

CHAPTER 11  
STATES OF MATTER AND INTERMOLECULAR FORCES

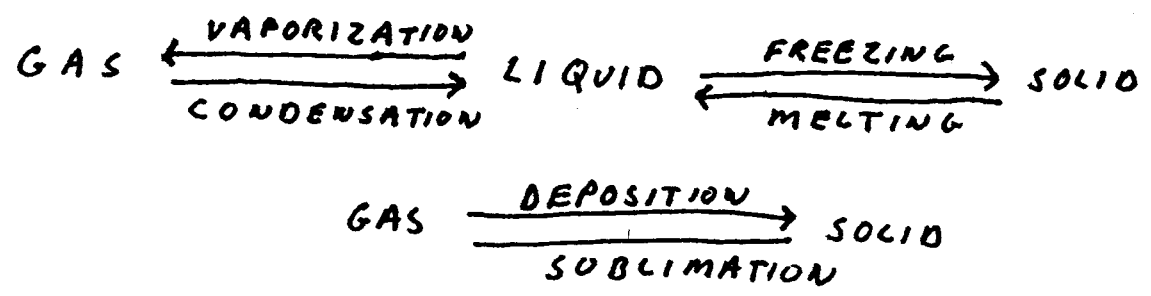
THE 3 STATES OF MATTER

GAS - FAST, ENERGETIC MOLECULES, NEARLY NO INTERMOLECULAR FORCES, NEITHER FIXED VOLUME OR SHAPE, COMPRESSIBLE

LIQUID - MOLECULES ARE CLOSE TOGETHER, INTERMOLECULAR FORCES STRONG ENOUGH TO HOLD A FIXED VOLUME, BUT WEAK ENOUGH TO ALLOW FLOW INTO ANY SHAPE

SOLID - MOLECULES IN DIRECT CONTACT, STRONG INTERMOLECULAR FORCES FIX SHAPE AND VOLUME. HARD TO COMPRESS

PHASE CHANGES

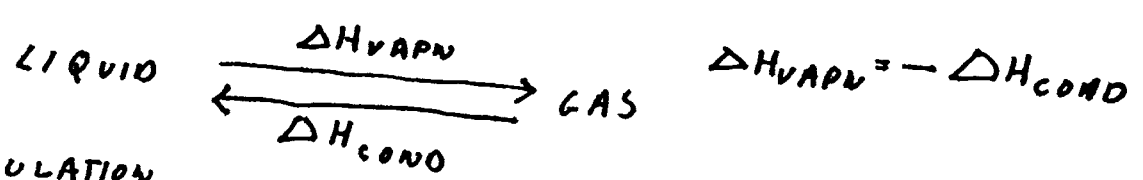


VAPORIZATION

WHEN HEATED, A LIQUID GAINS ENOUGH KINETIC ENERGY TO BOIL, OR VAPORIZE.  $\Delta H_{\text{VAPN}}$  = HEAT OF VAPORIZATION

$\Delta H_{\text{VAPN}}$  IS DIFFERENT FOR EACH TYPE OF MOLECULE.

MOLECULES WITH STRONG INTERMOLECULAR FORCES REQUIRE MORE ENERGY TO BREAK FREE OF THE LIQUID STATE



EXAMPLE CALCULATION

HOW MANY KJ DOES IT TAKE TO BOIL (VAPORIZE) 1 L OF H<sub>2</sub>O?  
 $\Delta H_{\text{VAPN}} = 44.0 \text{ KJ/mol}$  FOR H<sub>2</sub>O

$$\frac{1000 \text{ g}}{18 \text{ g/mol}} = 55.5 \text{ mol H}_2\text{O} \times 44.0 \text{ kJ/mol} = 2,442 \text{ kJ}$$

## VAPOR PRESSURE

DEFINED AS THE PARTIAL PRESSURE OF A LIQUID'S VAPOR WHEN LIQUID AND VAPOR ARE IN EQUILIBRIUM

THE VAPOR PRESSURE OF A LIQUID IS TEMPERATURE DEPENDENT

EXAMPLE CALCULATION USING THE IDEAL GAS LAW

AT  $50^\circ\text{C}$ , THE VAPOR OVER A LIQUID  $\text{H}_2\text{O}$  SAMPLE CONTAINS  $0.076 \text{ g H}_2\text{O}$  PER LITER. WHAT IS THE VAPOR PRESSURE OF  $\text{H}_2\text{O}$  AT  $50^\circ\text{C}$ ?

$$PV = nRT \quad P = \frac{nRT}{V}$$

$$\frac{0.076 \text{ g}}{18 \text{ g/mol}} = .0042 \text{ mol}$$

$$P = \frac{.0042 \text{ mol} \times .0821 \frac{\text{L} \cdot \text{ATM}}{\text{MOL} \cdot ^\circ\text{K}} \times 348^\circ\text{K}}{1.0 \text{ L}}$$

$$P = 0.12 \text{ ATM}$$

## BOILING POINT

VAPORIZATION OCCURS NOT ONLY AT THE SURFACE, BUT THROUGHOUT THE LIQUID

THE NORMAL B.P. IS WHEN THE PRESSURE =  $1.0 \text{ ATM}$

## THE CRITICAL POINT

HEATING A LIQUID IN A CLOSED CONTAINER PREVENTS BOILING BECAUSE THE PRESSURE KEEPS BUILDING

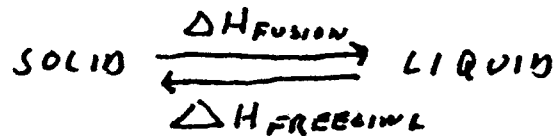
EVENTUALLY THE VAPOR DENSITY INCREASES TO THE POINT WHERE LIQUID AND VAPOR ARE INDISTINGUISHABLE

THIS IS THE CRITICAL POINT, THE CRITICAL TEMP, THE CRITICAL PRESSURE ABOVE THIS POINT A SUPERCRITICAL FLUID EXISTS

## PHASE CHANGES IN SOLIDS

IN A SOLID, ATOMS OR MOLECULES HAVE VIBRATIONAL ENERGY. THEY VIBRATE AROUND A FIXED POSITION.

AS TEMPERATURE INCREASES, VIBRATIONS BECOME STRONGER UNTIL THEY ARE STRONG ENOUGH TO BREAK THE INTERMOLECULAR FORCES. THIS IS MELTING, OR FUSION

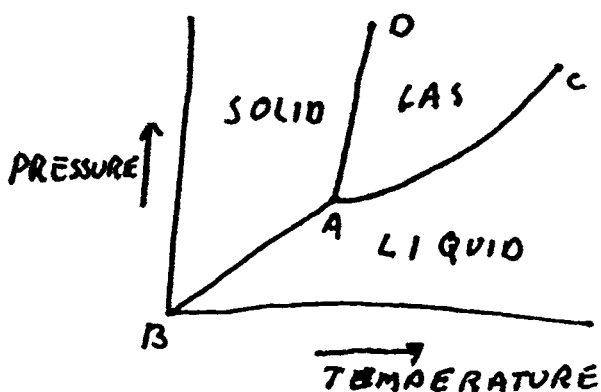


A SOLID MAY TRANSITION DIRECTLY TO A GAS. THIS IS SUBLIMATION

$$\Delta H_{\text{SUBLIM}} = \Delta H_{\text{FUSION}} + \Delta H_{\text{VAPOR}} \quad (\text{BY HESS'S LAW})$$

THE TRIPLE POINT IS THAT POINT ON A PHASE DIAGRAM WHERE SOLID, LIQUID AND GAS CAN COEXIST.

A PHASE DIAGRAM REPRESENTS TEMPERATURE AND PRESSURE CONDITIONS AT WHICH EACH PHASE EXISTS



- A IS THE TRIPLE POINT
- A-D IS THE FUSION CURVE
- A-B IS THE SUBLIMATION CURVE
- A-C IS THE VAPOR PRESSURE CURVE
- C IS THE CRITICAL POINT

## INTERMOLECULAR FORCES

- ARE ELECTROSTATIC - THE + IS ATTRACTED TO THE -
- ARE ALL DIPOLAR - A DIPOLE HAS A + END AND A - END
- DIPOLES MAY BE VERY SMALL AND TEMPORARY
- OR LARGE AND PERMANENT



# SOLID STRUCTURE

## NETWORK COVALENT SOLIDS

THE ALLOTROPES OF CARBON - DIAMOND, GRAPHITE, BUCKYBALLS AND NANOTUBES

## THE STRUCTURE OF CRYSTALS

A REGULAR ARRAY OF IONS HELD TOGETHER BY ELECTROSTATIC ATTRACTIONS

THE ATTRACTIVE FORCE BETWEEN A CATION AND AN ANION INCREASES AS THE CHARGES INCREASE AND AS THE IONIC RADII DECREASE. LATTICE ENERGIES INCREASE ACCORDINGLY

COMPARE  $MgO$ ,  $NaCl$ ,  $Al_2O_3$

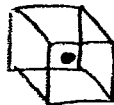
UNIT CELLS - THE SMALLEST REPEATING UNIT IN A CRYSTAL



SIMPLE CUBIC  
EIGHT ATOMS  
AT THE CORNERS  
OF A CUBE

52.4%  
FULL

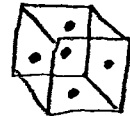
1 ATOM TOTAL



BODY-CENTERED  
ADD 1 ATOM  
IN THE CENTER  
OF THE CUBE

68% FULL

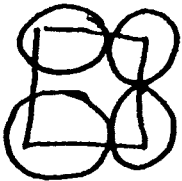
2 ATOMS TOTAL



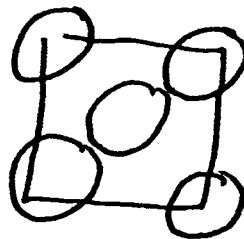
FACE CENTERED  
EACH FACE  
HAS AN ATOM

74% FULL

ONLY IN THE SIMPLE CUBIC DO CORNER ATOMS TOUCH



IN BCC  
CONTACT  
ALONG  
A BODY  
DIAGONAL



IN FCC  
CONTACT  
ALONG A  
FACE DIAGONAL

## IONIC STRUCTURES

DEPEND ON THE RATIO OF RADII  $R_c/R_a$

$R_c/R_a$  FROM 0.225 TO 0.414 → TETRAHEDRAL

0.414 TO 0.732 → OCTAHEDRAL

> 0.732 → CUBIC

## CHAPTER 11

### SKILLS

HEATS OF VAPORIZATION

WORK WITH VAPORIZATION,  
IDEAL GAS LAW

DO CALCULATIONS AT PHASE  
CHANGES

USE PHASE DIAGRAMS

INTERMOLECULAR FORCES

CRYSTAL STRUCTURES

NOT COVERED

SURFACE TENSION

### PROBLEMS

EX 1.1, 27, 29

EX 11.3, 37, 39

EXERCISE 11.5, 47  
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EX 11.5, 53

EX 11.6, EX 11.7  
59, 61, 63

EX 11.8, EX 11.9  
73, 75