Objective 14

States of Matter – Liquid and Solids
Relate liquid and solid types to chemical forces and properties
Use phase diagrams

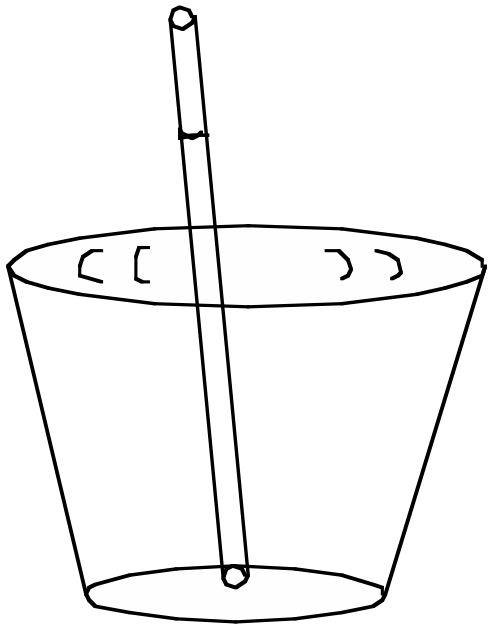
The Properties of Liquids Depend on IM Forces

State of Matter	distance between molecules	volume/ shape	density	compress ibility	motion of molecules	chemical forces
Liquid	Intermediate	Definite/ Fits shape of container	High H_2O=1 Hg=13.5	no	2 layers sliding past each other	IM forces

Viscosity - the internal resistance to flow or the shear stress of a liquid (fluid)

Surface tension (Latin: *tendere* - to stretch) - the amount of energy required to increase the surface area of a liquid by a unit area (units: J/ m^2) or the force within a liquid that acts parallel to the surface and tends to stretch the surface out.

Surface tension explains Capillary Action



Motor oil consists of large non-polar hydrocarbons (C_{19} to C_{35})

http://www.aeconline.org/recycling/materials/others/motor-oil

Explain why oil has a higher viscosity than water using your knowledge of bonding, structure, and properties.

What's happening here??

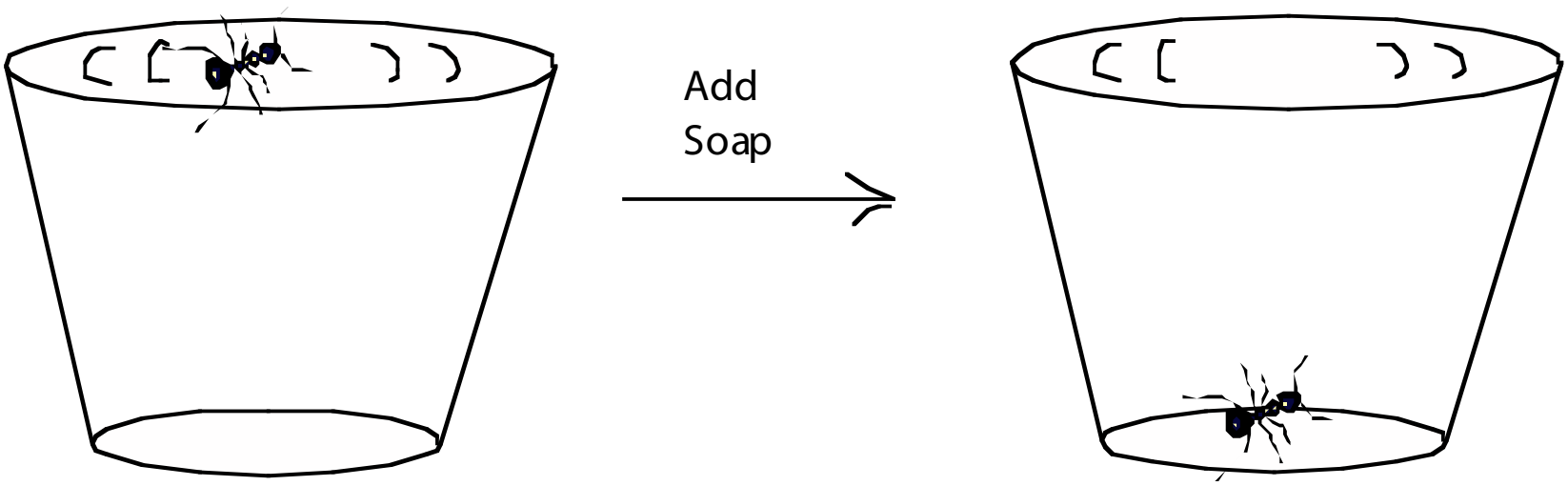
http://live-n-learn.hubpages.com/hub/How-to-Change-Your-Oil--Recycle-It

You want to slide *better* on your Slip 'N Slide.
Will acetone work better than water?

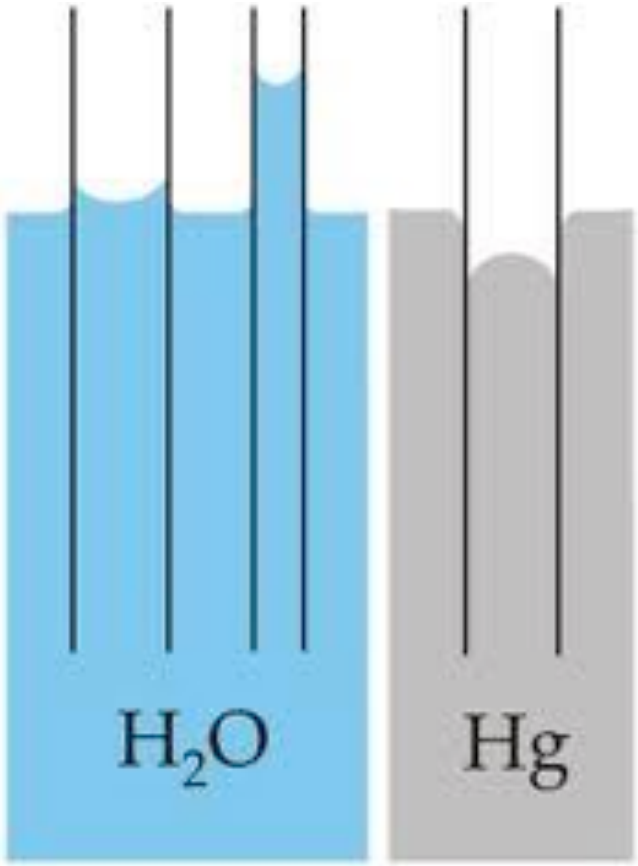
http://www.wham-o.com/product/slip_n_slide.html

Which liquid has the higher viscosity? Give reasons.

A bug floats on the surface of water due to surface tension. Add a drop of soap to the water and the bug sinks. Explain.



Capillary Action (wicking) is the movement of liquid in thin tubes
(e.g., the flow of liquids through porous media, like water through soil)

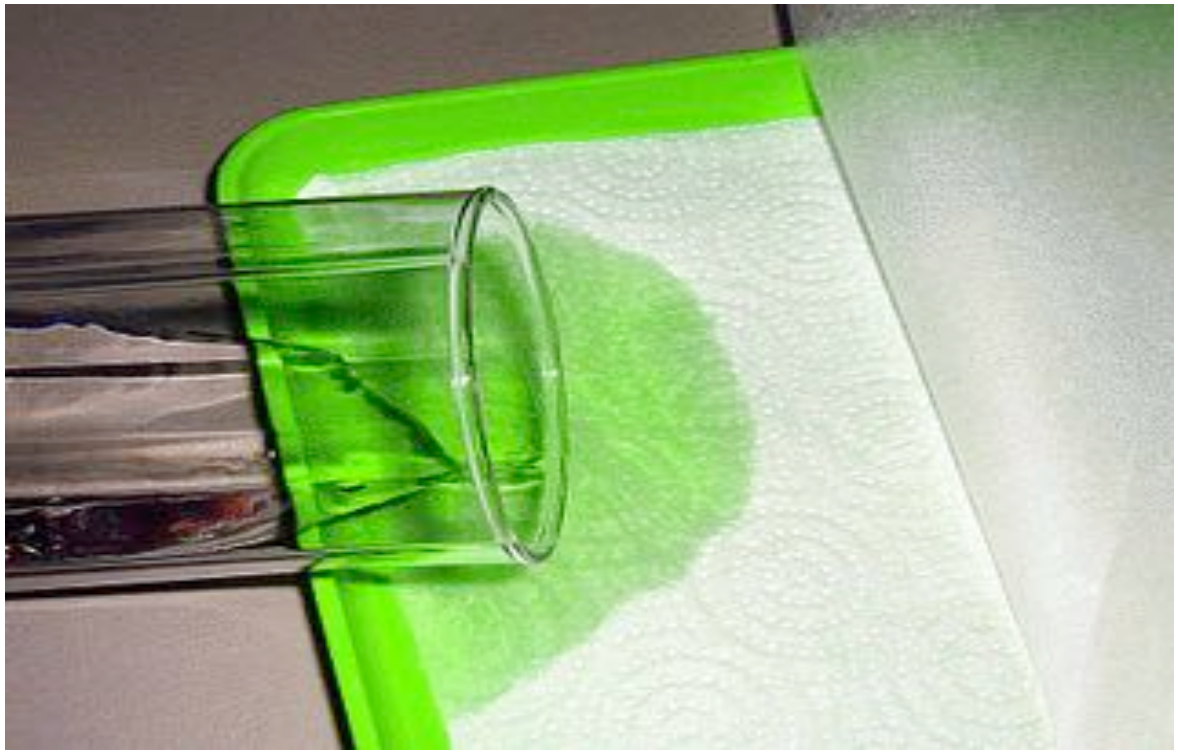


http://
www.thefullwiki.org/
Capillary_action

Explain why **water** has a **concave** meniscus
whereas **mercury** has a **convex** meniscus.

Capillary Action (wicking) is the movement of liquid in thin tubes
(e.g., the flow of liquids through porous media, like water through soil)

How does a paper towel “wick” water?



http://maiaspaintings.blogspot.com/2009/03/wet-palette-acrylics-cheep-solutions.html

https://cen.acs.org/articles/95/i42/science-meets-snacks.html
http://usustatesman.com/how-to-avoid-soggy-cookies-the-optimal-dunking-time/

How LONG should you DUNK your *Cookie* in Milk?

Time to structural failure for Oreos, Chips Ahoy, Nutter Butter, or Graham Crackers

a. 1 sec
b. 2 sec
c. 5 sec
d. 10 sec

http://usustatesman.com/how-to-avoid-soggy-cookies-the-optimal-dunking-time/

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d. 10 sec

CAPILLARY ACTION

2 sec = 80% milk absorbed

5 sec = 99% milk absorbed

8 sec = lower bound at which breakoff occurs

IDEAL = 2 – 5 sec dunk followed by brief waiting period for desired softness without breaking

The tallest living tree (until 2000), at 370 feet tall, is the Mendocino Tree, a coast redwood tree near Ukiah, CA. The exact process by which water is taken up by plants against the force of gravity is not fully known (see http://interactive.usask.ca/ski/forestry/activities/lesson_waterworks.html)

One way water gets to the top of trees is by capillary action. What chemical forces determines capillary action?

http://oddstuffmagazine.com/10-highest-trees-of-the-planet.html

If trees used hexane instead of water, would trees grow as high?

You may have mixed, or seen a bartender mix, alcoholic beverages. When a measured volume of ethanol is mixed with a measured volume of water, the sum of the volumes does not equal the actual volume. *The actual volume is actually less than the sum of the volumes*. Use your knowledge of chemical forces to explain this observation.

http://www.esquire.com/the-side/feature/bartending-tools-052709#slide-1

http://cen.acs.org/articles/90/i30/Olympicene-Speedy-Swimming-Old-Time.html

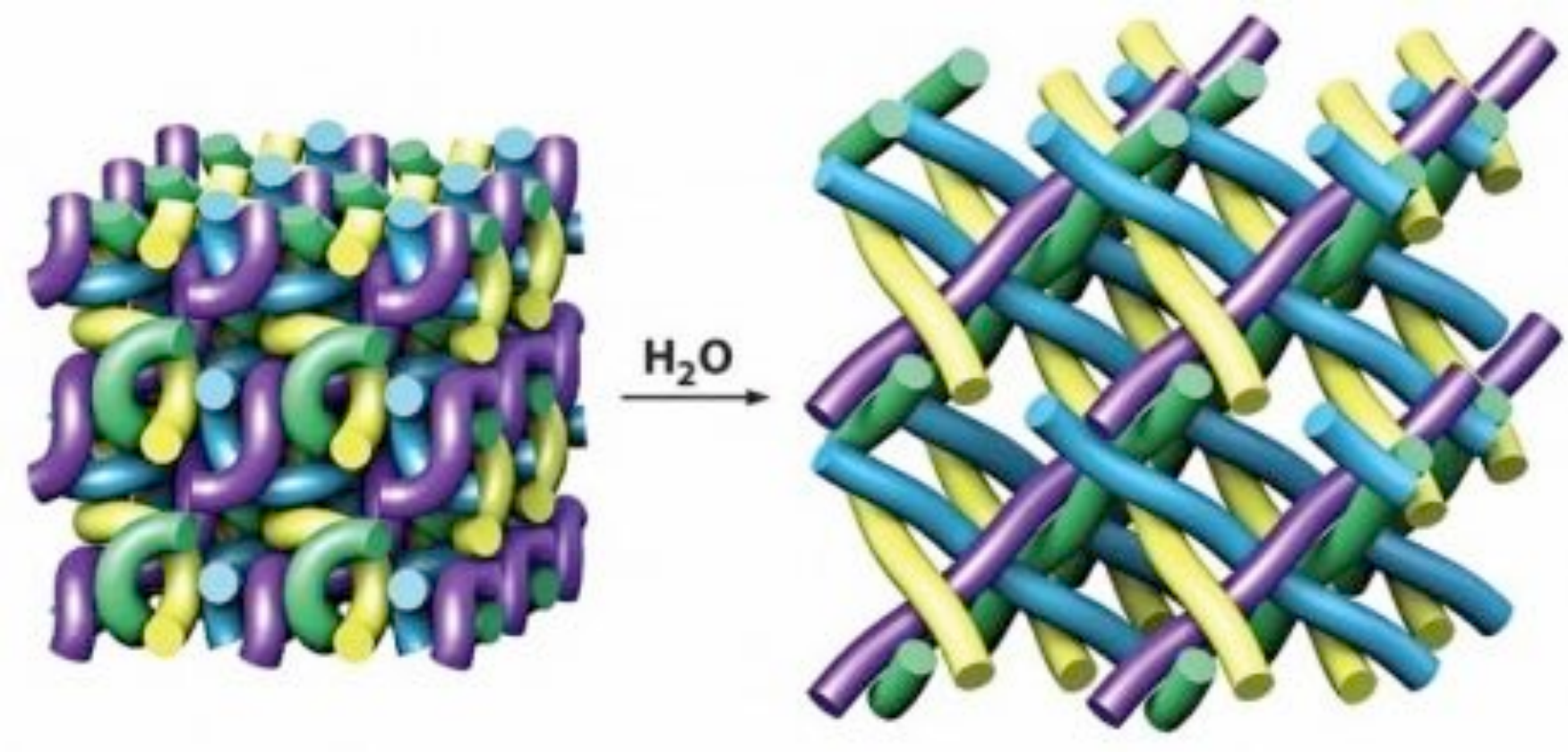
Swimmers can gain a competitive edge by ***SPREADING THEIR FINGERS***, rather than cupping them together.

Spread the fingers just right (between 0.2 and 0.4 times the diameter of the individual fingers), and the ***boundary layers form an effective web between the digits***, making the hand a bit more like a paddle and maximizing the force it can exert on the water.

Explain this finding using chemical forces.

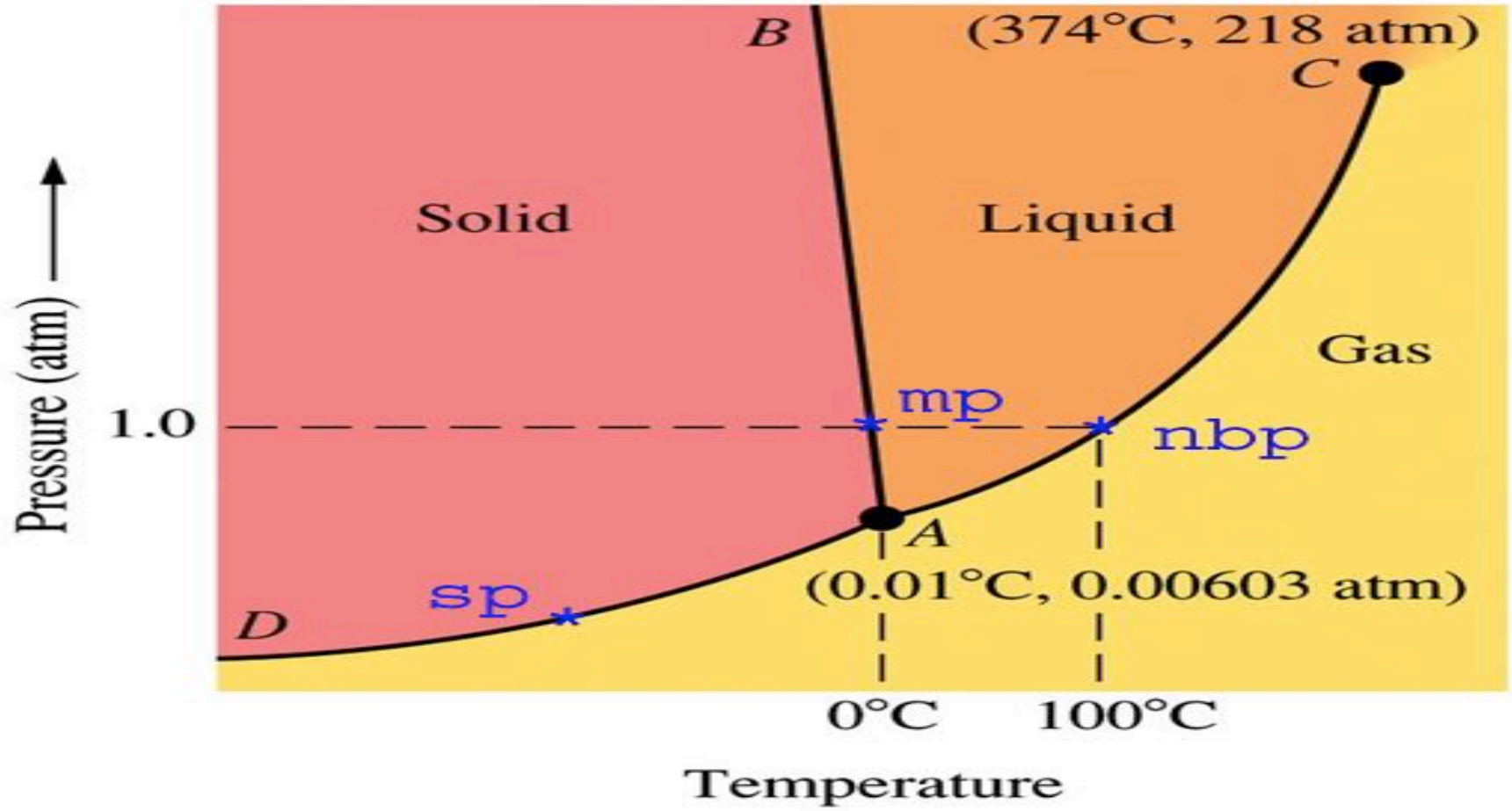
Journal of Theoretical Biology (DOI: 10.1016/j.jtbi.2012.05.033)

2/3/14, C&EN, p. 26 ‘Pruney’ Skin Physics Revealed



A lattice of interwoven **KERATIN FILAMENTS** (helical structure and hydrophilic) swells in the presence of water.

A ***Phase Diagram*** Tells You the State of Matter of a Substance at Different Temperatures and Pressures



Phase Diagram of Water (http://math.nyu.edu/~gladish/teaching/eao/week2.html)

What happens to the b.p. of water as the pressure increases?

What happens to the m.p of water as the pressure increases?

Phase Changes Involve Energy

What is the name of each phase change?
Determine q (> 0 or < 0) for each phase change.

Phase Change	Name	q
Solid --> Liquid		
Liquid --> Solid		
Liquid --> Gas		
Gas --> Liquid		
Solid --> Gas		
Gas --> Solid		

Changing P Changes b.p. and m.p.

At high altitudes, e.g., Lake Tahoe, certain foods take longer to cook than at sea level, e.g., Salinas. Explain why.

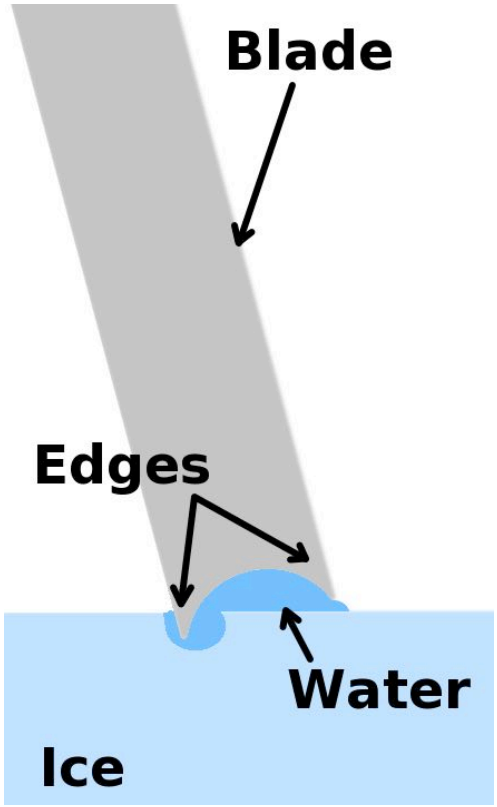
http://www.amazon.com/All-American-921-2-Quart-Pressure/dp/B00004S88Z

A pressure cooker cooks certain foods much faster. Explain how a pressure cooker works.

Changing P Changes b.p. and m.p.

The ice in a typical ice skating rink is cooled to about –20°C. Ice skaters (figure skaters and hockey players) glide so smoothly across the ice because a layer of liquid water forms between the solid ice and their skate. Explain how this water layer is formed using the phase diagram of water.

http://www.achildgrows.com/ice-skating-best-excuse-drink-hot-chocolate/



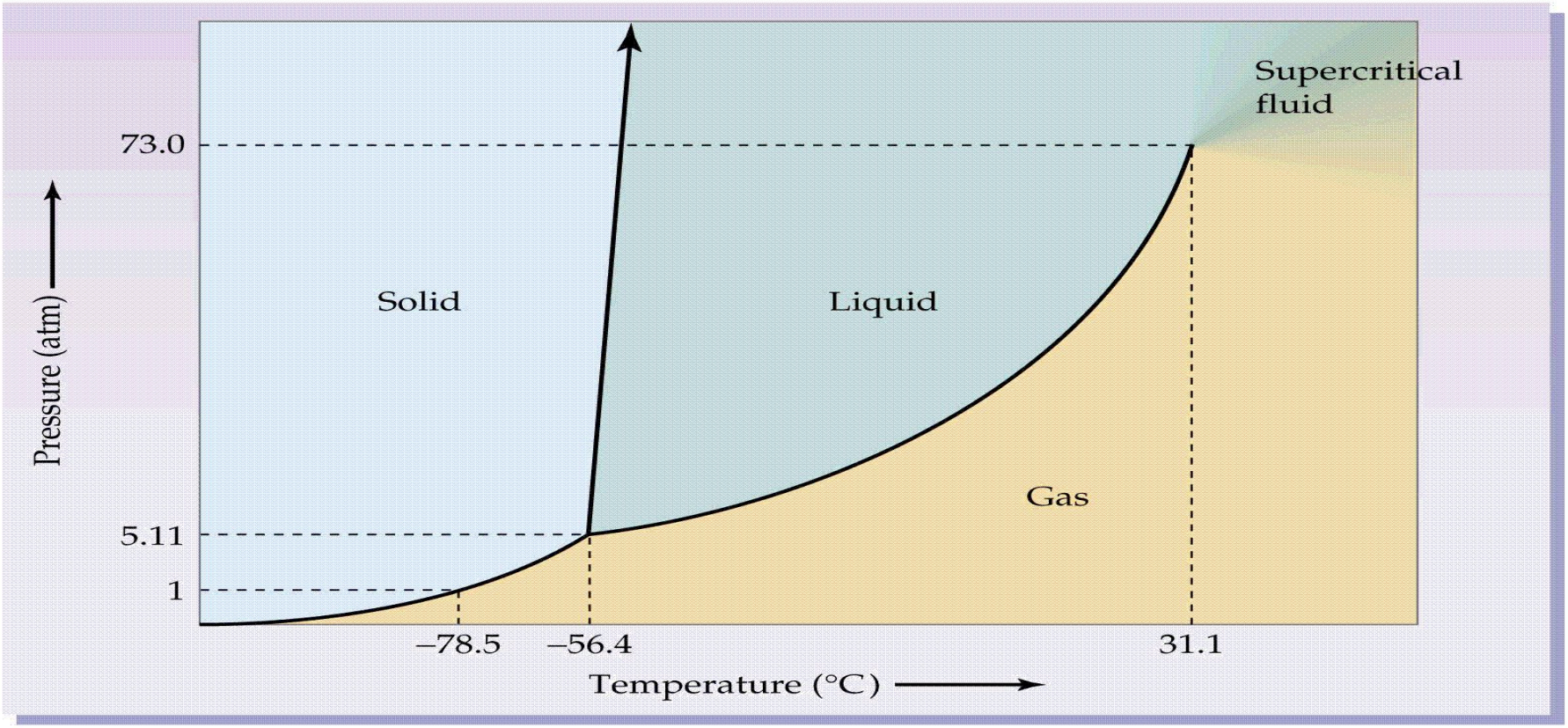
http://commons.wikimedia.org/wiki/File:Ice_Skate_Blade_Cross_Section.png

Changing P Changes b.p. and m.p.

News story: after East Coast snow storm, reporter said that most of the snow is removed by sublimation. Is this true?

http://www.joe-ks.com/archives_mar2005/SnowCar.htm

Lab 10 Problem 1 Demonstration: Heat water to boiling in a flask. Remove flask from heat. Stopper flask. Rub ice on the outside walls of the flask. Water boils.



Phase diagram of CO_2. http://www.teamonslaught.fsnet.co.uk/co2_info.htm

Dry ice is solid CO_2. Explain why dry ice sublimes under normal temperature and pressure conditions.

At what P does CO_2 melt?

What is a supercritical fluid?

From Strange but True, by Bill Sones and Rich Sones (The Valley Advisor, 12/9/01, p. 21).

Breathing blanks? Q. Armchair astronauts, if you removed your helmet in space and tried to breathe, what would happen?

A. Even most astronomers can't answer this but NASA can, reports Cornell's "Ask an Astronomer" Web site. This is because astronauts' helmets occasionally pop off accidentally during training.

Exposed to a vacuum, you would feel the air immediately forced out of your lungs. You could still breathe in, but you'd be drawing airless blanks. There'd be no exploding eyeballs or embolisms, as the movies like to show, but you might suffer a case of the bends.

"You'd also feel the spit on your tongue and sweat on your body boil away, described as a fizzy sensation like drinking soda. Otherwise, you wouldn't feel much—until you died of oxygen deprivation." BTW, NASA's helmet poppers have all survived.

a. Using your knowledge of science, why is the air immediately forced out of your lungs when exposed to a vacuum?

b. Using your knowledge of science, why isn't there any exploding eyeballs or embolisms? Why might you suffer a case of the bends?

c. Using your knowledge of science, explain why the spit on your tongue and sweat on your body would boil away.

1. 1 liter of air at 25^{o}C and 1 atm expands to 1.5 liter under constant T and n conditions. Will the air rise or fall? Calculate the new P to support your answer.
2. Cold air sinks. The density of air at 1 atm and 0^{o}C is ____.
3. The partial pressure of O_2 on top of Mt. Everest (elevation = 29,029 ft, Patm = 0.33 atm) is __.
4. As temperature decreases, the vapor pressure of a liquid ____.
5. It is hot and humid. If the temperature drops, what happens? Why?
6. A pressure cooker cooks food faster because ___.
7. A Slip 'N Slide works better with __ (acetone or water)___ because ___.
8. If trees used hexane instead of water, would trees grow as high? Give reasons.

1. 1 liter of air at 25°C and 1 atm expands to 1.5 liter under constant T and n conditions. Will the air rise or fall? Calculate the new P (0.7 atm) to support your answer. ($P_1V_1 = P_2V_2$)
2. Cold air sinks. The density of air at 1 atm and 0°C is __1.3 g/l__. (gas density = Molar mass P/RT)
3. The partial pressure of O_2 on top of Mt. Everest (elevation = 29,029 ft, Patm = 0.33 atm) is _(0.07 atm)_.
4. As temperature decreases, the vapor pressure of a liquid _(decreases)___.
5. It is hot and humid. If the temperature drops, what happens? Why? (Vapor pressure drops, RH rises. Rain.)
6. A pressure cooker cooks food faster because _ (P increases, b.p. of water increases) __.
7. A Slip 'N Slide works better with __ (acetone or water)___ because _ (water has a higher viscosity than acetone) __.
8. If trees used hexane instead of water, would trees grow as high? Give reasons. (No. Lower IM forces, lower capillary action.)

The Properties of Solids Depend on the Solid Type

Solid Type	Chemical Force	Properties	Example
Molecular Solid	IM forces	Low m.p. Soft Insulator	Sugar
Ionic Solid	Ionic Bond	High m.p. Hard, brittle Insulator	NaCl
Covalent Network Solid	Covalent Bond	High m.p. Hard Insulator	Diamond Quartz
Metallic Solid	Metallic Bond	Variable m.p. Soft (malleable, ductile) Conductor	Fe Cu Au

The hardest known substance is:

a) Chem 1A Exam 2
b) Water
c) Coffee mug
d) Concrete
e) Diamond

The softest known solid substance is:

a) Ice
b) Cotton
c) Talc
d) Gold
e) Baby's bottom

The substance used to dry your bottom when you were a baby is _____.

http://geology.about.com/library/bl/blmohsscale.htm

The **Mohs Scale of Relative Mineral Hardness** was devised by Friedrich Mohs in 1812 and is a valuable aid to identifying minerals ever since.

Scale	Mineral	Common Substance
1	Talc	
2	Gypsum	Fingernail (2.5)
3	Calcite	Penny, Gold (2.5)
4	Fluorite	
5	Apatite	Knife blade, glass
6	Feldspar	Steel file
7	Quartz	
8	Topaz	
9	Corundum	
10	Diamond	

Test an unknown mineral against one of these standard minerals.

==> ***Whichever one scratches the other is harder***.

Will your fingernail scratch glass?

"Soft" Glass (Na_2CO_3) is _____.

Borosilicate Glass (B_2O_3/Na_2SiO_3) is ____.

Pyrex is Borosilicate Glass.

http://sciencekit.com/griffin-low-form-heavy-duty-pyrex-beakers/p/IG0025896/

A "dopant" is added to change properties.

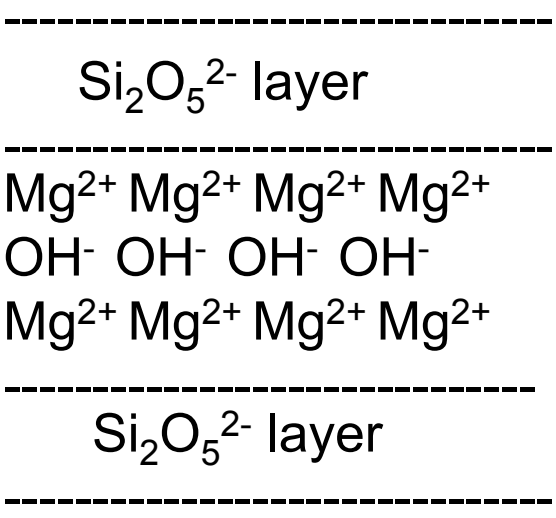
Iron is soft.

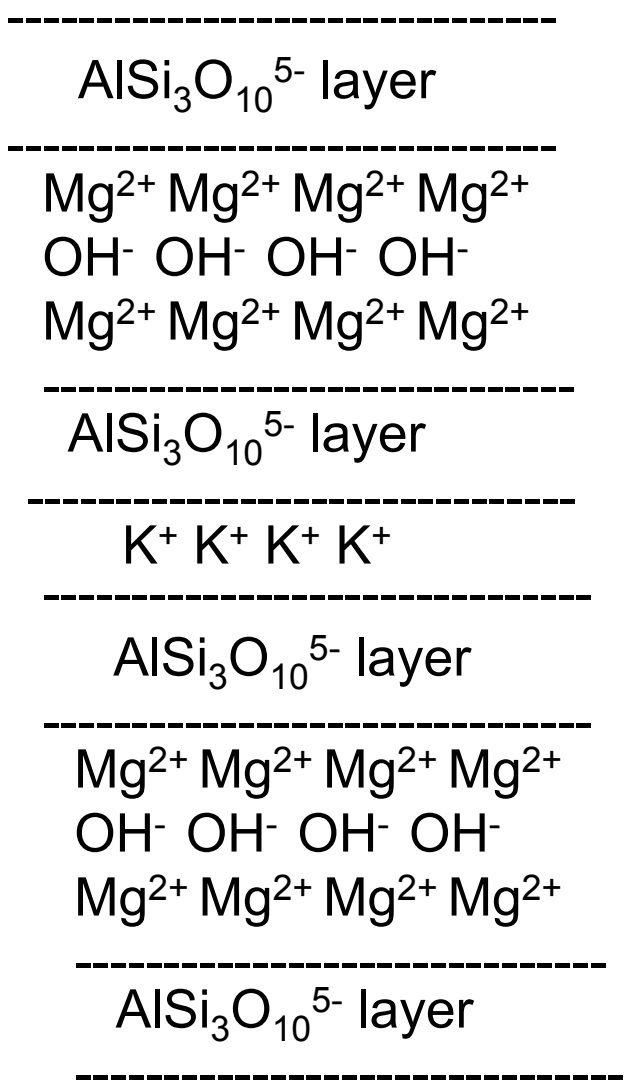
Add carbon to iron --> *hard* (but brittle).

Add _____ to carbon steel to make _____ steel.

http://physicsofscifi.blogspot.com/2012/07/physics-of-iron-man-2008-and-iron-man-2.html

Mica is ***Harder*** than Talc because _____.





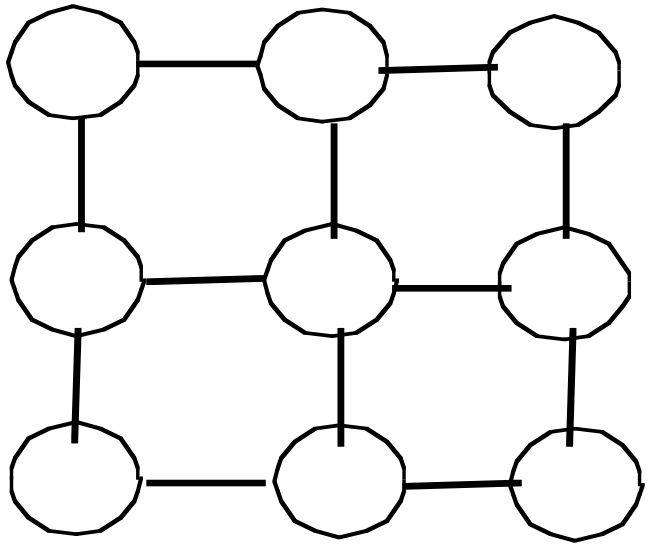
Talc ($Mg_3(Si_2O_5)_2(OH)_2$) has a *layered* structure.

Mica ($KMg_3AlSi_3O_{10}(OH)_2$): Replace Si^{4+} with Al^{3+} results in net (-) charge for the whole sandwich and attracts (+) ions, like K^+. One Si is replaced by K and Al (charge balance).

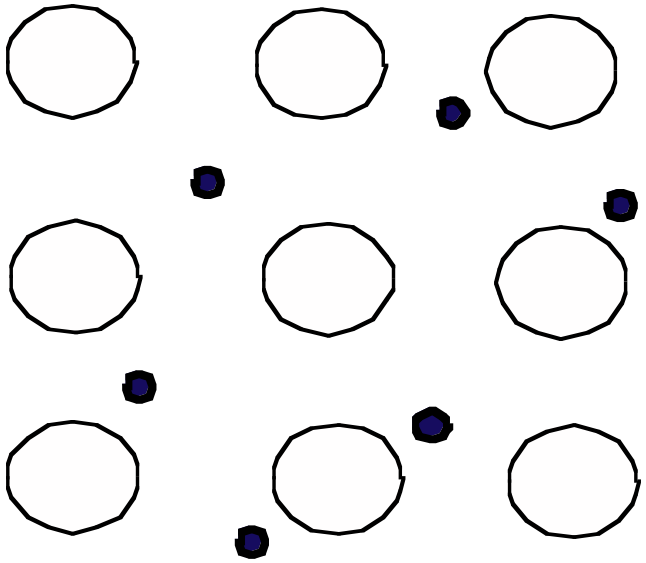
Localized/Delocalized Electrons Explain Conductivity and Hardness in Solids

In a *Covalent Bond*, Electrons are shared between **2** atoms ==> *localized* electrons ==> these electrons are "locked" between the 2 atoms ==> insulator, hard.

In a *Metallic Bond*, Electrons are shared between **3** or more atoms ==> *delocalized* electrons ==> these electrons are "free" to move about the atoms in a metal ==> conductor, soft.



Localized electrons in ionic solids, molecular solids, covalent network solids.

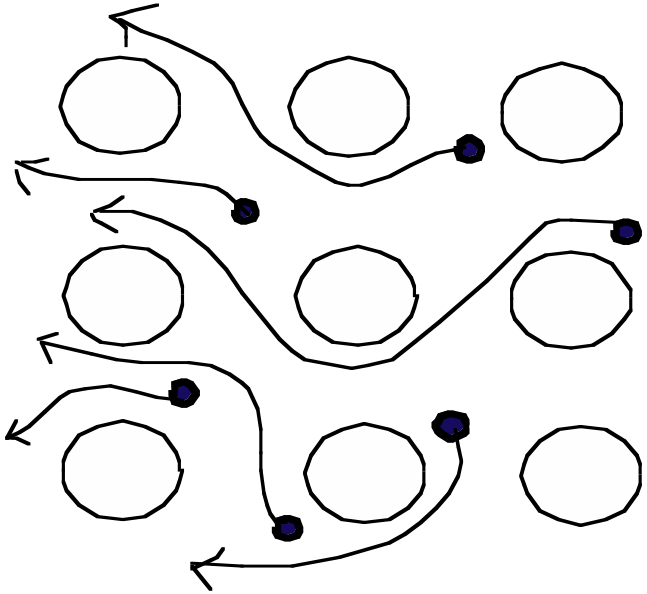


Delocalized electrons in metallic solids.

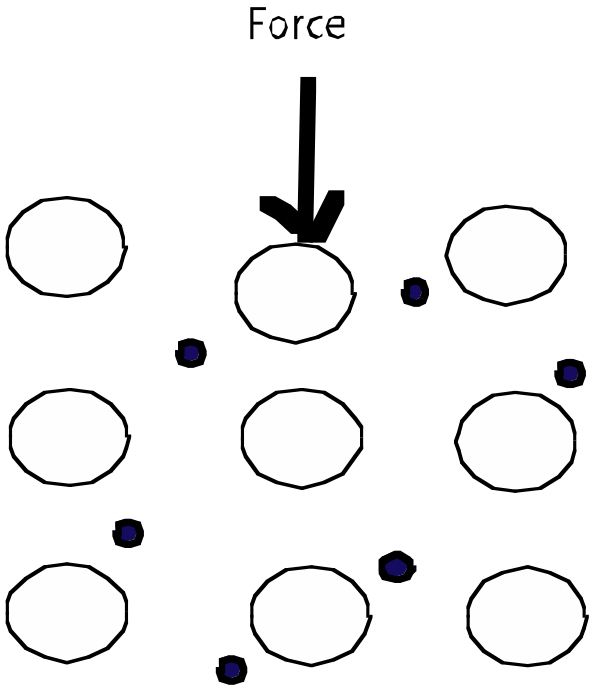
“Sea of Electrons” Describes Conductivity and Softness of Metals

http://www.ausetute.com.au/metallic.html

http://www.drkstreet.com/resources/metallic-bonding-animation.swf



Electrons freely move = conductor

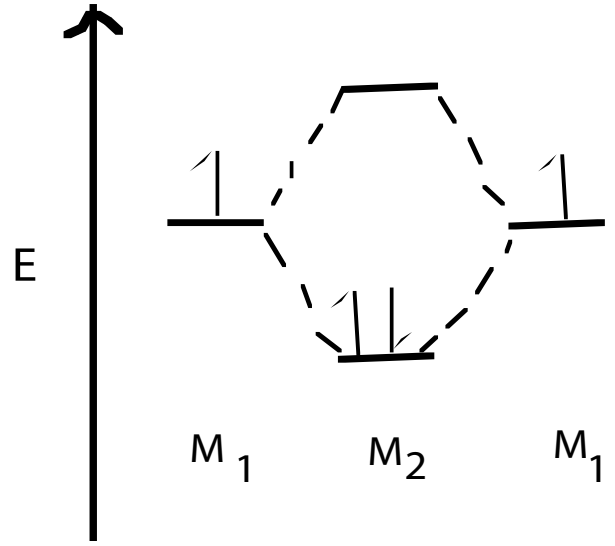


Apply force ==> atom moves and e^- readjusts around atoms = soft

Atoms Bond Together to Form Molecules
Atomic Orbitals Combine Together to Form Molecular Orbitals

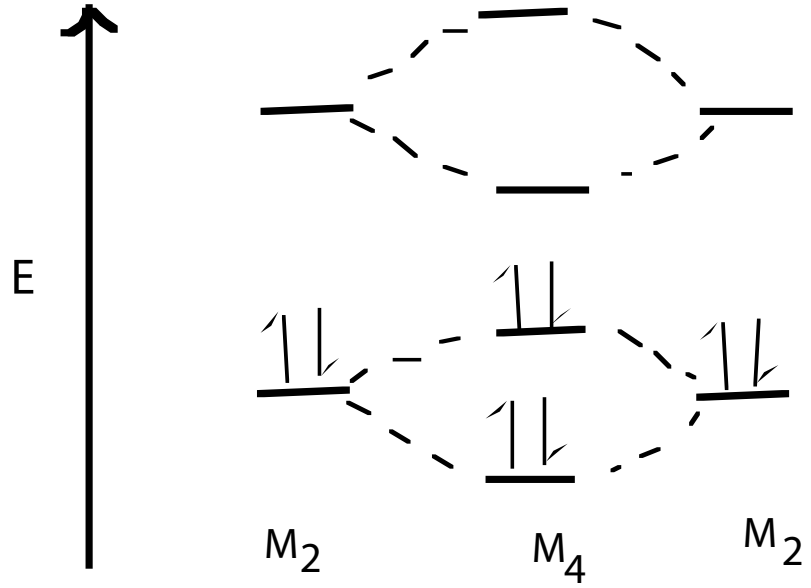
Atom M_1 bonds to Atom M_1 to form diatomic molecule M_2.

One atomic orbital (AO) from M_1
+ one AO from M_1
= Two molecular orbitals (MO) for M_2.



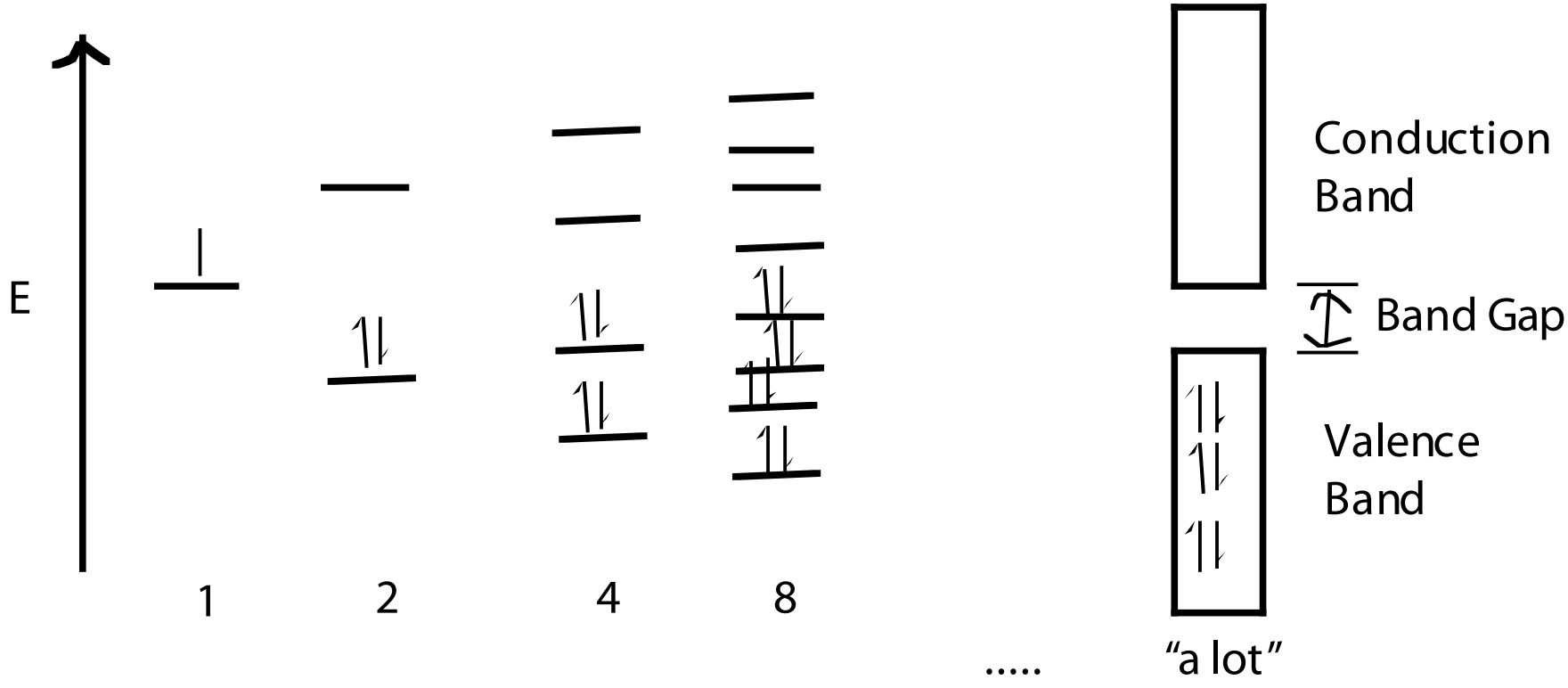
Diatomic molecule M_2 bonds to diatomic molecule M_2 to form tetraatomic molecule M_4.

Two MO from M_2
+ Two MO from M_2
= Four MO for M_4



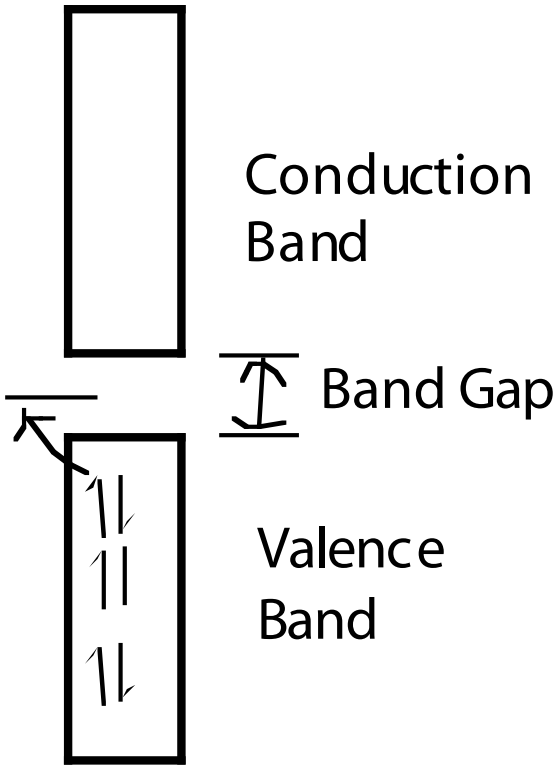
A solid has a lot of atoms and a lot of orbitals (**Band)**

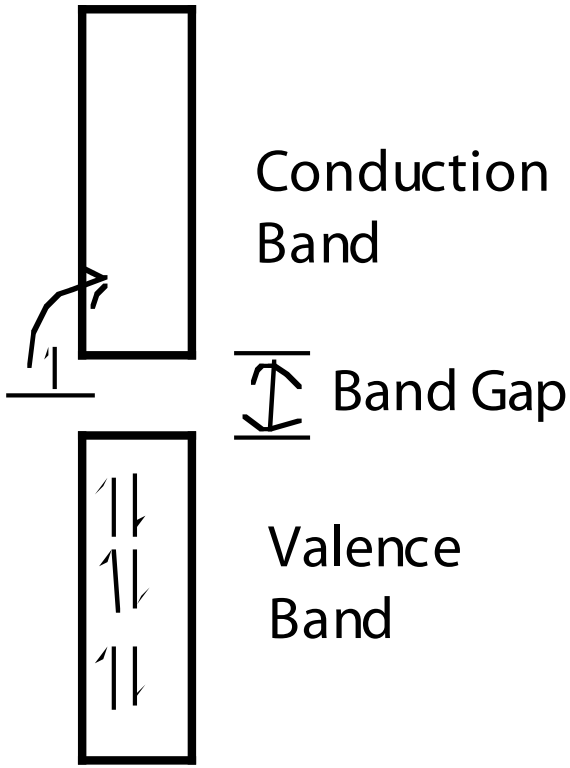
Band Theory Describes Conductivity



Metal has Band Gap = 0 ==> Conductor (Cu, Au)
Non-metal has Band Gap >> 0 ==> Insulator (S)
Semimetal has Band Gap = small ==> Semiconductor (Si)

iPad (Solid State Electronic Devices): **Si (Group 4) is "Doped" with Another Element to Change its Conductivity.**

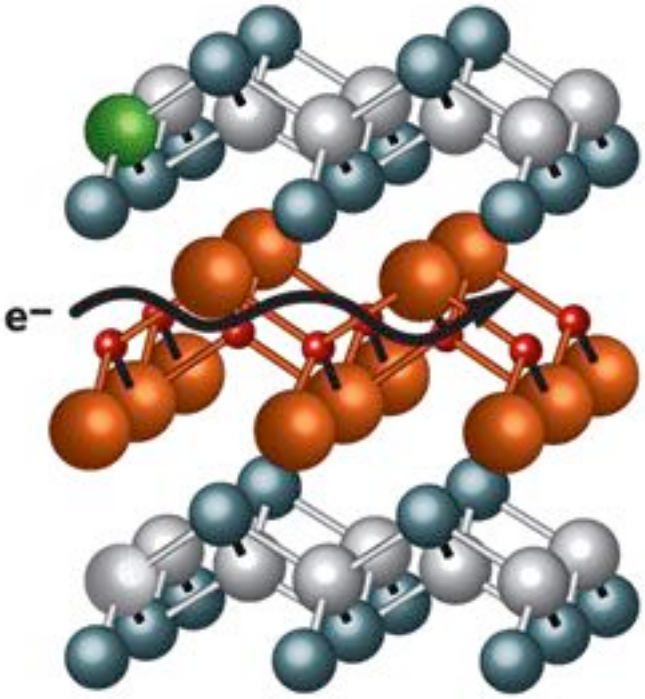




Dope Si with Group 3 element (Ga) to form a <u>p-type semiconductor</u>.

Dope Si with Group 5 element (P) to form a <u>n-type semiconductor</u>.

In Ordinary conductors, such as copper, as electrons flow through the conductors' lattice, they ricochet off impurities and vibrating atoms. The scattering process leads to loss of energy as heat, akin to an electronic form of friction.



Superconductors conduct electricity with no resistance.

Electrons glide through superconductors in a frictionless manner.

Meissner Effect (http://cen.acs.org/articles/86/i42/Superconductivity-Rekindles.html)

Electron Speedway
Doping La-O (blue and gray) layers with F (green) injects electrons into the Fe-As (red and orange) layers, through which they are conducted across the crystal.
CEN, 10/20/08, p. 15

1.Compare salt (NaCl) to sugar ($C_{12}H_{22}O_{11}$).
a. Use bonding theories to explain why salt is hard and brittle.
b. Explain why sugar is soft.

2. Which solid type would you choose to use in a coffee cup? Give one example and give reasons.

3. Use band theory to explain the conductivity of metals, non-metals, semi-metals. Apply band theory to semiconductors, p-type and n-type.
How semiconductors work
(http://electronics.howstuffworks.com/diode.htm)

"A Diamond is Forever" (DeBeers, 1947)

Advertising Age magazine named "A Diamond Is Forever" the best advertising slogan of the twentieth century (2000).

But it's just carbon!

Properties: very hard, heat conductor, wide bandgap, high optical dispersion

1. a. Name the three allotropes of carbon.

b. Why are diamonds hard?

c. Why is graphite used as a solid lubricant?

d. Are diamonds forever?

http://www.bris.ac.uk/Depts/Chemistry/MOTM/diamond/diamond.htm

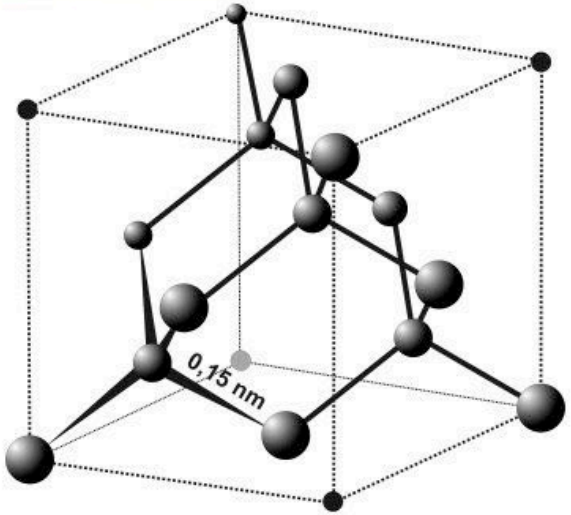
http://commons.wikimedia.org/wiki/File:Carbon_basic_phase_diagram.png

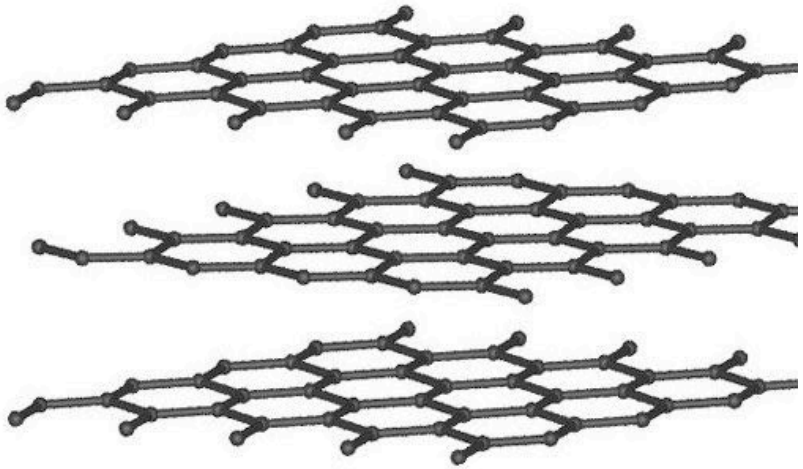
History of Diamonds http://www.amnh.org/exhibitions/diamonds/

Synthetic diamonds http://pubs.acs.org/cen/coverstory/8205/8205diamonds.html

Diamond vs. Graphite

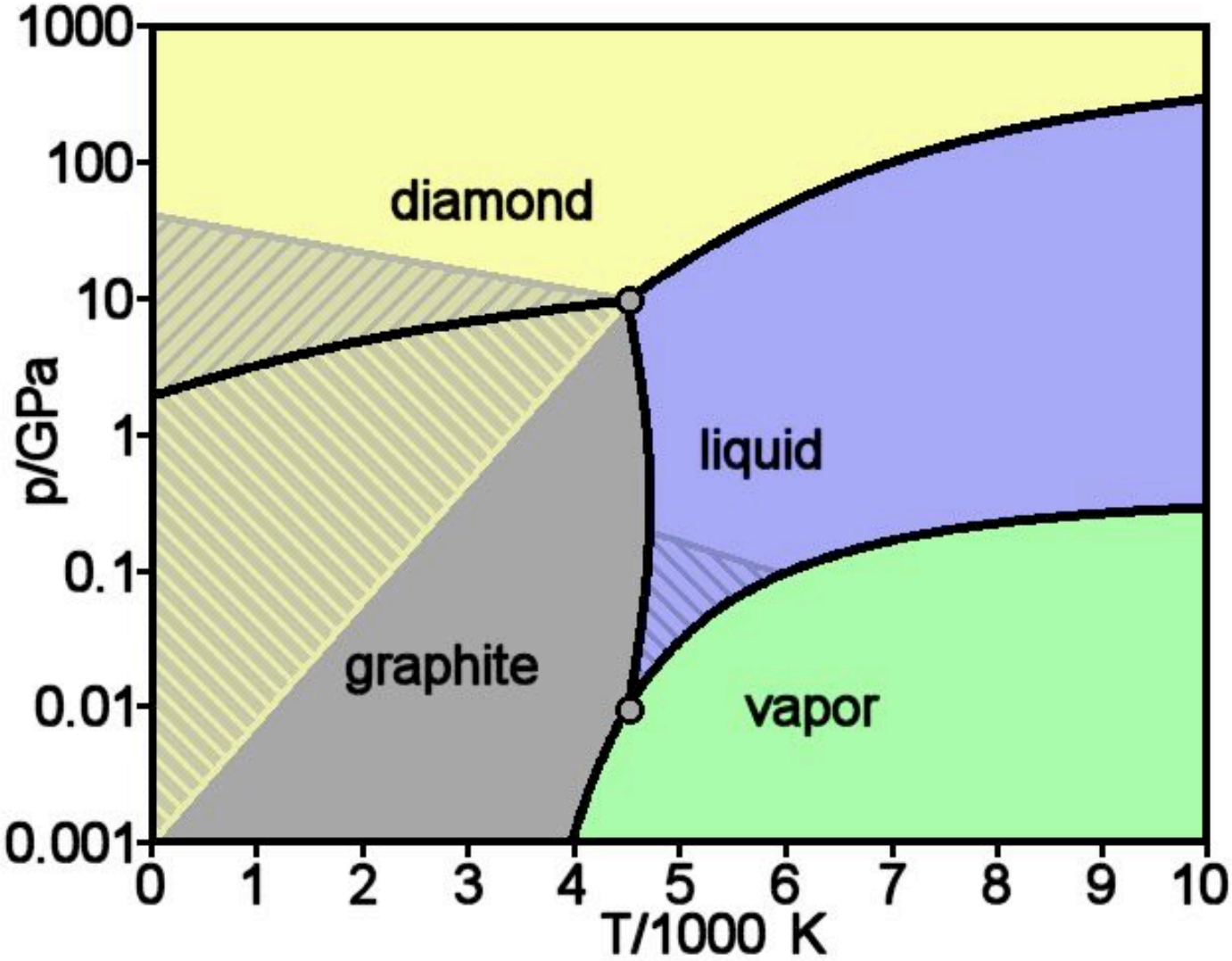
3D covalent network solid vs. 2D sheets stacked on top of each other





http://en.wikipedia.org/wiki/Diamond

How do you make Diamond from Graphite?



Phase Diagram of Carbon

(http://commons.wikimedia.org/wiki/File:Carbon_basic_phase_diagram.png)

"THE MANY FACETS OF MAN-MADE DIAMONDS" (2004)

http://pubs.acs.org/cen/coverstory/8205/8205diamonds.html

Gemesis (Florida)

Graphite (with seed diamond crystal) ---- T=1500°C, P = 58,000 atm, Metal-based catalyst ----> Diamond (2.5 days)

Apollo Diamond (Boston)

Chemical Vapor Deposition

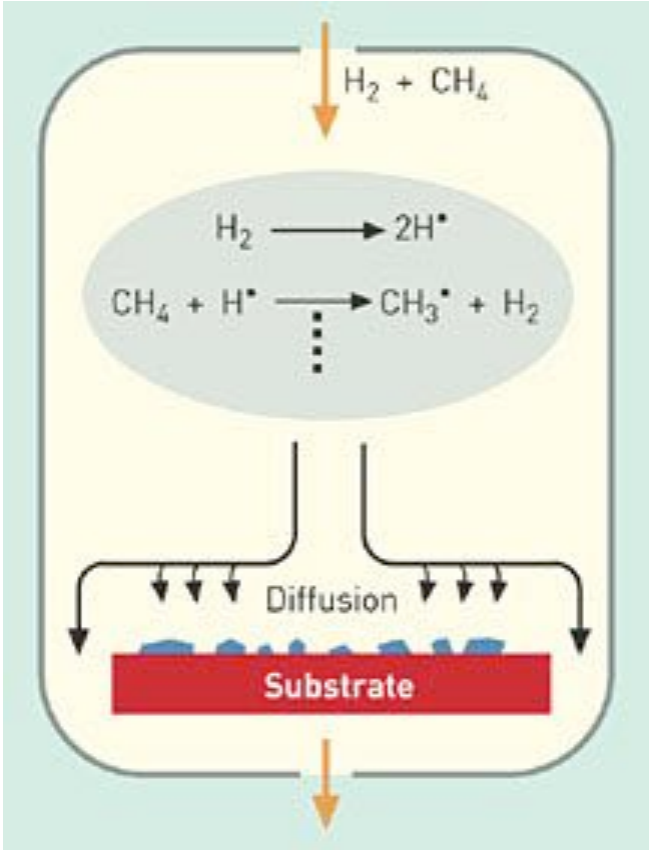
Lower pressure

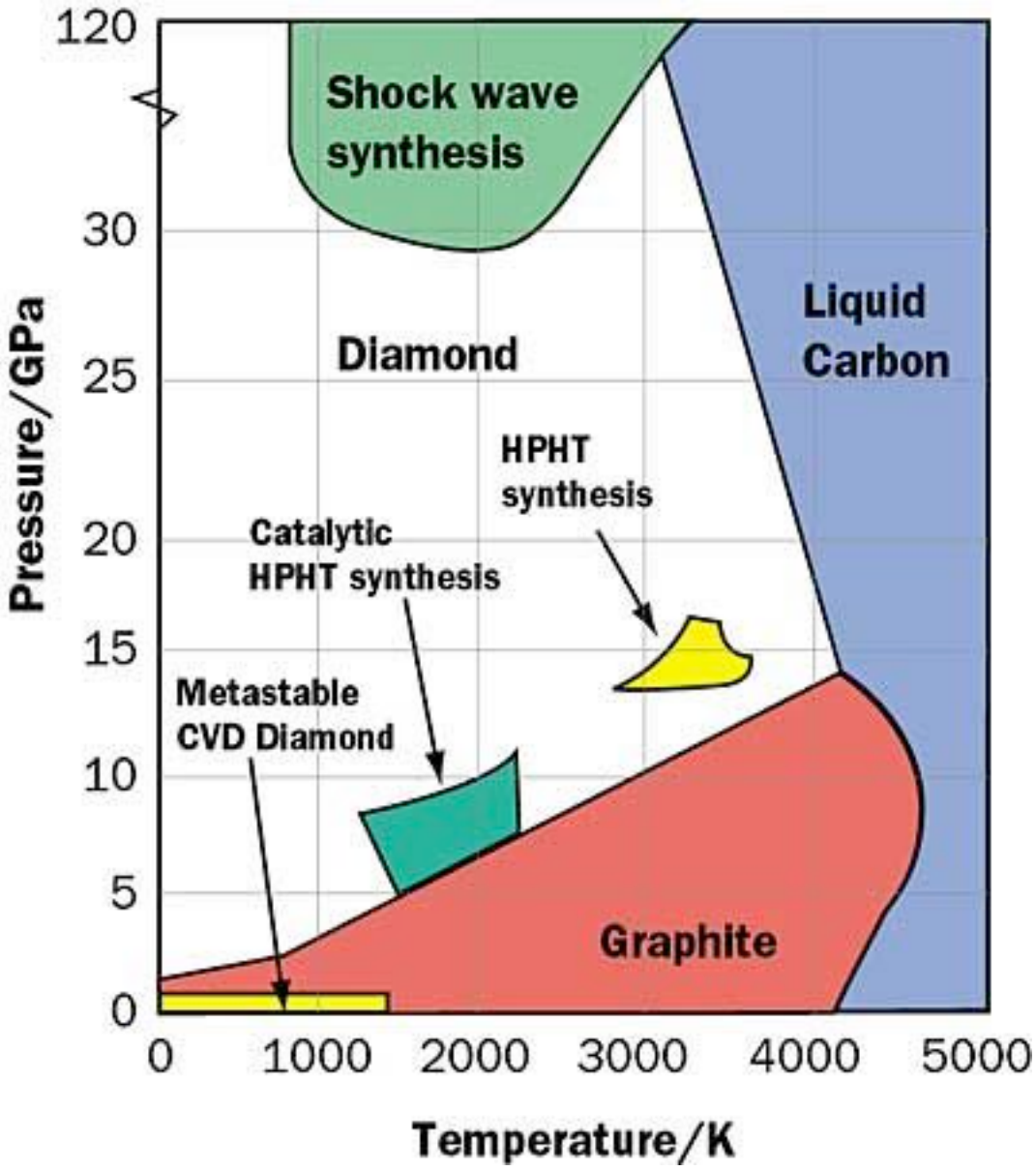
Controls impurities

Grows bigger crystals

Different colors

(blue = B, yellow = N_2)





Phase Diagram of Carbon

(http://www.electronics-cooling.com/2002/02/diamonds-are-a-thermal-designers-best-friends/)

Diamond from Methane?

Science, 286, 100 (1999)

Uranus and Neptune are rich in CH_4 and could produce diamond:

$$CH_4 \xrightarrow[T = 2{,}000\text{-}3{,}000\ K]{P = 10\text{-}50\ GPa} C\ (diamond) + \text{polymeric hydrocarbons}$$

Use Diamonds to get Very High Pressures!

More evidence for inorganic origin of oil

(http://pubs.acs.org/isubscribe/journals/cen/82/i38/html/8238scic.html, CEN, 10/20/04, p. 40)

Crude oil is widely believed to have formed from plant and animal material encased in near-surface sedimentary rocks in Earth's crust. A counterclaim holds that petroleum is formed abiotically from carbonates at high temperatures and pressures deep in Earth's mantle. Now, a research team led by Henry P. Scott of Indiana University, South Bend, reports some of the first experimental evidence to bolster the inorganic theory [Proc. Natl. Acad. Sci. USA, published online, http://www.pnas.org/cgi/doi/10.1073/pnas.0405930101]. Scott and coworkers reacted iron oxide, calcite ($CaCO_3$), and water in a diamond anvil cell and observed in situ formation of methane at a range of temperatures and pressures. The most favorable conditions for methane formation were 500°C and 70,000 atm, corresponding to a depth of 100 to 200 km below Earth's surface. In 2002, a different group reported formation of methane as well as heavier hydrocarbons for a similar set of experiments in which the reactions were quenched before the products were characterized.

Solids Are Amorphous or Crystals

An **Amorphous** solid does not have a regular, repeating pattern of atoms.
E.g., glass, thin films, gels, nanostructured materials

A **Crystalline** solid has a regular, repeating pattern of atoms. E.g., metals, ionic compounds (NaCl)

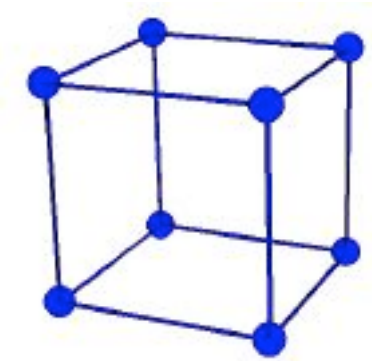
When a liquid (Fe or NaCl) is cooled, the Fe atoms or Na^+ and Cl^- ions always arrange (organize) themselves in the same pattern ==> ***Crystal***.

Lattice is array of points (atoms) repeating periodically in three dimensions.

The **Structure** and **Symmetry** of a Crystal has a role in its properties: density, cleavage, refractive index, piezoelectricity

Scientists Use Properties to Make New Materials

Crystals are Classified by Lattice Systems
Cubic is the Simplest and Most Symmetric



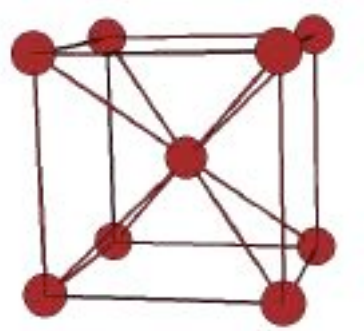
Simple cubic

http://cst-www.nrl.navy.mil/lattice/

Not close packed

52% Packing Efficiency

Po (very rare)



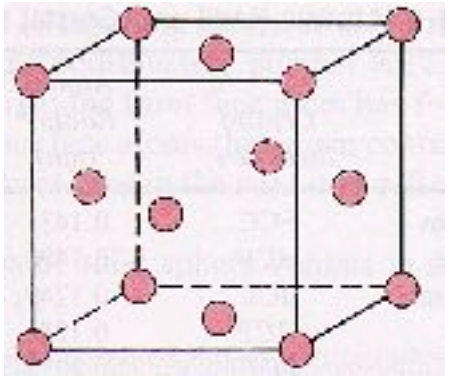
Body center cubic

http://cst-www.nrl.navy.mil/lattice/

Not close packed

68%

Fe, Cr, W



Face center cubic

http://www.jwave.vt.edu/crcd/farkas/lectures/structure/tsld002.htm

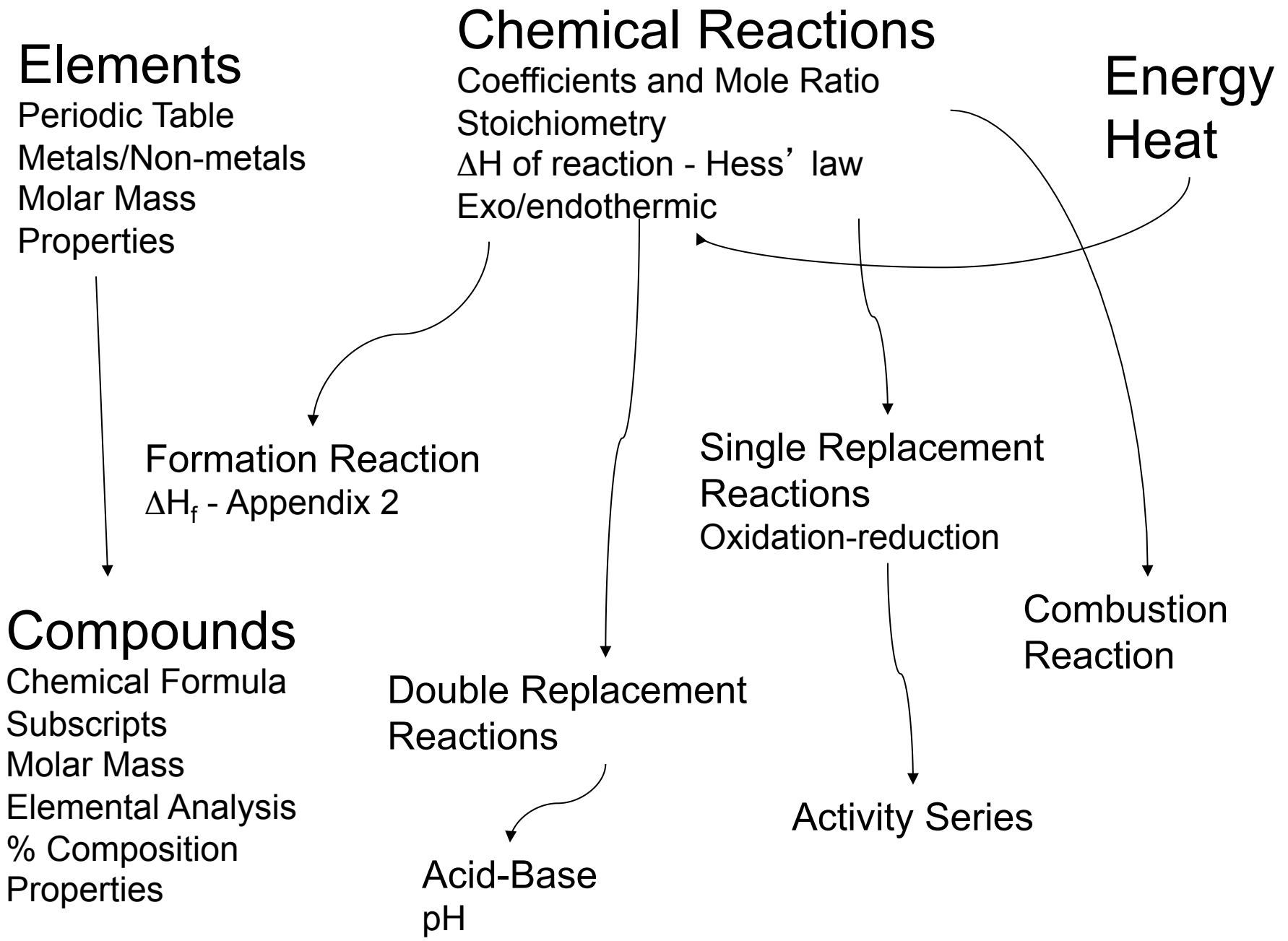
Close packed

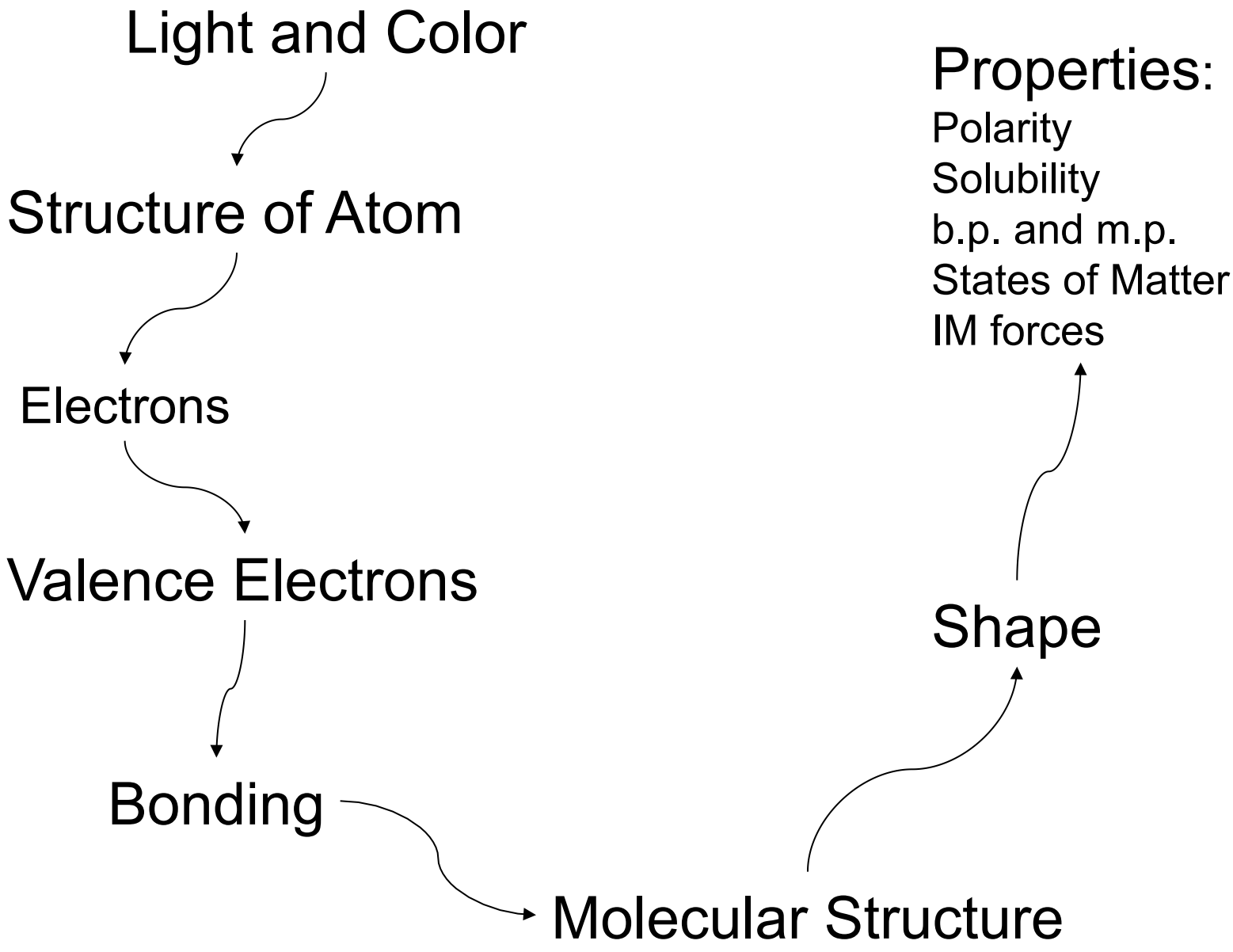
74%

NaCl

http://www.seas.upenn.edu/~chem101/sschem/metallicsolids.html

2011 Nobel Prize in Chemistry: Quasi-crystals


Elements
Periodic Table
Metals/Non-metals
Molar Mass
Properties
Chemical Reactions
Coefficients and Mole Ratio
Stoichiometry
ΔH of reaction - Hess' law
Exo/endothermic
Energy
Heat
Formation Reaction
ΔH$_f$ - Appendix 2
Single Replacement
Reactions
Oxidation-reduction
Compounds
Chemical Formula
Subscripts
Molar Mass
Elemental Analysis
% Composition
Properties
Double Replacement
Reactions
Combustion
Reaction
Activity Series
Acid-Base
pH


Light and Color
Structure of Atom
Electrons
Valence Electrons
Bonding
Molecular Structure
Shape
Properties:
Polarity
Solubility
b.p. and m.p.
States of Matter
IM forces

Bubbles = CO_2 (g)

http://casualkitchen.blogspot.com/2010/12/why-davis-baking-powder-put-in-stealth.html

BAKING POWDER contains:

Baking soda:

$NaHCO_3$ + acid --> CO_2 (g)
+ other products

Acid:

$3\ Ca(H_2PO_4)_2 \rightarrow Ca_3(PO_4)_2 + 3\ HPO_4^{2-} + H_2PO_4^{-} + 7\ H^+$

$NaAl(SO_4)_2 + 3\ H_2O \rightarrow Al(OH)_3 + Na^+ + 2\ SO_4^{2-} + 3\ H^+$

Can you use just *baking soda*?

An acid (like buttermilk) is needed to react with baking soda, but

$NaHCO_3$ + heat ---> Na_2CO_3 + CO_2 (g)

What makes the bubble bigger? See temperature (gas laws)

(From Fall 2010 Final Exam) Concentrated sulfuric acid (18 M, density = 1.84 g/ml) is used in new car batteries. As a car battery gets discharged, the acid reacts with the lead metal plates leaving the acid less concentrated and dense. You don't have a hydrometer (a device that measures the density of a liquid) to measure the density of the acid; however, you can titrate the acid with NaOH and relate the concentration to density.

a. Write a balanced chemical equation that represents the reaction of lead with sulfuric acid. (Hint: activity series)

b. Describe how you would make 400 ml of 2.5 M NaOH solution from solid NaOH. Calculate the mass of NaOH that you need to prepare this solution.

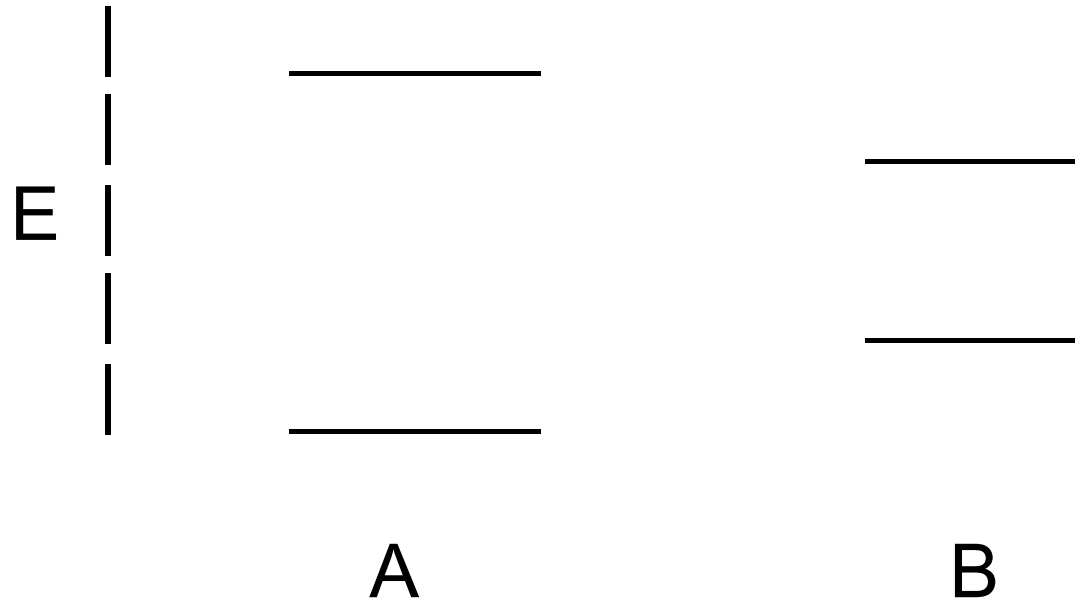
c. You standardized your NaOH solution with _____ and stopped adding NaOH, which was contained in a _____, when the solution turned _____ due to the addition of a few drops of _____. Your titration results for your three runs are 2.55 M, 2.41 M, and 2.62 M. Fill in the blanks. Comment on the accuracy and precision of this standardization. Calculate the % error or % difference or both from these results.

d. 98.25 ml of your NaOH solution from part c is used to titrate 10.00 ml of battery acid. Calculate the concentration of the battery acid. Then, calculate the pH of this battery acid solution.

e. Do you think your battery needs to be replaced based on your results? Give reasons.

(From Fall 2010 Final Exam)
In Lab 9, you heated up water in a flask, put a rubber stopper on the flask, removed it from the heating source, and rubbed ice on the outside walls of the flask. The water boiled.
a. Explain why water boils. Discuss what happens to the pressure, temperature, and volume in the flask. What diagram helps you support your explanation?
b. Right after you did this demonstration, the stopper was hard to remove from the flask. Explain why.
c. What could you have done to make the stopper easier to remove from the flask?

Two simple energy level diagrams, A and B, are shown below. Which diagram represents red food coloring? Give reasons.



You are fixing your car and get grease all over your hands. Grease is a high molecular weight, non-polar substance. You have the following substances at your disposal to clean your hands: water, alcohol (ethanol: C_2H_5OH), gasoline (octane: C_8H_{18}), ammonia, hydrochloric acid, and salt (sodium chloride).

a. Identify the ionic compounds. Give reasons.

b. For each compound, do the following:

(i) draw the Lewis structure.

(ii) Determine the molecular geometry. If the molecule has more than one central atom, circle one of the central atoms and determine the molecular geometry at that central atom.

(iii) Determine the polarity.

(iv) Specify the intermolecular forces that exist in this substance.

c. Using your knowledge of solubility, liquid properties, and intermolecular forces, which substance would you use to clean your hands? Choose <u>one</u> substance only. Give reasons for your choice.

While half asleep in the morning, you accidentally mix sugar (sucrose, $C_{12}H_{22}O_{11}$) with baking soda ($NaHCO_3$). You wonder how you are going to sweeten your coffee.

a. Which compound, sugar or baking soda, is harder? Give reasons.

b. Sugar is dissolved in a cup of water. Baking soda is dissolved in a different cup of water. Which solution has a higher conductivity? Give reasons. Which solution has the higher pH? Give reasons.

c. Describe how you would separate the sugar/baking soda mixture. State the property you would use to accomplish the separation.

Experiments show that burning steel wool (Fe) results in an increase in the mass in the solid remains whereas burning a wood splint results in a decrease in the mass of the solid remains. Burning implies that oxygen is a reactant in these reactions. A well-read, non-science person says, "These experiments show that the law of conservation of mass is violated!" Note: wood consists of C, H, and O and burns in air to produce CO_2 and water.

a. Write a balanced chemical equation that represents burning steel wool.

b. Did this person make a valid conclusion? Give reasons to support your answer.

c. What information would you need to show and conclude that the law of conservation of mass is obeyed in these experiments?

d. Chemical reactions go in a “downhill” direction, i.e., less stable reactants form more stable products. Compare iron metal to rust. Which substance is more stable? Give reasons. Draw a reaction energy diagram to support your answer.

Aluminum metal is produced by dipping an electrode in molten aluminum ore (cryolite, $Na_xAl_yF_6$) and passing a direct current through it (World of Chem video on The Electron).

a. Determine the subscripts x and y in $Na_xAl_yF_6$.

b. The molten aluminum ore is at a temperature of 1000^oC. We discussed four types of solids in class. What type of solid would you use to contain the molten aluminum ore? Give reasons.

c. When Al metal is produced from cryolite, what is the oxidizing agent? What is the reducing agent? Give reasons.

d. Calculate the % composition by mass of Na, Al, and F in cryolite.

Ethanol, C_2H_5OH, is used as a fuel additive to oxygenate gasoline. The main component of gasoline is octane, C_8H_{18}. E-15 gasoline is a blend of 85% gasoline and 15% ethanol. E-85 is 85% ethanol and 15% gasoline and is used in flex fuel vehicles.

(i) Draw the Lewis structure of ethanol and octane. Determine the polarity of each substance.

(ii) Is ethanol soluble in octane? If not, how is ethanol blended with gasoline to make a single phase fuel mixture? Cite the reference where you found this information.

(iii) Does ethanol have a higher boiling point or lower boiling point than octane? Give reasons in terms of intermolecular forces.

(iv) Ethanol is used to "oxygenate" fuel. What does it mean to oxygenate fuel? Cite the reference where you found this information.

(v) According to zfacts.com (http://zfacts.com/p/436.html), it takes about 3 gallons of ethanol to drive as far as with 2 gallons of gasoline (assume gasoline is octane, C_8H_{18}). Prove or refute this statement.