**Intermolecular Forces and States of Matter** Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

*AP Chemistry Lecture Outline*

Chemical properties are related only to chemical composition; physical properties are related to chemical composition AND the physical state of the substance at the time.

intermolecular forces (IMFs):

-- largely determine the physical properties of molecular liquids and solids

STRENGTH OF IMFs…

GASES LIQUIDS SOLIDS

**Intermolecular Forces (IMFs)**

-- these are much weaker than ionic or covalent bonds

-- In vaporizing water, we overcome the IMFs between water molecules, but...

State of matter is determined by two opposing influences.

If KE of particles is… and IMFs are… then the state of matter is…

SOLID

LIQUID

GAS

Temp. affects… Pres. affects…

-- BP and FP/MP depend on IMFs

strong IMFs 🡪

weak IMFs 🡪

**Types of IMFs**

When ions are present: ion-dipole forces

For neutral molecules: dipole-dipole forces

electrostatic

forces

London dispersion forces

hydrogen bonding forces

Ion-Dipole Forces (IDFs)

-- exist between an ion and a partial charge on the end of a polar molecule

-- important for...

Dipole-Dipole Forces (DDFs)

-- exist between neutral polar molecules that are close together

--

-- as dipole moment  (i.e., the polarity) increases...

London Dispersion Forces (LDFs)

-- exist between all molecules, but are the ONLY forces between nonpolar molecules that

are close together

--

-- polarizability: the ease with which the charge distribution in a molecule can be distorted

by an external magnetic field

--

Hydrogen Bonding Forces (HBFs)

--

-- exist between a hydrogen atom in a polar bond and an unshared electron pair on a

nearby, small, highly electronegative ion or atom

--

-- important in structures of proteins and DNA

**Some Properties of Liquids**

viscosity: a liquid’s resistance to flow

-- high viscosity =

-- depends on IMFs

--

Molecules on a liquid’s surface experience a net inward force

--

surface tension: the energy required to increase a liquid’s surface area by 1 m2

--

--

cohesive forces: IMFs that bind...

adhesive forces: IMFs that bind...

--

capillary action: the rise of liquids up narrow tubes

-- adhesion “\_\_\_\_\_\_\_\_\_\_” the liquid, while cohesion…

**Phase Changes** (i.e., changes of state)

--

-- energy changes required are related to IMFs

heat of fusion (cf): energy per “something” required to melt a substance

-- also called...

heat of vaporization (cv): energy per “something” required to boil a substance

How do magnitudes of cv cf compare?

-- specific heat capacity: energy req’d to change temp. of 1 \_\_\_ of a substance 1oC (or 1 K)

-- molar heat capacity: energy req’d to change temp. of 1 \_\_\_ of a substance 1oC (or 1 K)

Heating curves are graphs of temperature v. heat added (or heat removed).

Temp.

Heat Added or Removed

Typical Heating Curve

for a Pure Substance

EX. Find the enthalpy change when 82.4 g of ice at –13.5oC

Phase Change Constants for Water

cp,ice = 2.077 J/g-K

cf = 333 J/g

cp,water = 4.18 J/g-K

cv = 2256 J/g

cp,wv = 2.042 J/g-K

turns to water at 72.8oC.

supercooling: temporarily cooling a liquid below its freezing point without it forming a solid

--

critical temperature: the highest temperature at which a substance can be a liquid

-- as IMFs increase, crit. temp…

critical pressure: the pressure required to bring about liquefaction at the critical temp.

A substance’s vapor pressure is the pressure exerted by a vapor in dynamic equilibrium with its liquid or solid phase.

-- as IMFs increase, VP...

-- as temperature increases, VP...

-- liquids that evaporate easily are said to be \_\_\_\_\_\_\_\_\_\_\_\_

-- boiling occurs when...VP =

-- normal boiling point (NBP): the boiling temp. of a liquid at 1 atm of pres.

**Phase Diagrams**

-- graphs showing the conditions under which equilibria exist between different

states of matter

T

P

SOLID

LIQUID

GAS

1 atm

**Phase Diagram for**

**a Typical Substance**

Water is NOT a typical substance. Its phase diagram differs slightly, as shown below.

T

P

SOLID

LIQUID

GAS

1 atm

**Phase Diagram**

**for Water**

supercritical fluid: how we describe a substance at or beyond its critical point

**Structures of Solids**

amorphous solid: the particles have no orderly structure

-- e.g.,

-- IMFs are highly variable, so these solids have no specific…

crystalline solid: the particles are in well-defined arrangements

-- e.g.,

--

crystal lattice: a 3-D array of points showing the crystal’s structure

unit cells: the repeating units of a crystalline solid

primitive (or simple) cubic body-centered cubic face-centered cubic

A

o

EX. Gold exhibits a face-centered cubic unit cell that is 4.08 on a side.

Estimate gold’s density, in g/cm3.

Roughly equal-sized spheres, such as those in metallic solids, are arranged in one of several configurations. These configurations are collectively called the close packing of spheres.

-- In a given layer, the atoms are arranged such that each atom in that

layer is surrounded by six others. This is called a...

|  |  |  |
| --- | --- | --- |
| **Layer Number** | **close-packed**  **layer position** | **close-packed**  **layer position** |
| 4 (top) | ------ B | ------ A |
| 3 | ------ A | ------- C |
| 2 | ------ B | ------ B |
| 1 (bottom) | ------ A | ------ A |
| Name of Pattern | **hexagonal**  **close packing** | **cubic**  **close packing** |

\*\* Cubic close packing is equivalent to the face-centered cubic unit cell.

The coordination number for a packing pattern is equal to the number of equidistant,

**nearest** neighbors for any atom within the matrix.

-- for particular packing arrangements:

HCP: CCP/FCC: BCC: P/SC:

For unequal-sized spheres, sometimes the larger spheres assume a close-packed

arrangement, and then the smaller particles fit into the spaces in between.

**Bonding in Solids**

In molecular solids, the particles are held together by IMFs.

--

**benzene**

**toluene**

**phenol**

OH

CH3

MP (oC)

Why?

80

111

182

43

–95\*

5

BP (oC)

In covalent-network solids, particles are held together in large networks by covalent bonds.

-- e.g., diamond, graphite

--

NOTE: Graphite has layers of covalently-bonded C atoms w/delocalized,  e–s (similar to

benzene). Therefore, graphite is a...

The layers are held to each other by…

Ionic solids consist of ions held together by ionic bonds.

-- MPs depend largely on magnitude of charges.

-- e.g., MP of KCl = \_\_\_\_\_\_; MP of CaO = \_\_\_\_\_\_ 🡪

Metallic solids consist entirely of metal atoms.

-- these have HCP, CCP/FCC, or BCC structures, w/each atom touching 8 or 12 others

-- bonding is due to delocalized valence e– that are free to move throughout solid

\*\*

-- metallic bond strength increases w/# of v. e–

e.g. MP of Li = \_\_\_\_\_\_; MP of Fe = \_\_\_\_\_\_