Chemistry 11

Atomic Theory V

Name: Key
Date:
Block:

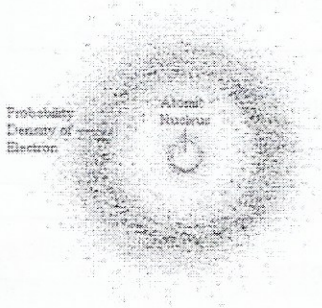
1. **Atomic Radius**
2. **Ionization Energy**
3. **Electronegativity**
4. **Chemical Bonding**

Atomic Radius

Periodic Trends

- As we move across a period or down a chemical family, there are regular changes in elemental properties.

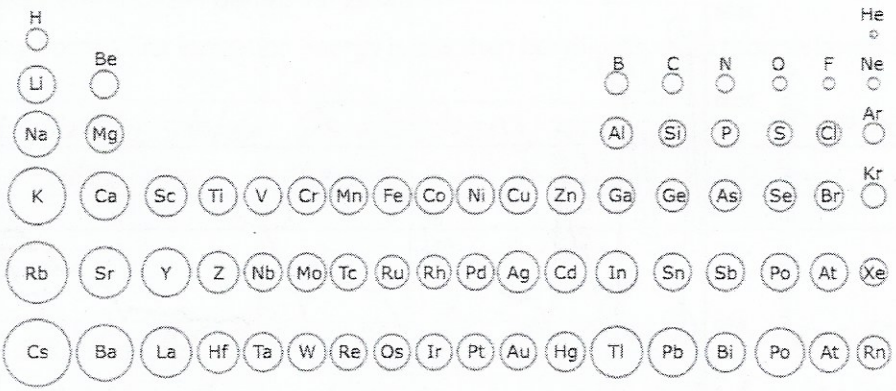
1. Atomic Radius
2. Ionization energy
3. Electronegativity



The size of an atom

- The volume of an atom is the result of a cloud of electrons.
- The outer boundary of an atom depends on the size of a cloud in which electrons spend approximately 90 % of their time.
- What affects the size of an atom's electron cloud?

larger

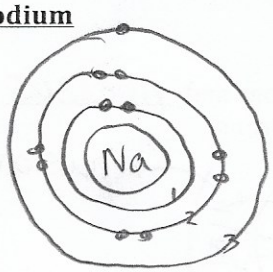


As we move DOWN a family...

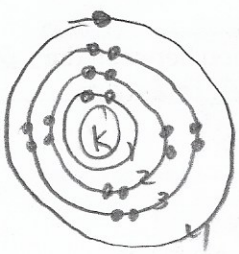
- As the number of energy levels (n) increases, the outer electrons will be farther from the nucleus. This makes the atom larger.

- **Draw the Bohr Diagrams for the following atoms:**

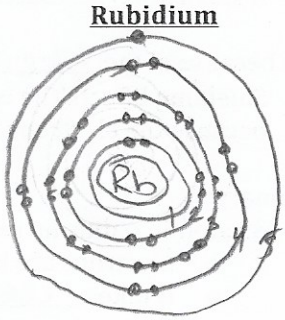
Sodium



Potassium



Rubidium



As we move ACROSS a period...

- As the atomic number increases, the number of protons increases.
- The greater the positive charge on the nucleus, the more the electrons are attracted to the nucleus. This decreases the size of the radius.

Consider this...

Rank the following from largest to smallest by determining:

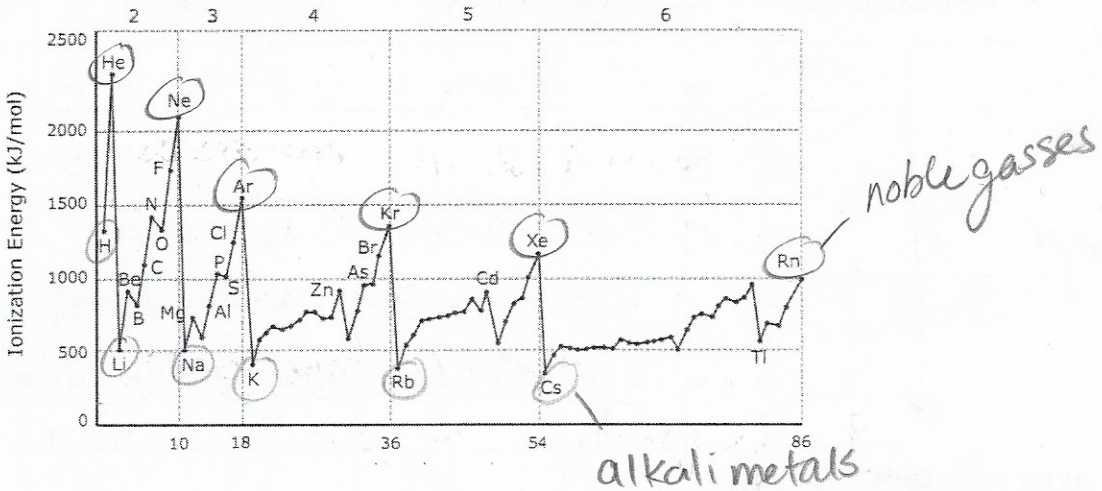
- How many electrons are in each?
- How many protons are in each?

	Al^{3+}	F^-	Mg^{2+}	N^{3-}	Na^+	Ne	O^{2-}
# of electrons	10	10	10	10	10	10	10
# of protons	13	9	12	7	11	10	8

Ranking: $N^{3-} > O^{2-} > F^- > Ne > Na^+ > Mg^{2+} > Al^{3+}$

Ionization Energy

Ionization Energy: The energy required to remove an electron from a neutral atom.

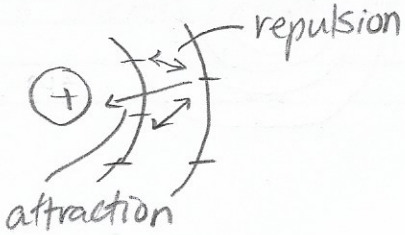


Ionization Energy tells us how strongly an atom holds onto its outermost electrons.

- A large atom has outer electrons that are held less strongly
- A small atom has outer electrons that are held more strongly

This is because of the Sheilding Effect

- Shielding Effect: The weakening of the attraction between the outer electrons and nucleus because the electrons in the inner shells are repelling the outer electrons



In summary:

- As atomic radius increases...
  - Electrons are held less tightly
  - It takes less energy to remove electrons
  - Ionization energy decreases

- As atomic radius decreases...
  - Electrons are held more tightly
  - It takes more energy to remove electrons
  - Ionization energy increases

Practice Problems — Trends in Ionization Energy

1. Using only the periodic table, rank the following alphabetical list of elements in order of decreasing first ionization energy.

   aluminum argon cesium magnesium rubidium silicon sodium sulphur

   Ar > S > Si > Al > Mg > Na > Rb > Cs

2. Using the periodic table, write the correct number in the space after each statement below:

   Members of this chemical family have the highest IE_1 in their period. 18

   Members of this chemical family have the lowest IE_1 in their period. 1

   Members of this chemical period have the highest IE_1 in their family. 1

   Members of this chemical period have the lowest IE_1 in their family. 7

3. Extension: The nature of the 2s sublevel is such that 2s electrons have a higher probability of being found closer to the nucleus than electrons in the 2p sublevel. Consider this and the following electron configurations:

   beryllium: $1s^2\,2s^2$ boron: $1s^2\,2s^2\,2p^1$

   Suggest a reason why boron's first ionization energy is less than beryllium's, even though boron is a smaller atom.

   full subshell is more stable 2s electrons are closer to nucleus ∴ are shielding 2p electrons. 1 electron on p-subshell is easier to remove

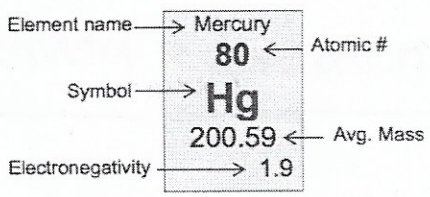
Electronegativity

Electronegativity

Electron affinity is the ability for atoms to attract electrons towards themselves

Electronegativity is the ability of an atom to draw bonded electrons towards itself.

- Smaller atoms are better at attracting electrons because their bonded electrons are so close to their nucleus
- Therefore, smaller atoms have a higher electronegativity (EN)



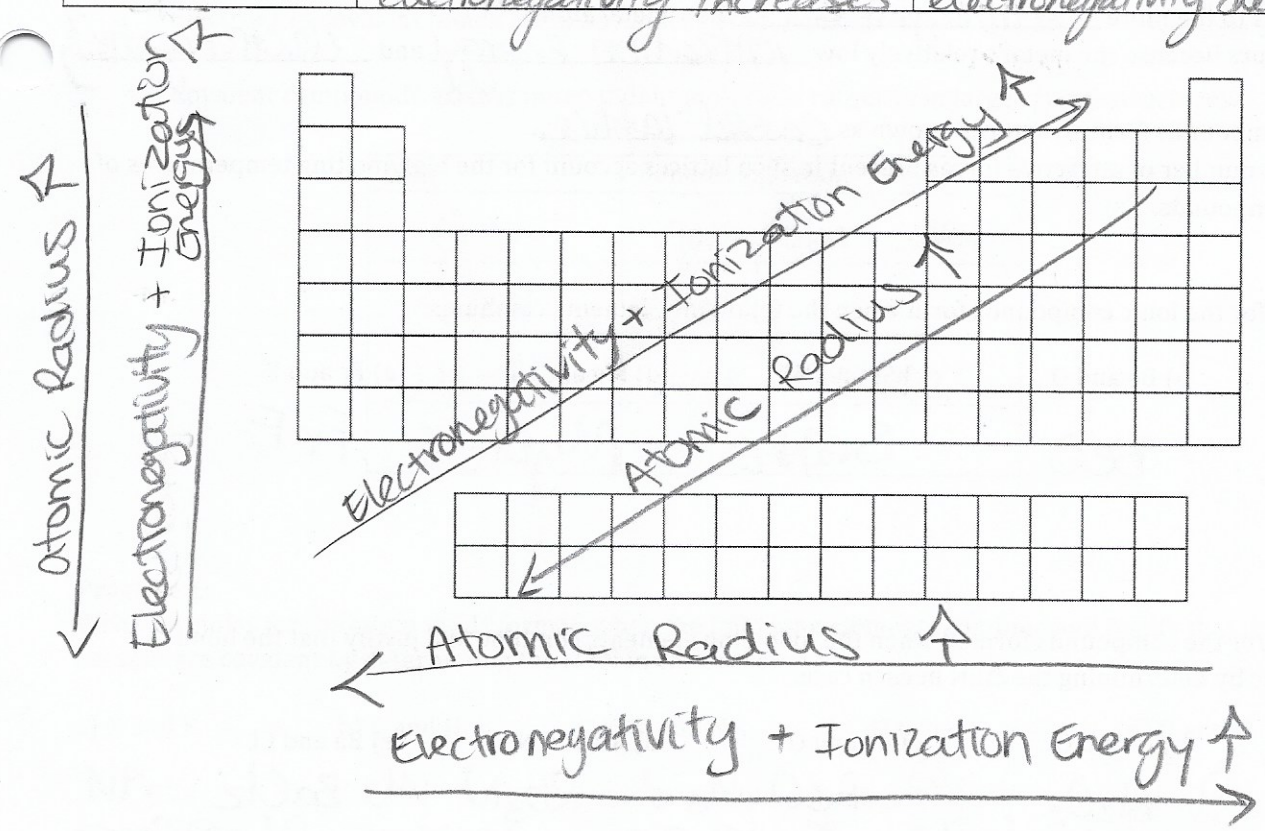
H 2.1																
Li 1.0	Be 1.5											B 1.5	C 2.5	N 3.0	D 3.5	F 4.0
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 3.5	Cl 3.0
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.9	Ni 1.8	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5
Cs 0.7	Ba 0.9		Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.9	Bi 1.9	Po 2.0	At 2.2
Fr 0.7	Ra 0.9															

- **As atomic radius increases...**
  - The nucleus is farther from the bonding electrons
  - The atom has a lower ability to attract an electron
  - Electronegativity decreases
- **As atomic radius decreases...**
  - The nucleus is closer to the bonding electrons
  - The atom has a higher ability to attract an electron
  - Electronegativity increases

Summary...

Decreases or increases?

	Moving LEFT to RIGHT Across A Period	Moving DOWN a Chemical Family
Atomic Size	decreases	increases
Reason:	positive nucleus pulls electrons closer	outer shell electrons are farther from nucleus as you go down.
Ionization Energy (IE)	increases	decreases
Reason:	electrons are more tightly held together ∴ take more energy to remove electrons. thus higher IE	electrons are less tightly packed ∴ takes less energy to remove electrons thus lower IE
Electronegativity	increases	decreases
Reason:	Nucleus is closer to the bonding electron, higher ability to attract electrons. ∴ electronegativity increases	nucleus is farther from bonding electrons, atoms have a lower ability to attract electrons ∴ electronegativity decreases

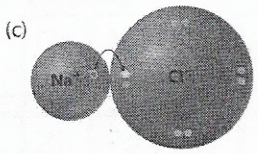


Chemical Bonding

Atoms Involved	Type of Bond
1. metal bonded to non-metal	Ionic bond
2. non-metal bonded to non-metal	Covalent bond
3. metal bonded to metal	Metallic bond

Ionic Bonding

- Ionic bonding occurs because of the electrostatic attractive force between the oppositely charged ions produced when a metal atom transfers one or more electrons to a non-metal atom.



Ionic bond
Complete transfer of one or more valence electrons.
Full charges on resulting ions.

Important Points:

1. Ionic compounds form between large metal and small non-metal whose electronegativity difference (ΔEN) exceeds 1.7. They typically form when metals from groups 1 or 2 react with non-metals from groups 16 or 17 of the periodic table.

2. During the formation of an ionic bond, metal atoms will share one or more valence electrons to the more electronegative non-metal atoms. This occurs because the metal's relatively low ionization energy and electronegativity.

3. Ionic compounds form structures known as crystal lattice. The vast number of attractive forces present in such lattices account for the high melting temperatures of ionic compounds.

Practice 1:
Write formulas for the ionic compounds form when the following elements combine:

a) Ba and Br $BaBr_2$

b) Be and O BeO

c) Sr and N Sr_3N_2

d) Mg and Cl $MgCl_2$

e) Fr and F FrF

Practice 2:
Write formulas for the compounds formed when the following elements combine and justify that the bonds present are ionic by determining the ΔEN in each case.

a) Ca and Br $CaBr_2$
2.8 − 1.0 = 1.8
ionic

b) Al and O Al_2O_3
3.5 − 1.5 = 2.0
ionic

c) Be and O BeO
3.5 − 1.5 = 2.0
ionic

d) Rb and N Rb_3N
3.0 − 0.8 = 2.2
ionic

e) Ba and Cl $BaCl_2$
3.0 − 0.9 = 2.1
ionic

Practice 3:
Justify that the bonds in the following compounds are ionic by calculating the ΔEN values for each.

a) RbF
4.0-0.8
= 3.2 ionic

b) NaCl
3.0-0.9
= 2.1
ionic

c) $RaCl_2$
3.0-0.9
= 2.1
ionic

d) KBr
2.8-0.8
= 2.0
ionic

e) Na_2O
3.5-0.9
= 2.6
ionic

Covalent Bonding

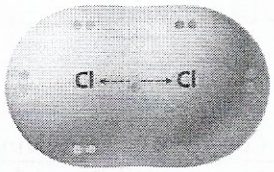
- A bond formed from the sharing of electron pairs between atoms
- Can be non-polar covalent or polar covalent
- Important Points:

1. Covalent compounds form between two non-metals.

2. Because no electron transfer occurs and no ions form, all of the species prior to and following covalent bond formation between two atoms are electrically neutral.

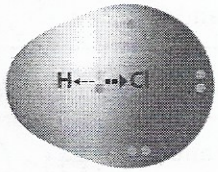
3. The force of attraction in a covalent bond is between a pair of electrons and two adjacent positive nuclei, rather than between a cation and an anion.
   Electrons in covalent bonds are always associated in pairs.

(a)



Nonpolar covalent bond
Bonding electrons shared equally between two atoms.

(b)



Polar covalent bond
Bonding electrons shared unequally between two atoms. Partial charges on atoms.

4. Covalent compounds exist as independent molecules rather than large crystal structures.

ΔEN	Bond Designation
0	non-polar covalent
< 0.4	mostly
0.4-1.7	Polar covalent
> 1.7	ionic

Practice 1:
Write formulas for the compounds formed when the following elements combine and justify that the bonds present are covalent by determining the ΔEN in each case.

a) N and F
NF_3
4.0-3.0=1.0
polar covalent

b) C and H
CH_4
2.5-2.1=0.4
polar covalent

c) Si and N
Si_3N_4
3.0-1.8
= 1.2
polar covalent

d) C and S
CS_2
3.5-2.5
=1.0
polar covalent

e) O and O
O_2 3.5-3.5
=0
non-polar covalent

Practice 2:
Calculate the ΔEN values for the bonds in the following compounds. Then arrange the compounds in order from those containing bonds in which the electrons are shared most equally to those in which the electrons are shared most unequally.

a) H_2O — 3.5 − 2.1 = 1.4 — polar covalent

b) PCl_3 — 3.0 − 2.1 = 0.9 — polar covalent

c) Cl_4 — 3.0 − 3.0 = 0 — non-polar Covalent

d) SiO_2 — 3.5 − 1.7 = 1.7 — polar Covalent

e) AlN — 3.0 − 1.5 = 1.5 — polar covalent

$Cl_4 > PCl_3 > H_2O > AlN > SiO_2$

Practice 3:
Complete the following table:

Elements Present	Formula	ΔEN values	Nature of Bonds	Atom Possessing Greater Electron Density
C and S	CS_2	3.5 − 2.5 = 1.5	polar Covalent	S
B and Cl	BCl_3	3.0 − 1.5 = 1.5	polar Covalent	Cl
Al and O	Al_2O_3	3.5 − 1.5 = 2.0	ionic	O
N and I	NI_3	3.0 − 2.5 = 0.5	polar covalent	N
Ca and F	CaF_3	4.0 − 1.0 = 3.0	ionic	F

Practice 4:
Determine the type of bonds present in the following compounds:

	Li	Be	B	C	N	O	F
F	ionic	ionic	ionic	P.C	P.C	P.C	N.PC

	Na	Mg	Al	Si	P	S	Cl
Cl	ionic	ionic	P.C	P.C	P.C	P.C	N.PC

	K	Ca	Ga	Ge	As	Se	Br
Br	ionic	ionic	P.C	P.C	P.C	PC	N.PC

Does every metal & non-metal combination result in an ionic bond? Explain.
NO!! for instance Gallium (a metal) forms covalent bond with Bromine (a non-metal)