CHEMISTRY 110 LECTURE

EXAM V Material

PART 1 GASES

I. PROPERITIES OF GASES

A. Gases have an indefinite shape.

B. Gases have a low density

C. Gases are very compressible

D. Gases exert pressure equally in all directions on the walls of a container.

E. Gases mix spontaneously and completely with one or more other gases.

II. KINETIC MOLECULAR THEORY

A. Gases are composed of such extremely tiny atoms or molecules that are widely separated by empty space.

B. Gas particles move in a random, rapid, and continuous motion, thus has kinetic energy.

C. Gas particles move so rapidly and are so far apart the there is essentially no force of attraction between the particles.

D. Particles collide frequently with each other and with the walls of the container, the collisions are perfectly "elastic" - (No net loss of energy as a result of a collision)

III. AVERAGE KINETIC ENERGY

The average kinetic energy (energy of motion) of the gas particles are directly proportional to its absolute T^{o} (Kelvin)

IV GRAHAM'S LAW OF EFFUSION

The rate of diffusion of a gas is inversely proportional to it's size [Molar Mass]

V. GAS MEASUREMENTS

A. Pressure

1. Pressure = $\frac{\text{force}}{\text{Unit area}}$

2. Gases exert pressure equally in all directions on wall of a container.

3. Units

   a) Types

Pascal	mm Hg	torr	Atmosphere	Psi
Pa			atm	

   b) Conversions

   KNOW → 1 atm= 760 mm Hg = 760 torr (exactly)

   1.013×10^{5} Pa = 1 atm = 14.68 psi

B. Temperature

Absolute temperature (Kelvin) Conversions

$$K = {}^{o}C + 273.15$$

C. Volume

1. The volume of a gas is the volume of the container it occupies.
2. Units: liters or milliliters

V. RELATIONSHIP BETWEEN ^{o}T, VOLUME, AND PRESSURE.

A. Boyle's law P & V

As the pressure increases the volume decreases in the same proportion.

B. Charles's law ^{o}T & V

As the temperature (Kelvin) is increased the volume is increased proportionally.

C. Gay-Lussac's Law

When temperature (K) increases pressure increases proportionally.

D. COMBINED GAS LAW

P,V, and ^{o}T varying. Assume that the mass is constant.

Problems:

1.

P_1 = 3.0 atm P_2 = ?

T_1 = 2 ^{o}C T_2 = 300.0 K

V_1 = 29 L V_2 = 100.0 L

2. A certain mass of gas occupies 5.50 L at 34^{o}C and 655 mm Hg. What will its volume in liters be if it is cooled to 10.0^{o}C and its pressure remains the same.

E. GAY-LUSSAC'S LAW OF **COMBINING VOLUMES**

At the same ^{o}T and Pressure, the volumes of gases that combine in a chemical reaction are in the ratio of small whole numbers.

F MOLAR GAS VOLUME; AVOGARDO'S HYPOTHESIS

At the same temperature and pressure the same number of moles of different gases have the same volume. The *Molar Volume* is the volume of one mole of any gas at a given ^{o}T & P. [STP]
Standard temperature and Pressure = [STP]:

1 mole of gas = 22.4 L At: 273 K and
1 atm (760 torr)

Conversion factors: $\frac{\text{1 mole}}{\text{22.4 L}}$; $\frac{\text{22.4 L}}{\text{1 mole}}$ *Warning: Use only with STP!

Calculations using STP

1. A 2.00 L sample of a gas at 0^{o}C and 1.00 atm has a mass of 3.94g. Calculate.......
   a) Density

   b) Molar mass

2. What is the density of ammonia gas at 273K and 760 torr?

3. The density of an unknown gas is 1.43 g/L at 0 ^{o} C and 760 torr. What is the molar mass of the unknown gas?

G. IDEAL GAS EQUATION:

Derivation:

KNOW: **PV=nRT** Where: n = moles of gas

$$R = \frac{0.0821 \text{ L-atm}}{\text{mole-K}}$$

H. Problems using PV=nRT

1. What volume in liters will be occupied by 6.00 mol carbon dioxide gas at 105 mm Hg and 28^{o}C?

2. What is the temperature in degrees Celsius of 0.500 mole hydrogen gas in a 463 mL container at a pressure of 0.500 atm?

I. Molar Mass Calculations using PV=nRT

An 2.00 L sample at an unknown gas had a pressure of
755 mm Hg and temperature of 259 K. The mass of the sample was 3.94 g. What is it's molar mass?

WHEN TO USE:

1. PV = nRT

2. $\frac{22.4 \text{ L}}{\text{mole}}$ at STP

2. $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Problems:

1. Calculate the molar mass of nitrogen gas at O ^{o}C and 1 atm, if the density is 1.25 g/L.

2. How many grams of ammonia gas in a 3999 ml sample at 9.8 atm and 20.0 °C?

3. At 45^{o}C and 1.20 atm the volume of 1390 mg of fluorine gas is 794 mls. Use this data to calculate the molar mass of fluorine gas.

4. A balloon has a volume of 2.50 L at 25^{o}C. When the balloon is placed in a refrigerator, its volume decreases to 2.33L assuming the pressure is the same inside and outside the refrigerator, what is the temperature of the gas in the balloon inside the refrigerator in degrees Celsius?

5. A 415 ml sample of gas in a steel cylinder has a pressure of 3.29 atm and a temperature of 125^{o}C. If the closed cylinder is cooled to 20.0^{o}C at constant volume, what is the new pressure of the gas in atmospheres?

J. DALTON'S LAW OF PARTIAL PRESSURES; Mixtures of gases

The total pressure of a mixture of gases is equal to the sum of the partial pressures exerted by each gas.

$P_{total} = P_1 + P_2 + P_3 + ...$

Example: The total pressure in a 1.00 liter container is 725 mm Hg. The container contains water vapor and nitrogen gas.
If the partial pressure of the water vapor is 225 mm Hg, what is the partial pressure of the nitrogen gas.

$P_{total} = P_{N_2} + P_{H_2O}$

Problem: The partial pressures of a mixture of nitrogen, oxygen and carbon dioxide gases are, respectively, 325 mm Hg, 0.128 atm, and 159 mm Hg. What is the total pressure of the mixture of gases.

K. GAS STOICHIOMETRY

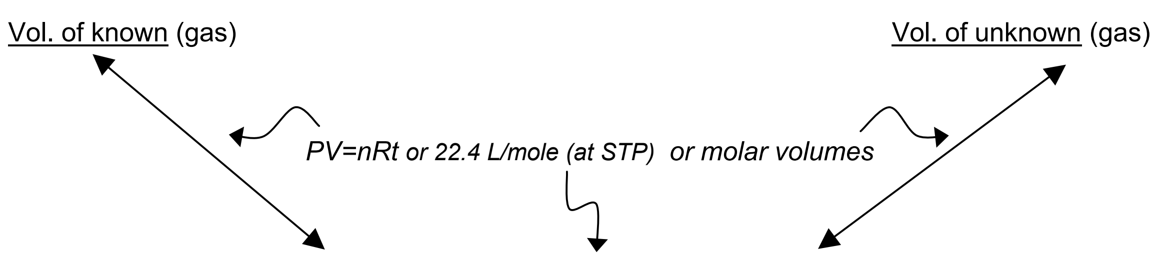
Certain chemical reactions involve gas as a reactant or product. For these types of reactions, the stoichiometric calculations involve the use of:

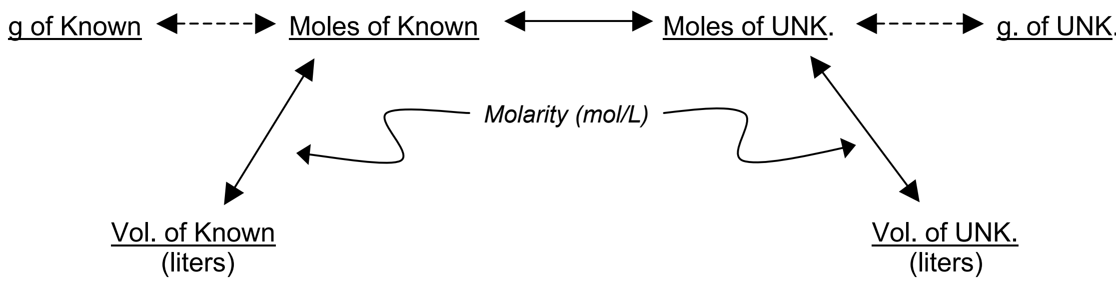
1) PV = nRT

2) $22.4 \frac{L}{mole}$ at STP

3) Molar volumes

The general stoichiometric scheme




g of Known
Moles of Known
Moles of UNK.
g. of UNK.
Molarity (mol/L)
Vol. of Known
(liters)
Vol. of UNK.
(liters)

Problems:

1. How many liters of ammonia gas can be produced by the reaction of 735 ml hydrogen gas with an excess nitrogen gas at 425 ^{o}C and 135 atm? nitrogen + hydrogen → ammonia

2. How many liters of carbon dioxide gas at 0 ^{o}C and 1 atm are produced by the complete combustion of 60.0 mol of liquid glucose, $C_6H_{12}O_6$?

3. How many liters of the air pollutant NO(g) could be produced at 985 ^{o}C and a pressure of 30.0 atm by the reaction of oxygen gas with 455 g of nitrogen gas.

4. How many mls of 6.0 M hydrochloric acid are needed to react to produce 124 mls of hydrogen gas at 1.3 atm and 25^{o}C

   Zinc metal + hydrochloric acid →

Part 2 PHYSICAL STATES OF MATTER-

I. Liquids, Solids, and Gases

Gas ------→ Liquid ------→ Solid

SOLID	LIQUID	GAS
Strong attraction between species	Some attraction between species	No attraction

	SOLID	LIQUID	GAS
Shape			
Density			
Ability to flow			
Compressability			

A. EVAPORATION OF LIQUIDS

Evaporation is the change from the liquid state to the gaseous or vapor state at the surface.

$$\text{Liquid} + \text{heat} \rightleftharpoons \text{Vapor}$$

B. VAPOR PRESSURE OF LIQUIDS

The vapor pressure of a liquid is the pressure exerted by the vapor above a liquid.

Dynamic equilibrium : rate of evaporation = rate of condensation

Vapor Pressure of Water at various Temperatures	
Temperature (°C)	Vapor pressure (mm Hg)
0	4.6
10	9.2
20	17.5
30	31.8
40	55.3
50	92.5
60	149.4
70	233.7
80	355.1
90	525.8
100	760.0

C. BOILING POINT

The boiling point of a liquid is the temperature at which a liquid is changed to a gas *within* the liquid (bubbles formed underneath the surface)

Variation of the Boiling Point of Water with Elevation		
Location	Elevation (ft. above sea level)	Boiling Point (°C)
San Francisco, CA	0	100.0
Salt Lake City, UT	4,390	95.6
Denver, CO	5,280	95.0
La Paz, Bolivia	12,795	91.4
Mount Everest	28,028	76.5

D. INTERMOLECULAR FORCES - Review!

The attractive forces between molecules

I. Types

a. Dipole-Dipole interaction:

Dipole - dipole interactions are electrostatic attractions between polar molecules

b. Hydrogen bonds:

A hydrogen bond is a relatively strong dipole-dipole attractive force between a hydrogen atom and a pair of nonbonding electrons on a F, O, or N atom

c. London forces

London forces are very weak electrostatic forces of attraction between molecules with "temporary" dipoles.

E. EFFECTS OF INTERMOLECULAR FORCES ON PROPERTIES OF LIQUIDS

STRENGTHS OF INTERPARTICLE (MOLECULAR FORCES)

VAPOR PRESSURE

BOILING POINT

EVAPORATION

EXAMPLES:

1. Which has the higher boiling point....N_2 or H_2S?

2. Which has the lowest vapor pressure...Water or PH_3?

II. CHANGES IN TEMPERATURE AS A SUBSTANCE IS HEATED [Energy Added]

As a substance absorbs heat, the temperature rises. Different substances can absorb and store more heat than others.
ex. Al vs. water

A. HEAT CAPACITY [Specific heat]

The amount of heat required to raise the temperature of 1 g of a substance exactly 1°C.

Example: How many degrees Celsius will the temperature rise if 25 g ether absorbs 160. cal of energy.

$$\text{Specific heat}_{\text{ether}} = \frac{0.529\ \text{cal}}{\text{g °C}}$$

B. ENERGY AND CHANGE OF STATE

Energy (as heat) is either lost or absorbed when a substance changes its state

Solid → Liquid

Liquid → Gas

Gas → liquid

C. HEAT OF VAPORIZATION- The quantity of heat needed to convert a liquid at its boiling point to the gaseous state.

Prob: Who much heat is needed to convert 155 g water to steam at it's B.P.? $\Delta H_{vap} = \frac{2.26\ \text{KJ}}{\text{g}}$

D. HEAT OF FUSION- The quantity of heat needed to convert a solid at its melting point to the liquid state.

Prob: Who much energy is needed to convert 35 g of ice to water at it's M.P.? $\Delta H_{fus} = \frac{3.35J}{g}$

E. CHANGES IN TEMPERATURE AND PHYSICAL STATE

Summary of T^{o} & State changes when Energy [heat] is added:

Specific Heat = $\frac{J}{g\ °C}$ or $\frac{cal}{g\ °C}$ ...etc.

Heat of Fusion = $\frac{KJ}{g}$ or $\frac{KJ}{mole}$ or $\frac{Kcal}{g}$ ...etc.

Heat of Vaporization = $\frac{KJ}{g}$ or $\frac{KJ}{mole}$ or $\frac{Kcal}{g}$ ...etc.

Problem. How much energy [Heat in kilojoules] is needed to convert 500.0 g of ice at -15.0 ^{o}C to steam at 105.0 ^{o}C?

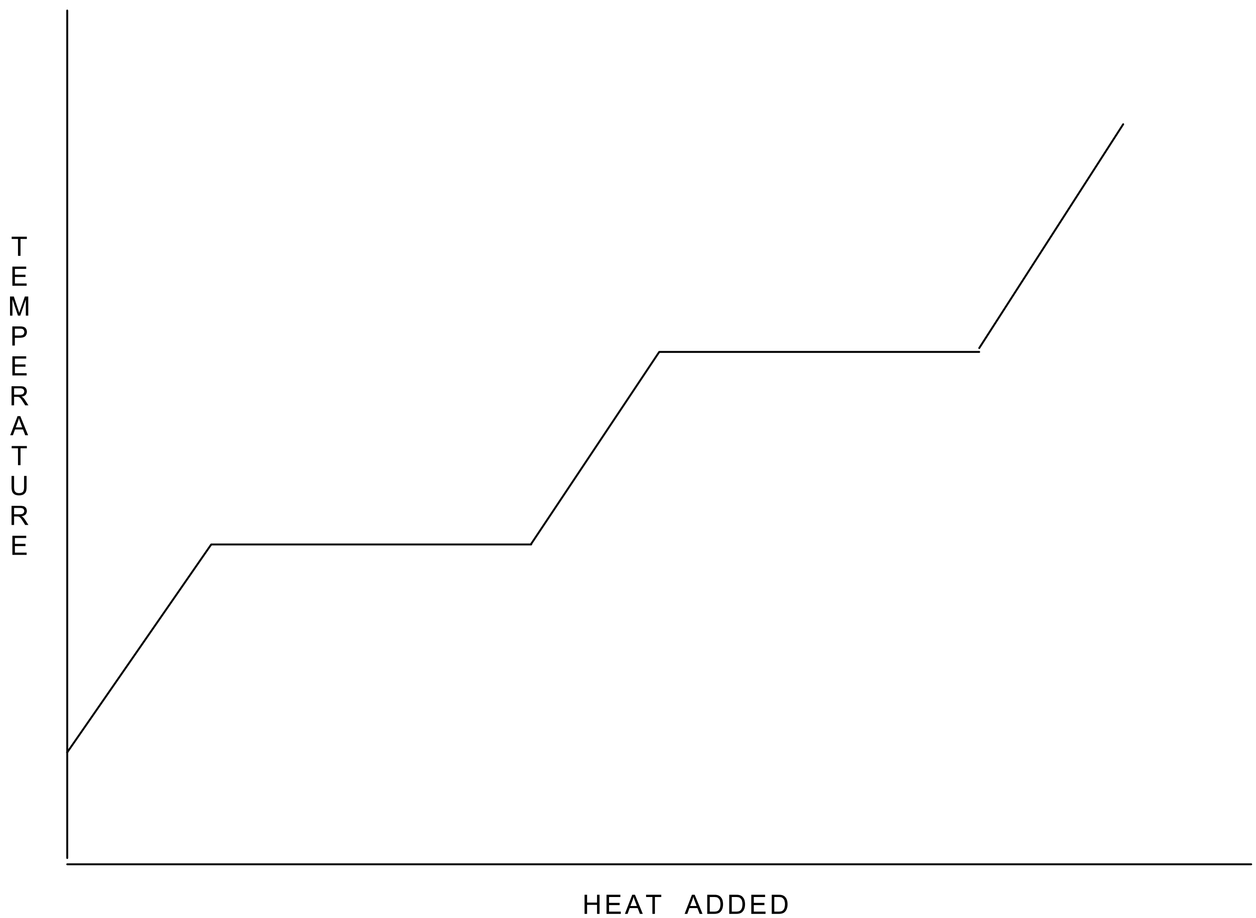
$H_{fusion} = \frac{335\ J}{g}$ - $H_{vap} = \frac{2.26\ kJ}{g}$

Specific heat of ice = $\frac{2.10\ J}{g\ ^{o}C}$

Specific heat of water = $\frac{4.18\ J}{g\ ^{o}C}$

Specific heat of steam = $\frac{2.0\ J}{g\ ^{o}C}$

GRAPH:



Calculations:

A → B HEATING A SOLID

B → C SOLID → LIQUID

C → D HEATING A LIQUID

D → E LIQUID → GAS

E → F HEATING A GAS

TOTAL HEAT ADDED

Problems:

1. Calculate the number of joules required to convert 58.9 g of ice at $0^{o}C$ to water at $81\ ^{o}C$

2. Given a sample of 30.0 g of water at $37\ ^{o}C$, calculate the quantity of heat in kilojoules that would be required to convert it to steam at $100^{o}C$.

Part 3 COLLISION THEORY OF CHEMICAL REACTIONS

For a reaction to occur:

1) A collision between reactants must occur
2) Bonds are broken
3) Bonds are made to produce products

Example: $CO + NO_2 \rightarrow CO_2 + NO$

What is involved for a successful collision?

[e.g. a reaction occurs]

1) Energy- There must be sufficient (kinetic) energy to break bonds
2) Proper orientation upon collision

Ineffective collision:

Effective collision:

ENERGY FACTORS INVOLVED IN A COLLISION

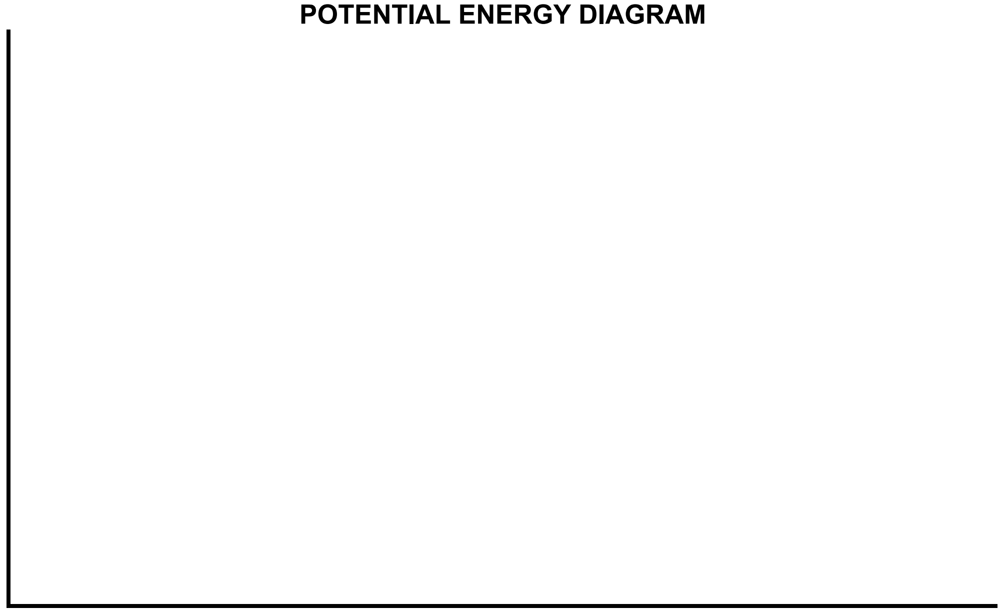
$$\text{Wood} + O_2 \rightarrow CO_2 + H_2O$$

Does this reaction occur spontaneously?

Energy of activation, E_a

The minimum amount of energy to get a reaction started

POTENTIAL ENERGY DIAGRAM



FACTORS THAT AFFECT REACTION RATES

Effect of Concentration on Reaction Rate

When the concentration of reactants is increased the frequency of collisions increases: Reaction rate increases as concentration increases

Effect of temperature on reaction rate

Raising the temperature increases the kinetic energy and frequency of collisions: Reaction rate increases as T^o increases

Effect of a catalyst on reaction rate

Catalysts speeds up the reaction as an "outside" substance. It is involved in the reaction but is not used up.

Catalysts work by lowering the activation energy

CHEM.2

CLS

PRACTICE EXAM V

THERE ARE 5 PAGES TO THIS EXAM

PROBLEMS

1. The partial pressures of a mixture of nitrogen, oxygen, and carbon dioxide gases are, respectively, 325 mm Hg, 0.128atm, and 159 mm Hg. What is the total pressure of this mixture of gases in torr?

2. The gas in an inflated balloon has a volume of 125 ml at 29 ^oC. What volume in liters will the gas in the balloon occupy at 137 ^oC if its pressure is held constant

3. A gas occupies a volume of 410.0 mL at 27^oC and 740.0 mm Hg pressure. Calculate the volume the gas would occupy at STP.

4. Use the kinetic molecular theory to explain each of the following characteristic properties of gases:
   a. Low density

   b. Exerts pressure on any surface they contact

   c. high compressibility

   d. Assume shape of any closed container they are in.

5. Smelling salts contain ammonium carbonate, which can decompose to form ammonia, a mild heart stimulant. The ammonium carbonate decomposes according to the following reaction:

$$(NH_4)_2CO_3(s) \rightarrow 2NH_3(g) + CO_2(g) + H_2O(l)$$

$$MM\text{-}(NH_4)_2CO_3=96.1$$

How many liters of NH_3 at 25^oC and 1.00 atm are formed from 0.500 g of $(NH_4)_2CO_3$

6. A 2.00 g sample of gas has a pressure of 3.00 x 10^3 mm Hg, a volume of 1.95 x 10^4 mL, and a temperature of 455 K. What will be its pressure in atmospheres if the temperature is changed to 325 ^oC and volume is changed to 7.00 L?

7. How many moles and how many molecules of a gas are in a 255 ml aerosol can at a pressure of 855 torr and a temperature of 48 ^{o}C?

8. Some commercial drain cleaners contain two components: sodium hydroxide and aluminum powder. When the mixture is poured down a clogged drain, the following reaction occurs:

$$2NaOH\,(aq) + 2Al(s) + 6H_2O(l) \rightarrow 2NaAl(OH)_4(aq) + 3H_2(g)$$

The heat generated in this reaction helps to melt away obstructions such as grease.

a. Calculate the volume of H_2 formed at STP by the reaction of 3.12 g of Al with NaOH?

b. How many mLs of 5.0 M NaOH are needed to react to form 6.7 liters of H_2 gas at 755 torr and 25^{o}C?

9. What is the molar mass of a gas if a 1.50 L sample of the gas at 25 ^{o}C and 745 mm Hg has a mass of 2.89 g

10. Calculate the density for CH_4, (methane) at 0 ^{o}C and 1.00 atm.

13. At 300 K, which molecules will have the greater average kinetic energy? Sulfur dioxide or ammonia molecules?

14. Classify the intermolecular forces between molecules of each of the following liquids.
   a. CO
   b. O_2
   c. CH_3OH
   d. HF
   e. CO_2
   f. CH_2O

15. Circle the correct answer for the following
   a. The higher boiling point: N_2 or CO?
   b. Weaker intermolecular forces: H_2O or H_2S?
   c. Lower vapor pressure: NH_3 or IF?
   d. Lower boiling point SO_2 or HF

16. Calculate the molar mass of 8.00 g of gas with a volume of 12.0 L at STP

17. If 40.0 g of acetylene[C_2H_2] undergoes *combustion*...

The balanced equation is:

   a. How many liters of oxygen are required to burn the acetylene if the reaction takes place at 155 ^{o}C and 2.60 atm

   b. How many mLs of carbon dioxide are produced at STP?

18. How many grams of liquid carbon tetrachloride [CCl_4] can be converted to vapor at its normal boiling point by the addition of 485 kJ of energy. The molar heat of vaporization for CCl_4 is 33.5 kJ/mol.

19. Calculate the quantity of heat in kJ needed to raise the temperature of 125 g of liquid water from 25.0 ^{o}C to steam at 125 ^{o}C.

20. How many kilojoules are required to change 5.0 moles of ice at -30.0 ^{o}C to liquid water at 89.0 ^{o}C?

21. List three factors that affect reaction rates and give the reasons why they affect the rate

22. Draw a potential energy diagram for a reaction. Label all the components as well as both axis of the graph.

23. a. Give the properties of gases, liquids and solids.
b. Explain the differences in the strength of the attractive forces between molecules in the gas, liquid and solid phase.