

GENERAL CHEMISTRY LECTURE NOTES © 2007 MM

CHAPTER 5 GASES

MATTER EXISTS IN THREE STATES: SOLID, LIQUID, AND GAS
FOR EXAMPLE: WATER ICE, WATER, WATER VAPOR

IN EACH STATE, THIS IS STILL WATER

CHANGES IN STATE ARE PHYSICAL CHANGES

THE STATE OF MATTER DEPENDS ON TEMPERATURE + PRESSURE

THE KINETIC-MOLECULAR THEORY

- 1) MATTER IS COMPOSED OF TINY PARTICLES CALLED MOLECULES
- 2) THE PARTICLES ARE IN CONSTANT MOTION THEREFORE THEY HAVE KINETIC ENERGY
- 3) PARTICLE SPEED INCREASES AS TEMPERATURE INCREASES. KINETIC ENERGY ALSO INCREASES
- 4) PARTICLES TRANSFER ENERGY FROM ONE TO ANOTHER DURING COLLISIONS
- 5) ATTRACTIVE FORCES BETWEEN PARTICLES TEND TO HOLD THEM TOGETHER

KINETIC ENERGY

THE ENERGY A PARTICLE HAS AS A RESULT OF ITS MOTION

KINETIC ENERGY IS PROPORTIONAL TO MASS AND TO THE

SQUARE OF VELOCITY

$$KE = \frac{1}{2} MV^2$$

M = MASS

V = VELOCITY

THE GAS STATE

IN THE GAS STATE MOLECULES HAVE VERY LITTLE ATTRACTIVE FORCE BETWEEN THEM. THE MOLECULES ARE USUALLY SMALL. THEY HAVE LOTS OF KINETIC ENERGY AND VERY HIGH VELOCITIES.

GAS MOLECULES COLLIDE FREQUENTLY, WITH EACH OTHER AND WITH THE WALLS OF THEIR CONTAINER

CHARACTERISTICS OF GASES INCLUDE:

LOW DENSITY - PARTICLES ARE FAR APART

INDEFINITE SHAPE - PARTICLES MOVE TO FILL THEIR CONTAINER

HIGH COMPRESSIBILITY - INCREASING PRESSURE MOVES THE PARTICLES CLOSER TOGETHER

LARGE THERMAL EXPANSION

- HIGHER TEMPERATURES GIVE THE PARTICLES MORE SPEED SO THEY PUSH EACH OTHER AWAY MORE STRONGLY.

IN A FIXED VOLUME, PRESSURE INCREASES

IN A VARIABLE VOLUME, VOLUME INCREASES

THE LIQUID STATE

LIQUID STATE MOLECULES ARE IN RANDOM MOTION, SLIDING FREELY OVER ONE ANOTHER.

THEY DO NOT HAVE SUFFICIENT KINETIC ENERGY TO SEPARATE FROM EACH OTHER

HIGH DENSITY - PARTICLES ARE CLOSE TOGETHER

INDEFINITE SHAPE - THEY FLOW TO FILL A CONTAINER

SMALL COMPRESSIBILITY - PARTICLES ARE ALREADY CLOSE

SMALL THERMAL EXPANSION - WARMING DOES NOT GIVE THE PARTICLES ENOUGH ENERGY TO SEPARATE

THE SOLID STATE

MOTION IS MINIMAL, STRONG COHESIVE FORCES KEEP PARTICLES IN RIGID POSITIONS

HIGH DENSITY - AS HIGH AS POSSIBLE

DEFINITE SHAPE - NO CONTAINER IS NEEDED

SMALL COMPRESSIBILITY - NO ROOM TO COMPRESS

VERY LITTLE THERMAL EXPANSION - PARTICLES ARE TOO TIGHTLY HELD

THE GAS LAWS

GASES BEHAVE SIMPLY AND PREDICTABLY

INCREASING THE PRESSURE ON A GAS COMPRESSES IT INTO A SMALLER VOLUME

MATHEMATICALLY $PV = k$ THIS IS BOYLE'S LAW

UNITS OF PRESSURE

1 ATMOSPHERE IS LITERALLY THE WEIGHT OF OUR ATMOSPHERE PRESSING DOWN ON US

1 ATM = 14.7 POUNDS PER SQUARE INCH (PSI)

1 ATM WILL SUPPORT A COLUMN OF LIQUID MERCURY 760 mm HIGH - IN A MERCURY BAROMETER

1 mm Hg = 1 TORR

1 ATM = 760 mm Hg = 760 TORR

USING PRESSURE

CONVERT 500 PSI TO mmHg, TORR AND ATM

$$500 \text{ PSI} \times \frac{1 \text{ ATM}}{14.7 \text{ PSI}} = 34.0 \text{ ATM}$$

$$34 \text{ ATM} \times \frac{760 \text{ mmHg}}{1 \text{ ATM}} = 2.58 \times 10^4 \text{ mmHg OR TORR}$$

UNITS OF TEMPERATURE

RECALL FROM CHAPTER 1 PG 15-17

DEGREES ARE THE SAME SIZE IN KELVIN AND CELCIUS

ONLY THE 0 POINT DIFFERS

0 FOR CELCIUS IS THE FREEZING/MELTING PT OF H₂O

0 FOR K IS ABSOLUTE ZERO, WHERE PARTICLES HAVE ZERO KINETIC ENERGY AND MOTION CEASES

ALL CALCULATIONS IN K

BUT, WE OFTEN MAKE MEASUREMENTS IN °C

TO CONVERT $K = C + 273$ SO, $37^\circ C = 310 K$

THE GAS LAWS

THE VARIABLES FOR A SAMPLE OF GAS IN A CONTAINER ARE:

PRESSURE $\rightarrow P$ (ATM, TORR)

VOLUME $\rightarrow V$ (L)

TEMPERATURE $\rightarrow T$ (K)

BOTH PRESSURE AND VOLUME INCREASE AS T INCREASES

THIS IS CALLED DIRECTLY PROPORTIONAL

$P = kT$ WHERE k IS THE PROPORTIONALITY CONSTANT

$$V = k'T$$

$$PV = k''T, \text{ SO } \frac{PV}{T} = k$$

NOTICE THAT P AND V ARE
INVERSELY PROPORTIONAL
FOR PROBLEM SOLVING

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

THE
COMBINED
GAS LAW

EXAMPLE

A SAMPLE OF GAS HAS A VOLUME OF 5.00 L AT
25.0°C AND 0.951 ATM

WHAT IS THE VOLUME AT 50°C AND 1.41 ATM

$$\frac{0.951 \text{ ATM} \times 5.00 \text{ L}}{298 \text{ K}} = \frac{1.41 \text{ ATM} \times V_2}{323 \text{ K}}$$

$$V_2 = \frac{323 \text{ K} \times 0.951 \text{ ATM} \times 5.00 \text{ L}}{298 \text{ K} \times 1.41 \text{ ATM}} = 3.66 \text{ L}$$

THE IDEAL GAS LAW

THE MAIN IDEA IS THAT EQUAL VOLUMES OF GAS CONTAIN EQUAL NUMBERS OF MOLECULES (T AND P BEING EQUAL)

THEREFORE, 1 MOLE OF ANY GAS FILLS THE SAME VOLUME

THIS IS TRUE AT ANY TEMPERATURE AND PRESSURE

WE PICK A STANDARD, TEMPERATURE AND PRESSURE CALLED STP 1.00 ATM AND 273 K (0°C)

AT STP, 1 MOLE OF ANY GAS OCCUPIES 22.4 L

THE IDEAL GAS LAW COMBINES THE P, V AND T RELATIONSHIPS

WITH $n = \text{number of moles}$
AND

$R = \text{THE GAS CONSTANT } 0.0821 \frac{\text{L} \cdot \text{ATM}}{\text{MOL} \cdot \text{K}}$

THE GAS CONSTANT CAN BE CALCULATED FROM THE EXPERIMENTAL FACT THAT 1 MOL (AT STP) = 22.4 L

THE IDEAL GAS LAW

$$PV = nRT$$

FOR 1 MOL

$$\underline{1.00 \text{ ATM} \times 22.4 \text{ L}} = \underset{\text{MOL}}{1} \times 273 \text{ K} \times R$$

$$R = \frac{1.00 \text{ ATM} \times 22.4 \text{ L}}{1.00 \text{ MOL} \times 273 \text{ K}} = 0.0821 \frac{\text{L} \cdot \text{ATM}}{\text{MOL} \cdot \text{K}}$$

R IS THE SAME FOR ALL GASES AT ANY S, T, OR V

IDEAL GAS LAW PROBLEMS

$$PV = nRT$$

WHAT IS THE VOLUME OF 0.413 MOL H_2 AT $20^\circ C$ AND 1.59 ATM?

$$PV = nRT \quad \text{so,} \quad V = \frac{nRT}{P}$$

$$V = 0.413 \text{ mol} \times 0.0821 \frac{\text{L} \cdot \text{ATM}}{\text{mol} \cdot \text{K}} \times 293 \text{ K} \times 1.59 \text{ ATM}$$

$$V = 6.29 \text{ L}$$

ANOTHER EXAMPLE

2.0 MOL OF O_2 GAS OCCUPIES 10.7 L AT $25^\circ C$.
WHAT PRESSURE DOES IT EXERT?

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

$$P = \frac{2.0 \text{ mol} \times 0.0821 \frac{\text{L} \cdot \text{ATM}}{\text{mol} \cdot \text{K}} \times 298 \text{ K}}{10.7 \text{ L}} \quad P = 4.6 \text{ ATM}$$

ANOTHER

A GAS OCCUPIES A VOLUME OF 44.8 L AT 298 K AND 1.7 ATM. HOW MANY MOLES OF GAS?

$$PV = nRT \quad \text{so} \quad n = \frac{PV}{RT}$$

$$n = \frac{1.7 \text{ ATM} \times 44.8 \text{ L}}{0.0821 \frac{\text{L} \cdot \text{ATM}}{\text{mol} \cdot \text{K}} \times 298 \text{ K}} \quad n = 3.11 \text{ mol}$$

THE IDEAL GAS LAW WAS ONE OF THE FIRST, AND MOST SUCCESSFUL METHODS FOR DETERMINING MOLECULAR WEIGHT.

IF THE MASS OF A SAMPLE IS MEASURED, AND n CALCULATED FROM $PV = nRT \dots$

1.43 g OF A GAS OCCUPIES 1.0 L AT STP. WHAT IS ITS MOLECULAR WEIGHT?

1) CALCULATE n FOR 1.0 L AT STP

$$n = \frac{PV}{RT} = \frac{1.00 \text{ ATM} \times 1.0 \text{ L}}{0.0821 \frac{\text{L} \cdot \text{ATM}}{\text{MOL} \cdot \text{K}} \times 273 \text{ K}} = \frac{1.0}{22.4} = 0.0446$$

$$1.43 \text{ g} = 0.0446 \text{ mol} \quad \text{so} \quad \frac{1.43 \text{ g}}{0.0446 \text{ mol}} = 32.06 \text{ g/mol}$$

DALTON'S LAW OF PARTIAL PRESSURE

THE PARTIAL PRESSURE OF ANY GAS IN A MIXTURE IS THE SAME AS THE PRESSURE IT WOULD EXERT IF IT WAS ALONE IN THE CONTAINER

DALTON'S LAW

THE TOTAL PRESSURE IN A CONTAINER IS EQUAL TO THE SUM OF THE PARTIAL PRESSURES

$$P_{\text{TOTAL}} = P_1 + P_2 + P_3$$

FOR EXAMPLE, OUR ATMOSPHERE IS ABOUT 70% N_2 , 21% O_2 SO, AT 1 ATM, THE pp OF $N_2 = 0.70 \text{ ATM}$ AND $pp O_2 = 0.21 \text{ ATM}$

A PARTIAL PRESSURE PROBLEM

THE TOTAL PRESSURE IN A DIVERS AIR TANK IS 100 ATM. THE PARTIAL PRESSURE OF N_2 IN THE TANK IS 69.5 ATM. THE PARTIAL PRESSURE OF ALL OTHER GASES, EXCEPT O_2 IS 9.0 ATM. WHAT IS THE PARTIAL PRESSURE OF O_2

$$P_{TOT} = P_1 + P_2 + P_3$$

$$100 = 69.5 + 9.0 + P_3$$

$$P_3 = 100 - (69.5 + 9.0)$$

$$P_3 = 100 - 78.5 = 21.5 \text{ ATM } O_2$$

CHANGES IN STATE

THE STATE OF MATTER IS USUALLY CHANGED BY HEATING OR COOLING

A CHANGE OF STATE THAT REQUIRES HEATING OR THE CONSUMPTION OF HEAT IS CALLED

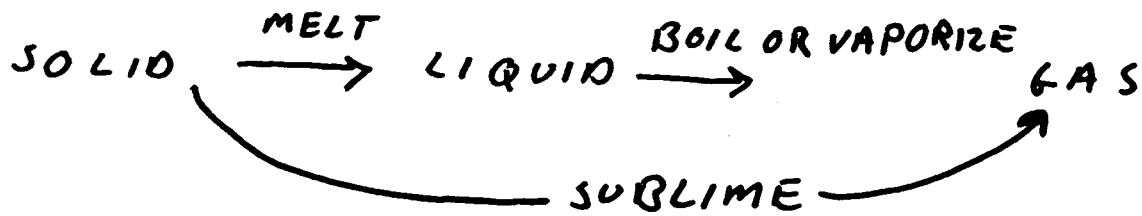
ENDOOTHERMIC

A CHANGE IN STATE THAT PRODUCES HEAT IS CALLED

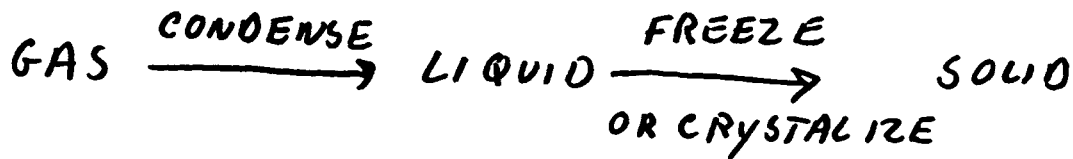
EXOTHERMIC

ENDOOTHERMIC CHANGES INVOLVE OVERCOMING COHESIVE FORCES BETWEEN PARTICLES, MOVING THE PARTICLES FARTHER APART

ENDOOTHERMIC CHANGES OF STATE



EXOTHERMIC CHANGES OCCUR WHEN PARTICLES GIVE UP ENERGY AND MOVE CLOSER TOGETHER



EVAPORATION AND VAPOR PRESSURE

EVAPORATION IS AN ENDOOTHERMIC PROCESS IN WHICH A LIQUID IS CHANGED INTO A GAS AS MOLECULES WITH ENOUGH ENERGY LEAVE THE LIQUID SURFACE ESCAPING INTO THE GAS STATE

IN A CLOSED CONTAINER, MOLECULES CAN'T ESCAPE AND A VAPOR PRESSURE BUILDS UP

AN EQUILIBRIUM DEVELOPS



VAPOR PRESSURE IS THE PRESSURE EXERTED BY A VAPOR OR GAS THAT IS IN EQUILIBRIUM WITH ITS LIQUID

SKILLS

WORK WITH UNITS OF PRESSURE

5, 21A, B

CALCULATE THE PRESSURE EXERTED BY A COLUMN OF GAS OR LIQUID

UNDERSTAND HOW A BAROMETER WORKS

2,

USE KINETIC MOLECULAR MODEL TO EXPLAIN THE GAS LAWS

1, 6, 7, 8, ~~89~~, 91

WORK WITH CHARLES', BOYLE'S AND AVOGADRO'S LAWS

3, 4, 9, 11, 31, 33
37, 41, 43

WORK WITH THE COMBINED GAS LAW

12, 47, 49, 51
53, 55, 57

CALCULATE MOLECULAR WEIGHT FROM MASS AND VOLUME OF A GAS

71, 121

UNDERSTAND THE VOLUME OF COMBINED GAS SAMPLES AND PARTIAL PRESSURE

81, 83

CALCULATE RATES OF EFFUSION

EXERCISE 5.23A

USE KINETIC MOLECULAR MODEL TO DESCRIBE NON-IDEAL GASES

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