Chemistry is both physical and chemical - physical attractive forces

1. Understanding physical structure of substances is very important in understanding physical state, physical behavior & physical changes.
2. Physical state depends on the physical structure of the substance. Whether a substance is either a molecule (a discrete unit) like water, or a nonmolecule (a 3D lattice of ions) like sodium chloride depends upon physical structure.
3. Physical changes are concerned with energy and states of matter. A physical change does not produce a new substance. Changes in physical state—going from solid to liquid, liquid to gas states (melting, boiling, vaporization, sublimation)—are physical changes. Examples of physical changes include bending wire, melting an ice cube, and evaporating a liquid into the gasous state, or dry ice sublimes.
4. Why do substances physically behave the way they do under varying temperature conditions? In this presentation, we will try to gain a firmer grasp as to the physical structure of matter and physical states observed at room temperature (25°C).
5. Since you are mostly likely reading this while sitting comfortably, perhaps your in living room or study, we will consider the temperature around us, room temperature @ 25°C, to be a good reference point in making comparisons between the solid, liquid and gaseous states of substances when we been to evaluate physical structure.

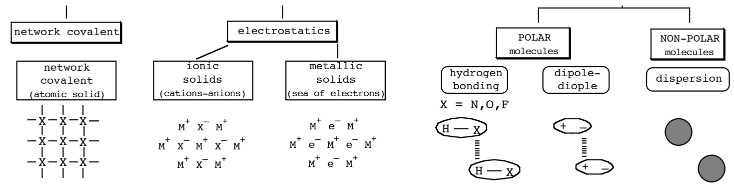
physical state (solid, liquid, gas) at room temperature 25°C.

The concept map on the next slide is a helpful guide in identifying and understanding substance type as being non-molecular and molecular, and shows how generic physical representations can be used to describe how physical structure can influence physical properties like Bp & Mp and substance behavior

Study the "Substance Chart" given in your Supplemental packet, p 99

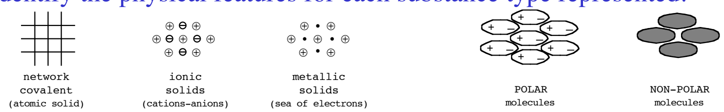
A. Begin by ICAO'ing on each substance to determine whether it is a(n): ionic, covalent, acid, organic, –, ⊕, metallic or atomic solid

B. Next, using this substance chart, determine if a substance is nonmolecular or molecular, and then:



C. Identify the attractive forces between each substance type represented.

D. Identify the physical features for each substance type represented.



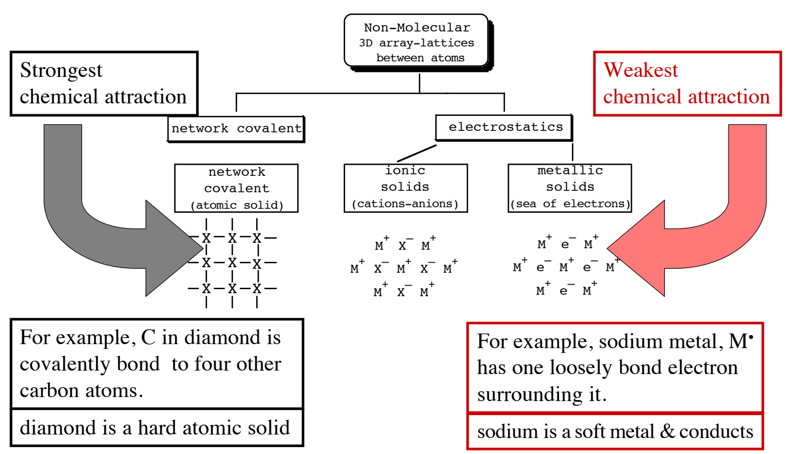
E. State at least four physical properties for each crystalline solid type, and

F. Give examples (name and formula) for each type of solid.

Non-Molecular Substances

• **<u>extended arrangements of repeating units</u>**

• **every connecting atom is closely associated with neighboring atoms**



Non-Molecular Substances

• **extended arrangements of repeating units**

• **every connecting atom is closely associated with neighboring atoms**

- Examples of each type of non-molecular solid
- A. Network Covalent Substances as solids
  - (- X - X - X - X - X - X - X - X -) diamond, graphite, sand SiO_2
- B. Ionic Salts as solids
  - (M^+ X^- M^+ X^- M^+ X^- M^+ X^-) NaCl, $MgSO_4$, $BaSO_4$
- C. Metallic solids
  - (M^+ e^- M^+ e^- M^+ e^- M^+ e^-) Na, Fe, Hg, alloys, steel

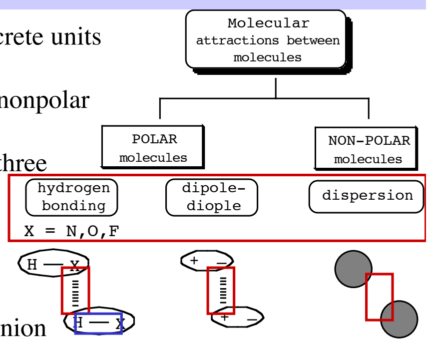
Molecular Compounds

• **individual molecules behaving like independently of each other**

A. Molecules are individual discrete units
For example, H_2O, HCl, CH_4

B. Molecules are either polar or nonpolar

C. Between molecules, there are three types of physical attractions

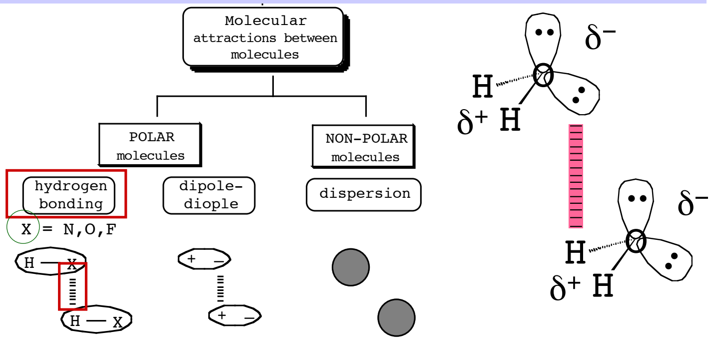


D. Physical attractions identified by "|||||||||" a hash mark not a covalent bond "_____" chemical union

E. Learn the criteria in order to identify type of physical attraction.

F. hydrogen bonding (**strongest**) > dipole-dipole > dispersion (**weakest**)

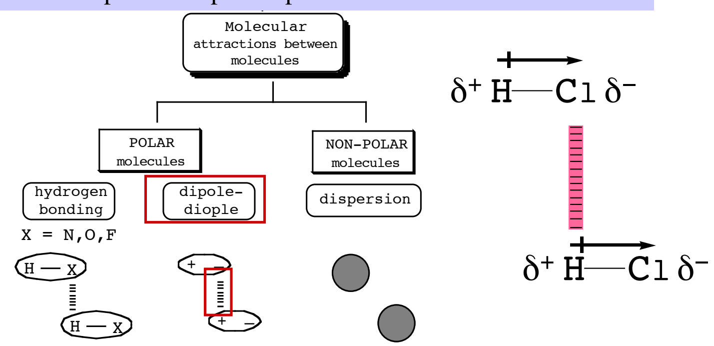
An example of a hydrogen bonding interaction force of attraction



Criteria for hydrogen bonding

1. Small electronegative atom, X, in the structure of the molecule.
2. H bonded to X where X = N, O, F ; H–N, H–O, H–F
3. There is an available electron pair attached to X:

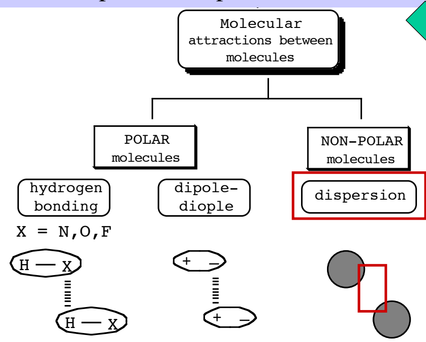
An example of a dipole-dipole interaction force of attraction

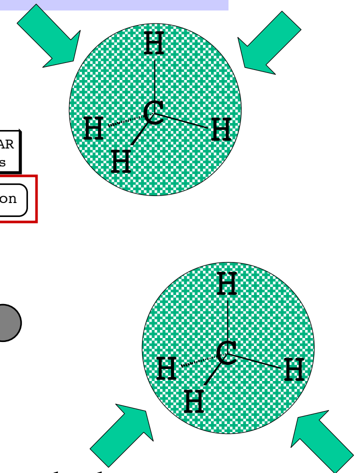


Criteria for dipole-dipole bonding

1. The molecule is polar.
2. Molecule has a net dipole ⟶
2. Molecule does not contain a H–N, H–O, H–F bond.

An example of a dispersion interaction force of attraction

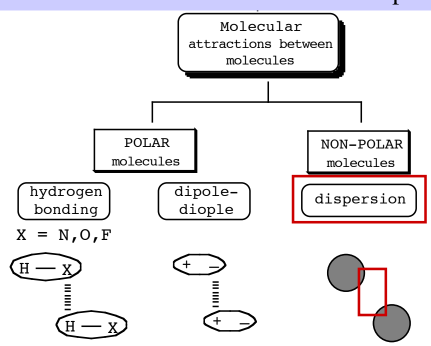


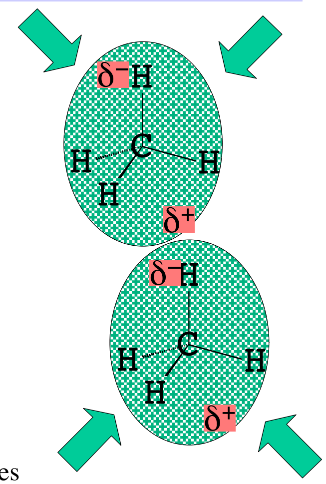


Criteria for dispersion bonding

1. The molecule is nonpolar
2. No net dipole
3. No major attractive force between molecules
   Until molecules are pushed close together

ATTRACTIVE force if molecules are pushed together under pressure

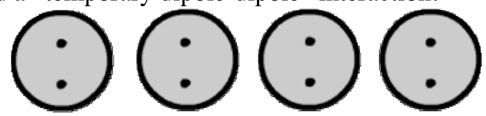




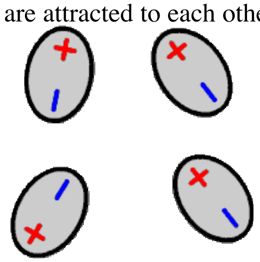
Criteria for dispersion bonding

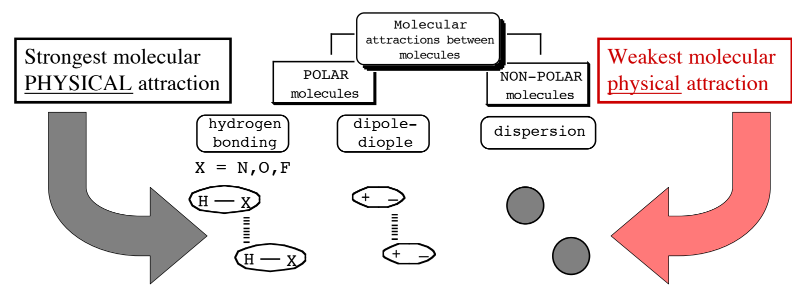
1. The molecule is nonpolar
2. No net dipole
3. No attractive force between molecules
4. Greater ATTRACTIVE force if molecules are pushed together

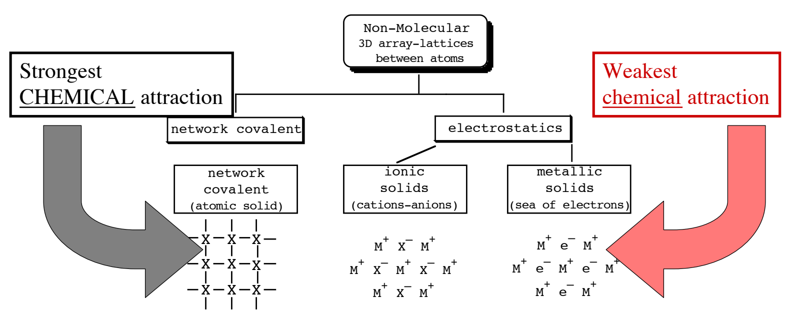
The molecule shown, , is nonpolar and shows dispersion forces. As shown in the animation, if pushed together with other molecules o itself, a temporary dipole will occur between nonpolar molecules and is called a "temporary dipole-dipole" interaction.



The molecule shown, is polar and shows has a permanent dipole. The polar molecules are attracted to each other by dipole-dipole forces.







Non-Molecular (extend arrangements) versus Molecular (discrete units)

•Looking for clues whether a substance is non-molecular or molecular:

A. First ICAO to get a broad general sense of substance type.

B. Non-Molecular Substances are:

network covalent / ionic salt / metallic

C. Molecular Compounds exist as discrete units as molecules:

polar molecules / nonpolar molecules

Knowing a substance's structure & physical properties and behavior at room temperature, 25°C, can also be used as a gauge to determine whether a substance is non-molecular or molecular.

Additional questions we can ask about every substance are:

A. What do we know about its physical state (solid, liquid, gas) at 25°C?

B. Does it have a high melting point or a low melting point?

C. Does it have a high boiling point or a melting boiling point?

D. Is the substance as a solid physically hard, brittle, malleable, ductile?

E. Is the substance conductor or a non-conductor?

F. What is its physical solubility of the substance in varying solvents?

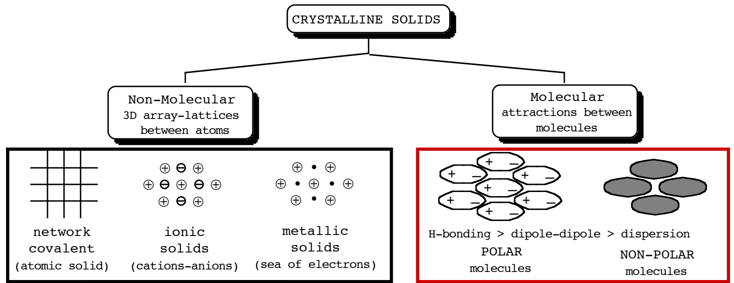
Chemical & physical attractive forces - Crystalline Solids

1. The strength of chemical & physical attractive forces can be gauged by further evaluating the physical melting and boiling point of a substances.
2. Melting Point. The melting point of a substance is the conversion of a solid to a liquid at a given pressure. The stronger the attractive forces between particles in a substance, the higher the melting point of the solid. Generally speaking, if the substance is solid at room temperature, its melting point is higher that 25°C otherwise it would melt into a liquid having a temperature of 25°C. For example, solid water overtime sitting at 25°C will melt from the solid state to the liquid state and the final temperature of the liquid water will be 25°C.
3. Boiling Point. The boiling point of a liquid in a very general sense is the conversion of a liquid to a gaseous vapor at a given pressure. When a liquid boils, the pressure of the gaseous vapor equals the external pressure (atmospheric).
4. Normal boiling point. The normal boiling point of a substance in the liquid state is the conversion of the liquid to a gas at atmospheric pressure at sea-level, or at 1 atm (one-atmosphere of pressure). When a liquid boils, the pressure of the gaseous vapor pressure, VP, will equal one-atmosphere, VP = 1 atm.
5. The next slide shows how the crystalline solid physical state may generically appear for both non-molecular and molecular solids.

Crystalline Solids

Understanding how subtances stick around as solids:

- chemical union versus physical attractions
  for non-molecules and molecules
- using Mp and Bp as a gauge of chemical and physical strength



Chemical Unions

Non-Molecules having
<u>high</u> melting points, Mp and
<u>high</u> boiling points, Bp

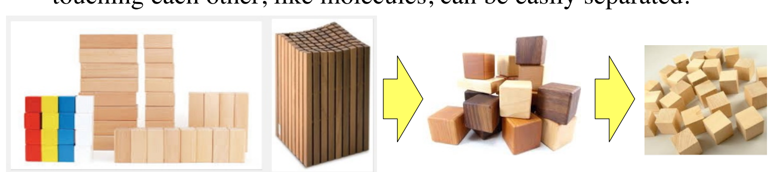
Physical Attractions

Molecules having
<u>low</u> melting points, Mp and
<u>low</u> boiling points, Bp

Like these fences, 2D and 3D lattices allow for

1. Networking, being bound together allows for:
    - Improved strength and support
    - Rigid solid structure

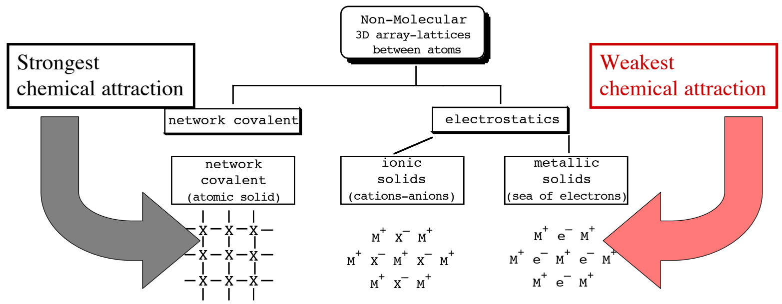
Unlike lattices which are networked, these blocks are physically just touching each other, like molecules, can be easily separated.



Non-Molecular Substances

• **<u>extended arrangements of repeating units</u>**

• **every connecting atom is closely associated with neighboring atoms**



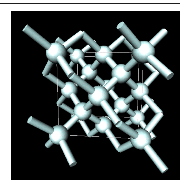
For example, C in diamond is covalently bond to four other carbon atoms.

diamond is a hard atomic solid

For example, sodium metal, M• has one loosely bond electron surrounding it.

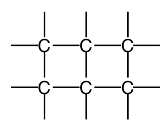
sodium is a soft metal & conducts

Why are diamonds (allotrope of pure carbon) a girls best friend?
No pressure, carbon atoms in diamond are designed to stick around!
Every carbon atom in diamond is tetrahedral in geometry.



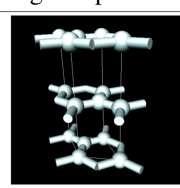
Appears Transparent

- no mobile electrons in the single C—C bonds



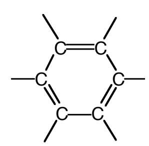
Not planar, each is C tetrahedral

Why is graphite (allotrope of pure carbon) used as a lubricant?
High boiling graphite sheets are designed to stick and slide around.
A trigonal planar in geometry forms flat planes or sheets that slide



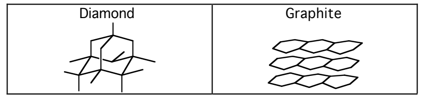
Appears Black

- mobile electrons in the double C=C bonds

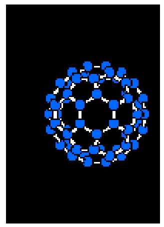


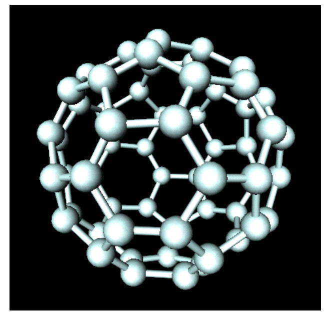
Planar, each C is trigonal planar

Allotropes of Carbon

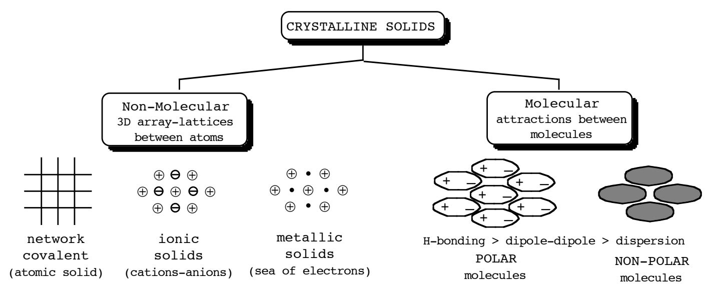


C_{60} - Nobel Prize in Chemistry 1996 to
Professor Robert F. Curl, Jr., Rice University, Houston, USA,
Professor Sir Harold W. Kroto, University of Sussex, Brighton, U.K., and
Professor Richard E. Smalley, Rice University, Houston, USA,



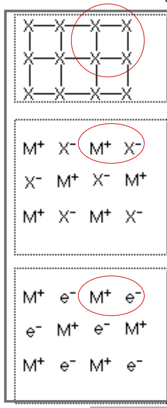


Why are non-molecular substances solids are room temperature?
Why is diamond the hardest substance known?
Why do metals conduct electricity and heat?
Why are ionic salts brittle?



Look closely at these generic structures.
These generic structures hold the answers to above questions.
The answers to these questions are shown on the next slide.

II. **Nonmolecular** Crystalline Solids — Know these physical properties for each substance

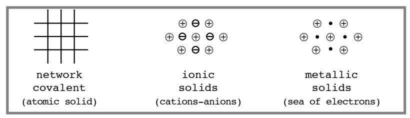


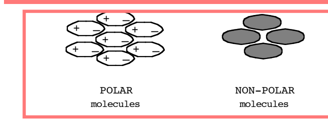
1. A network of atoms that don't separate under high temperature thus high melting
2. Tightly bound electrons don't move thus don't conduct
3. Bonds are fixed and hard to move thus the substance is physically hard

1. Ions don't separate under high temperature thus have high melting points.
2. Ions hold onto their electrons to maintain noble gas configurations thus salts as solids don't conduct.
3. When melted into a liquid, ions can move an carry electrical charge and conduct.
4. Ions lattices can be forced to slide apart thus ion salts are physically brittle
5. Some ionic salts dissolve in polar solvents like water

1. M^+e^- easily move at high temperatures thus metals have variable melting points.
2. M^+e^- electrons easily travel between M^+e^-'s, thus metals can:
   - electrically conduct.
   - thermally conduct
   - ductile (easily drawn into wire)
   - malleable (easily hammered into sheets)
3. Metal are insoluble in water or other common solvents

Non-molecular CRYSTALLINE SOLIDS molecular will be discussed next

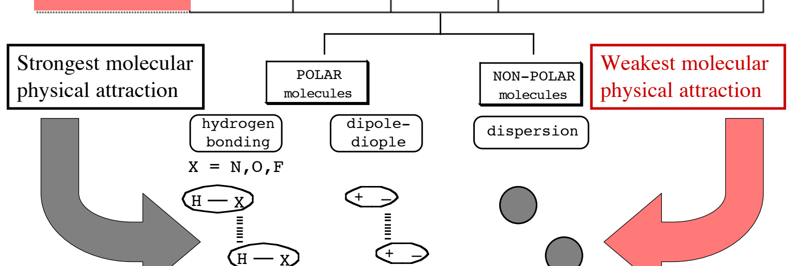




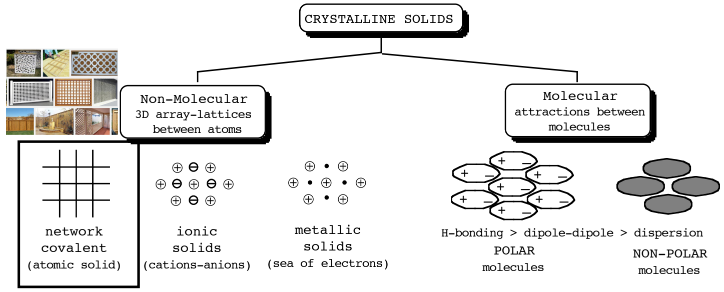
I. **Molecular** Compounds (variable physical state)

A. Virtually all substances that are gases or liquids at 25 °C and 1 atm are molecular.

	Structural Particles	Forces within particles	Forces between particles	Physical Properties
X—X X—X X—X X—X X—X X—X	molecules			
	a. nonpolar	covalent bond	dispersion	LOW m.p. & b.p.; HIGH vapor pressure often gas or liquids at room temp. insoluble in water soluble in nonpolar organic solvents
molecular discrete units	b. polar		dispersion dipole-dipole H-bonding	similar properties to that of nonpolar but generally higher in m.p. & b.p. more likely to be water-soluble

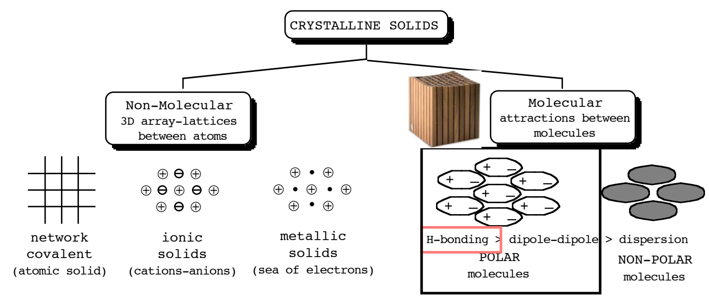


In general, the stronger the physical attraction:
The higher the melting & boiling point for the substance

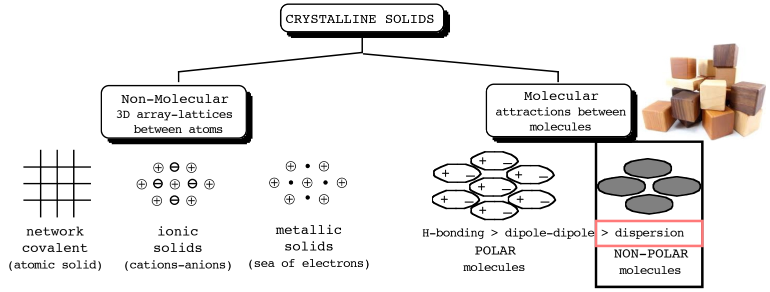


Why are diamonds (allotrope of pure carbon) a girls best friend?
No pressure, carbon atoms in diamond are designed to stick around!
Every carbon atom in diamond is tetrahedral in geometry.
Diamond as network covalent solid has a Mp = 3500°C, Bp = 6400°C

Why is graphite (allotrope of pure carbon) used as a lubricant?
Every carbon atom in graphite is trigonal planar in geometry.
Graphite as network covalent solid has a Mp = 3000°C, Bp = 6000°C



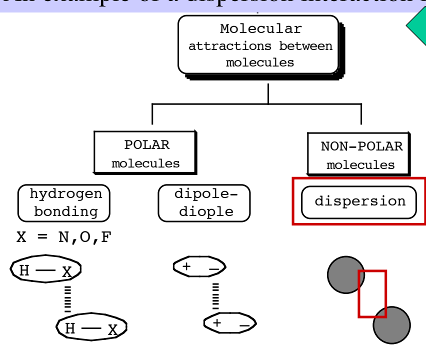
Why is solid water low melting H_2O? Mp = 0°C, Bp = 100°C
Unlike carbon in diamond, there are NO chemical unions between water molecules, only physical attractions. Water molecules are NOT chemically networked like carbon atoms in diamond. Water is a polar molecule physically attracted to other water molecules by the physical force of hydrogen bonding in the solid state. It take less thermal kinetic energy from heating to physically separate water molecules than atoms of carbon chemically bonded in diamond.

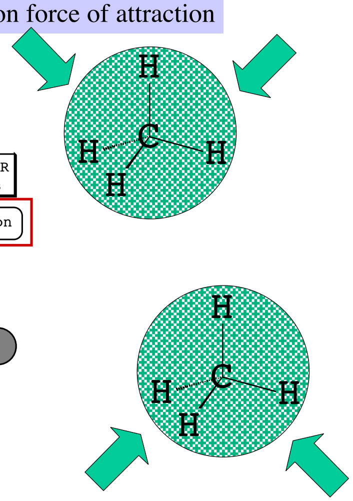


Why is butane a gas at room temperature and one atmosphere?

Butane, C_4H_{10}, is a nonpolar hydrocarbon showing only weak dispersion forces. Unlike water, butane is a nonpolar molecule having only the weakest of physical attractive forces of dispersion between molecules. Nonpolar molecules showing dispersive forces don't want to stick to each other, they want to disperse. The amount of thermal kinetic energy need to disperse is very low, thus butane is low melting, and low boiling. Mp = -140°C, Bp = -1°C

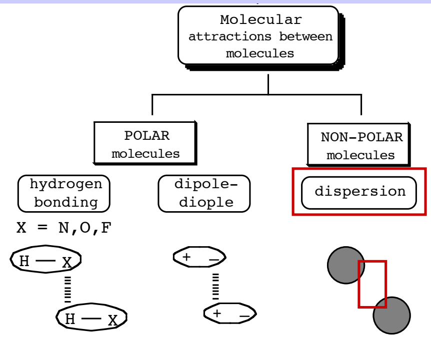
An example of a dispersion interaction force of attraction

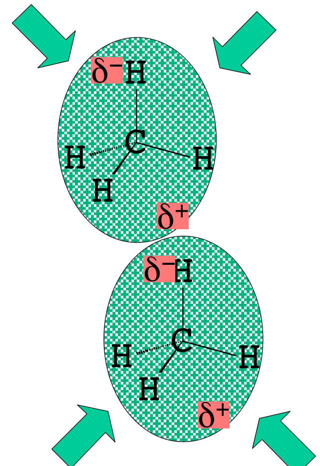




LNG - Liquidfied Natural Gas

ATTRACTIVE force if molecules are pushed together under pressure





LNG - Liquidfied Natural Gas

1. The molecule is nonpolar
2. No net dipole
3. No attractive force between molecules
4. Greater ATTRACTIVE force if molecules are pushed together under pressure while being cooled to afford a temporary dipole-dipole attraction

Homework Problems

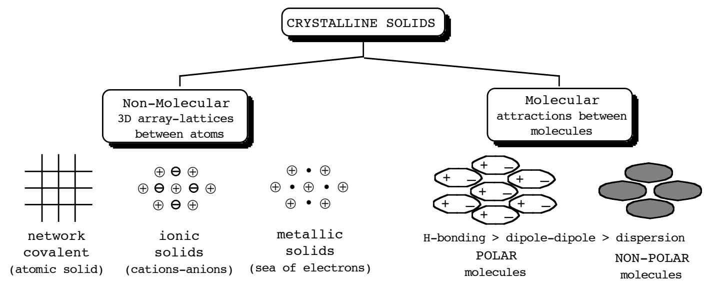
Identify the general classification (molecular or nonmolecular) for each substance then identify the predominant intermolecular force. (Hint: Before answer use what your already know, call it expert knowledge, about the physical state of each substance.

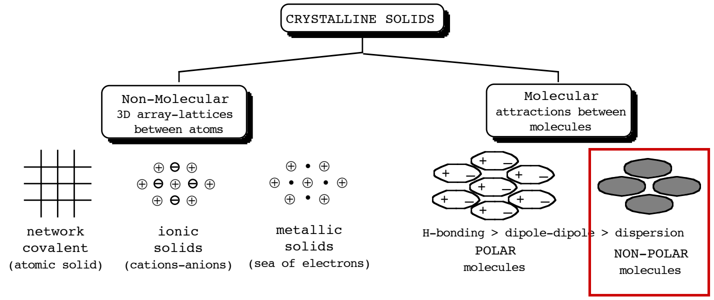
diamond C, network covalent non-molecular	potassium bromide KBr, ionic salt non-molecular	tungsten wire W, metallic bond non-molecular
dihydrogen sulfide gas H_2S, polar, dipole-dipole molecular	quartz (sand) SiO_2, network covalent non-molecular	glass SiO_2, network covalent non-molecular
ethyl alcohol C_2H_5OH, polar, hydrogen bonding molecular	helium gas He, non-polar dispersion molecular	graphite C, network covalent non-molecular
ammonium chloride NH_4Cl, ionic salt non-molecular	bromine liquid Br_2, non-polar dispersion molecular	iodine solid I_2, network covalent molecular

1. Which substances are molecular?
2. Which substances are nonmolecular?
3. Which substance is highest melting?
4. Which substances can conduct electricity as solids?
5. Which substances are good insulators as solids?
6. Which substances are brittle?
7. Which substances are soluble in water?

Some additional thought questions:

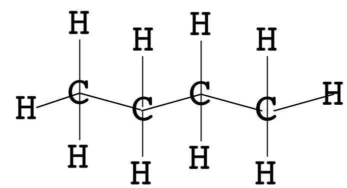
Why are molecules of water a solid at 0°C but a liquid at 25°C?
Why are molecules of carbon dioxide a solid at -78°C but gas at 25°C?
Why are molecules like butane placed under high pressure a liquid?
Why are molecules like butane under low pressure a gas?

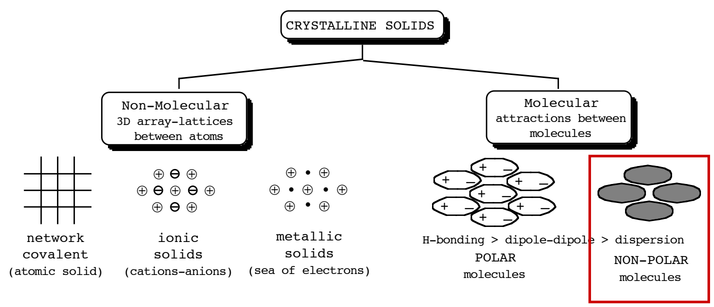




Why is pressured butane in a cigarette lighter a liquid at 25°C?
Why is unpressurized butane a gas at 25°C and 1 atmosphere?
Butane's formula is C_4H_{10}

Butane's structure





In a physical relationship, "cool" headed advice and "pressure" from friends and family may persuade you to <u>stick</u> around.
Just think about the <u>pressurized</u> butane in a butane cigarette lighter.
Pressured butane is a liquid at 25°C

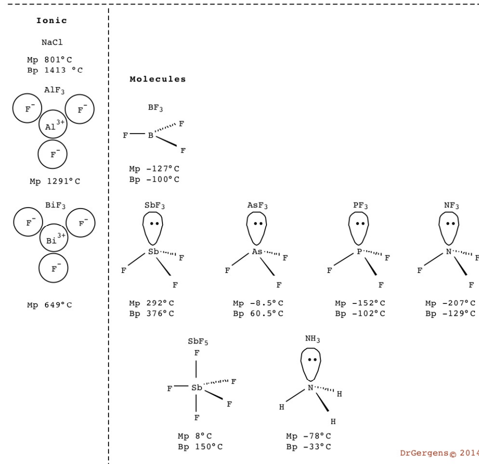
What happens when the pressure and stress on butane is relieved?
Molecules escape, separate and disperse into a gas at 1 atmosphere

What can happen when tempers flare in a heated physical relationship?
You may physically separate for a time. Time wounds all heals.

Name:________________________ E15C

Network Covalent

Allotrops of Carbon — DIAMOND: Mp 3500°C, Bp 6400°C — Graphite: Mp 3000°C, Bp 6000°C



Circle ammonia. Draw another ammonia molecule & show the hydrogen bonding between them.

Due next time we meet

Using the data given on the left:

Circle the substance type which is <u>highest</u> boiling.
network covalent ionic molecular

Circle the substance type which is <u>highest</u> melting.
network covalent ionic molecular

Circle the substance type which is <u>lowest</u> boiling.
network covalent ionic molecular

Circle the substance type which is <u>lowest</u> melting.
network covalent ionic molecular

Circle the <u>highest</u> melting, AlF_3 BF_3, and explain your reasoning.

Match the <u>geometry</u> for each
SbF_3 AsF_3 PF_3 NF_3 BF_3
linear bent pyramidal trigonal planar tetrahedral

Match the predominant physical attractive force observed between molecules of
SbF_3 AsF_3 PF_3 NF_3 BF_3
hydrogen bonding dipole-dipole dispersion

Insert SbF_5 & NH_3 into the bp ranking below:
SbF_3 AsF_3 BF_3 PF_3 NF_3

Explain why NH_3 is <u>higher</u> boiling than NF_3

Match the predominant physical attractive force observed between molecules of
SbF_5 NH_3
hydrogen bonding dipole-dipole dispersion

Circle the substance that is <u>nonpolar</u>
SbF_5 NH_3

Explain why SbF_5 is <u>higher</u> boiling than NH_3

Define allotrope and give examples.

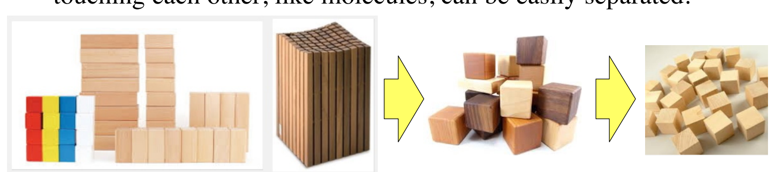
For video help, http://homework.sdmesa.edu/dgergens/chem100/polarity/polar1of1.htm#physical_force (click here)

I. **Molecular** Compounds (variable physical state)

A. Virtually all substances that are gases or liquids at 25 °C and 1 atm are molecular.

	Structural Particles	Forces within particles	Forces between particles	Physical Properties
X—X X—X X—X X—X X—X X—X	molecules a. nonpolar	covalent bond	dispersion	LOW m.p. & b.p.; HIGH vapor pressure often gas or liquids at room temp. insoluble in water soluble in nonpolar organic solvents
	b. polar		dispersion dipole-dipole H-bonding	similar properties to that of nonpolar but generally higher in m.p. & b.p. more likely to be water-soluble

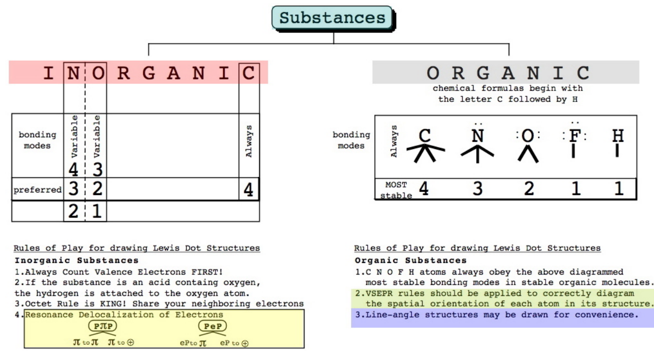
Unlike lattices which are networked, these blocks are physically just touching each other, like molecules, can be easily separated.



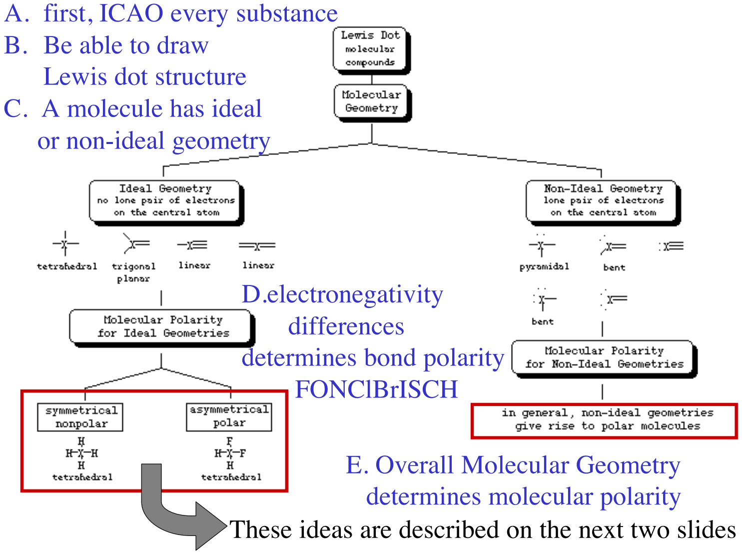
More on Evaluating Molecular Polarity

A. Structure determines a substances physical property
B. Lewis dot structures for substances need to be drawn or accuracy and precision
C. Molecular Polarity (polar versus nonpolar) needs to be determined.
D. Review your NOTES on ICAO'ing and drawing Lewis Dot structures

Begin your Lewis dot structure always by ICAO'ing on each substance to determine whether it is a(n): ionic, covalent, acid, organic, –, ⊕, metallic or atomic solid



A. first, ICAO every substance
B. Be able to draw Lewis dot structure
C. A molecule has ideal or non-ideal geometry



D. electronegativity differences determines bond polarity FONClBrISCH

E. Overall Molecular Geometry determines molecular polarity

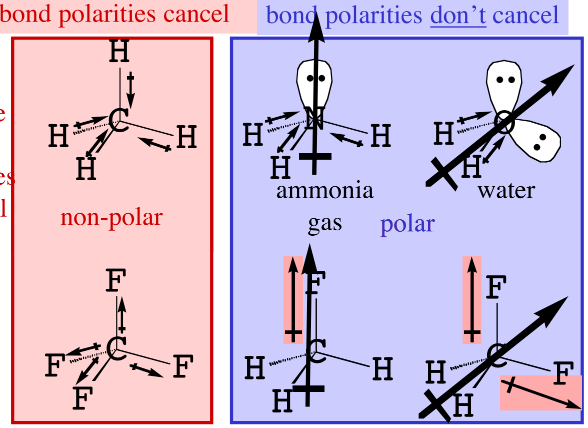
These ideas are described on the next two slides

Symmetric versus Asymmetric

<u>Symmetrical</u> <u>arrangement</u>
of polar bonds
bond polarities cancel

<u>Asymmetrical</u> <u>arrangement</u>
of polar bonds
bond polarities <u>don't</u> cancel

<u>NO</u>
Net
Dipole
Bond
Dipoles
Cancel

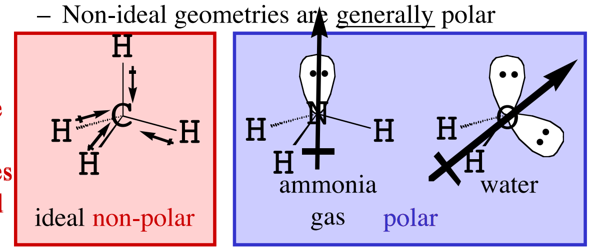


These
Molecules
Have a
<u>Net</u>
<u>Dipole</u>

Molecular Substances (discrete units)

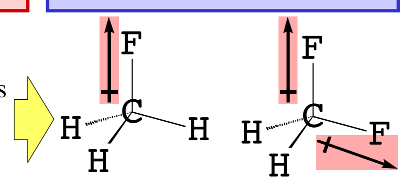
- Molecular Geometry and Bond Polarity
  - Ideal geometries can show <u>variable</u> polarity
  - Non-ideal geometries are <u>generally</u> polar

<u>NO</u>
Net
Dipole
Bond
Dipoles
Cancel



These
Molecules
Have a
<u>Net</u>
<u>Dipole</u>

<u>These</u> ideal geometries
however shown here
are polar

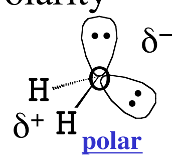


These
Molecules
Have a
<u>Net</u>
<u>Dipole</u>

Molecular Polarity & Physical Solubility

- Determining the polar nature of molecular substances
  - Empirical Observations - We can take a common sense approach in evaluating solubility for substances by applying the empirical observation "like disolves like." For example, sugar dissolves in water, water is polar thus sugar must be polar.
  - Evaluating Substance Structure - We can draw out Lewis dot structure in determining substance polarity
- Physical Solubility (solute/solvent interactions) in preparing solutions to gauge molecular polarity
  - "Like will dissolve Like"
    - Polar solutes will have highest solubility in polar solvents
    - Nonpolar solutes will have highest solubility in nonpolar solvents
    - Polar solutes will have lowest solubility in nonpolar solvents
    - Nonpolar solutes will have lowest solubility in polar solvents

Substance physical solubility in water "Like dissolves Like" can be used to gauge Molecular Polarity

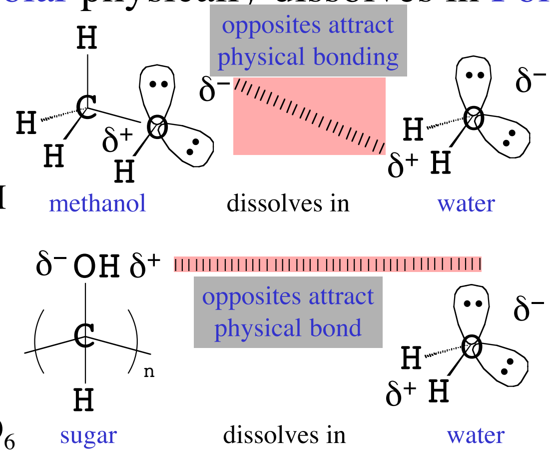


- Sugar, $C_6H_{12}O_6$, dissolves in water
  - Thus sugar molecules must be polar
- Methanol, CH_3OH, dissolves in water
  - Thus methanol molecules must be polar
- Gasoline -(CH_2)- does not dissolve in water
  - Thus gasoline molecules, C_8H_{18}, must be NONPOLAR

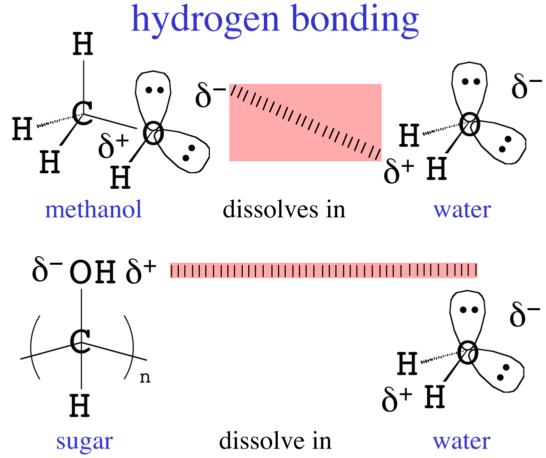
Polar physically dissolves in Polar

CH_3OH

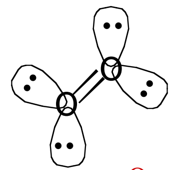
$C_6H_{12}O_6$

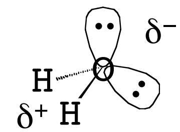


The highlighted area is an example of hydrogen bonding

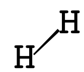


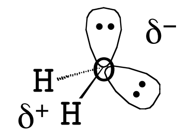
Nonpolar does not dissolve Polar



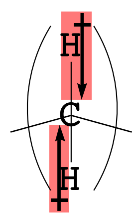


O_2 oxygen, O_2 does not dissolve in water



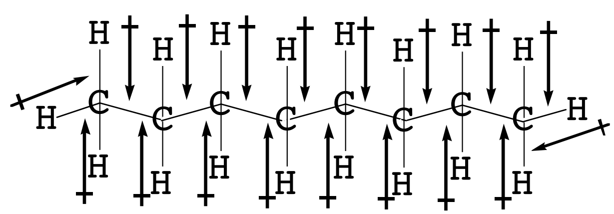


H_2 hydrogen, H_2 does not dissolve in water



A gasoline molecule is a hydrocarbon made of repeating –(CH_2)– units is non-polar; NO net dipole

hydrocarbons are non-polar

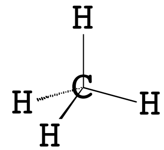


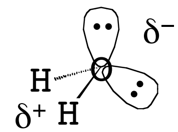
C_8H_{18}

A gasoline hydrocarbon

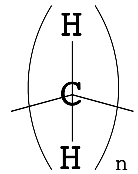
All dipoles cancel

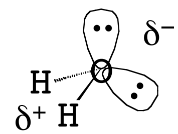
Nonpolar <u>does not</u> dissolve Polar





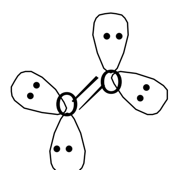
CH_4 methane <u>does not</u> dissolve in water

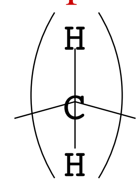




C_8H_{18} gasoline <u>does not</u> dissolve in water

Nonpolar dissolves Nonpolar



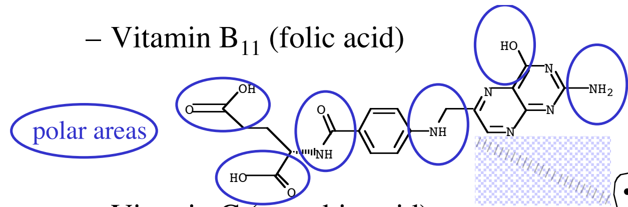


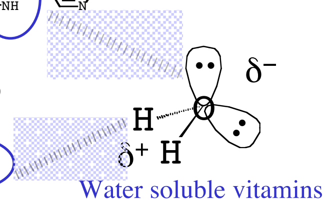
O_2 oxygen, O_2 <u>does</u> dissolve in gasoline

“Like dissolves Like”

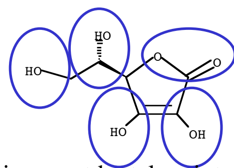
Where there are N and O atoms, these are polar areas

– Vitamin B_{11} (folic acid)





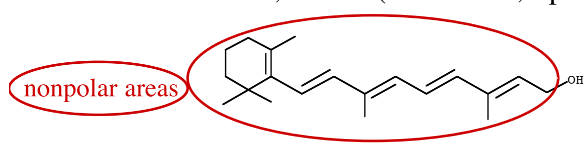
– Vitamin C (ascorbic acid)



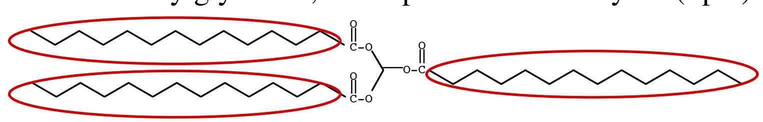
Water-soluble vitamins must be taken into body daily, as they cannot be stored are excreted within four hours to one day, ref. Nutritional Healing

“Like dissolves Like”

- Non-Polar dissolves Non-Polar
  - Vitamin A, retinol (fat soluble; lipid soluble)



  - triacylglycerine, a non-polar human body fat (lipid)



Vitamins D, E, and K are fat soluble as well

What would their overall polarity be?

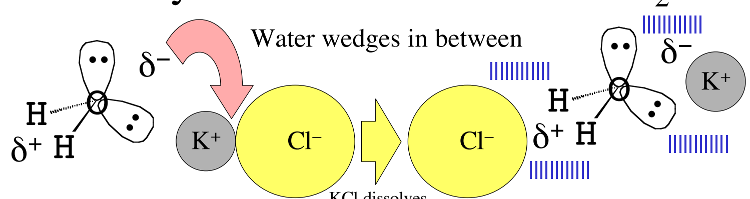
Polar or Nonpolar

Predict whether the substance is polar or nonpolar:

sugar	$C_6H_{12}O_6$	polar, dissolves in H_2O
baby oil	$C_{20}H_{42}$	nonpolar, insoluble in water
candle wax	$C_{40}H_{82}$	nonpolar, insoluble in water
ethanol	C_2H_5OH	polar, dissolves in H_2O
oxygen	O_2	nonpolar, insoluble in water
iodine	I_2	nonpolar, insoluble in water

Non-Molecular Substances **(large 3D-arrangements of atoms)**

Solubility Rules for Ionic Salts in H_2O



- Memorize the below rules:
- All ionic salts of group I ions,
  - Li^+, Na^+, K^+ are solubule in water
- All ionic salts of nitrate ion,
  - NO_3^- are solubule in water
- All ionic salts of ammonium ion,
  - NH_4^+ are solubule in water

This solubility separation is called "solvation-dissociation" with "**ion-dipole**" physical attractions

between the polarity of water and ion charge