Objective 14: States of matter - liquids and solids: relate liquid and solid types to chemical forces and properties. Use phase diagrams.

Quiz Practice problems:

Key ideas:

Valence electrons --> Structure --> Shape --> Polarity --> IM forces --> Properties

Liquids – intermolecular forces (London, dipole-dipole, and hydrogen bonds) determine the properties (boiling point, viscosity, surface tension) of a liquid.

Example: Explain why H_2O has a higher b.p. than H_2S.

Answer: draw structure of each molecule, determine shape, polarity, and IM forces.

bent	bent
polar	polar
London	London
dipole-dipole	dipole-dipole
H bonds	

Water has stronger IM forces than H_2S so more energy is needed to break the IM forces ==> higher boiling point.

Solids types: molecular solids, ionic solids, covalent network solids, and metallic solids.

Different chemical forces exist between each solid type:

Intermolecular forces in molecular solids,

ionic bonds in ionic solids,

covalent bonds in covalent network solids, and

metallic bonds in metallic solids.

The chemical forces determine the properties of each solid type.

Skills: Identify the intermolecular forces in a liquid.

Relate intermolecular forces to liquid properties.

Given a solid, identify solid type.

Identify chemical forces in a solid.

Relate chemical forces to solid properties.

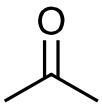
1. Viscosity is the internal resistance to flow in a liquid (also called the shear stress).

a. Explain why H_2O has a higher viscosity than acetone. Look up the structure of acetone.

b. Motor oil consists of large non-polar hydrocarbons (C_{19} to C_{35}, e.g., $C_{20}H_{42}$). Explain why oil has a higher viscosity than water using your knowledge of bonding, structure, and properties. Hint: London forces are proportional to the size of a molecule.

Answers:

a.

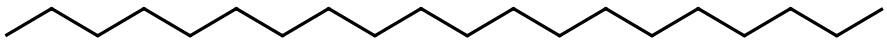
Acetone 

H_2O has London, dipole-dipole forces, and hydrogen bonds. Acetone has London and dipole-dipole forces.

Stronger IM forces between H_2O than acetone.

Viscosity depends on IM forces so water has a higher viscosity than acetone.

b. motor oil = $C_{20}H_{42}$



H_2O has London, dipole-dipole forces, and hydrogen bonds. Motor oil is non-polar so London forces only.

But motor oil is a much larger molecule than water.

London forces α size so the IM forces between motor oil molecules is greater than water ==> motor oil has a higher viscosity than water.

2. a. 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 why this happens.

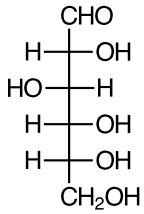
b. The tallest living tree today, at 370 feet tall, is the Mendocino Tree, a coast redwood tree near Ukiah, CA. The exact process by which water is taken up by plants against the force of gravity is not fully known (see http://interactive.usask.ca/ski/forestry/activities/lesson_waterworks.html) One way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

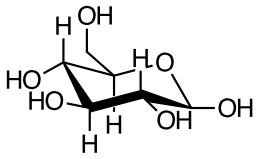
(i) What is capillary action?

(ii) What chemical forces determine capillary action?
(iii) If trees used hexane instead of water, would trees grow as high?
c. 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.
Answers:
a. Water has strong IM forces. Strong IM forces mean high surface tension that allow a bug to float on water.
Adding soap to water breaks some of the hydrogen bonds between water molecules and lowers the surface tension so bug sinks.
b. (i) Capillary action is the movement of liquid through thin tubes ("wicking" action).
Example: water in a straw. Water creeps up the sides of the straw because water is more attracted to the straw than to itself. You will see a convex meniscus.
(ii) Intermolecular forces.
(iii) No. Hexane is non-polar so only London forces exist between hexane molecules. Hexane is not attracted to the "capillaries" in trees so hexane can't get to top of trees.
c. Water is attracted to the ethanol. Hydrogen bonds form between water and ethanol so volume of the mixture is less than the volumes of the individual liquids.

Solids
Solids are classified into 4 types: molecular solids, ionic solids, covalent network solids, and metallic solids.
Each solid type is held together by different chemical forces.
The chemical forces determine the properties (melting point, hardness, conductor or insulator) of a solid.

1. Two common solids are sugar (glucose) and salt.
a. Gucose is $C_6H_{12}O_6$. What type of solid is glucose? What intermolecular forces exist between two glucose molecules?
b. Salt is NaCl. What type of solid is salt? What chemical force exists between two salt compounds?
c. Salt has a melting point of 800°C. Gucose has a melting point of 150°C. Explain why salt has a higher melting point that glucose based on chemical forces.
Answers:
a. Glucose is a molecular solid.
Intermolecular forces between two glucose molecules are London, dipole-dipole forces, and hydrogen bonds.



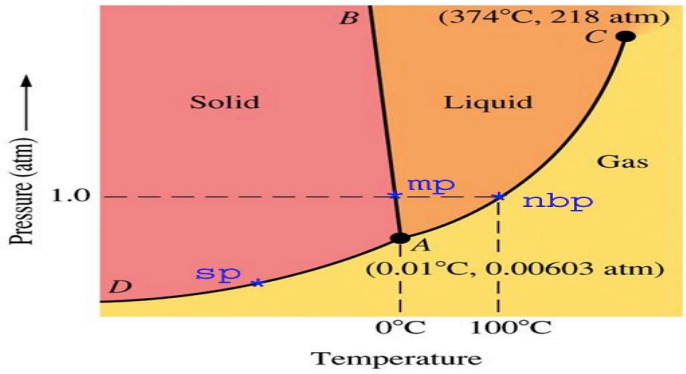


b. NaCl is an ionic solid.
Chemical force = ionic bonds between Na^+ and Cl^- ions.
c. When a solid melts, the chemical forces between atoms or molecules or ions have to break for the atoms or molecules or ions to move farther apart to phase change to a liquid.
Salt has a higher melting point that glucose because ionic bonds are much stronger than IM forces.

2. a. Your ceramic coffee cup is an ionic solid. Ionic solids are hard but brittle. Explain why ionic solids are hard but brittle.
b. You measure the properties of a solid. This solid conducts heat, is malleable (can be formed into shapes), and has a relatively high melting point. What type of solid do you have?
Answers:
a. Ionic solids are hard because the ions are held rigidly in place by ionic bonds.
Ionic solids are brittle because a strong force breaks the ionic bond between ions ==> ionic solid cracks and breaks.
b. This solid conducts heat, is malleable (can be formed into shapes), and has a relatively high melting point. These properties describe a metallic solid.

3. A Phase diagram of a substance tells you the temperature and pressure conditions for the different states of matter of the substance and the melting points and boiling points at different pressures.
See the phase diagram of water in the textbook.
a. 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.
b. At high altitudes, e.g., Lake Tahoe, certain foods take longer to cook than at sea level, e.g., Salinas. Explain why.
c. A pressure cooker cooks certain foods much faster. Explain how a pressure cooker works.
Answers:

a. The solid line between the solid and liquid phases represents the freezing/melting point.
As P increases, the melting point decreases.
So the skate applies high P on the ice and melts the cold ice so the skater glides smoothly across the ice.



b. The solid line between the liquid and gas phases represents the boiling point.
As P decreases, the boiling point decreases.
So food takes longer to cook in Lake Tahoe because it is cooking at a lower T.
c. The solid line between the liquid and gas phases represents the boiling point.
As P increases, the boiling point increases.
So food cook faster in a pressure cooker because it is cooking at a higher T.

4. 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 blacks. 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.
Answers:
a. Pressure difference (P = 1 atm in lungs, P = 0 atm in space) forces air out of lungs. See exhalation process.
b. No exploding eyeballs or embolisms because there are small pores (holes) in our eyes and veins so gases can pass through.
c. Spit on your tongue and sweat on your body would boil away because as P decreases, the boiling point of water decreases. See phase diagram of water.