Chapter 11

Intermolecular Forces, Liquids, and Solids

Chapter 11 suggested problems
10th Ed.: 9, 11, 15, 17, 19, 23, 25, 39, 45, 55, 79, 85, 88

Class Notes

I. A molecular comparison of gases, liquids, and solids

   A. Gases: no fixed volume or shape, particles far apart and do not interact; compressible

   B. Liquids: fixed volume, no fixed shape, particles close together and interact weakly; non-compressible

   C. Solids: fixed volume and shape, particles very close together and do interact strongly; non-compressible

   D. Gases and liquids are fluids - flowable and pourable

   E. Solids and liquids are referred to as condensed phases since there is little space between the particles at a molecular level and it is difficult to force the particles closer together

   F. Solids can be fluidized but remain solids at a molecular level

II. Intermolecular forces

   A. The distinction between intramolecular forces and intermolecular forces

   B. Forces between molecules are based on electrostatic interactions, just as the forces between atoms within a molecule are based on electrostatic attractions

      1. Hooke's law

C. In general these forces are 1-2 orders of magnitude weaker than ionic and covalent bonds

D. London forces (dispersion forces, induced dipole-induced dipole interactions)

1. The result of instantaneous dipoles inducing dipole moments in adjacent molecules and the propagation of this phenomena
2. Generally very weak, but can become significant in large and polarizable molecules (electron cloud is distorted)
3. Present between all molecules in all substances in the liquid and solid states

E. Dipole-dipole interactions

1. Caused by the alignment of polar molecules with respect to one another
2. The greater the dipole moment, the stronger the interactions (i.e., more polar molecules bond more strongly)
3. A strong (relatively speaking) intermolecular force
4. Can *only* occur in polar substances (i.e. substances with polar molecules)

F. Hydrogen bonds

1. Special case of dipole-dipole interaction
2. Occur when H is bonded to N, O, F
3. Due to large EN between hydrogen and N, O, F
4. The polarity of the X-H bond results in a particularly strong dipole-dipole interaction
5. Can be up to 10% as strong as covalent bonds
6. Responsible for numerous "aberrations" in chemistry
7. Some substances are capable of forming multiple H-bonds (e.g. diols)
8. Are only found *between* molecules, *never* within molecules - unless they are very large molecules such nucleic acid strands, proteins, etc.

G. van der Waals forces: (vdW interactions) the generic name for London forces, dipole-induced dipole interactions, dipole-dipole interactions, and hydrogen bonds

H. Ion-dipole interactions are the interactions that occur between ions and polar molecules; stronger than hydrogen bonds

I. Explain the following data:

substance	BP (°C)	solubility	substance	BP (°C)	solubility
methane	-162	no	methanol	65	yes
ethane	-89	no	ethanol	78	yes
propane	-42	no	1-propanol	97	yes
butane	-1	no	1-butanol	117	moderate
pentane	36	no	1-pentanol	138	slight
hexane	69	no	1-hexanol	158	no

J. Intermolecular forces are found in all substances, atomic and molecular. Predict the types of IM forces found in liquid:

1. Argon
2. Nitrogen
3. Iso-octane
4. Acetone
5. Acetic acid
6. Ethylene glycol

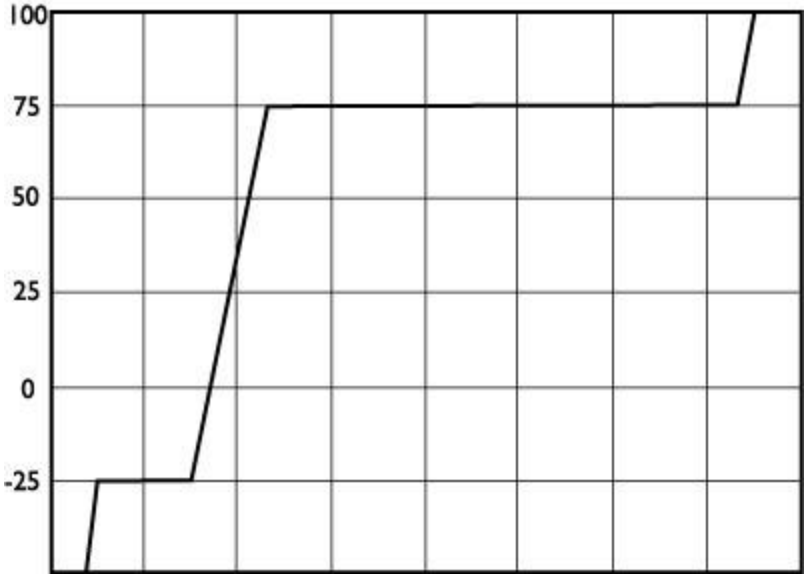
K. Viscosity and surface tension are the result of intermolecular forces

III. Phase changes

A. Types of phase changes and related phenomena

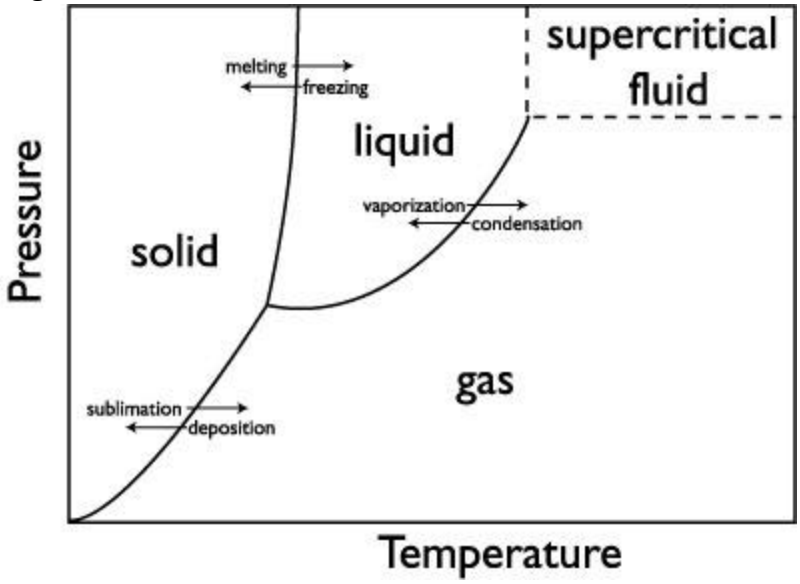
1. Melting, boiling, sublimation, condensation, freezing, deposition
2. Vapor pressure: in an equilibrium system of liquid and vapor, the partial pressure of vapor over the liquid
3. Normal boiling point: the temperature at which the VP of a liquid is equal to atmospheric pressure
4. Normal freezing point: the temperature at which the l-s transition occurs at atmospheric pressure

B. Enthalpy of transition and heat curves



1. Different specific heats ((J/g•K): ice - 2.092, water - 4.184, steam - 1.841) result in different slopes

C. Phase diagrams



1. Melting point curve
2. Vapor pressure curve
3. Triple point
4. Critical point

IV. Types and structures of solids

A. Metallic - "electron sea" model

B. Ionic - 3-D network of ionic bonds, the actual type of bond in many crystalline

solids of ionic compounds

C. Covalent (covalent network) - 3-D network of covalent bonds; as in diamond, graphite, silicon dioxide, etc.

D. Molecular - the result of van der Waals forces

E. MP and BP are a function of the strength of the IM forces in the substance

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