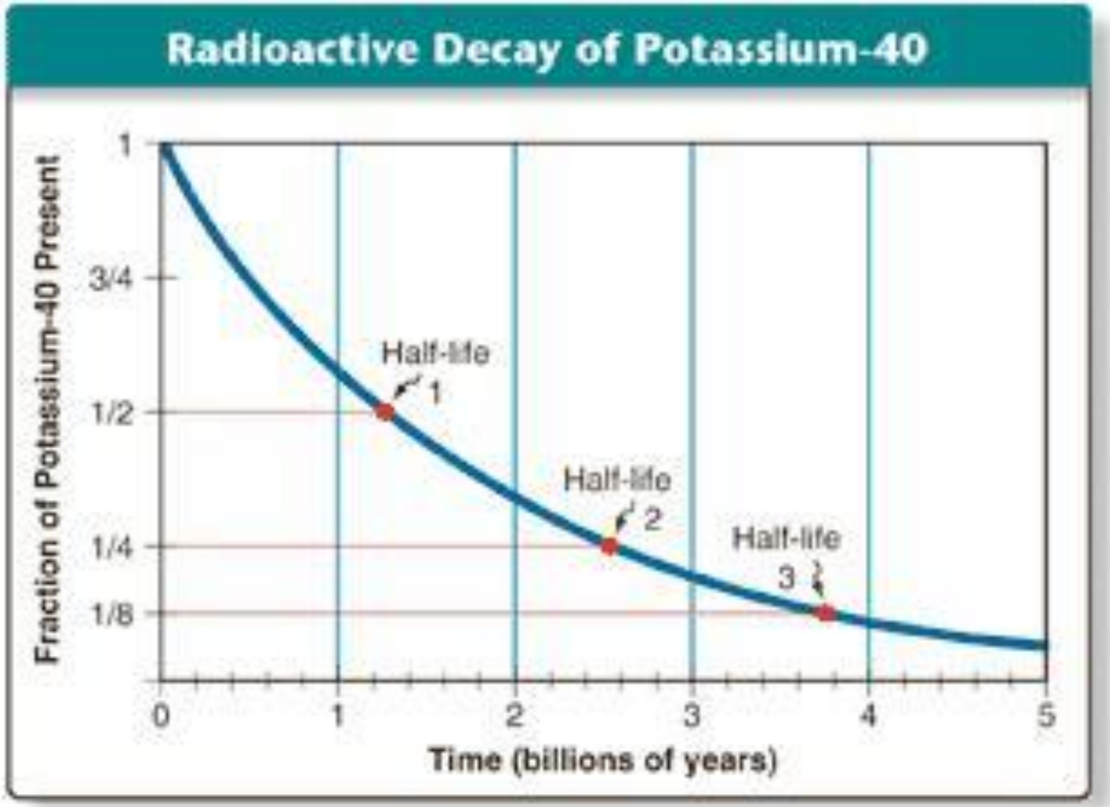
Radioactive Isotope – the nucleus decays spontaneously. Thus it is not as stable as other isotopes.



Unstable - Radioactive

Radioactive Dating

Radioactive Dating – the decay of radioactive isotopes can be mapped out to determine the age of a fossil.

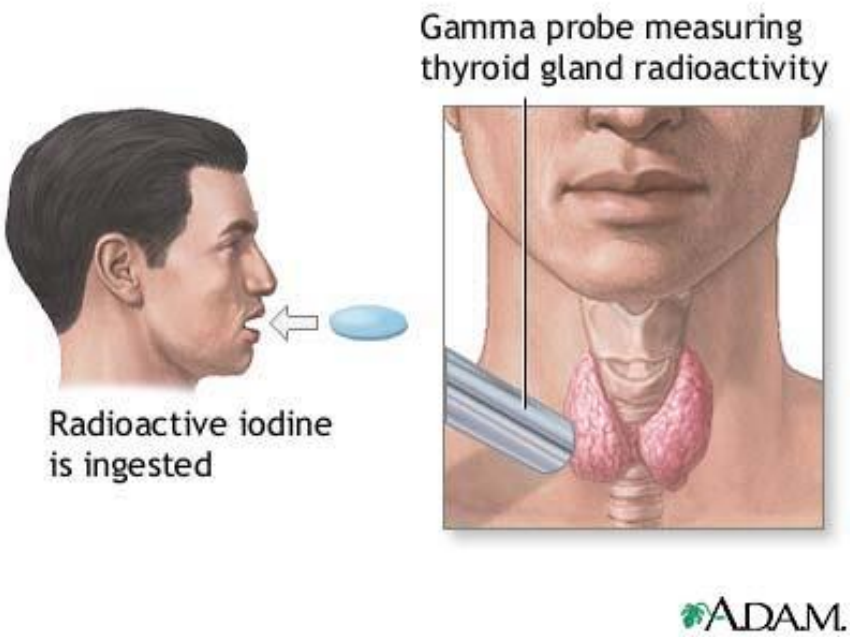


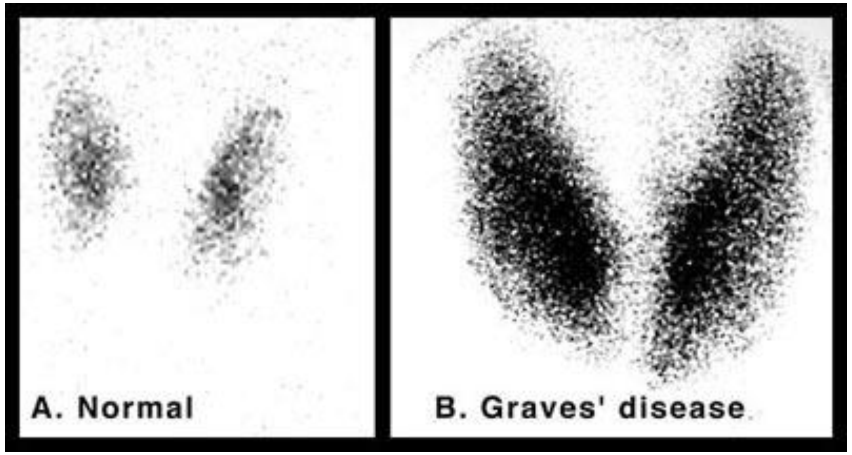
Each radioactive isotope has a ***half-life*** *before it decays into another element.*

By calculating the half-life of the atom, scientists can identify the age of the fossil.

Radioactive Tracers

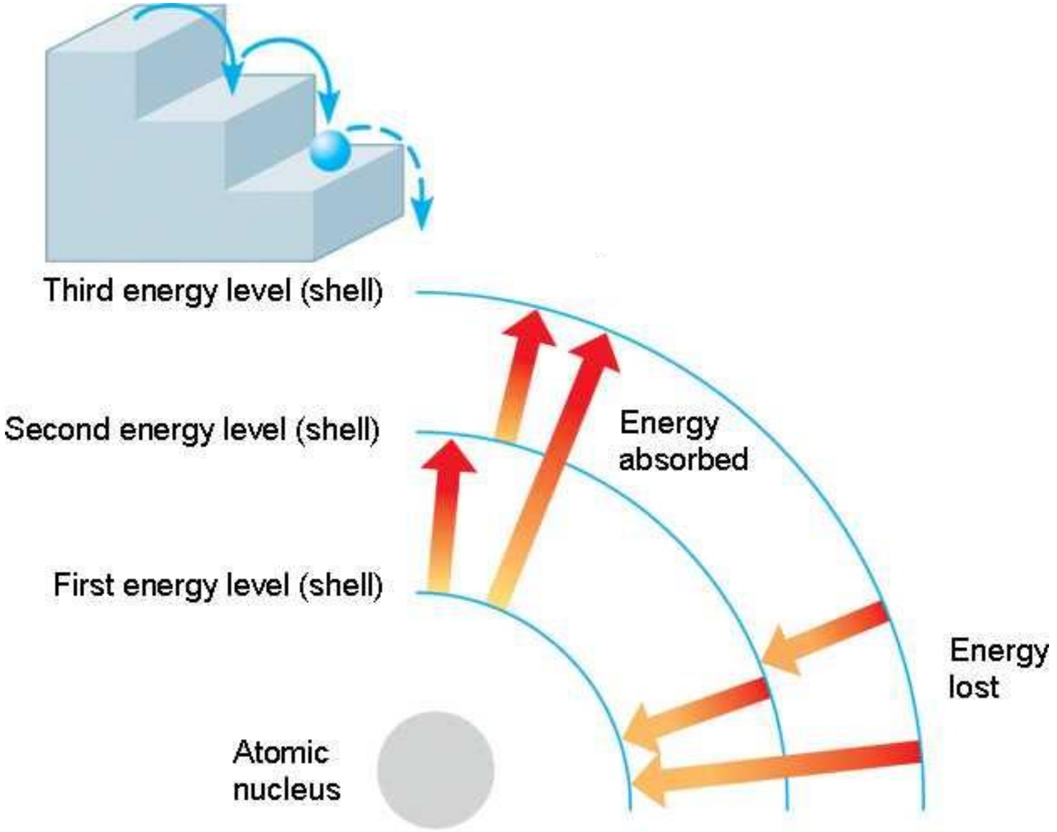
Radioactive tracers are radioisotopes used to follow chemicals through chemical reactions and trace their path as they move through the bodies of organisms.





Iodine – 131 is an isotope used to identify the presence of cancerous cells in the thyroid gland.

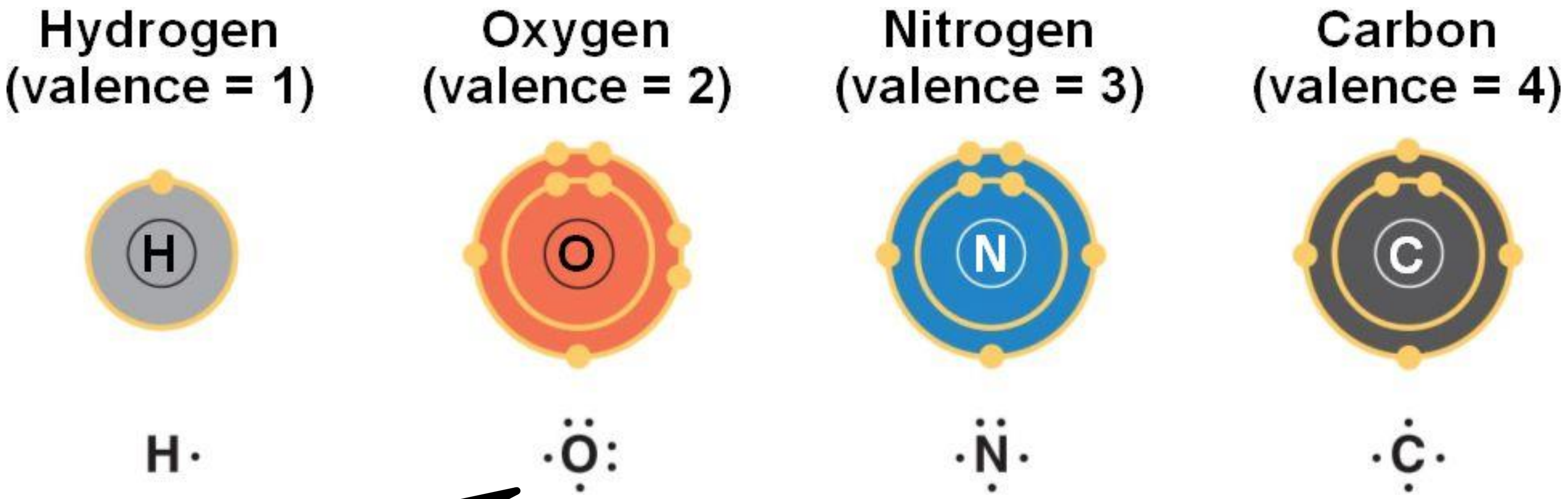
Energy Levels of Electrons



Electrons have a ***potential energy*** *due to their attraction to the protons and their position in the atom.*

Importance of Electrons

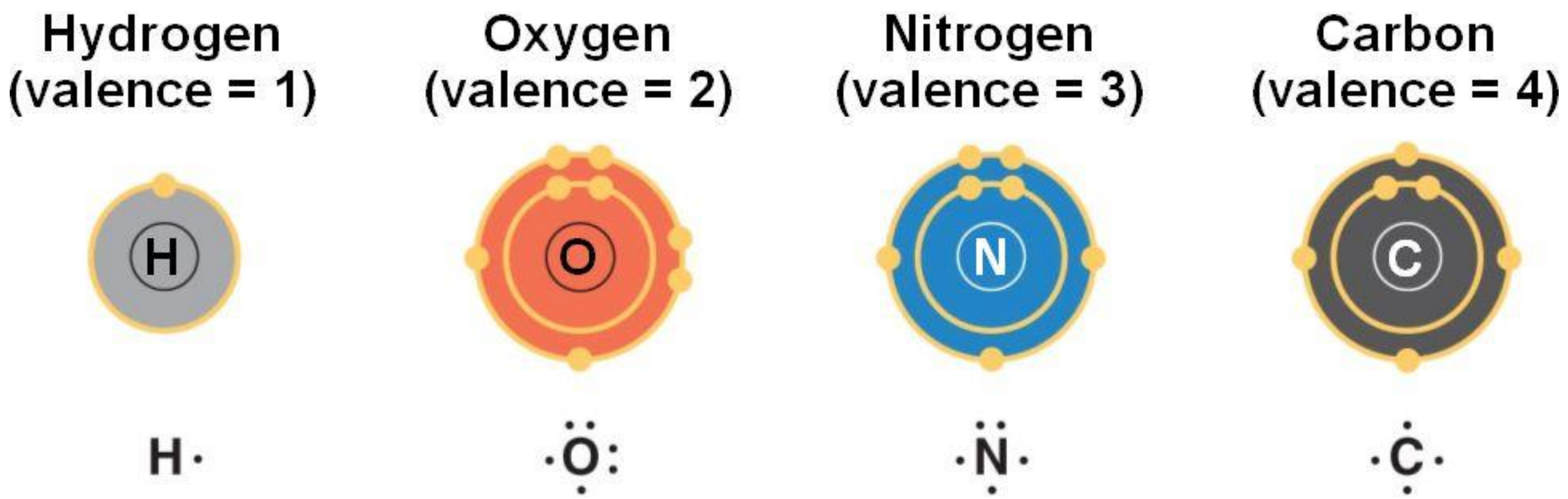
The chemical behaviour of an atom depends mostly on the number of electrons in its outermost shell (valence shell).



Lewis Dot diagrams only show the valence electrons.

Importance of Electrons

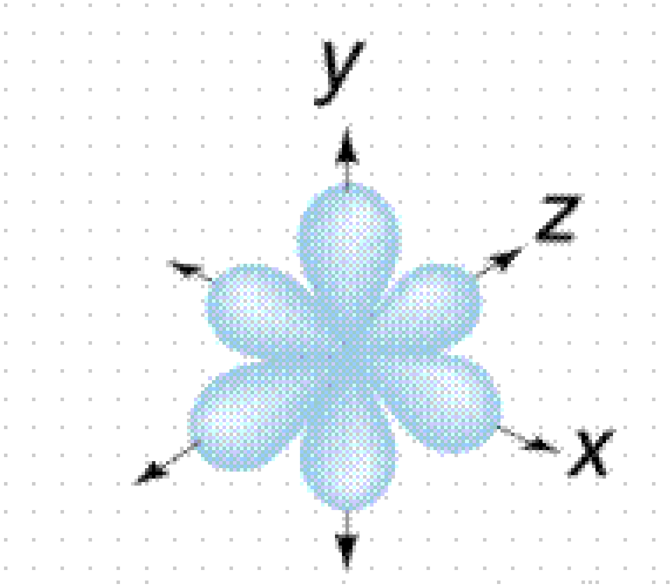
Octet Rule: atoms tend to gain, lose or share electrons so that it can have 8 electrons in its valence shell.



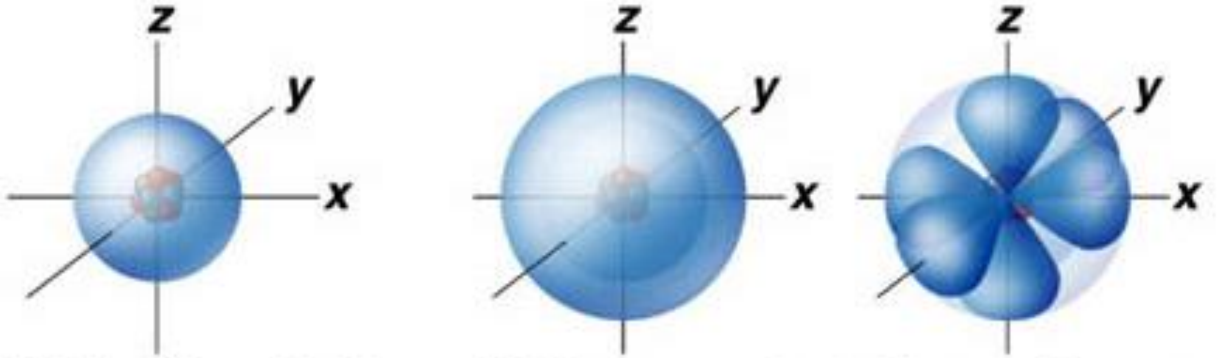
Gain 1 e- **Gain 2 e-** **Gain 3 e-** **Gain 4 e-**

Electron Orbitals

- It is difficult to predict the path of an electron.
- Instead of the 2-D model, scientists have predicted the space in which electrons spent the most amount of time.



Electron Orbitals



A The first shell contains up to 2 electrons in one spherical orbit (1s).

B The second shell contains up to 8 electrons, 2 electrons in one spherical orbit (2s) and 6 electrons in three perpendicular dumbbell-shaped orbits (2p).

Forming Compounds

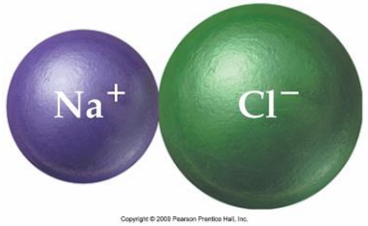
- Compounds are made up of at least two different kinds of atoms (e.g. H_2O)

- Bonds are formed by the sharing or transfer of electrons.

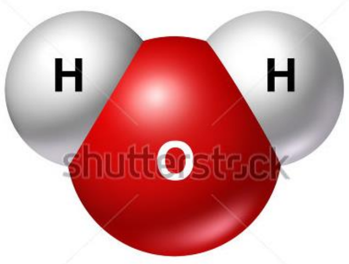
Intramolecular forces:

2 types of chemical bonds

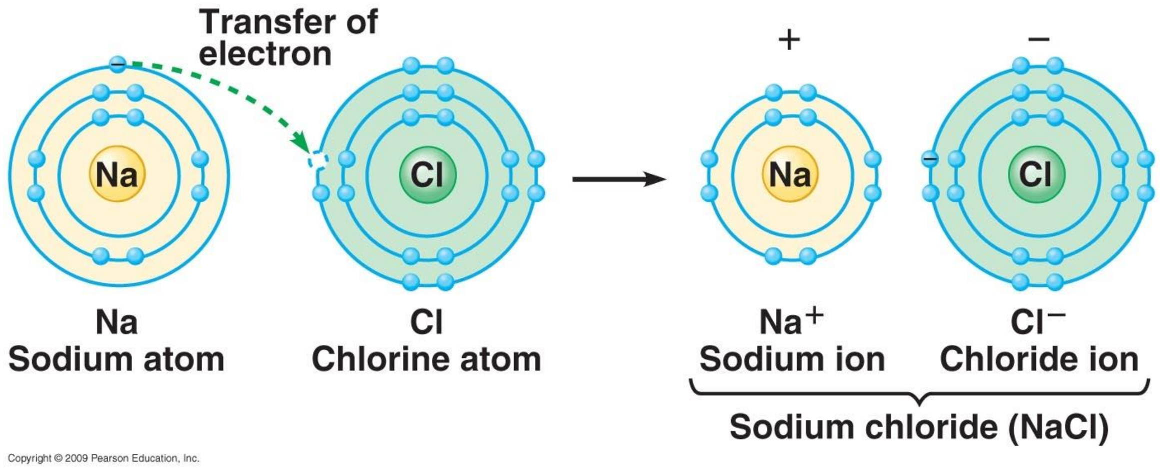
- **Ionic Bonds**



- **Covalent Bonds**

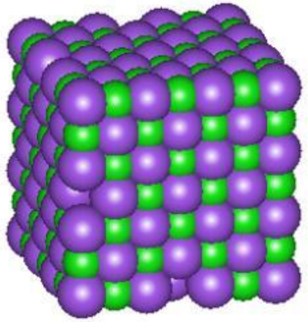


Ionic Bonds



Opposite charges attract to form ionic bonds

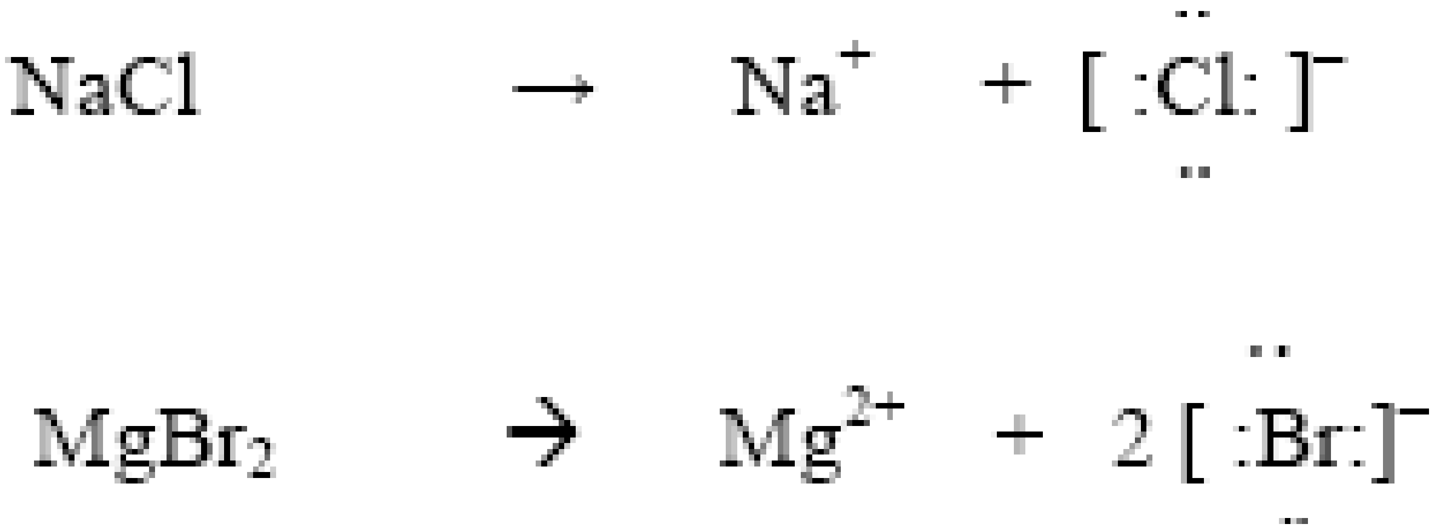
Salt Crystals



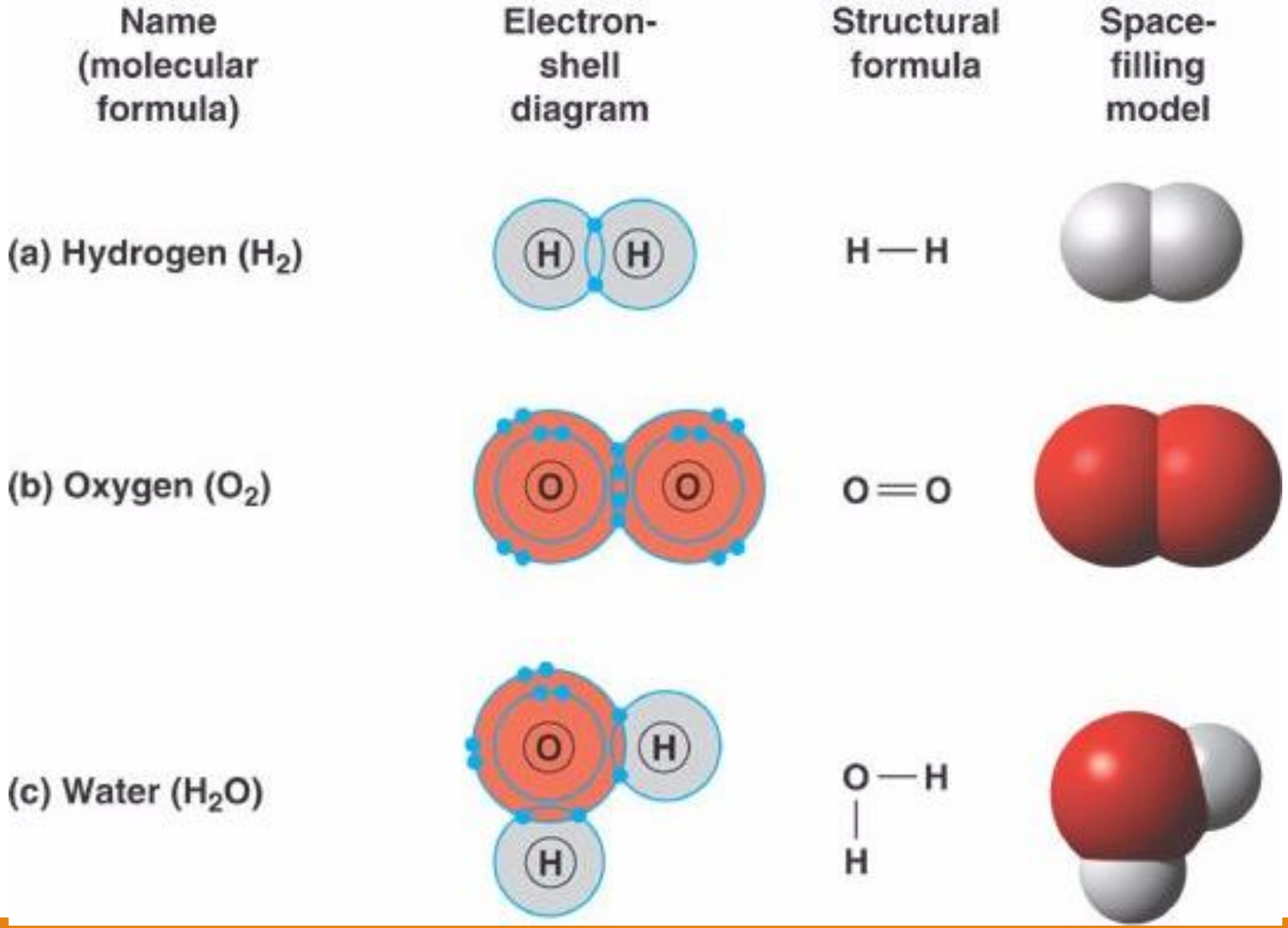
Ionic Compound (NaCl)

Ionic Bonds and Lewis Dot Diagrams

Ionic bonds can also be represented using Lewis Dot Diagrams.



Covalent Bonds



Covalent Bonds and Lewis Dot Diagrams

Covalent Bonds can be represented using a Lewis Dot diagram. Complete the following:

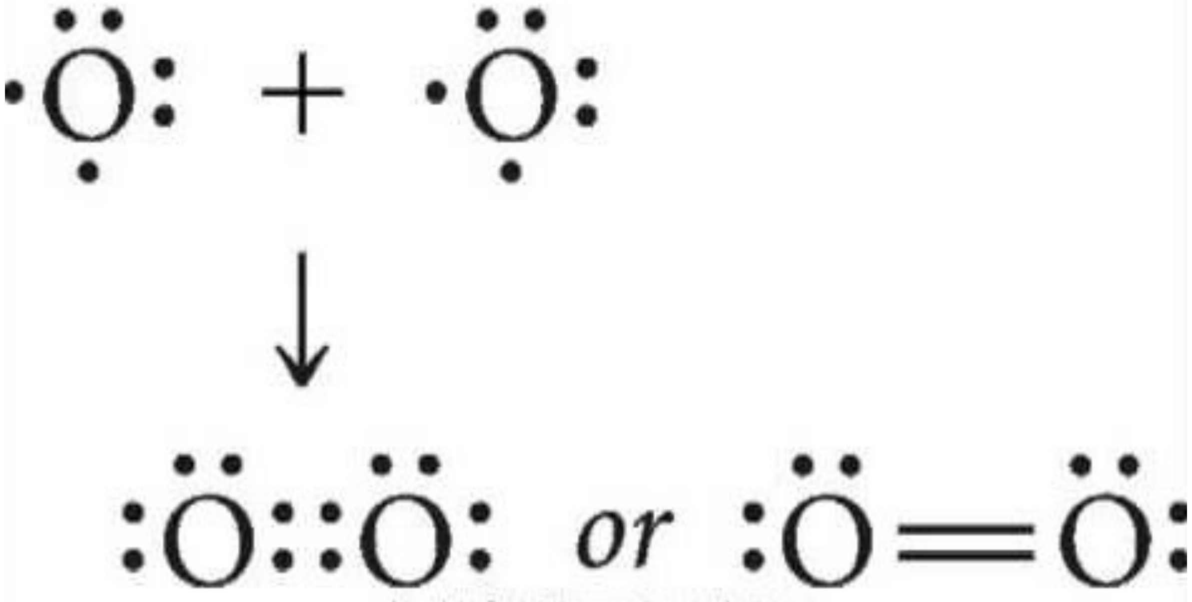


TABLE 8.4 Average Bond Enthalpies (kJ/mol)

Single Bonds

C—H	413	N—H	391	O—H	463	F—F	155
C—C	348	N—N	163	O—O	146		
C—N	293	N—O	201	O—F	190	Cl—F	253
C—O	358	N—F	272	O—Cl	203	Cl—Cl	242
C—F	485	N—Cl	200	O—I	234		
C—Cl	328	N—Br	243			Br—F	237
C—Br	276			S—H	339	Br—Cl	218
C—I	240	H—H	436	S—F	327	Br—Br	193
C—S	259	H—F	567	S—Cl	253		
		H—Cl	431	S—Br	218	I—Cl	208
Si—H	323	H—Br	366	S—S	266	I—Br	175
Si—Si	226	H—I	299			I—I	151
Si—C	301						
Si—O	368						

Multiple Bonds

C=C	614	N=N	418	O_2	495
C≡C	839	N≡N	941		
C=N	615	N=O	607	S=O	523
C≡N	891			S=S	418
C=O	799				
C≡O	1072				

What general difference can you see between single and double bonds?

2 Types of Covalent Bonds

Polar Covalent

Unequal sharing of electrons

Non- Polar Covalent

Equal sharing of electrons

Determined by the atoms

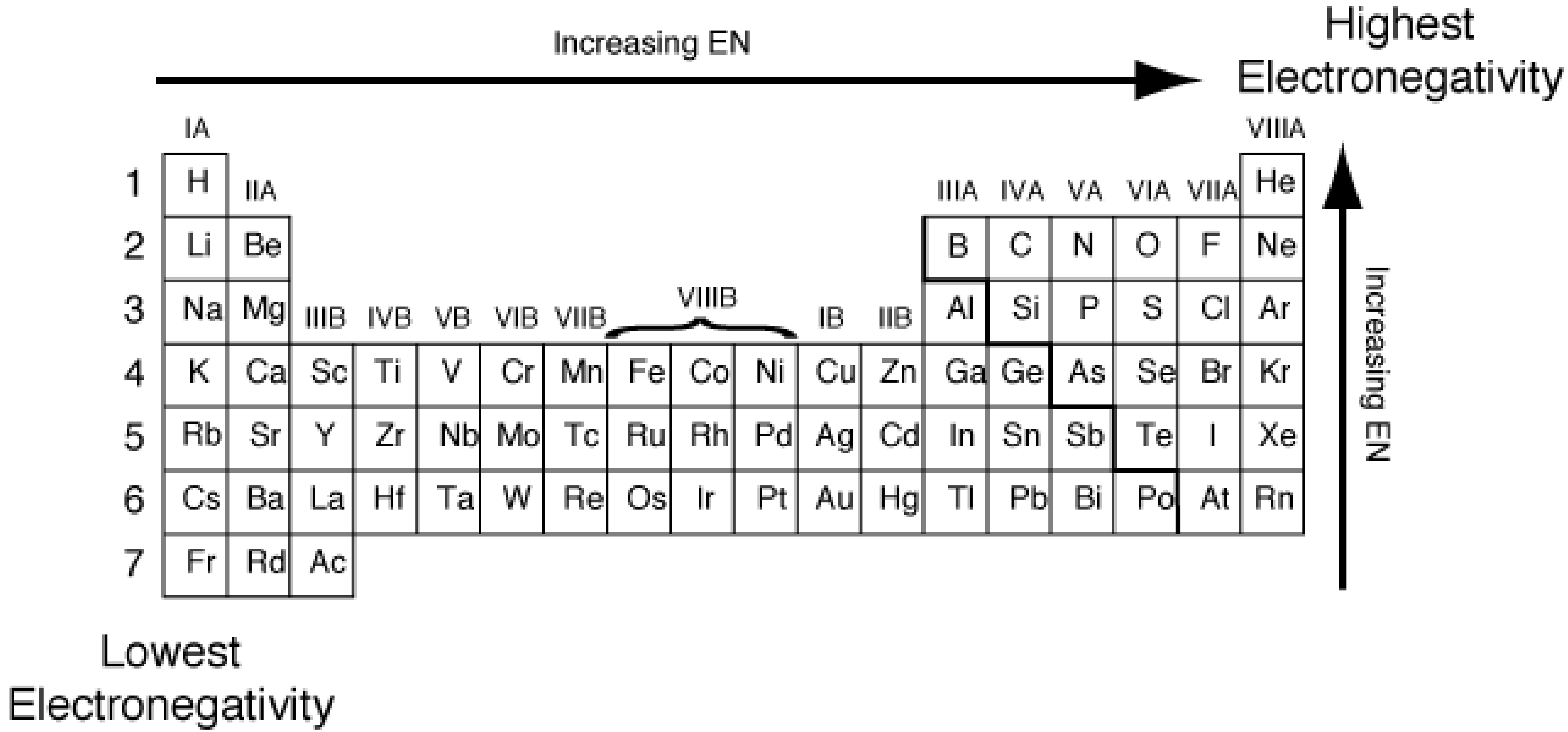
ELECTRONEGATIVITY

Electronegativity

↑ Electronegativity = Stronger pull of shared electrons

Atoms will differ in terms of the electronegativity. In a covalent bond, the atom with the ***stronger electronegativity will have a stronger pull*** *on the electrons.*

Electronegativity



Electronegativity

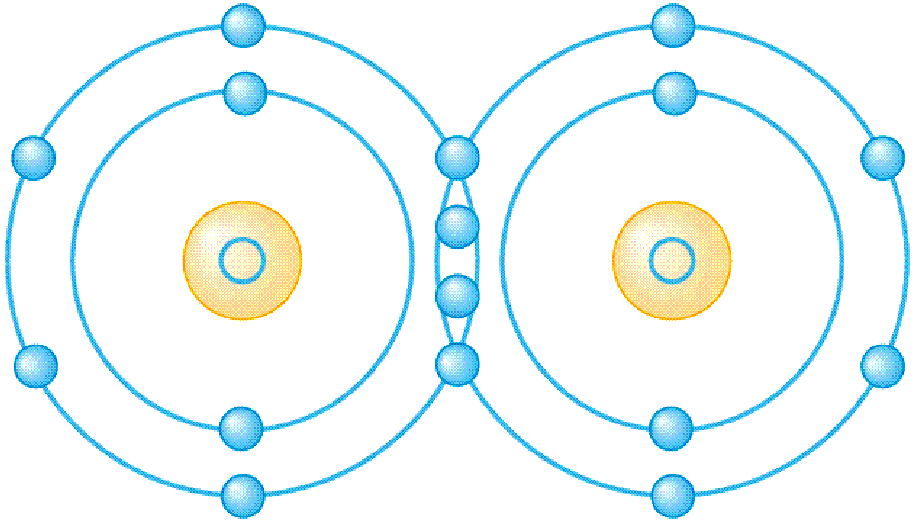
Pauling Electronegativity Values

1 **H** 2.20																
3 **Li** 0.98	4 **Be** 1.57											5 **B** 2.04	6 **C** 2.55	7 **N** 3.04	8 **O** 3.44	9 **F** 3.98
11 **Na** 0.93	12 **Mg** 1.31											13 **Al** 1.61	14 **Si** 1.90	15 **P** 2.19	16 **S** 2.58	17 **Cl** 3.16
19 **K** 0.82	20 **Ca** 1.00	21 **Sc** 1.36	22 **Ti** 1.54	23 **V** 1.63	24 **Cr** 1.66	25 **Mn** 1.55	26 **Fe** 1.83	27 **Co** 1.88	28 **Ni** 1.91	29 **Cu** 1.90	30 **Zn** 1.65	31 **Ga** 1.81	32 **Ge** 2.01	33 **As** 2.18	34 **Se** 2.55	35 **Br** 2.96
37 **Rb** 0.82	38 **Sr** 0.95	39 **Y** 1.22	40 **Zr** 1.33	41 **Nb** 1.6	42 **Mo** 2.16	43 **Tc** 1.9	44 **Ru** 2.2	45 **Rh** 2.28	46 **Pd** 2.20	47 **Ag** 1.93	48 **Cd** 1.69	49 **In** 1.78	50 **Sn** 1.96	51 **Sb** 2.05	52 **Te** 2.1	53 **I** 2.66
55 **Cs** 0.79	56 **Ba** 0.89	57 **La** 1.1	72 **Hf** 1.3	73 **Ta** 1.5	74 **W** 2.36	75 **Re** 1.9	76 **Os** 2.2	77 **Ir** 2.20	78 **Pt** 2.28	79 **Au** 2.54	80 **Hg** 2.00	81 **Ti** 1.62	82 **Pb** 2.33	83 **Bi** 2.02	84 **Po** 2.0	85 **At** 2.2
87 **Fr** 0.7	88 **Ra** 0.9															

Pauling Scale set electronegativities on a scale from **0.7 to 4.0**

Electronegativity – Nonpolar Bond

E.g O_2 - oxygen atoms have the same electronegativity

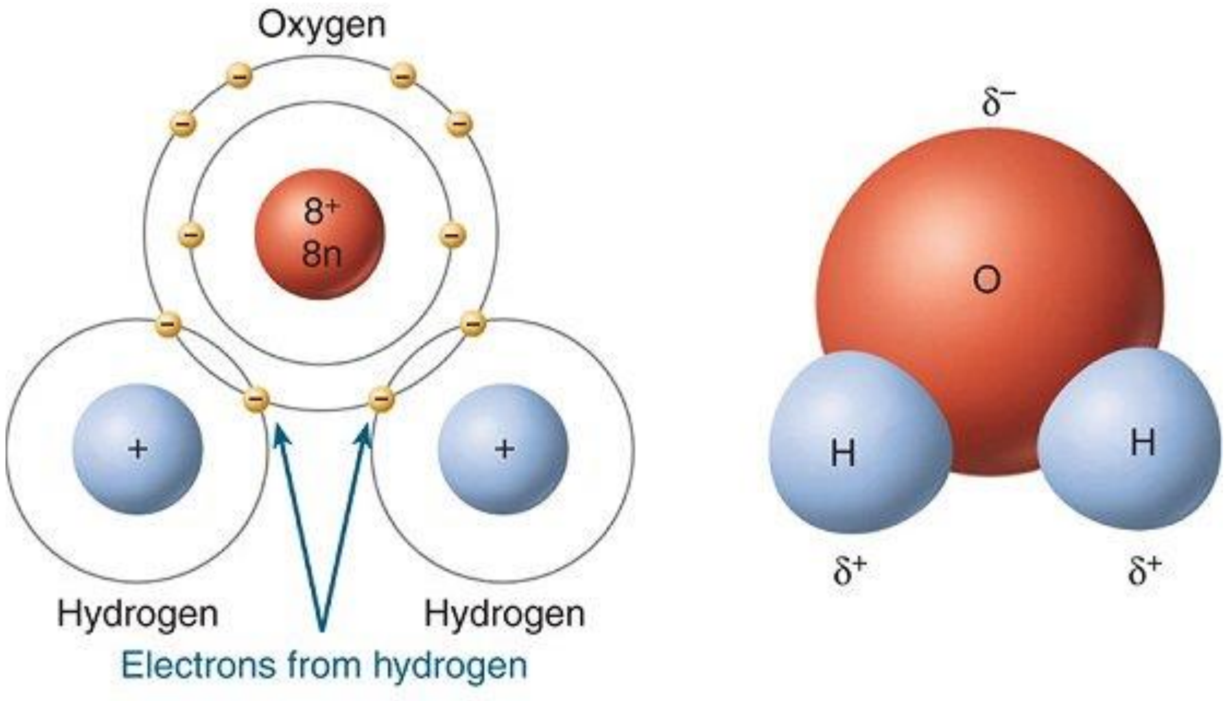


Both oxygen atoms have the same electronegativity. This causes the electrons to be shared equally and there is no partial charge on either atom.

Electronegativity – Polar Bond

E.g H_2O

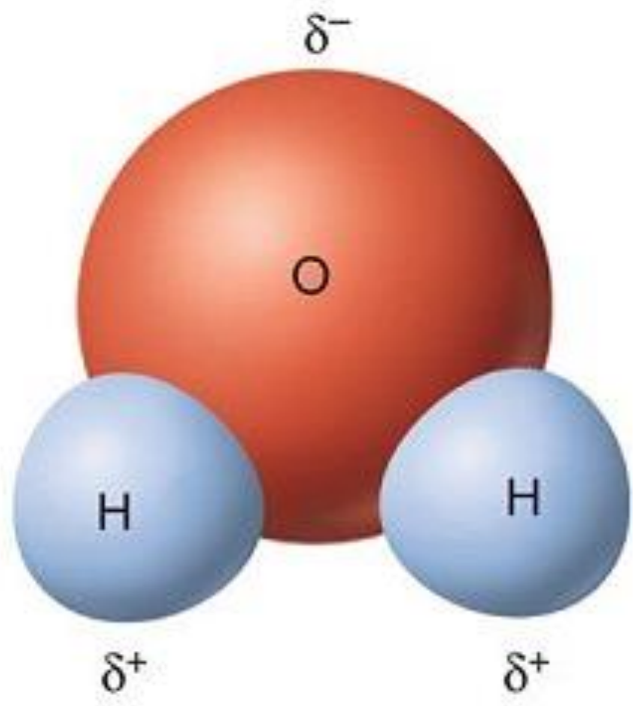
Which atom is more electronegative? What can this do to the polarity of the molecule?



(a) Electron shells in a water molecule

(b) Distribution of partial charges in a water molecule

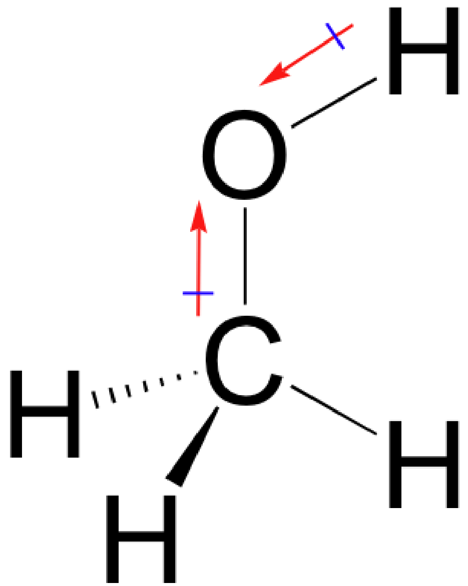
Polar Covalent Bond



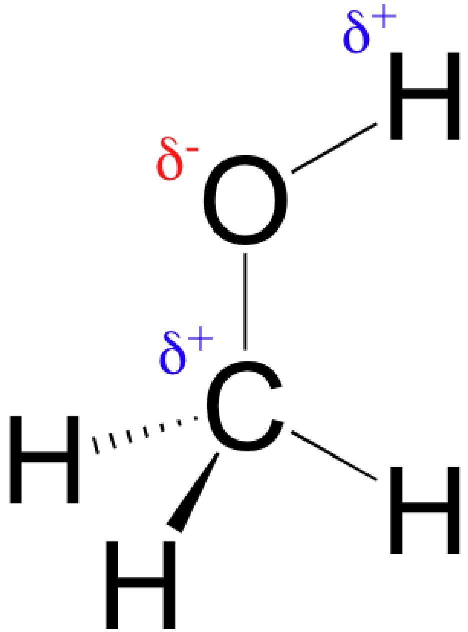
Shared electrons spend more time near the oxygen nucleus.

As a result, the oxygen atoms gains a slightly *negative charge* and the hydrogen atoms become slightly *more positive charge.*

Electronegative Notations – Polar Bonds



bond dipole arrows



partial charge notation

Homework

- Complete Polarity Worksheet

- Complete questions from the textbook: pg. 4-5 # 1-14 (Chemistry Review)