Chemical Bonding and Periodic Trends

Reading:	Ch 12 sections 1 – 4	Homework:	12.1 questions 4, 6
	Ch 11 section 11		12.2 questions 8, 10, 12*, 14*, 16
			12.3 questions 24, 26, 28
			11.11 questions 74, 76, 80*, 82*

* = 'important' homework question

Discussion: In simple terms, what is a chemical bond? What does a chemical bond do?

Recall: From *Modern Atomic Theory 1* we know there are two general types of bond – IONIC and COVALENT

Ionic bonds – form due to a ***large*** difference in electronegativity between the bonding atoms (which subsequently form ions via ***electron transfer***)

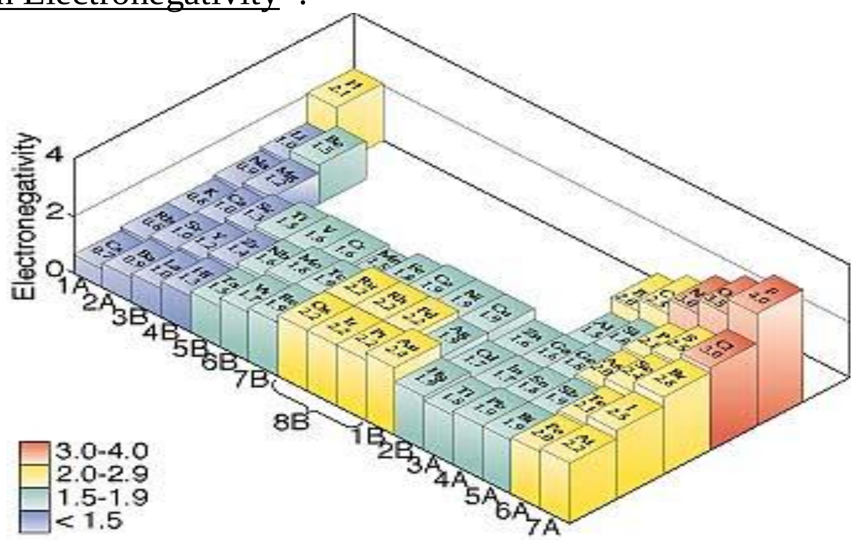
Generic

Lithium Fluoride

Recall that ELECTRONEGATIVITY is the ability of an atom to *attract* electrons.

The trend is *low* (metal, left of p. table, electrons easily lost) → *high* (non-metals, right of p. table, electrons more greatly attracted)

<u>Trends in Electronegativity</u>*:



*Electronegativity is not a true atomic property – it is a derived mathematically from other atomic properties (see later)

<u>Covalent bonds</u> – form due to a ***low*** difference in electronegativity between the bonding atoms (which subsequently ***share a pair of electrons***)

<u>Examples</u>: H_2 (slide),F_2 (both have *pure* covalent bonds – no difference in electronegativity)

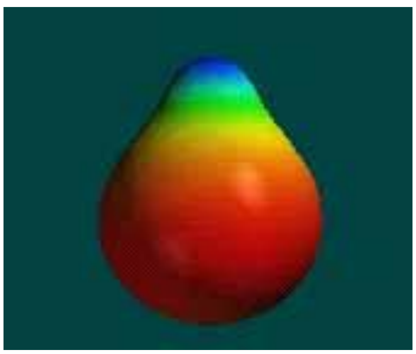
<u>Recall</u>: the driving force behind the formation of covalent (and ionic) bonds is the formation of a full valence shell.

Polar Covalent Bonds - are a *mixture of ionic and pure covalent bonding types*. The electrons are shared (as in a covalent bond) but are drawn closer to the more electronegative atom (as in an ionic bond)

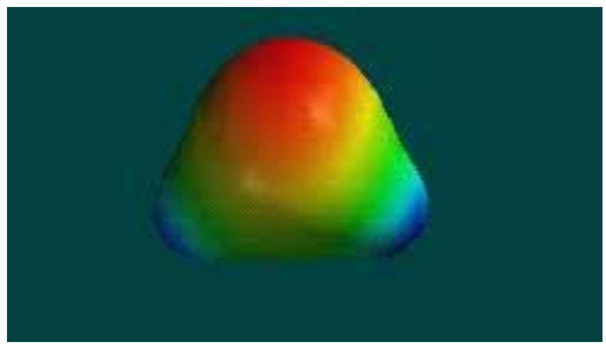
The atoms involved in POLAR covalent bonds are typically BOTH non-metals, but ALSO have a large difference in electronegativity.

Common examples of polar covalent bonds are H-F and H-O

Examples: H-F and H_2O



Electron density map of HF



Electron density map of H_2O

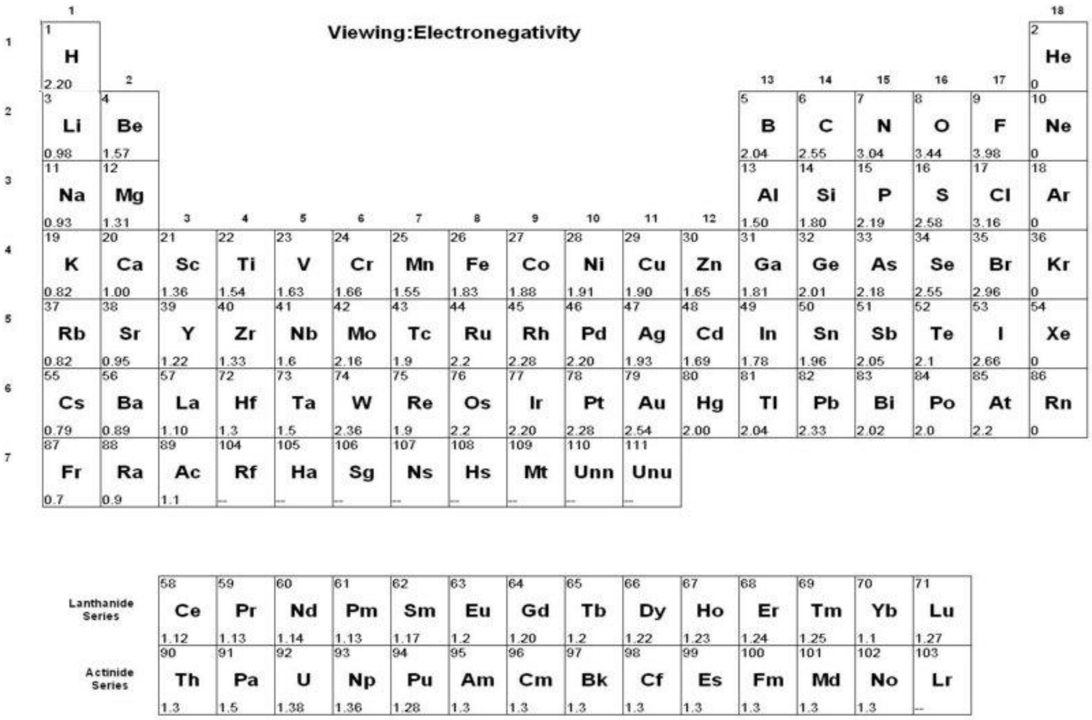
Molecules with dipoles

Polar covalent bonds create a separation of charge in the respective molecule

Such a separation of charge is known as a dipole. Molecular dipoles are represented by an arrow with a ‘+’ at the positive end of the molecule

Task: Sketch diagrams of HF and H_2O that show their respective molecular dipoles (slide)

Electronegativity Values



Viewing:Electronegativity

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 2.20																	2 He 0
2	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	10 Ne 0
3	11 Na 0.93	12 Mg 1.31											13 Al 1.50	14 Si 1.80	15 P 2.19	16 S 2.58	17 Cl 3.16	18 Ar 0
4	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	36 Kr 0
5	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	54 Xe 0
6	55 Cs 0.79	56 Ba 0.89	57 La 1.10	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 Tl 2.04	82 Pb 2.33	83 Bi 2.02	84 Po 2.0	85 At 2.2	86 Rn 0
7	87 Fr 0.7	88 Ra 0.9	89 Ac 1.1	104 Rf --	105 Ha --	106 Sg --	107 Ns --	108 Hs --	109 Mt --	110 Unn --	111 Unu --							

Lanthanide Series	58 Ce 1.12	59 Pr 1.13	60 Nd 1.14	61 Pm 1.13	62 Sm 1.17	63 Eu 1.2	64 Gd 1.20	65 Tb 1.2	66 Dy 1.22	67 Ho 1.23	68 Er 1.24	69 Tm 1.25	70 Yb 1.1	71 Lu 1.27
Actinide Series	90 Th 1.3	91 Pa 1.5	92 U 1.38	93 Np 1.36	94 Pu 1.28	95 Am 1.3	96 Cm 1.3	97 Bk 1.3	98 Cf 1.3	99 Es 1.3	100 Fm 1.3	101 Md 1.3	102 No 1.3	103 Lr --

<u>Discussion</u>: Do you think that electronegativity values are determined experimentally or calculated? Look at the values presented in the above table to help make your decision. How can electronegativity *differences* between atoms be determined? How does this relate to bond type?

Electronegativity values for ***most*** atoms are known – they are calculated from a variety of atomic properties, including nuclear charge and atomic radius (see next section)

The type of bond that exists between two atoms depends on the respective atoms' *difference* in electronegativity

‘Ball Park’ determination of bond type (based on electronegativity differences)

Δ Electronegativity	Bond Type
0 → 0.2	Covalent
0.3 → 1.6	Polar Covalent
1.7 → 3.3	Ionic

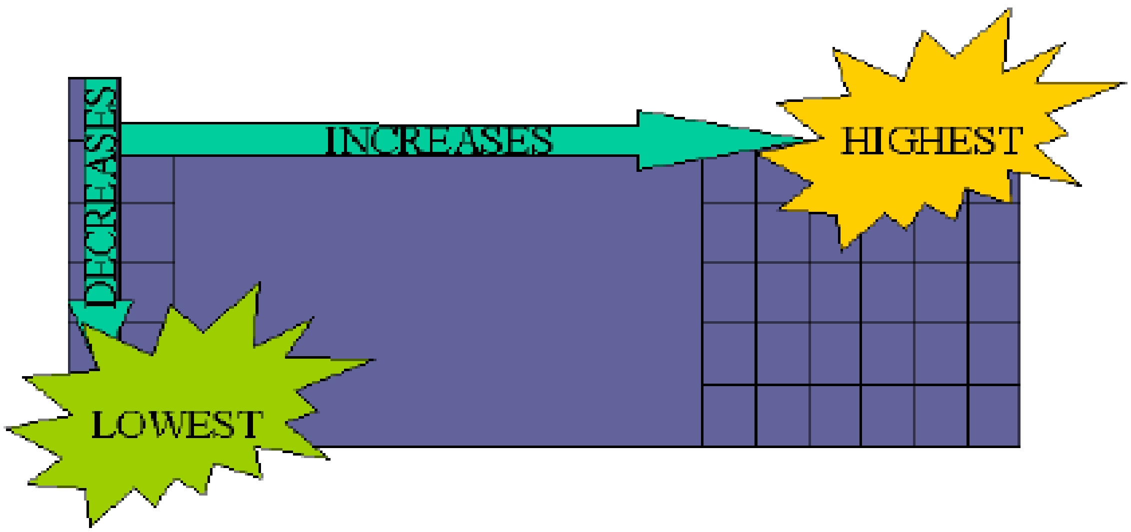
Task: Determine the type of chemical bond that exists between the following pairs of atoms

Bonded atoms	Δ Electronegativity	Type of bond
H-Cl		
Cl-Br		
Na-F		
N-O		
C-O		

The Origins of Electronegativity – 'True' Atomic Properties

As with electronegativity, essentially all other periodic trends follow the same general 'bottom left to top right' scheme. This is because electronegativity is determined from these 'true' atomic properties. See generic diagram the below. The periodic trends examined will be:

Atomic Size (radius) **1st Ionization Energy**



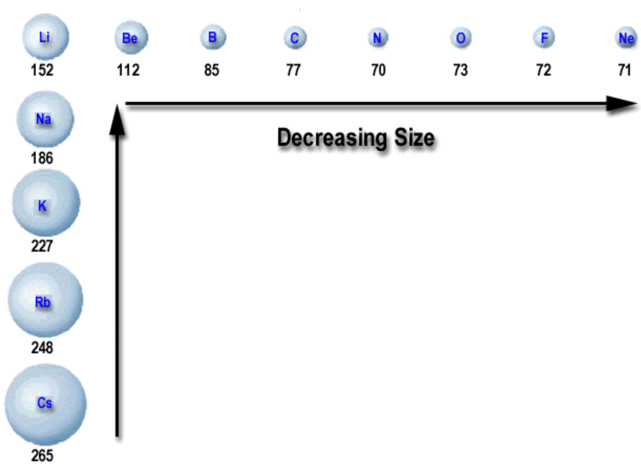
Atomic Radius

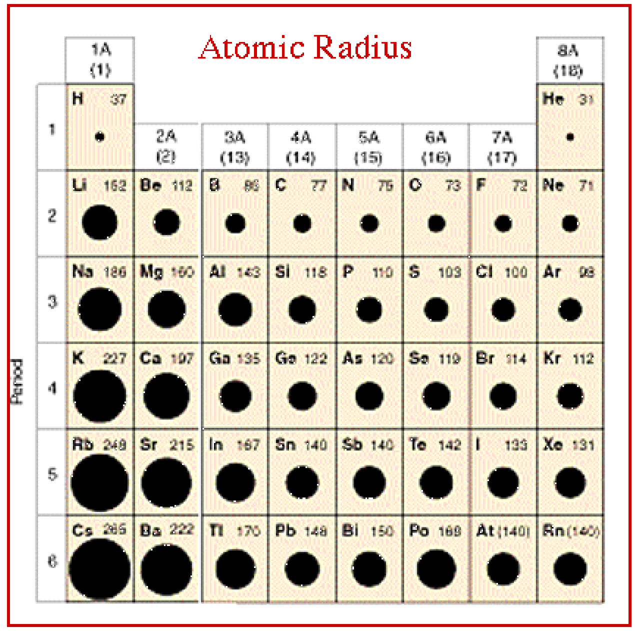
<u>Discussion</u>: How do trends in the size (radius) of atoms 'across a row' and 'down a column' in the periodic table vary? Use the following figures as a guide. Why do you think this is so?

1. 'Across a Row'

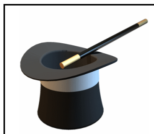
2. 'Down a Column'

Atomic Radius Trends



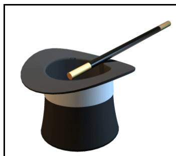


Trends and established values (pm) of atomic radii for various elements



Recall: The atomic radii of the atoms follow a classic 'bottom left → top right' periodic trend.

Typical Question: Arrange the following atoms in order of increasing atomic radii: Na, Be, Mg.



	Be
Na	Mg

Questions of this type (as well as for other periodic trends) often select three elements from the periodic table that have a 'triangular' relationship. Understanding the classic 'bottom left → top right' periodic trend allows for the answer to be determined.

Answer:

1^{st} Ionization Energy

<u>Discussion</u>: What is *ionization*? What then is *1^{st} ionization energy*?

<u>1^{st} Ionization Energy</u>: Energy *required* to remove the first electron from a gaseous atom or ion.

<u>Example</u>: Sodium

$$Na\ (g) \rightarrow Na^{+}\ (g) + e^{-}\ ;\ I_1 = 496\ kJ/mol$$

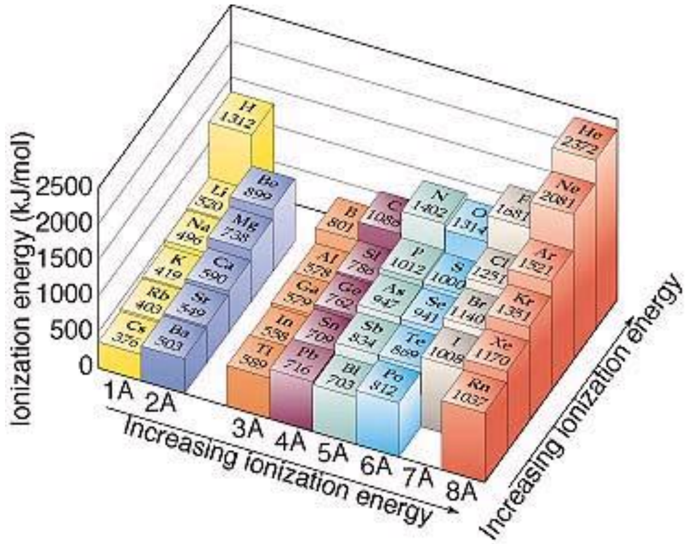
<u>Task</u>: Draw electron dot diagrams illustrating this process

<u>Discussion</u>: How do trends in 1^{st} ionization energy of atoms 'across a row' and 'down a column' in the periodic table vary? Use the following figurse as a guide. Why do you think this is so?

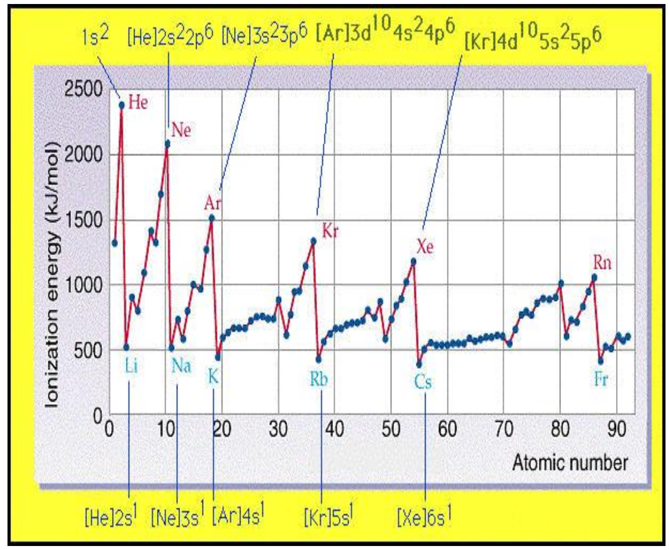
1. 'Across a Row'

2. 'Down a Column'

Trends in 1st Ionization Energy

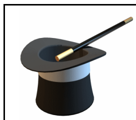


‘Geographical’ map of 1st ionization energy. Note the classic bottom left → top right trend



Line graph of I_1 vs atomic number.

Typical Question: Arrange the following atoms in order of increasing 1st ionization energy: Na, Cs, F, C.



As with similar atomic radii, understanding the classic ‘bottom left → top right’ periodic trend allows for the answer to be determined.

Answer: