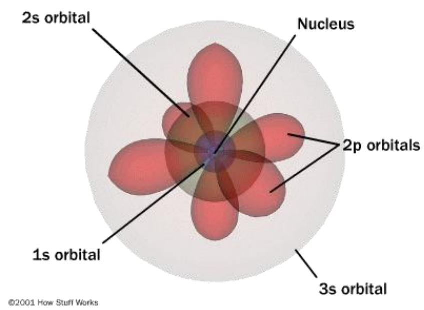
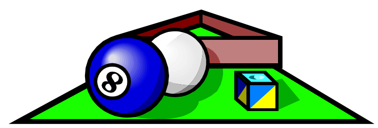
Bonding



A matter of geometry

atoms only contact outer regions

Octet Rule



Eight valence electrons, ns^2np^6, is especially stable
Noble gases do not tend to form compounds

To reach stability of the octet:
Atoms lose or gain (transfer) electrons (for ionic compounds)
Atoms share electrons (for molecular or covalent bonded compounds)

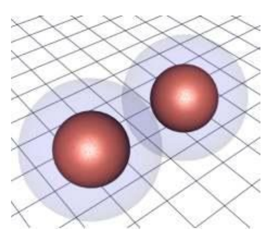
Product: both atoms with "inert configuration"

Chemical Bonds

Attractive force that holds 2 or more atoms together in a unit
Energy of bonded pair less than energy of separated atoms

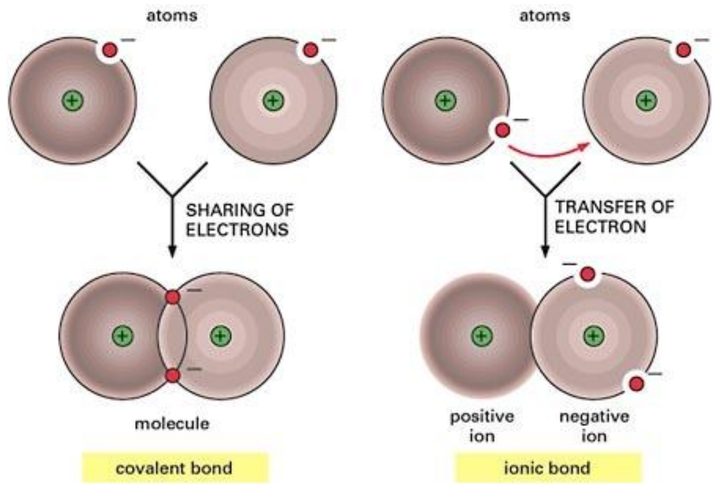
Basic Types

Ionic:
Transfer of electrons from one atom ➔ ions
+/- ions attracted to one another
Strong electrostatic forces hold ions within crystal matrix



Covalent:
Sharing a pair of electrons between two nuclei

Covalent and Ionic



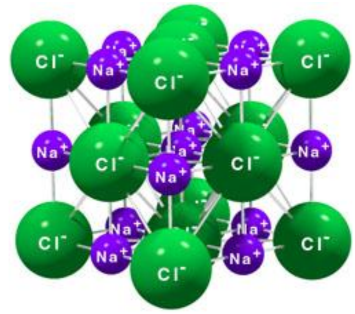
Bond Properties

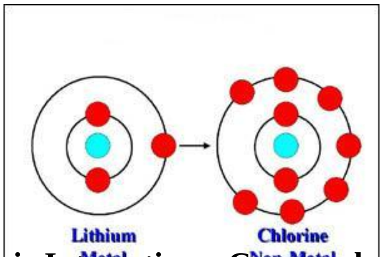
	Ionic	Covalent
Basic Component	**Ions (Charged Matrix)**	**Atoms/Molecules**
Constituents	**Metal + Non-Metal**	**2 Non-Metals**
State (RT)	**Solid**	**Solid, Liquid, Gas**
Melting Point	**Very High (> 200 ^{o}C)**	**Lower (< 200 ^{o}C)**
Odor	**None**	**May Be Present**
Flammability	**No**	**Can Be**
Conductivity	**Solids: Poor Melted: Good Aqueous: Good**	**Solids: Poor Melted: Poor Aqueous: Poor**

In general covalent molecules are not electrical conductors, but some exceptions (acids) do occur

Ionic Bonding

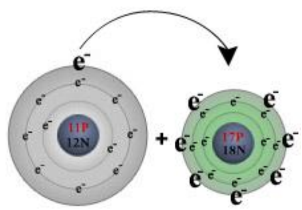
Ionic = separation of charge
Not a single entity between individual atoms …
Strong electrostatic forces hold ions within crystal matrix

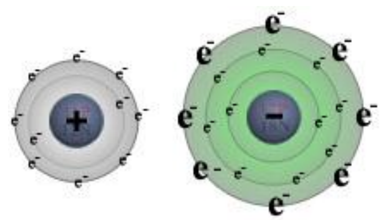




Ionic Interactions: Commonly, Metal Cation & Non-Metal Anion

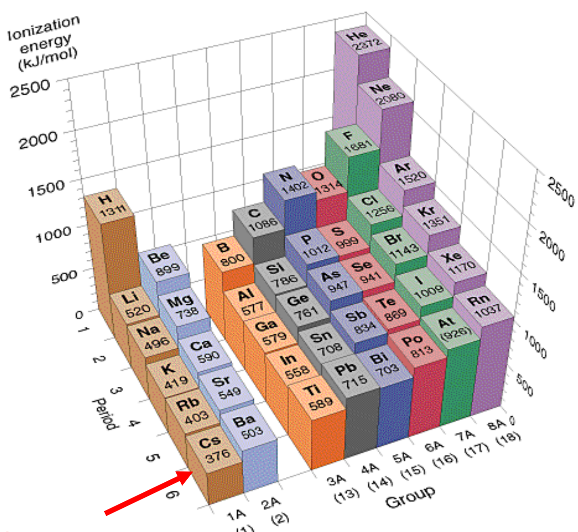
Transfer of electrons from one atom to another to form ions





Both atoms have inert (filled outer shells) configuration
Cation smaller than neutral atom
Anion larger than neutral atom

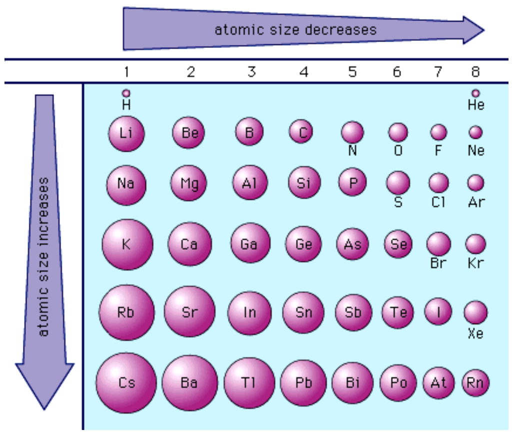
Ionization Energy = Amount of energy required to REMOVE electron



Most likely to form cation

Atom Size

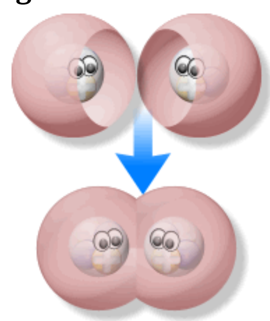
Lowest ionization energyè ➔ largest distance from nucleus



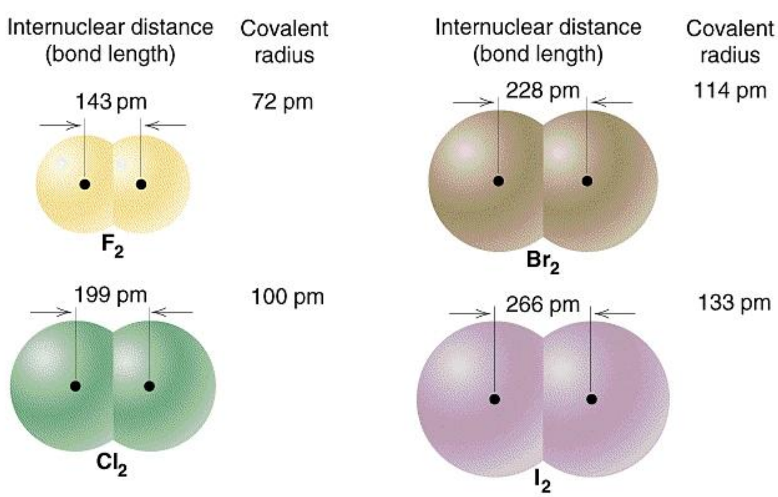
Covalent Bonding

Covalent = Sharing

Electron density shared between atoms

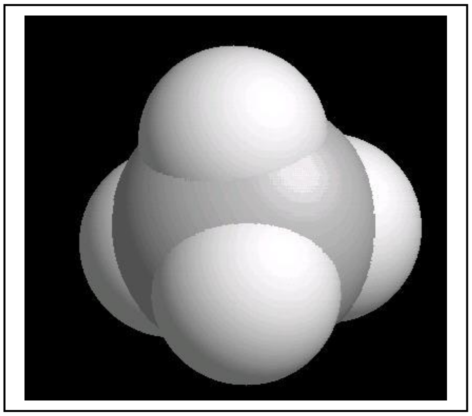


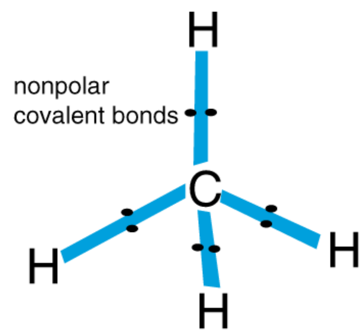
Nonpolar Covalent: equal sharing of e⁻



Atomic Radius Influences Bond Length (Strength)

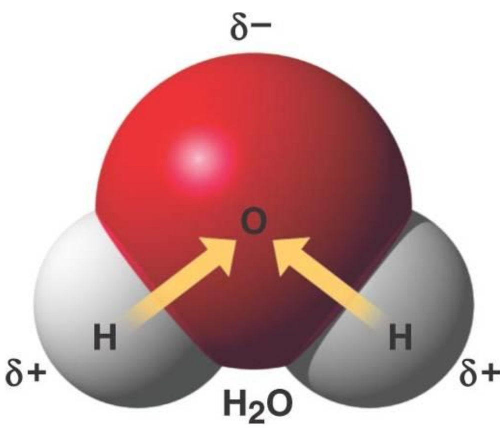
Covalent Bonding in Methane (CH_4)

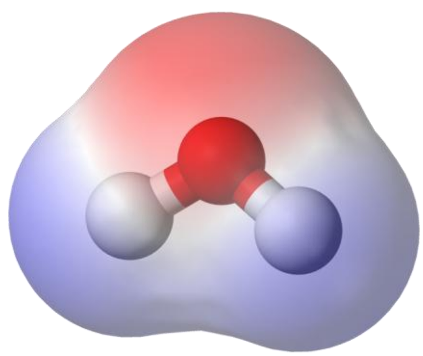




Carbon & Hydrogen ~ Same Electronegativity
Equal Electron Sharing ➔ Non-Polar Covalent Bond

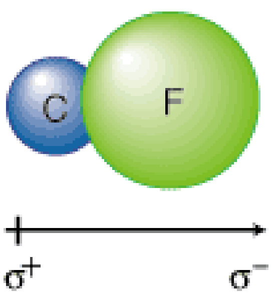
Polar Covalent: unequal sharing of e⁻





Oxygen More Electronegative than Hydrogen
Unequal Electron Sharing ➔ Polar Covalent Bond

Dipole



Result of non-uniform distribution of electrons (charges):

Arrow ➔ drawn with arrowhead at most negative
Direction reflects relative direction of charge separation
(Result of orbital geometry)

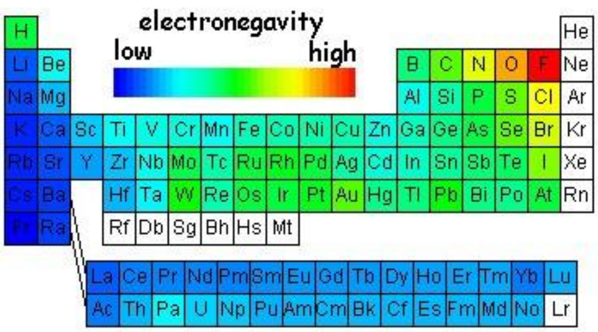
Electronegativity

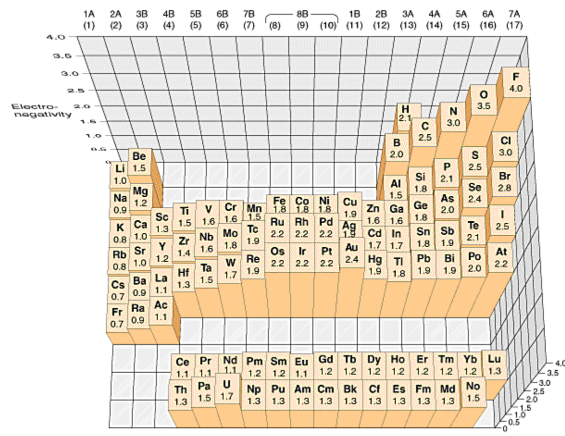
Measure of
ability to acquire electrons
strength by which atoms attract bonded electron pair

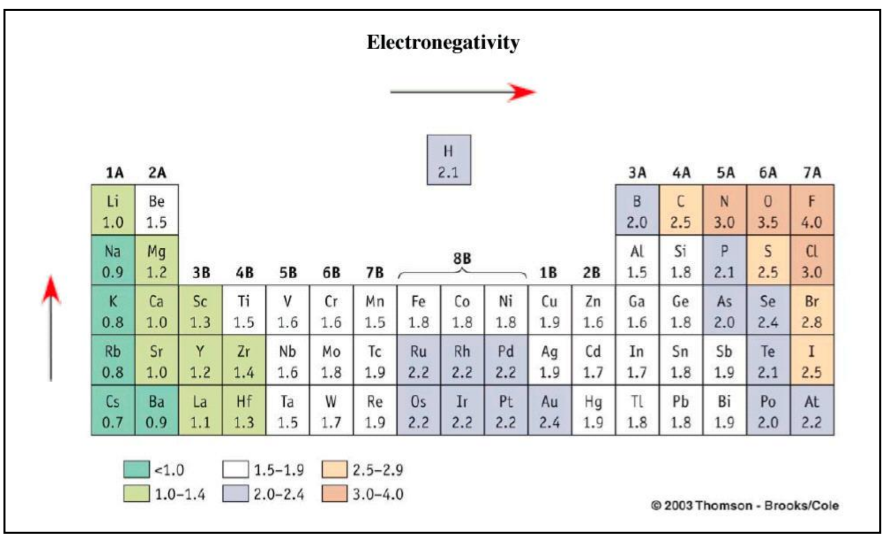
High Electronegativity ➔ easiest to add electrons to outer shell

Measure of ability to acquire electrons

Most electronegative ➔ negative end of dipole







Electronegativity Differences

Δ ≤ 0.4 ➔ non-polar covalent
Δ 0.4 - 1.9 ➔ polar covalent
Δ > 1.9 ➔ ionic
Δ = difference in electronegativity of the bonded atoms

Use Table of Electronegativities to determine bonds type

H–F	Cl–F
F = 4.0	F = 4.0
H = 2.1	Cl = 3.0
1.9 Polar-Covalent	1.0 Polar-Covalent

Na–F	Ca–F
F = 4.0	F = 4.0
Na = 0.9	Ca = 0.7
3.1 Ionic	3.3 Ionic

Indicate which is the more polar bond
Indicate the polarity of the dipole

C–O or Si–O H–O or H–S H–S or H–I H–P or H–S

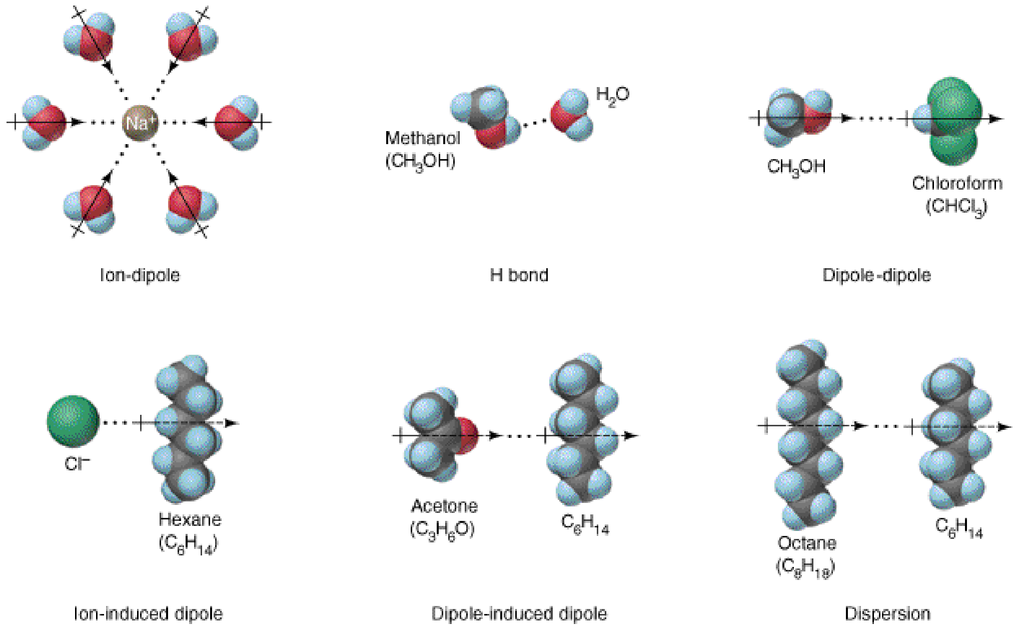
> Electronegativity difference, > polarity
Most electronegative atom ➔ negative end of dipole

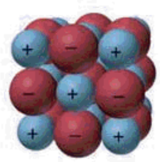
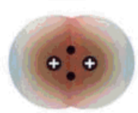
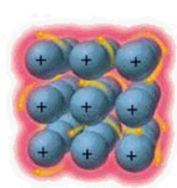
C–O or Si–O	H–O or H–S	H–S or H–I	H–P or H–S
C = 2.5	H = 2.1	H = 2.1	H = 2.1
O = 3.5	O = 3.5	S = 2.5	P = 2.1
Si = 1.8	S = 2.5	I = 2.5	S = 2.5
Δ CO = 1.0	Δ HO = 1.4	Δ HS = 0.4	Δ HP = 0.0
Δ SiO = 1.7	Δ HS = 0.4	Δ HI = 0.4	Δ HS = 0.4
SiO more polar	OH more polar	Same polarity	HS more polar
O is negative	O & S negative	S & I negative	S is negative

LPT

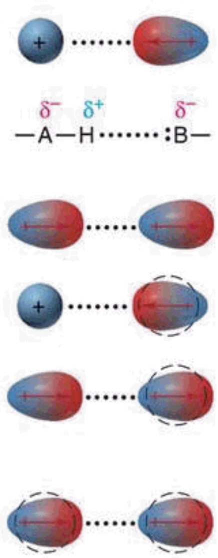
Inter-molecular Forces

Interactions Between Molecules



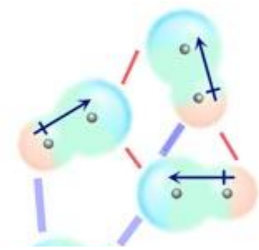
Force	Model	Basis of Attraction	Energy (kJ/mol)	Example
Bonding				
Ionic		Cation–anion	400–4000	NaCl
Covalent		Nuclei–shared e^- pair	150–1100	H—H
Metallic		Cations–delocalized electrons	75–1000	Fe

Nonbonding (Intermolecular)

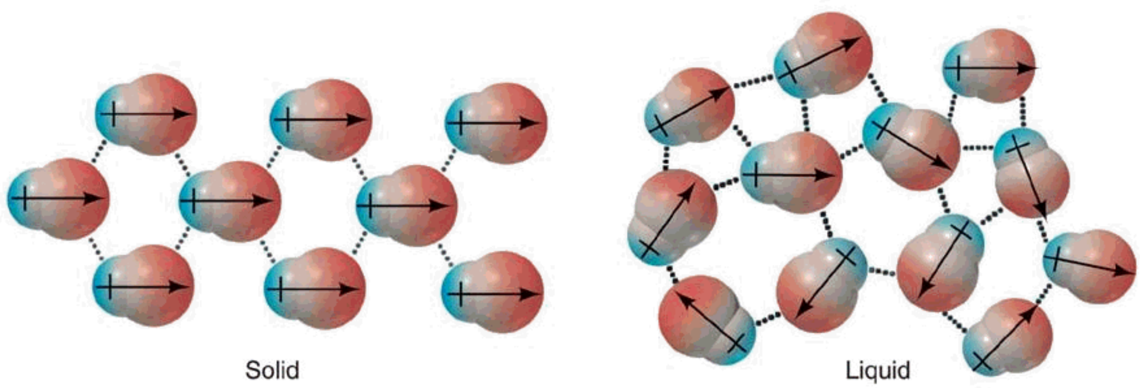


Ion-dipole	Ion charge–dipole charge	40–600	$Na^+\cdots O$ (with two H)
H bond	Polar bond to H–dipole charge (high EN of N, O, F)	10–40	:Ö—H····:Ö—H (H under each O)
Dipole-dipole	Dipole charges	5–25	I—Cl····I—Cl
Ion–induced dipole	Ion charge–polarizable e^- cloud	3–15	$Fe^{2+}\cdots O_2$
Dipole–induced dipole	Dipole charge–polarizable e^- cloud	2–10	H—Cl····Cl—Cl
Dispersion (London)	Polarizable e^- clouds	0.05–40	F—F····F—F

Dipole-Dipole Interactions



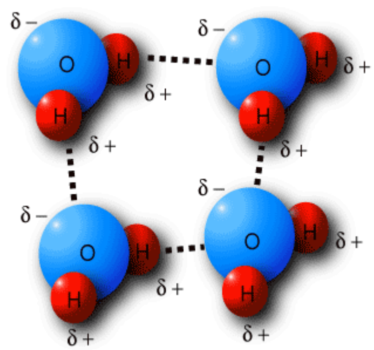
Molecules with permanent Dipole
Dipoles align … cohesive attraction



Alters physical properties - Typically increases melting/boiling point energy needed to overcome multiple interactions

example: bp of CH_3F >> CH_4

Hydrogen Bonds



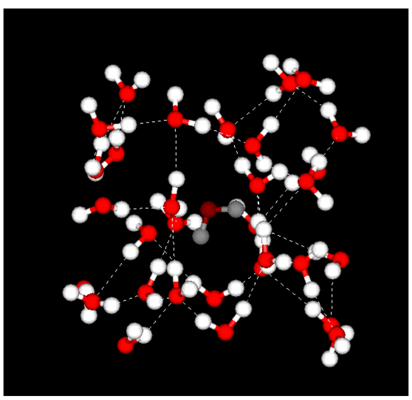
A strong dipole-dipole interaction

Low Energy (weak)
Individually weak,
But, significant in quantity

Pairs
H & Electronegative Atom
(especially N & O; F)

Very important
In biological systems

Hydrogen Bonds-Water

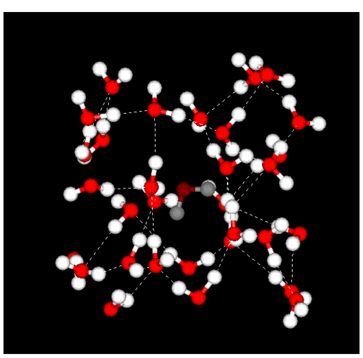


Boiling Point (^oC)

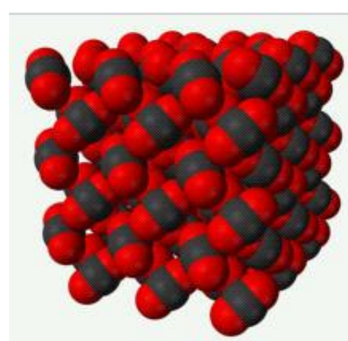
H_2O = 100
H_2S = - 60.7
H_2Se = - 42
H_2Te = - 2
H_2Po = 37

Energy needed to overcome H-bonded network is considerable

Water & Dry Ice



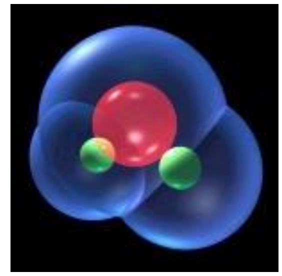
Water Ice
H-Bonded Network
Melts 0 ^oC



"Dry Ice" (CO_2)
No-Bonding Network
Sublimes (-78 ^oC)

London Dispersion Forces (Van der Waals's)

Weakest interaction
(inversely proportional to r^6 between atoms)
Temporary; when adjacent atom electrons create dipole
All atoms; more prevalent in heavier/larger
Stronger when atoms easily polarized
At 3 Angstrom, ~ 1 kcal/mole

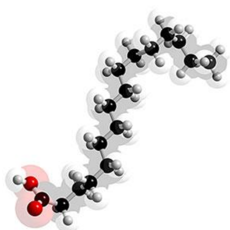


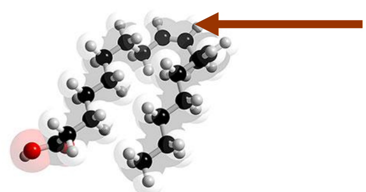
Van der Waal Radii
Volume of space where significant

Biologically (especially in lipids) significant

London Dispersion Forces in Fats

"Saturated" Fats are mostly linear molecules





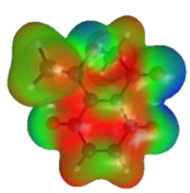
Site of Unsaturation
(a double bond)
Puts a "kink" in the
otherwise, linear chain

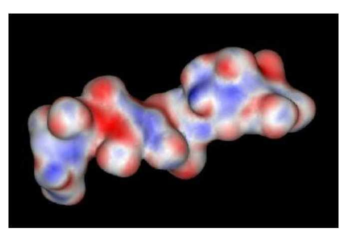
"Unsaturated" Fats are bent molecules

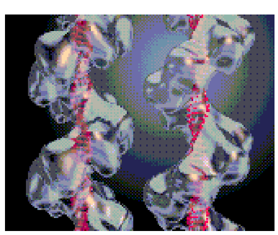
Saturated fats - linear molecules bundle together
This takes a lot of energy to undo (melt) ➔ solids

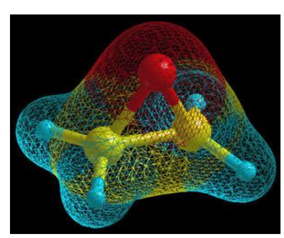
Unsaturated fats – "kinks" prevent bundling ➔ liquids

Van der Waal Radii Approximates Molecular Influence





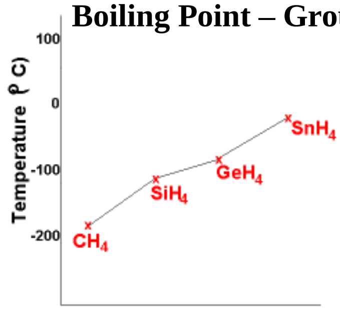




Physical Properties & Intermolecular Forces

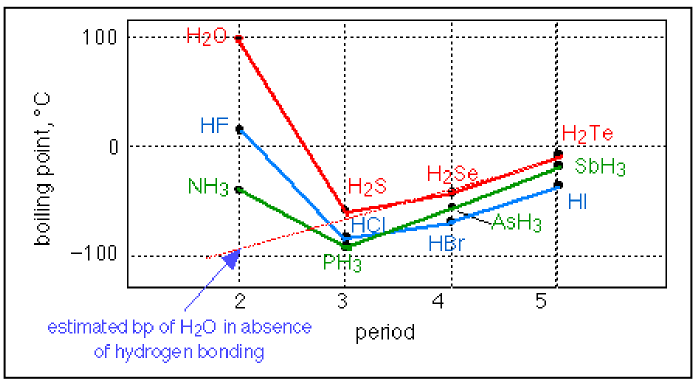
Control Physical properties (State of Matter)
Melting & Boiling points
Result of progressive elimination of intermolecular forces
> intermolecular forces, > energy required to melt/boil

Boiling Point – Group 4 Hydrides



If only dispersion forces present (no H-bonding), the more mass present (higher Z), > boiling point

Boiling Point – Some H containing Compounds



If H-bonding present, H bonded higher
&
Well off the curve

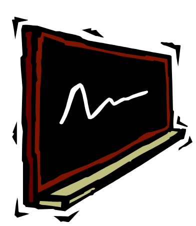
Intermolecular Forces Control Physical properties (State of Matter)
Melting & Boiling points
Result of progressive elimination of intermolecular forces
> intermolecular forces, > energy required to melt/boil

Solubility and Intermolecular Forces

"like Dissolves Like"
Polar solutes dissolve in water (polar solvents)
Non-polar solutes dissolve in non-polar solvents

Solvent	Chemical Formula	Boiling point	Dielectric constant	Density
Non-Polar Solvents				
Hexane	$CH_3-CH_2-CH_2-CH_2-CH_2-CH_3$	69 °C	2.0	0.655 g/ml
Benzene	C_6H_6	80 °C	2.3	0.879 g/ml
Toluene	$C_6H_5-CH_3$	111 °C	2.4	0.867 g/ml
Diethyl ether	$CH_3CH_2-O-CH_2-CH_3$	35 °C	4.3	0.713 g/ml
Chloroform	$CHCl_3$	61 °C	4.8	**1.498 g/ml**
Ethyl acetate	$CH_3-C(=O)-O-CH_2-CH_3$	77 °C	6.0	0.894 g/ml
Polar Aprotic Solvents				
1,4-Dioxane	$/-CH_2-CH_2-O-CH_2-CH_2-O-\backslash$	101 °C	2.3	**1.033 g/ml**
Tetrahydrofuran (THF)	$/-CH_2-CH_2-O-CH_2-CH_2-\backslash$	66 °C	7.5	0.886 g/ml
Dichloromethane (DCM)	CH_2Cl_2	40 °C	9.1	**1.326 g/ml**
Acetone	$CH_3-C(=O)-CH_3$	56 °C	21	0.786 g/ml
Acetonitrile (MeCN)	$CH_3-C\equiv N$	82 °C	37	0.786 g/ml
Dimethylformamide (DMF)	$H-C(=O)N(CH_3)_2$	153 °C	38	0.944 g/ml
Dimethyl sulfoxide (DMSO)	$CH_3-S(=O)-CH_3$	189 °C	47	**1.092 g/ml**
Polar Protic Solvents				
Acetic acid	$CH_3-C(=O)OH$	118 °C	6.2	**1.049 g/ml**
n-Butanol	$CH_3-CH_2-CH_2-CH_2-OH$	118 °C	18	0.810 g/ml
Isopropanol (IPA)	$CH_3-CH(-OH)-CH_3$	82 °C	18	0.785 g/ml
n-Propanol	$CH_3-CH_2-CH_2-OH$	97 °C	20	0.803 g/ml
Ethanol	CH_3-CH_2-OH	79 °C	24	0.789 g/ml
Methanol	CH_3-OH	65 °C	33	0.791 g/ml
Formic acid	$H-C(=O)OH$	100 °C	58	**1.21 g/ml**
Water	$H-O-H$	100 °C	80	1.000 g/ml

Assignment



Blackboard Unit 11 Practice Quiz

Optional Quiz on Electronegativity (Unit 11)
(Covers material that will be on the Unit 11 exam, but is not covered in Practice Quiz 11)