UNIT 3: INTERMOLECULAR FORCES & PROPERTIES--Guided Notes

TOPIC 3.1: INTERMOLECULAR FORCES

Learning Objective: Explain the relationship between the chemical structure of molecules and the relative strength of their intermolecular forces when:

a. The molecules are of the same chemical species
b. The molecules are of two different chemical species

I. Intermolecular Forces

A. Definition:

1. Dependent on:

B. Strength vs. intramolecular forces?

C. IMF's explain:

D. Connection to Coulomb's law:

E. What determines the type of IMF(s) present?

F. Van der Waals Forces:

II. London Dispersion Forces

A. Occurs between:

B. Only type of IMF between:

C. **Temporary dipole**:

D. **Induced dipole**:

E. Why are LDFs weak?

F. Polarizability:

1. Easily polarized =
2. Difficult to polarize =

G. Effect of pi (multiple) bonding:

H. Effect of molecular size:

1. Larger molar mass =
2. Why?
3. LDF vs. boiling point:

4. How does this explain the trend in states at room temperature of the halogens on the periodic table?

I. Effect of molar shape:
    1. The larger the surface area =

    2. Why?

    3. **Isomer**:

III. Dipole-Dipole
    A. Occurs between:

    B. In polar molecules, the dipoles are _____

    C. More polar = more _____ of electrons

IV. Dipole-Dipole: Hydrogen Bonding
    A. NOT a _____

    B. Occurs in elements that **contain** H and _____, _____, or _____

    C. Very attractive force because:

        1.

        2.

D. Hydrogen bonding is strongest with:

1.

2.

E. List 3 things that hydrogen bonding makes possible:

1.

2.

3.

V. Ion-Dipole Force

A. Occurs when:

B. **Ion-dipole force**:

1. Explain how this happens:

2. **Hydration shell**:

C. Strength of this force determines the _____ of ionic compounds

D. Explain “like dissolves like”:

E. **Miscible**:

1. Example:

VI. Induced Dipoles

A. _____ and _____ can also induce dipoles

1. Similar to:

B. Define **polarization:**

C. Two-types (that we're concerned with):

1. Dipole-Induced Dipole Interactions
    a) Describe how these interactions are created:

2. Ion-Induced Dipole Interactions
    a) Describe how these interactions are created:

VII. Naming Interactions:

A. Give the IMF that will form for each combination below:

1. Nonpolar + nonpolar

2. Polar + polar

3. Polar with hydrogen bonding capacity + polar with hydrogen bonding capacity

4. Nonpolar + polar

5. Nonpolar + ion

6. Polar + ion

VIII. IMF & Molecular Properties

A. Which properties *increase* as a result of increasing IMFs?

B. Which properties *decrease* as a result of increasing IMFs?

IX. Practice:

A. I Do:

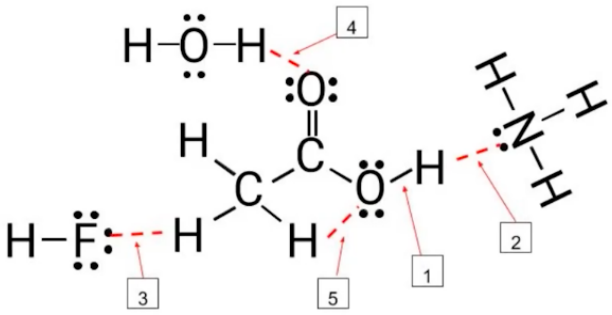
1. The boiling point of HF is 293K and the boiling point of F2 is 85K.
   a) Determine the type(s) of IMFs present

   b) Explain the difference in boiling points based on their IMFs

B. We Do:

SCAN ME

1. For each of the labeled bonds, identify if it is, or is not, hydrogen bonding and give your reasoning.

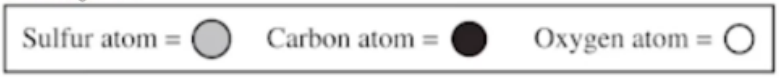


C. You Do:

1. The structures of the isomers ethanol and dimethyl ether are shown below. Based on their structure and intermolecular forces, account for their differences in boiling points.

2. The table below gives the molecular structure and boiling points of CS_2 and COS. In terms of types and relative strengths of IMFs in each compound, explain why the boiling point of CS_2 is higher than that of COS.

Image source: College Board



Compound	Molecular Structure	Boiling Point at 1 atm (K)
CS_2		319
COS		223

3. Place the following in order of *increasing* boiling point.

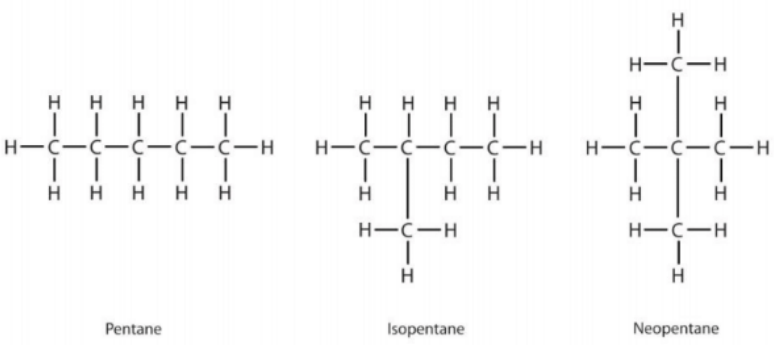
   C_3H_8, He, CH_3OH, $HOCH_2OH$, HCl

4. Which of the following would have the strongest ion-dipole interaction with water? Explain.

Ion	Ionic Radius (pm)
Tl^{3+}	95
Cd^{2+}	97
Na^{+}	95

5. Circle the molecules that are capable of hydrogen bonding with another of the same molecule. For all of the molecules that exhibit hydrogen bonding, draw the two molecules and show where the hydrogen bonding is likely to occur using a dotted line.
    a) H_2S
    b) HCl
    c) C_5H_{12}
    d) CH_3OH
    e) NCl_3
    f) CH_3NH_2

6. Pentane has 3 isomers (shown below). Use the structures to place them in order of increasing IMFs.



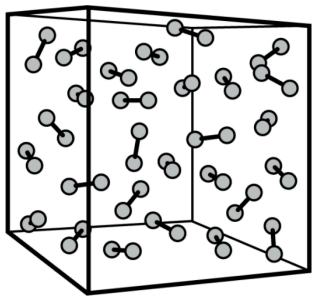
7. In each pair decide which would have the lower boiling point. Explain your choice.
    a) He or Ne

    b) CH_4 or CCl_4

    c) CF_4 or CF_3H

    d) NH_3 or PH_3

8. The diagram below is a molecular model of a gaseous diatomic element that is just above its boiling point. Intermolecular forces between the gas molecules will cause them to condense into the liquid phase if the temperature is lowered. Which of the following best describes how the model is limited in its depiction of the phenomenon?



    a) It does not show how hydrogen bonds are constantly forming, breaking, and reforming, which results in a net force of attraction between the molecules.

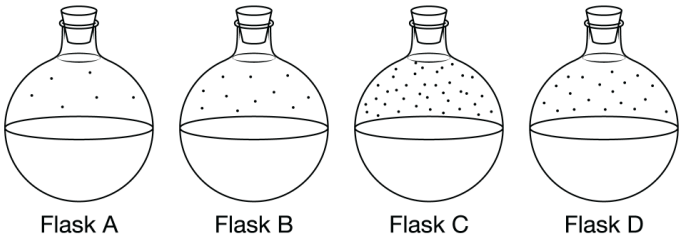
b) It does not show how the interactions between ions and the induced molecular dipoles result in a net force of attraction between the molecules.
c) It does not show how the interacting permanent dipoles of the molecules result in a net force of attraction between the molecules.
d) It does not show how the temporary fluctuating dipoles of the molecular electron clouds result in a net force of attraction between the molecules.

9. The electron cloud of HF is smaller than that of F_2, however, HF has a much higher boiling point than F_2 has. Which of the following explains how the dispersion-force model of intermolecular attraction does not account for the unusually high boiling point of HF?

Substance	Normal boiling point
HF	293 K
F_2	85 K

a) F_2 is soluble in water, whereas HF is insoluble in water.
b) The F_2 molecule has a greater mass than the HF molecule has.
c) Liquid F_2 has weak dispersion force attractions between its molecules, whereas liquid HF has strong ionic interactions between H^+ and F^-.
d) Liquid F_2 has weak dispersion force attractions between its molecules, whereas liquid HF has both weak dispersion force attractions and hydrogen bonding interactions between its molecules.

10. Four different liquid compounds in flasks at 20°C are represented below. The table below identifies the compounds. Flask C shows the most particles in the vapor phase. Which of the following is not shown in the model but best helps to explain why flask C must contain pentane?



Name	Chemical Formula	Boiling Point (°C)
Pentane	$CH_3CH_2CH_2CH_2CH_3$	36
Hexane	$CH_3CH_2CH_2CH_2CH_2CH_3$	69
Heptane	$CH_3CH_2CH_2CH_2CH_2CH_2CH_3$	98
Octane	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$	126

a) The random motion of the particles within the liquids
b) The relative speeds of the vapor particles in each flask
c) The strength of the intermolecular forces between the particles in the liquids
d) The structural formula of the molecules of the liquid and vapor in each flask

TOPIC 3.2: PROPERTIES OF SOLIDS

Learning Objective: Explain the relationship among the macroscopic properties of a substance, the particulate-level structure of the substance, and the interactions between these particles

Do Now: Why does a puddle evaporate even if the temperature is well below water's boiling point?

I. First things first
   A. Vapor pressure
      1. Definition:

      2. How is this different from boiling?

3. Explain how equilibrium is reached in a closed system:

4. Depends on:
    a) Chemical _____
    b) Temperature
        (1) Increase in temperature =
    c) IMFs
        (1) Different substances have different vapor pressures

            at different _____ due to _____

        (2) Stronger IMFs =

        (3) Weaker IMFs =

5. Surface area of the solid/liquid in contact with the gas has _____ effect on vapor pressure

    a) Explain:

6. Vapor is created by:

    a) _____

    b) _____

7. Volatility:
    a) Definition:

    b) Higher volatility =

B. Boiling point
    1. Definition:

    2. Disrupts the attractions:

    3. Stronger IMFs =

C. Quick Check:
    1. A bell jar is placed over two glasses of water and acetone. Acetone is a low polarity, volatile liquid. How will the vapor pressure of the water inside the bell jar compare with the vapor pressure of the acetone after one hour has passed? Explain your answer.

D. Heat of Fusion

1. Written symbolically:

2. Definition:

3. Melting is always _____ so values are always

   _____

4. Unique to every substance

5. Why doesn't the temperature change during the change from solid to liquid?

6. How does this relate to the enthalpy (heat) of fusion?

E. Heat of Vaporization

1. Written symbolically:

2. Definition:

3. Vaporization is always _____ so values are always _____

4. Unique to every substance

5. Describe what is happening to the energy during the change from liquid to gas:

F. Cooling Curve:
    1. Opposite of vaporization:
        a) Opposite of enthalpy of vaporization:
    2. Energy removed =
    3. Opposite of melting:
        a) Opposite of enthalpy of fusion:

G. Quick Check:
    1. Why is the heat of vaporization typically a larger amount of energy than the heat of fusion?

II. Classifying Solids

A. Classified by:

B. 4 types of crystalline solids:

1. _____
2. _____
3. _____
4. _____

C. All four types involve:

III. Ionic Solids

A. Between _____ and _____

1. Typically _____ and _____*

*Though there are some nonmetal _____

B. Formula represents:

C. Ionic solids tend to have:

1. _____
2. _____
3. _____

D. _____ ions or ions with _____ charges will have stronger interactions between ions resulting in _____ lattice energy

E. Brittle:

F. Conductive when:

1. More ions =

2. Why does 1.0 mol Na_2CO_3 conduct better than 1.0 mol of NaCl?

3. Soluble in:

IV. Molecular Solids

A. Discrete molecules:

B. Formed exclusively from:

C. Formula represents:

D. Do not conduct electricity

1. Except:

E. Strengths of IMFs vary based on:

F. Types:

1. Elemental solids:

2. Molecular solids:

V. Covalent Network Solids

A. _____ solid

B. _____ substance

C. Made up of:

1. Can think of them as:

D. Typically made up of _____ and _____

E. Properties:

F. Carbon-containing network solids:

1. Basis for:

2. Examples (include hybridization):

3. Describe the difference in structure between diamond and graphite:

G. Silicon-containing network solids:

1. Basis for:

2. Examples:

VI. Metallic Solids

A. _____ solid

B. Metallic bond:

C. Properties:

D. Metal alloys:

1. Substitutional:

a) Density:

2. Interstitial:

a) Malleability and ductility:

VII. Biomolecules & Polymers

A. Noncovalent interactions may occur between different

_____ or between different
_____ of the same biomolecule

B. Shape determines:

C. This creates _____ and _____ shapes

VIII. In Summary:

Strength (decreasing)	Type of Solid	Type of Particles	Type of Attractions	Properties	Examples
	Ionic				
	Metallic				
	Covalent network				
	Molecular				

IX. Practice:

A. I Do:

1. CO_2 melts at -78℃ and SiO melts at 1650℃

a) Identify the type of solid each substance forms

b) Justify the difference in melting points

B. We Do:

SCAN ME

1. Classify Cl_2, Ni, BN, and FeS as ionic, molecular, covalent network, or metallic solids and arrange them in order of increasing melting points.

C. You Do:

1. For each type of solid, indicate the type of attractive forces that are broken upon melting, and describe the individual particles that make up the resulting liquid. The types of bonds/forces: covalent bonds, ionic bonds, metallic bonds, and IMFs. The types of individual particles: atoms, ions, and molecules.

Type of Solid	Bond/forces broken upon melting	Individual particles in the liquid
Ionic		
Covalent Network		
Molecular		
Metallic		

2. Which of the following could be the identity of a white crystalline solid that exhibits the following properties:

   (1) It melts at 360℃

   (2) It does not conduct electricity as a solid

   (3) It conducts electricity in an aqueous solution

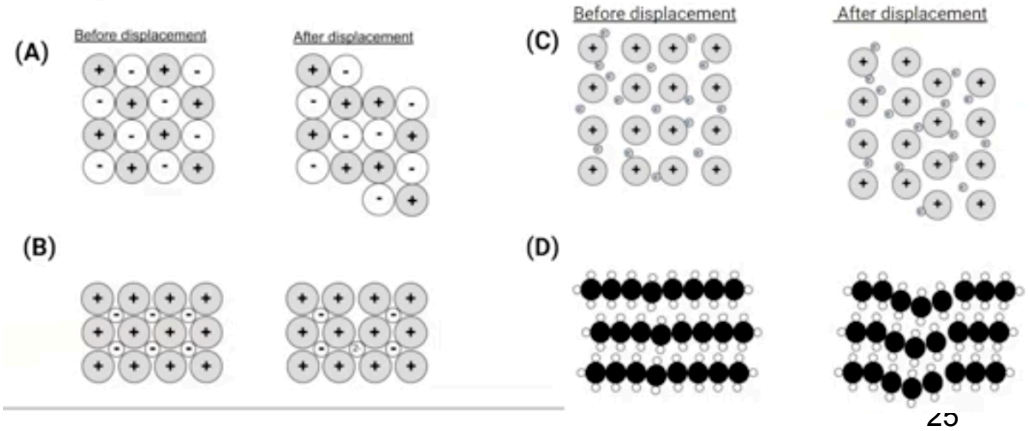
   b) $C_{12}H_{22}O_{11}$

   c) KOH

   d) SiC

   e) Ag

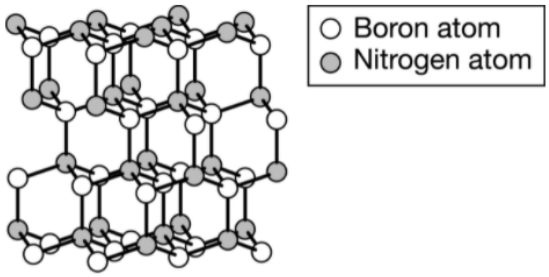
3. Which of the following diagrams best illustrates how a metallic solid is malleable after a displacement?



4. A student finds a bottle of magnesium chloride, $MgCl_2$, and hypothesizes that the solid is a good conductor of electricity because it contains magnesium which is a metal, and all metals are good conductors. Do you agree or disagree with the student? Explain.

5. Which statement best explains the observation that NH_3 (l) boils at -28℃, whereas PH_3 (l) boils at -126℃?
    a) The dispersion forces of NH_3 are weaker than the dispersion forces in PH_3
    b) The dispersion forces in NH_3 are stronger than the dipole-dipole forces in PH_3
    c) NH_3 has hydrogen bonding that is stronger than the dipole-dipole forces in PH_3
    d) NH_3 has hydrogen bonding that is weaker than the dipole-dipole forces in PH_3

6. The structure of one form of boron nitride is represented above. This form of boron nitride is one of the hardest substances known. Which of the following best helps explain why boron nitride is so hard?



Cubic Form of
Boron Nitride

a) Boron ions and nitrogen ions are held together by ionic bonds
b) Boron nitride is a network solid of atoms connected by covalent bonds with fixed bond angles
c) Boron nitride is an alloy, and alloys are typically harder than the elements used to make them
d) Boron nitride is a polymer made of long chains of boron atoms and nitrogen atoms held together by dispersion forces

7. Explain why covalent network solids melt at a much higher temperature than molecular solids.

8. The melting point of HBr is -87℃ and the melting point of NaBr is 747℃.
    a) Identify the type of solid in each substance

    b) Justify the difference in their melting points

TOPIC 3.3: SOLIDS, LIQUIDS, & GASES

Learning Objective: Represent the differences between solid, liquid, and gas phases using a particulate-level model.

I. Solids

A. Motion of individual particles is:

1. Most motion is:

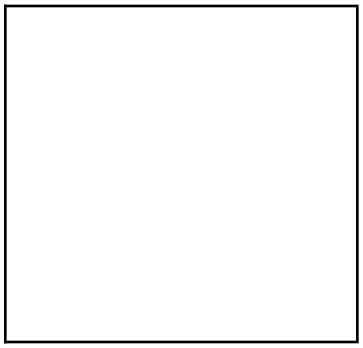
B. Particles are held:

1. By:

C. _____ volume and shape

D. _____ be compressed

E. Draw a particle diagram



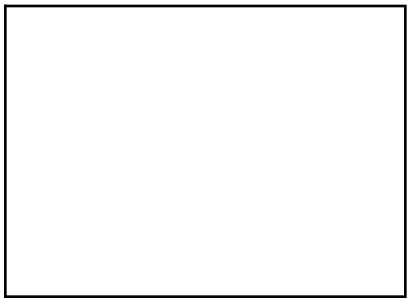
F. Amorphous solids:

1. Arrangement of particles is:

2. Describe macroscopic features:

a) Examples:

3. Draw the particle diagram:



G. Crystalline solids:
   1. Atoms/ions/molecules arranged in:

      a) Unit cells:

   2. Describe the macroscopic features:

      a) Examples:

II. Liquids
   A. Particles are constantly:

   B. Particles are still:

      1. Take the shape of _____

   C. _____ compressible

   D. What determines the motion and temperature range where a substance is liquid?

III. Liquids vs. Solids

A. Molar volumes:

1. How is water an exception to this?

B. Density:

IV. Gases

A. Particles are:

B. _____ compressible due to _____

C. Shape & volume =

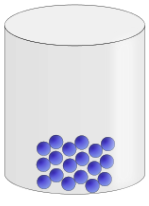
1. Particles are equally _____

D. Frequency and strength of collisions depends on:

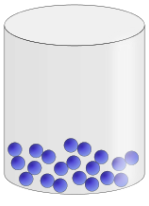
1. Collisions =

V. States of matter

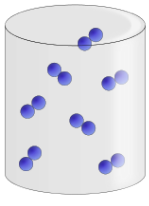
A. Complete the diagram below:
*Note: Between Liquid and Solid it should read + KE or **- Pressure**



Solid



Liquid



Gas

B. Complete the table below:

State	Density	Shape	Volume	Strength of IMFs
Gas				
Liquid				
Solid				

VI. Practice:

A. I Do:

1. Of the following, the best explanation for the fact that most liquids cannot be easily compressed, is that the molecules in a liquid:
    a) Are in constant motion
    b) Are relatively close together
    c) Have varying densities
    d) Have fixed volume
    e) Move slower as a temperature decreases

B. We Do:

1. Go to States of Matter: Basics and answer the following questions based on the simulation:
    a) Compare the solid state of all the substances. What is unique about water in the solid state?

    b) What happens to water when you add heat and it begins to liquify? How is this different from what happens in the other substances?

c) What is the vaporization (boiling) point temperature for water?

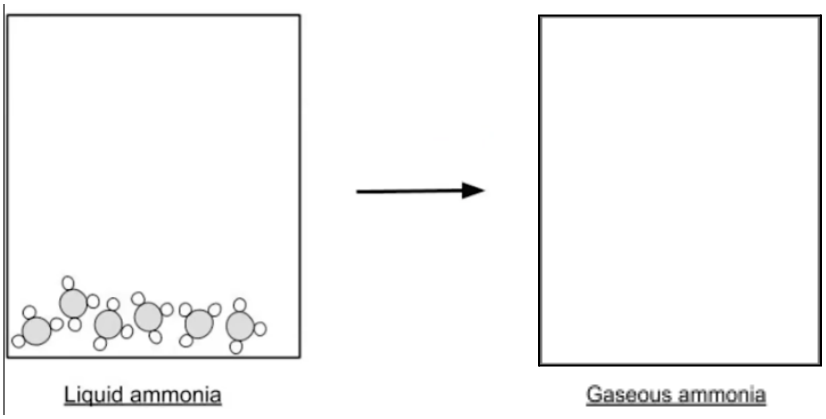
d) Increase the temperature to 337K and allow the water to move around for a bit. Why do a few molecules fly off? Where are they leaving from (throughout the water or just the surface)?

C. You Do:

1. A triple point is the set temperature and pressure where a substance occurs as a solid, liquid, and gas simultaneously at equilibrium. For water, this occurs at 273.16 K and 0.6117 kPa. Draw a set of particle diagrams to represent this point.

2. Molten (l) iron, Fe, and solid iron occupy almost the same volume. The density of molten iron is 6.98 g/mL while solid iron has a density of 7.87 g/mL. Draw a particle diagram for both; be sure to account for the differences.

3. The box below represents a closed container with liquid ammonia, NH_3, molecules. In the box on the right, represent the same sample of ammonia after undergoing complete evaporation.



NOTE: Topics 3.5-3.6 are out of numerical sequence

TOPIC 3.5: KINETIC MOLECULAR THEORY

Learning Objective: Explain the relationship between the motion of particles and the macroscopic properties of gases with:

a. The kinetic molecular theory (KMT)
b. A particulate model
c. A graphical representation

I. Kinetic Molecular Theory:

A. Definition:

B. It is a series of postulates based on:

1.

2.

3.

4.

II. Kinetic Molecular Theory--1

A. States that:

1. _____ are atoms

2. Everything else are:

B. Gas particles travel in straight lines until:

1. Translational motion:

2. 2 other types of motion:

III. Kinetic Molecular Theory--2

A. States that:

B. Ideal Gas Law assumes that:

IV. Kinetic Molecular Theory--3

A. States that:

1. Also no attraction/repulsion between:

B. Elastic collisions:

V. Kinetic Molecular Theory--4

A. States that:

1. Most of the kinetic energy is related to:

B. The higher the temperature:

1. The greater the:

2. There is a distribution of energy but:

C. Equation: (label variables and units)

VI. Maxwell-Boltzmann Distribution

A. Definition:

B. Velocity distributions are dependent on:

C. Labeled drawing:

D. Variation of velocity distribution with **temperature:**

1. By increasing the temperature of a gas, the distribution of the particles shifts:

2. The molecules have a greater:

    a) KE depends on _____ and

    _____

    b) The only way for particles of the **same masses** to have

    _____ kinetic energy is for them to

    have _____

3. Sketch the graph below:

E. Variation of velocity distribution with **mass**:

1. The atoms in a sample of Ar and He at the

   _____ have the same

   _____ but NOT the same

   _____

2. The only way for particles of the **different masses** to have

   _____ kinetic energy is for them to have

   _____

3. In a gas mixture at a given temperature, lighter particles:
4. Average velocity _____ as mass

   _____ (from the graph on slide 14)

5. Mathematical illustration: (slide 15)

6. Sketch the graph below:

VII. Rate of Effusion:

A. Definition:

B. Related to:

C. **Graham's Law:**

D. As particle size _____, the rate of effusion

_____

VIII. Practice:

A. I Do:

1. Given a sample of H_2, HCl, and Cl_2 at the same temperature, place the particles in order of **decreasing** average velocity

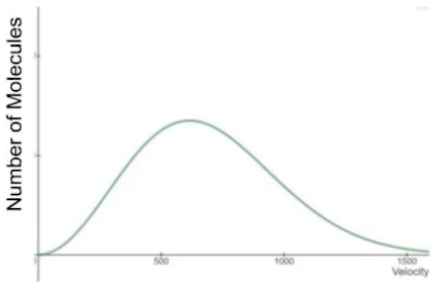
B. We Do:

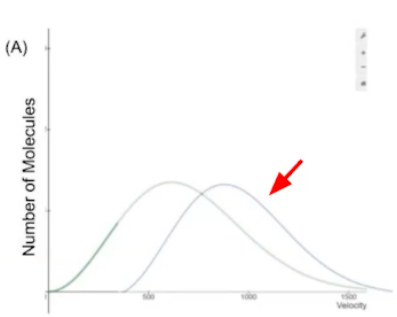
1. Consider an equimolar mixture of gases, H_2, N_2, and F_2, placed into a container with a pinhole opening. After some time has passed, place the gases in order of **increasing** amount remaining in the container.

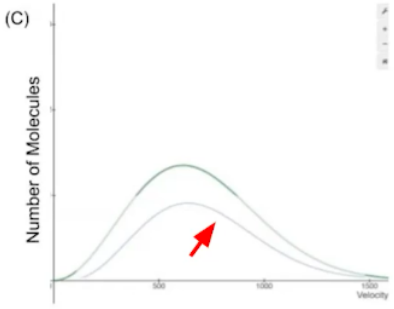
C. You Do:

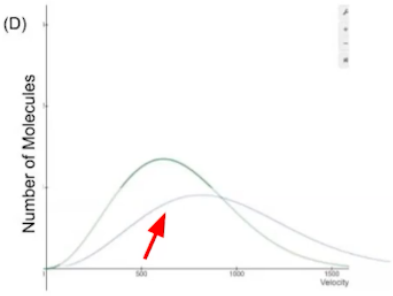
1. A student sets up an experiment to compare the deflation rate of 2 different gases. She chooses He and Ar and inflates the balloons to the same pressure, temperature, and volume. The student notices that the He balloon deflates significantly faster and hypothesizes that the He is smaller and therefore can more easily fit in the molecular sized holes in the rubber balloon. Do you agree or disagree with this claim? Base your answer on the principles of the kinetic molecular theory and properties of both gases.

2. The graph below represents a particle speed distribution for a gas at a certain temperature. Which of the following graphs represents the speed distribution of a heavier gas at the same temperature (indicated by the red arrow)

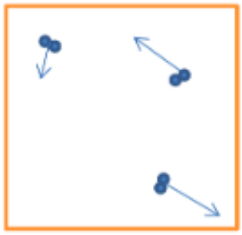








3. A 1L vessel containing 1 mol of H_2O at 200K is shown below. (The lengths of the arrows correspond to the speeds of the molecules)



Draw the following:

a.) A 1L vessel containing 2 mol of H_2O at 200K	b.) A 1L vessel containing 1 mol of Ne at 200K	c.) A 1L vessel containing 1 mol of H_2O at 100K	d.) A 1L vessel containing 2 mol of H_2O at 400K

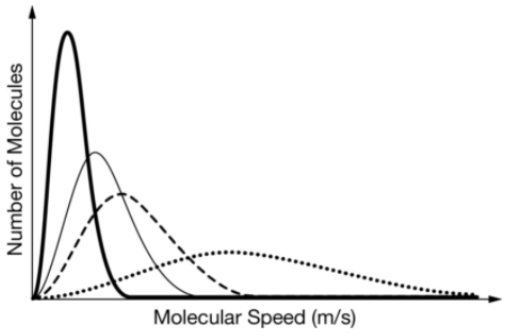
4. Equimolar samples of N_2 and O_2 are both at standard conditions (1 atm, 273 K)
    a) Which sample has more KE? Why?

    b) Which sample has the higher average molecular speeds? Why?

5. A rigid metal tank contains oxygen gas. Which of the following applies to the gas in the tank when additional oxygen is added at a constant temperature?
    a) The volume of the gas increases
    b) The pressure of the gas decreases
    c) The average speed of the gas molecules remains the same
    d) The total number of gas molecules remains the same
    e) The average distance between the gas molecules increases

6. A 1 L sample of He gas at 25℃ and 1 atm is combined with a 1 L sample of Ne gas at 25℃ and 1 atm. The temperature is kept constant. Which of the following statements about combining gases is correct?
    a) The average speed of the He atoms increases
    b) The average speed of the Ne atoms increases
    c) The average kinetic energy of the He atoms increases
    d) The average kinetic energy of the He atoms and Ne atoms does not change

7. The graph below shows the distribution of molecular speeds for four different gases at the same temperature. What property of the different gases can be correctly ranked using the information from the graph, and why?



    a) The densities of the gases, because as the density of a gas increases, the average speed of its molecules decreases
    b) The pressure of the gases, because the pressure exerted by a gas depends on the average speed with which its molecules are moving
    c) The volumes of the gases, because at a fixed temperature the volume of a gas can be calculated using the equation PV=nRT
    d) The molecular masses of the gases, because the gas molecules have the same average kinetic energy and mass can be calculated using the equation $KE_{avg} = ½ mv^2$

8. Two gases are placed at either ends of a tube at room temperature as shown. When they meet, a white/yellow precipitate will form. Where in the tube do you predict to see the precipitate?

9. A sample of NO was placed in a sealed, rigid container at 200K. The vessel was heated to 400K. What changes will occur and why? (Consider changes to volume, temperature, pressure, moles, and particle velocities)

TOPIC 3.4: IDEAL GAS LAW

Learning Objective: Explain the relationship between the macroscopic properties of a sample of a gas or mixture of gases using the ideal gas law

Do Now: List as many KMT properties as you can that you observe in the simulation:

I. Properties of Gases
   A. Pressure:

   B. Volume:

C. Temperature:

D. Moles:

II. Gas Pressure

A. Created by

B. Methods of measurement:

C. Pressure vs. moles:

D. Pressure vs. density:

III. Gas Laws--Boyle's Law

A. Definition:

B. Formula:

C. The volume of a gas _____ when the pressure is

_____

IV. Gas Laws--Charles' Law

A. Definition:

B. Temperature must be in:

1. _____ is proportional to _____

while _____ is not

C. Formula:

V. Gas Laws--Gay-Lussac's Law

A. Definition:

B. Formula:

VI. Gas Laws--Combination Gas Law

A. What do you do with the variable being held constant (if there is one)?

B. Formula:

VII. Gas Laws--Avogadro's Law

A. Definition:

B. Formula:

C. Avogadro's hypothesis (also known as Avogadro's law):

VIII. Ideal Gas Law

A. Definition:

B. Universal gas constant:

C. Formula:

D. Density of a Gas:

1. MM =

2. Density is measured in:

3. Formulas:

a) Density:

b) Molar mass:

IX. Dalton's Law of Partial Pressures

A. Definition:

B. Formula:

C. Describe the process of collecting gas "over" water:

D. How is Dalton's law used in this method?

X. Mole Fraction

A. Formula for mole fraction:

B. Formula for partial pressure:

XI. Practice:

A. I Do:

1. When heated strongly, solid calcium carbonate decomposes to produce solid calcium oxide and carbon dioxide gas, as represented by the equation below. A sample of calcium carbonate is placed in a rigid 35 L reaction vessel from which all the air has been evacuated. The vessel is heated to 437℃ at which time the pressure of CO_2 (g) in the vessel is constant at 1.00 atm. Calculate the number of grams of $CaCO_3$ (g) that reacted to produce the carbon dioxide gas.

$$CaCO_3\ (s) \rightarrow CaO\ (s) + CO_2\ (g)$$

B. We Do:

SCAN ME

1. A basketball is left outside in winter when the temperature is -2.00 ℃, has a volume of 6.88 L and the pressure inside the basketball is 0.795 atm.

Component	Mole fraction
N_2	0.780
O_2	0.209
Ar	0.009

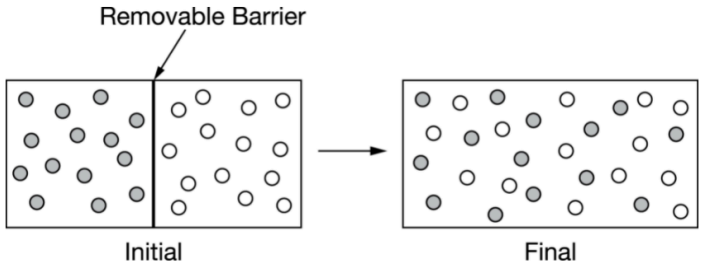
a) How many moles of gas are in a basketball?

b) What is the partial pressure of O_2 in the basketball?

C. You Do:

1. A gas mixture at 0℃ and 1.0 atm contains 0.010 mol of H_2, 0.015 mol O_2, and 0.025 mol N_2. Assuming ideal behavior, what is the partial pressure of H_2 in the mixture?

2. Diagram 1 below shows equimolar samples of two gases inside a container fitted with a removable barrier placed so that each gas occupies the same volume. The barrier is carefully removed as the temperature is held constant. Diagram 2 below shows the gases soon after the barrier is removed. Which statement decibels the changes to the initial pressure of each gas and the final partial pressure of each gas in the m mixture and also indicates the final total pressure?



a) The partial pressure of each gas in the mixture is double its initial pressure; the final total pressure is half the sum of the initial pressures of the two gases.
b) The partial pressure of each gas in the mixture is double its initial pressure; the final total pressure is twice the sum of the initial pressures of the two gases.
c) The partial pressure of each gas in the mixture is half its initial pressure; the final total pressure is half the sum of the initial pressures of the two gases.
d) The partial pressure of each gas in the mixture is half its initial pressure; the final total pressure is the same as the sum of the initial pressures of the two gases.

3. 193 mL of O_2 was collected over water on a day when the atmospheric pressure was 762.0 mmHg. The temperature of the water was 23.0℃. At 23℃ the vapor pressure of water is 21.1 mmHg)
    a) What is the partial pressure of the O_2 collected?

    b) How many moles of O_2 were collected?

    c) How many grams of O_2 were collected?

4. An ideal gas sample has a mass of 1.28 g in a 0.500 L container. The temperature of the container is 127℃ and the pressure is 2.00 atm. What is the molar mass of the gas?

5. Given the reaction below, how many liters of gaseous oxygen are needed to produce 6.50 L of gaseous nitrogen dioxide, if both gases are being measured at STP?

$$2NO\ (g) + O_2\ (g) \rightarrow 2NO_2\ (g)$$

6. Air at 30,000 feet is at a temperature of -35.0℃. A sample of air was collected and the mixture is 75.56% nitrogen, 23.15% oxygen and 1.29% argon (percentages are by mass). If 0.594 moles of air are captured in a 45.0 L container from a plane flying at 30,000 feet:
    a) Calculate the total pressure in the container

    b) Calculate the partial pressure of each gas

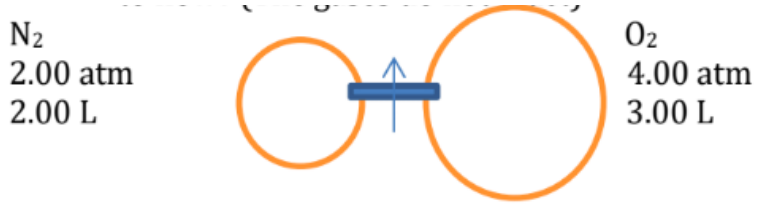
7. How many grams of potassium chlorate were reacted if 5.30 L of O_2 were produced at 117 ℃ and 0.995 atm?

$$2KClO_3 \rightarrow 2KCl + 3O_2$$

8. What is the density of NO_2 gas at 25.0℃ and 2.56 atm?

9. By what factor will the pressure of a sample of a gas change if the volume is reduced by ⅓ while the Kelvin temperature is doubled?

10. What is the final pressure in the container shown below after the valve is opened and the gases are allowed to flow?



TOPIC 3.6: DEVIATIONS FROM THE IDEAL GAS LAW

Learning Objective: Explain the relationship among non-ideal behaviors of gases, interparticle forces, and/or volumes

I. Ideal vs. Real

A. Gases behave ideally under normal conditions:

1. _____

2. _____

B. Under these conditions, KMT assumes:

1. Volume:

a) Because:

2. IMFs:

a) Because:

3. At STP:

C. Ideal gases are those with _____ molar mass and are _____ with _____ IMFs

D. In reality:

E. Gases do NOT behave ideally at:

F. High pressure:

G. High temperature:

II. The Effect of Finite Volume on Gas Particles

A. The actual size of gas particles becomes important at:

1. The volume of the particles themselves:

B. At higher pressure:

III. Volume Adjustment for High Pressure

A. At high pressures the experimentally measure value is

_____ than the value predicted by the ideal gas law

B. The volumes of the molecules must be _____ from the total volume of the container

C. Write and label the formula below:

IV. The Effect of IMFs on Gas Particles

A. Gas molecules typically have what two IMFs?

1. Weaker IMFs behave ideally unless the molecules are:

B. These attractions are typically small in gases and do not matter much at:

1. Low:

2. High:

C. At high pressure:

D. At high temperatures:

1. Collisions are:

E. This will _____ the number of collisions with the side of the container
    1. Why?

    2. Pressure is _____ than what we'd expect with an ideal gas

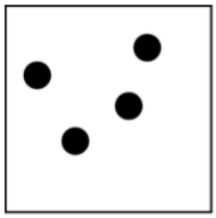
V. Practice:
    A. I Do:
        1. At 10 atm and 100 K, Rn deviates from its predicted volume based on the ideal gas law.
            a) If Rn has a **smaller volume** than predicted, propose an explanation to justify this observation

            b) If Rn has a **larger volume** than predicted, propose an explanation to justify this observation

    B. We Do:

SCAN ME

1. The diagrams below represent two samples of Xe gas in containers of equal volume at 280 K. Which one would deviate more from the ideal gas law and why?



Sample 1

Sample 2

C. You Do:

1. Explain why Ar (g) deviates more from ideal behavior at extremely high pressures than Ne (g) does.

2. Which of the following best helps explain why the pressure of a sample of CH_4 (g) (molar mass 16 g/mol) is closer to the pressure predicted by the ideal gas law than a sample of NH_3 (g) (molar mass 17 g/mol)?
    a) NH_3 molecules are polar while CH_4 molecules are not, and the greater attractions between NH_3 molecules cause the molecules to collide with the walls of the container with less force
    b) NH_3 molecules have a greater molar mass than CH_4 molecules, so the NH_3 molecules collide with the walls of the container with more force
    c) CH_4 molecules have more hydrogen atoms than NH_3 molecules, so CH_4 molecules have more hydrogen bonding and greater IMFs
    d) CH_4 molecules are larger than NH_3 molecules, so the actual CH_4 molecules take up a significant portion of the volume of the gas

3. If the volume of a gas is **greater** than you would expect based on the ideal gas law, the best explanation for this is:

4. If the volume of a gas is **less** than you would expect based on the ideal gas law, the best explanation for this is:

5. Which of the following gases will behave **least** ideally at a pressure of 1 atm and a temperature of 300 K?
    a) He
    b) O_2
    c) Cl_2
    d) HF

6. At what set of conditions of temperature and pressure will a gas behave most ideally?

	Temperature (K)	Pressure (atm)
a)	1000	100
b)	1000	1
c)	200	100
d)	200	1

TOPIC 3.7: SOLUTIONS & MIXTURES

Learning Objective: Calculate the number of solute particles, volume, or molarity of solutions

I. Solutions--What They're Not
    A. Suspension or mechanical mixture

II. Solutions--What They Are

A. Solution:

1. Macroscopic properties:
2. _____ be separated by filtration
3. Solvent:
4. Solute:
5. Aqueous solution:

B. Solution concentration can vary

1. Dilute solution:
2. Concentrated solution:

C. Solutions can be:

D. Solvation:

1. Also called:
2. Process:

III. Liquid Solutions

A. Solute may be:

B. Properties:

C. **Liquid-Liquid Solutions**

1. Differences in _____ can cause:

D. **Liquid-Solid Solutions**

1. Ionic compounds dissolve in:
    a) Creates what type of IMF:
    b) Example:
2. Polar compounds dissolve in:
    a) Creates what type of IMF:
    b) Example:
3. Nonpolar compounds dissolve in:
    a) Creates what type of IMF:
    b) Example:

4. Ion concentration *(after how to make a solution slide)*
    a) Describe how the ion concentration in a solution may differ from the concentration of the solution itself. Use examples:

E. **To Make a Solution**
    a) Describe the steps, including equipment needed, to make an aqueous solution:

F. **Liquid-Gas Solutions**
    1. Examples:

G. **Gas-Gas Solutions**

    1. Always _____ soluble

    2. Example:

H. **Gas-Solid Solutions**
    1. Gases can occupy:

    2. Examples:

I. **Solid-Solid Solutions**

1. Examples:

IV. Measuring Concentration

A. Molarity:

1. _____ change with temperature
2. "_____"
3. Molarity of a solution is always in terms of:
4. Formula:

5. Can be used to convert from **liters** to **moles**:

6. Can be used to convert from **moles** to **liters**:

7. **TIP:

B. Mole Fraction:

1. _____ change with temperature
2. Formula:

V. Practice:

A. I Do:

1. Calculate the volume of a 1.25M lithium chloride solution that can be made with 13.3g of lithium chloride.

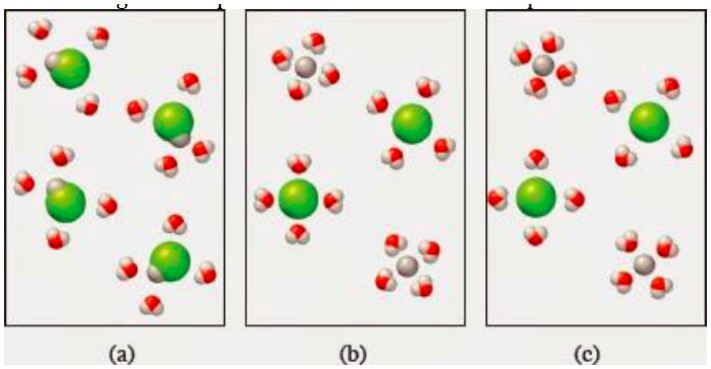
B. We Do:

1. What would be the concentration of chloride ions [Cl^{1-}], in a solution that is made by dissolving 10.0g zinc chloride in a solution that has a final volume of 500 mL?

SCAN ME

C. You Do:

1. Which image best represents a solution of KCl? Explain what is wrong with the other two images.



2. Potassium bromide is **least** soluble in which of the two liquids from each set below. Justify your choice.
    a) H_2O or CH_4

    b) CH_3OH or CH_3CH_2OH

    c) NH_3 or Br_2

3. How many grams of $MgSO_4 \cdot 9H_2O$ are needed to prepare 125 mL of a 0.200 M magnesium sulfate nonahydrate?

4. What volume of 0.25M lithium fluoride solution can be made by dissolving 5.0g lithium fluoride, LiF?

5. What is the molar concentration of a solution made by dissolving 2.9g sodium acetate, $NaC_2H_3O_2$ in water to a total volume of 25mL?

6. What is the calcium ion concentration, $[Ca^{2+}]$, in 1.5M calcium chloride, $CaCl_2$? What is the chloride ion concentration, $[Cl^{1-}]$?

7. What is the acetate ion concentration, $[C_2H_3O_2{}^{1-}]$, of a 100 mL calcium acetate solution, $Ca(C_2H_3O_2)_2$ with 25.0g dissolved $Ca(C_2H_3O_2)_2$?

8. How many moles of Na^+ ions are in 100 mL of 0.100 M Na_3PO_4 (aq)?

9. How many grams of $CaCl_2$ are needed to prepare 100 mL of 0.100 M Cl^- (aq) ions?
    a) 0.55 g
    b) 1.11 g
    c) 2.22 g
    d) 5.55 g

TOPIC 3.8: REPRESENTATIONS OF SOLUTIONS

Learning Objective: Using particulate models for mixtures:

a. Represent interactions between components
b. Represent concentration of components

I. Solutions & IMFs

A. Solids and liquids exhibit:

1. List them:

B. IMFs exist between:

1. _____

2. _____

3. _____

C. Miscibility:

D. A solution will form if:

E. A solution will <u>not</u> form if:

II. Types of Aqueous Solutions

A. Electrolytes:

1. _____ substances

B. Strong electrolytes:

1. Example:

C. Nonelectrolyte solutions:

1. _____ and _____ compounds

2. Example:

D. Based on the picture, describe a **hydration shell**:

III. Representations of Concentration

A. More particles =

B. Tip:

C. Particulate models can be used for:

D. Be sure that:

IV. Practice

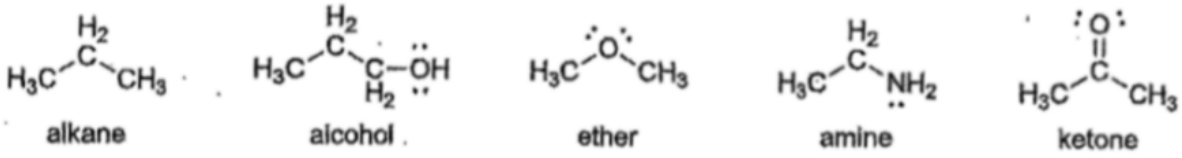
A. I Do:

1. Which solvent would be most effective for dissolving the following solutes, hexane (C_6H_{14}) or water. Identify the dominant type of IMF present between the solute and solvent particles and draw a particulate drawing showing where these interactions occur
   a) Ethanol (C_2H_5OH)

**Side Note:

   b) Potassium chloride

B. We Do:



SCAN ME

1. Of the molecules above, which would form hydrogen bonds with water, which would form dipole-dipole attractions with water, and which would form London dispersion forces only with water?

2. Draw particulate models of two of the alkane molecules. Draw how the strongest intermolecular force present acts between the molecules. What is the name of this force?

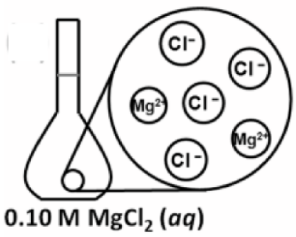
3. Draw particulate models of two of the ether molecules. Draw how the strongest intermolecular force present acts between the molecules. What is the name of this force?

C. You Do:

1. Draw particulate models of two of the amine molecules (use the diagram from the We Do problems). Draw how the strongest intermolecular force present acts between the molecules. What is the name of this force?

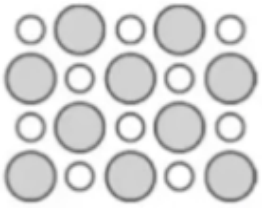
2. Complete a particle representation diagram that includes four water molecules with the proper orientation around the magnesium ion, Mg^{2+}. Represent water as:

3. If the drawing below represents 0.10 M $MgCl_2$, draw a particulate drawing of 0.05 M $MgCl_2$ with the appropriate number of magnesium and chloride ions.



4. The structures of a water molecule and a crystal of LiCl (s) are represented below. Show the interactions of the components of LiCl (aq) by making a drawing that represents the different particles present in the solution. Base the particles in your drawing on the particles shown in the representations below. Include only one formula unit of LiCl and no more than ten molecules of water. Your drawing must include the following details:
    a) Identity of ions (symbol and charge)
    b) The arrangement and proper orientation of the particles in the solution

H_2O molecule



LiCl crystal

TOPIC 3.9: SEPARATION OF SOLUTIONS AND MIXTURES USING CHROMATOGRAPHY

Learning Objective: Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents and the intermolecular interactions between particles

I. Separating Mixtures
    A. Key to separating substances:

    B. Physical separations:

        1. Non-mechanical means of separation:

2. Mechanical means of separation:

II. Mechanical Separation

A. Density Separation:

1. Separates mixtures based on:

2. Describe the procedure:

3. Sediment:

4. Decanting:

5. Filtration:

a) Residue:

b) Filtrate:

6. Sketch decantation vs. filtration below:

B. Centrifugation

1. How does it relate to density separation?

2. Describe the process:

III. Non-Mechanical Separation

A. Chromatography:

1. Separates a mixture based on:

2. Mobile phase:

3. Stationary phase:

4. A solution with a _____ solubility and _____ affinity for the stationary phase travels _____ through the chromatogram

5. Three types:

a) _____

b) _____

c) _____

B. Paper Chromatography

1. Summarize the process, include a sketch if helpful:

2. R_f value =

    a) Ratio of:

    b) Large R_f =

    c) Small R_f =

    d) Equation:

3. The more _____ in polarity the sample is to the **solvent** the _____ it will travel

4. “Like dissolves like” so:

5. Polar interacts with _____; nonpolar interacts with _____

6. Identification of a sample is possible only by:

C. Thin Layer Chromatography

1. How does it differ from paper chromatography?

2. Silica is _____ and paired with _____ mobile phase

3. Can be used to separate:

    a) So _____ light is used

4. Commonly used with:

5. Analysis:
    a) The more _____ the sample the _____ it will travel
    b) Identification of a sample is possible only by:

D. Column Chromatography

1. Stationary phase:

2. Mobile phase:

3. Describe the process, include a sketch if helpful:

4. The _____ parts of the mixture will travel the slowest

5. This procedure is meant more for:

6. R_f =

E. Electrophoresis:
    1. Stationary phase:

    2. _____ are placed at either end

    3. Species are separated based on:

F. Distillation:
    1. Separates a mixture based on:

    2. Equipment used:

3. Distillate:

4. Residue:

5. Most useful for:

6. Less useful for:

G. Fractional distillation:

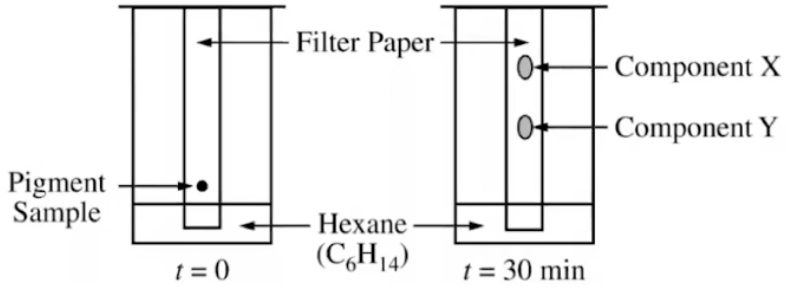
1. Uses a:

a) Purpose:

IV. Practice:

A. I Do:

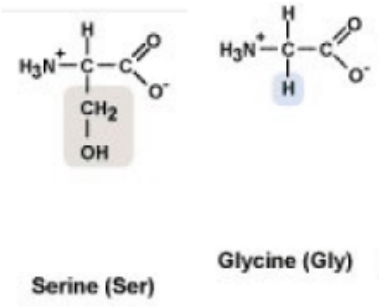
1. In a paper chromatography experiment, a sample of pigment is separated into 2 components, X & Y, as shown below. The surface of the paper is moderately polar. What can be concluded about X & Y based on the experimental results?



B. We Do:

SCAN ME

1. Serine and glycine are both amino acids where serine is polar and glycine is nonpolar. The two amino acids are not labelled and must be identified.



Serine (Ser)

Glycine (Gly)

a) Explain why thin layer chromatography is more appropriate than paper chromatography in this case.

b) Describe how to set up a thin layer chromatography experiment that will help identify the two amino acids.

c) Draw a chromatogram that would represent what we know about the two amino acids.

C. You Do:

1. Which of the following is the most appropriate to perform column chromatography over paper chromatography?
    a) The sample is a mixture of strictly polar particles
    b) The sample is a mixture of strictly nonpolar particles
    c) The goal is to separate and recover the parts of the mixture
    d) The densities of the component parts of the mixture differ

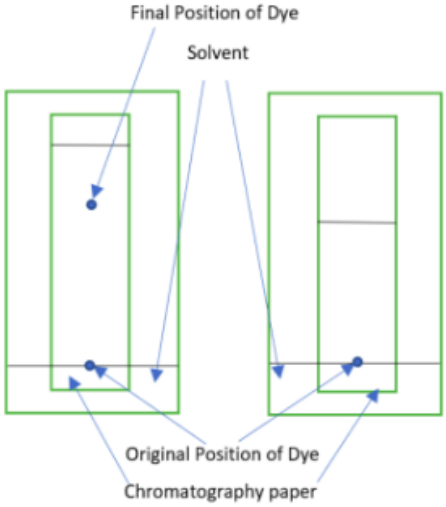
2. A student was performing paper chromatography and let the separation continue overnight. The student wished to determine if the mixture contained a substance with an R_f factor of 0.343 where:

    R_f = distance traveled by component/distance traveled by solvent

    a) What data would be affected by this error?

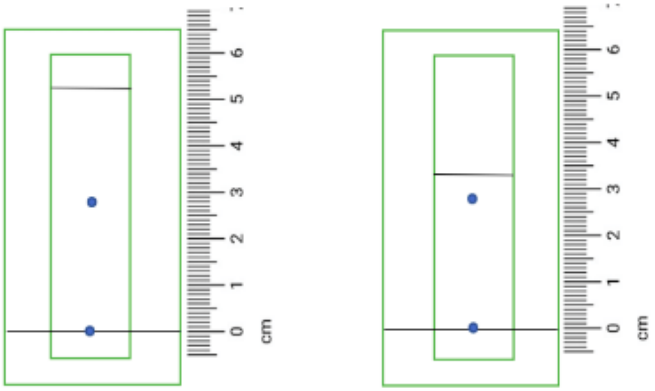
    b) Explain the effect on the calculated R_f

3. The image below shows the complete chromatography separation of a mixture on the left, and an incomplete image of the same mixture's separation on the right. The data on the left has a leading edge of solvent of 10.0 cm and the distance travelled by the dye was 8.0 cm. The data on the right shows the leading edge of the solvent as 6.0 cm. What distance would you predict the same dye to travel on the chromatography paper on the right ?



   a) 4.8 cm
   b) 6.0 cm
   c) 8.0 cm
   d) Cannot be determined

4. Calculate the R_f value for the following where the lines on the chromatography paper represent the starting point of the dye and the final distance travelled by the solvent



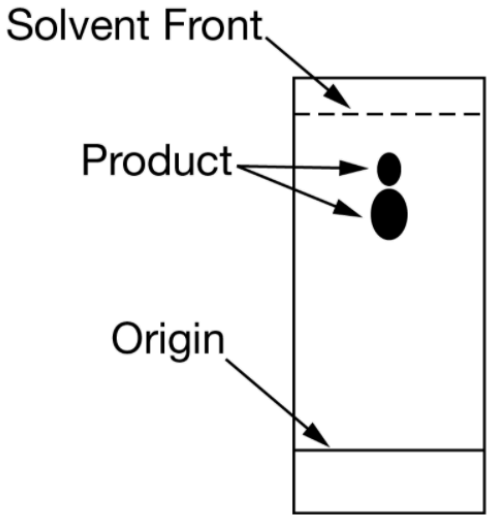
5. Which of the following would travel the farthest in column chromatography?
    a) $CH_3CH_2CH_2COOH$
    b) C_6H_6
    c) CH_3OH
    d) C_8H_{18}

6. In paper chromatography, what physical property is most important to the separation?
    a) Density
    b) Polarity
    c) Particle size
    d) Particle molar mass

7. A distillation of several compounds was performed. Based on the physical property provided, place the substances in order of extraction.

Name	Formula	Boiling Point (℃)
Acetone	CH_3COCH_3	56
Diethyl Ether	$C_2H_5OC_2H_5$	34.6
Ethanol	C_2H_5OH	78.4

8. The diagram below shows a thin-layer chromatogram of a mixture of products from a chemical reaction. The separation was performed using 50% ethyl acetate in hexane as the solvent (mobile phase) and silica gel as the polar stationary phase. On the basis of the chromatogram and the information about solvents in the table, which of the following would be the best way to **decrease** the distance that the products travel up the plate?

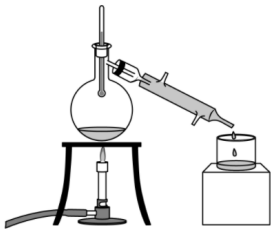


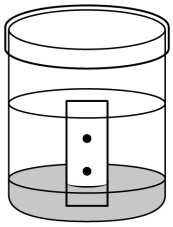
Solvent	Boiling Point (°C)	Relative Polarity
Pentane	36	0.1
Hexane	68	0.1
Ethyl acetate	77	4.4
Methanol	65	5.1

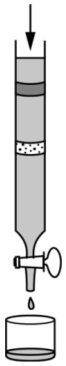
a) Use pentane instead of hexane
b) Decrease the percentage of ethyl acetate in the solvent
c) Increase the percentage of ethyl acetate in the solvent
d) Add up to 5% methanol to the solvent

9. A student obtains a liquid sample of green food coloring that is known to contain a mixture of two solid pigments, one blue and one yellow, dissolved in an aqueous solution of ethanol. Which of the following laboratory setups is most appropriate for the student to use in order to separate and collect a substantial sample of each of the two pigments?

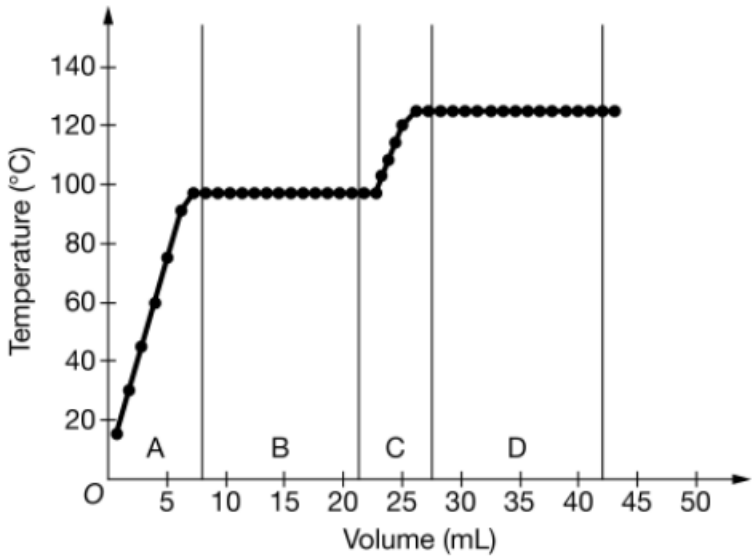
a. 

b. 

c. 

d. 

10. A student performed a fractional distillation of a mixture of two straight-chain hydrocarbons, C_7H_{16} and C_8H_{18}. Using four clean, dry flasks, the student collected the distillate over the volume ranges (A, B, C, and D) shown in the graph below. Over what volume range should the student collect the distillate of the compound with the stronger intermolecular forces?



a) A
b) B
c) C
d) D

TOPIC 3.10: SOLUBILITY

Learning Objective: Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents and the intermolecular interactions between particles

I. Solutions
   A. Review vocab:
      1. Solution:

      2. Solute:

3. Solvent:

4. Miscible:

5. Immiscible:

II. Solubility

A. Definition:

1. Highly soluble:

2. Slightly soluble:

B. Units:

C. Solubility depends (in part) on:

1. Polar substances dissolve:

2. Nonpolar substances dissolve:

3. Ionic compounds:

a) Name of attraction:

4. Molecular compounds:

    a) What results in more interactions with the solvent?

D. Water: the universal solvent
    1. Aqueous:

    2. Which part of the water is positive? Negative?

    3. Hydration:

    4. When can water dissolve non-ionic substances?

        a) Example:

E. Requirements for forming a solution:

F. The amount of energy needed for each step above depends on:

1. Stronger the IMFs:

2. Why can't polar dissolve nonpolar (and vice versa)?

G. Saturation:
    1. Unsaturated:

    2. Saturated:

    3. Supersaturated:

III. Solubility & Temperature
    A. Solids:

    B. Gases:

    C. What is a solubility curve?

IV. Common Solvents:
    A. Complete the table below:

Common Laboratory Solvents	
Common Polar Solvents	**Common Nonpolar Solvents**

V. Solubility Rules:

A. Complete the table below:

Ions that form SOLUBLE compounds	Exceptions

B. Remember SNAP:

VI. Practice:

A. I Do:

1. For each of the following substances, determine the type(s) of IMF present and then decide if the substance will dissolve better in hexanes (C_6H_{14}) or water (H_2O)

		Hexanes	Water
Substance	**Type(s) of IMF**		
NaCl			
C_3H_8			
CO_2			

CH_2O			

B. We Do:

1. With a partner, complete 7.2 Activity: Determining the Bond Type of a Solution on p. 451 (457) in your textbook.

C. You Do:

1. Rank the following from MOST soluble in water to LEAST soluble in water:
    a) $CH_3CH_2CH_2OH$
    b) $HOCH_2CH_2OH$
    c) $CH_3CH_2CH_2CH_3$

2. The following gases were bubbled through water. Which is most likely to dissolve?
    a) CO_2
    b) CH_4
    c) PH_3
    d) N_2

3. In each pair, determine which ion would be more strongly hydrated with water and explain why. Refer to the notes on Coulomb's Law if needed.

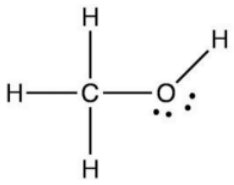
    a) Na^+ or Li^+

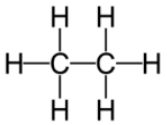
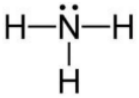
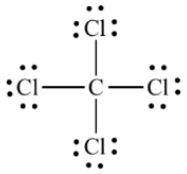
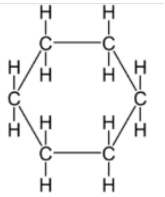
    b) Na^+ or Mg^{2+}

    c) ClO_4^- or ClO_2^-

4. Which of the following would be most likely to dissolve in methanol? Explain your selection based on the IMFs.

Methanol:



a. Ethane	
b. Ammonia	
c. Carbon tetrachloride	
d. Cyclohexane	

5. Which of the following pairs of substances are miscible? (choose all that apply)
   a) C_6H_{14} & C_5H_{12}
   b) H_2O & CH_3OH
   c) C_4H_{10} & C_4H_9OH
   d) $CHCl_3$ & CH_2Cl_2
   e) CH_3NH_2 & CH_3CH_3

6. The survival of aquatic organisms depends on the small amount of O_2 that dissolves in H_2O. The diagrams below show possible models to explain this phenomenon. Which diagram provides the better particle representation of the solubility of O_2 in H_2O and why?

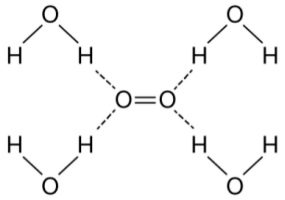


Diagram 1

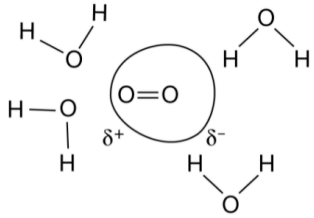
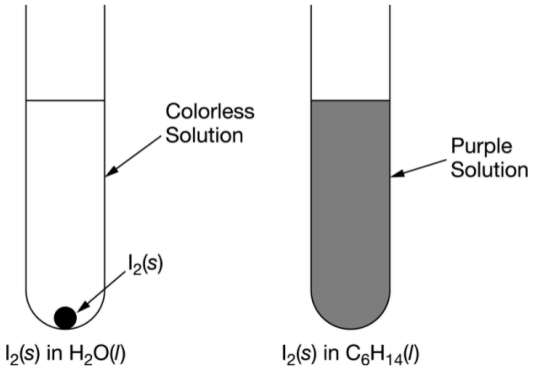


Diagram 2

a) Diagram 1; because O_2 molecules can form hydrogen bonds with the H_2O molecules
b) Diagram 1; because O_2 and H_2O are polar molecules that can interact through dipole-dipole forces
c) Diagram 2; because the polar H_2O molecules can induce temporary dipoles on the electron clouds of O_2 molecules
d) Diagram 2; because the nonpolar O_2 molecules can induce temporary dipoles on the electron clouds of H_2O molecules

7. A student places a piece of $I_2(s)$ in 50.0 mL of H_2O (l), another piece of I_2 (s) of the same mass in 50.0 mL of C_6H_{14} (l) and shakes the mixture. The results are shown below. What do the results indicate about the intermolecular interactions of the substances?



a) I_2 and H_2O have similar intermolecular interactions, and I_2 and C_6H_{14} do not
b) I_2 and C_6H_{14} have similar intermolecular interactions, and I_2 and H_2O do not
c) I_2, H_2O, and C_6H_{14} all have similar intermolecular interactions
d) I_2, H_2O, and C_6H_{14} have three completely different types of intermolecular interactions

TOPIC 3.11: SPECTROSCOPY & THE ELECTROMAGNETIC SPECTRUM

Learning Objective: Explain the relationship between a region of the electromagnetic spectrum and the types of molecular or electronic transition associated with that region

I. Electromagnetic Radiation
   A. Classified based on:
      1. Electromagnetic spectrum:
   B. Explain how light is emitted:
   C. Photon:
      1. Quantized:

D. Sketch the electromagnetic spectrum, including visible light, below:

II. Energy Calculations

A. Wavelength:

1. Units:

B. Frequency:

1. Units:

C. Speed of light:

D. h:

E. E_{photon}:

F. Equations:

III. Molecular Movement

A. Translational:

B. Rotational:

C. Vibrational:

1. Can be described as:

D. What conditions need to exist for molecular motion to stop?

IV. Spectroscopy

A. Definition:

B. Matter can _____ or _____ radiation in different regions of the EMS

C. Infrared Vibrational Spectroscopy

1. Describe the relative energy level and wavelength of IR:

2. Measures:

3. What happens to the molecular vibrations after an IR photon is absorbed?

4. There are distinct vibrational levels just as there are distinct electronic energy levels and distinct spin levels

5. How is IR spectroscopy analyzed?

6. Key point:

7. Quick Check:
    a) What group might be identified by the farthest left band in the IR spectrum in Figure 2.7.5?

    b) Rank the following N to N bonds in order of **increasing** vibrational frequency:
        (1) N-N
        (2) N=N
        (3) N≡N

D. Microwave Rotational Spectroscopy
    1. Describe the relative energy level and wavelength of microwave radiation:

    2. Striking particles with microwaves causes them to:

3. Key point:

E. Ultraviolet-Visible Light Spectroscopy
    1. Describe the relative energy level and wavelength of UV/Vis light:

    2. Visible light occurs between what wavelengths?

    3. UV radiation occurs between what wavelengths?

        a) In this region photons may affect:

        b) This effects:

    4. This type of spectroscopy involves:

    5. Electrons may be:

    6. Describe the analysis of UV/Vis spectroscopy:

        a) Equipment used:

    7. Key point:

V. Practice

A. I Do:

1. Two samples of copper (II) sulfate were analyzed using visible light spectroscopy. Sample 1 absorbed twice as much light as Sample 2.
    a) What can you deduce about the concentration of the two solutions?

    b) What must be true of the solution in order to get results from this type of spectroscopy?

    c) Describe the type of changes that occur within the molecule during the process of UV-Vis spectroscopy.

B. We Do:

1. What type of spectroscopy would be responsible for the change from $1s^2 2s^2 2p^5$ to $1s^2 2s^2 2p^4 3s^1$?

2. What type of spectroscopy would be responsible for the bending of the O-H bonds in water?

C. You Do:

1. Match the type of electromagnetic radiation with the type of molecular rotations or transitions that it causes--either Rotational motion, Electronic transitions, or Vibrational motion:

    a) Infrared:

b) Ultraviolet-Visible light:

c) Microwaves:

2. NO_2 is a reddish brown color while N_2O_4 is colorless. Based on this information only, which type of spectroscopy would be a good choice to determine the identity of an unknown sample that contains either NO_2 or N_2O_4?

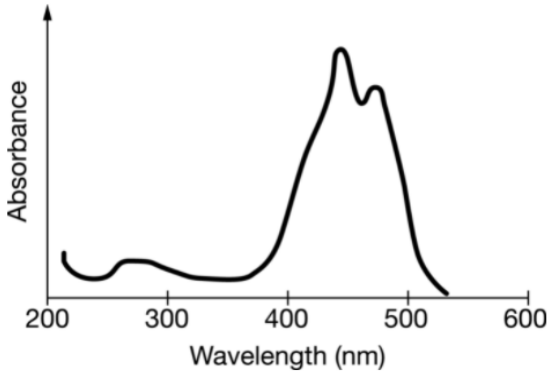
3. Infrared spectroscopy is a useful tool for scientists who want to investigate the structure of certain molecules. Which of the following best explains what can occur as the result of a molecule absorbing a photon of infrared radiation?
    a) The energies of infrared photons are in the same range as the energies associated with changes between different electronic energy states in atoms and molecules. Molecules can absorb infrared photons of characteristic wavelengths, thus revealing the energies of electronic transitions within the molecules.
    b) The energies of infrared photons are in the same range as the energies associated with different vibrational states of chemical bonds. Molecules can absorb infrared photons of characteristic wavelengths, thus revealing the types and strengths of different bonds in the molecules.
    c) The energies of infrared photons are in the same range as the energies associated with different rotational states of

molecules. Molecules can absorb infrared photons of characteristic wavelengths, thus revealing the energies of transition between different rotational energy states of the molecules.

d) The energies of infrared photons are in the same range as the total bond energies of bonds within molecules. Chemical bonds can be completely broken as they absorb infrared photons of characteristic wavelengths, thus revealing the energies of the bonds within the molecules.

4. Which statement correctly compares what occurs when molecules absorb photons in the microwave region with what occurs when molecules absorb photons in the infrared region?
    a) Microwave photons cause the molecules to increase their rotational energy states, whereas infrared photons cause the molecules to increase their vibrational energy states.
    b) Microwave photons cause electrons in the molecules to increase their electronic energy states, whereas infrared photons cause the molecules to increase their rotational energy states.
    c) Microwave photons cause the molecules to increase their vibrational energy states, whereas infrared photons cause electrons in the molecules to increase their electronic energy states.
    d) Microwave photons cause the molecules to increase their rotational energy states, whereas infrared photons cause electrons in the molecules to increase their electronic energy states.

5. Beta-carotene is an organic compound with an orange color. The diagram below shows the ultraviolet spectrum of beta-carotene. Which of the following statements is true about the absorption bands in the spectrum?



a) The absorption band between 250 and 320 nm is due to transitions in electronic energy levels, and the absorption band between 380 and 520 nm is due to transitions in molecular vibrational levels
b) The absorption band between 250 and 320 nm is due to transitions in molecular vibrational levels, and the absorption band between 380 and 520 nm is due to transitions in molecular rotational levels
c) The two main absorption bands are associated with transitions in electronic energy levels. The band in the region corresponding to shorter wavelengths shows a lower absorbance than the band in the region corresponding to longer wavelengths
d) The two main absorption bands are associated with transitions in molecular vibrational levels. The band in the region corresponding to shorter wavelengths shows a lower absorbance than the band in the region corresponding to longer wavelengths

TOPIC 3.12: PHOTOELECTRIC EFFECT

Learning Objective: Explain the properties of an absorbed or emitted photon in relationship to an electronic transition in an atom or molecule

I. Components of a Wave
   A. Draw and label a wave diagram below:

B. What is the relationship between wavelength and frequency?

II. Frequency vs. Wavelength

A. Can be expressed using the following equation:

B. Wavelength:

C. Frequency:

D. Speed of light:

III. Quantum Theory & Planck

A. Max Planck's hypothesis:

B. How does energy increase?

1. Energy increases by:

C. The magnitude of a quantum depends on:

D. Equation:

1. Can be used to find:

2. Or:

E. What is the relationship between frequency and energy?

F. Planck's constant:

G. E_{photon}:

H. Energy is _____ to _____

but _____ to _____

IV. Photoelectric Effect

A. Photoionization:

B. Photoelectric effect:

1. Most molecules require _____

_____ to produce this effect

C. What happens when light shines on a clean metal surface?

1. Each metal has a _____

of light below which _____

are emitted

D. Light has both:

E. What happens when a photon is absorbed by metal?

F. Threshold frequency:

G. What happens if the radiation interacting with the metal has a high intensity but low frequency?

H. Increasing the <u>intensity</u> of the light with the minimum frequency required for e^- emission will cause the emission rate to:

I. Increasing the <u>frequency</u> of the light:

1. All ejected electrons have the same:

2. Increasing the frequency increases the:

J. Work function:

K. Write and explain the equation:

V. Photoelectric Effect--In Summary

A. Summarize the 3 main points below:

VI. Practice:

A. I Do:

1. When a metal surface is exposed to light with increasing frequency and energy of photons, electrons first begin to be ejected from the metal when the energy of the photons is 3.3×10^{-19} J.

a) What is the frequency of light with photon energy 3.3×10^{-19} J?

b) Calculate the wavelength for light with energy of 3.3×10^{-19}J

c) What is the color of this light?

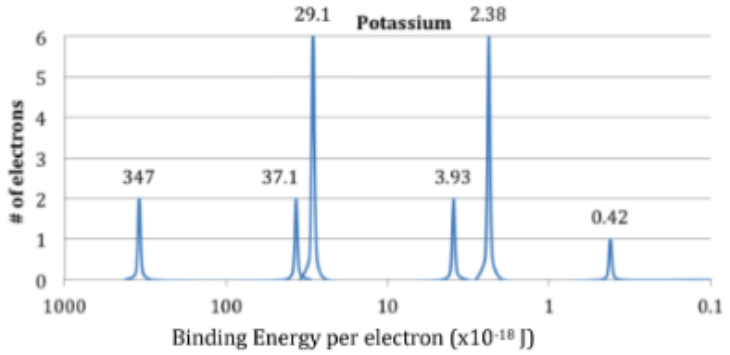
B. We Do:

SCAN ME

1. $CuSO_4$ solutions absorb light at a wavelength of 635 nm. Calculate the approximate energy of one photon of this light.

C. You Do:

1. The photoelectron spectrum (PES) for potassium is provided below.



a) Write the electron configuration for potassium using the PES above.

b) Identify the valence electron(s) on the graph above (circle)

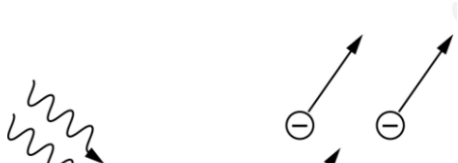
c) Calculate the frequency of light required to remove the valence electron(s)

2. The energy required to eject an electron from sodium metal using the photoelectric effect is 275 kJ/mol. What is the maximum wavelength in nm needed for this to occur?

3. Calculate the frequency of red light with a wavelength of 715 nm.

4. The ionization energy of silver is 731 kJ/mol. Is light with a wavelength of 415 nm sufficient to remove an electron from a silver atom in the gaseous phase?

5. The diagram below represents the photoelectric effect for a metal. When the metal surface is exposed to light with increasing frequency and energy of photons, electrons first begin to be ejected from the metal when the energy of the photons is 3.3 x 10^{-19} J. Which of the following is closest to the frequency of the light with photon energy of 3.3 x 10^{-19}J?



a) $5.0 \times 10^{-53}\ s^{-1}$
b) $5.0 \times 10^{-16}\ s^{-1}$
c) $5.0 \times 10^{14}\ s^{-1}$
d) $5.0 \times 10^{52}\ s^{-1}$

6. A student uses visible spectrophotometry to determine the concentration of CoCl2 (aq) in a sample solution. First the student prepares a set of CoCl2 (aq) solutions of known concentration. Then the student uses a spectrophotometer to determine the absorbance of each of the standard solutions at a wavelength of 510 nm and constructs a standard curve. Finally, the student determines the absorbance of the sample of unknown concentration. A wavelength of 510 nm corresponds to an approximate frequency of $6 \times 10^{14}\ s^{-1}$ What is the approximate energy of one photon of this light?
   a) 9×10^{47} J
   b) 3×10^{17} J
   c) 5×10^{-7} J
   d) 4×10^{-19} J

7. When the metal surface is exposed to light with increasing frequency and energy of photons, electrons first begin to be ejected from the metal when the energy of the photons is 3.3×10^{-19} J. Using the wavelength information provided below and the diagram from question #5, what is the color of the light?

Color	Wavelength
Red	$647 - 760$ nm
Orange	$585 - 647$ nm
Yellow	$575 - 585$ nm
Green	$491 - 575$ nm
Blue	$424 - 491$ nm
Violet	$300 - 424$ nm

   a) Red

b) Orange
c) Yellow
d) Blue

TOPIC 3.13: BEER-LAMBERT LAW

Learning Objective: Explain the amount of light absorbed by a solution of molecules or ions in relationship to the concentration, path length, and molar absorptivity

I. Absorbance

A. One way we can measure the concentration of a colored substance is by:

B. Absorbance:

C. Equipment used:

D. Concentration vs. absorbance:

E. Different colors of solutions absorb:

1. When does maximum absorbance occur?

F. Steps to measuring absorbance:

II. Beer-Lambert Law

A. Molar absorptivity:

1. Describes:

B. Path length:

1. As the path length increases:

C. Write the equation and label the components below:

D. In most experiments the path length and wavelength _____

_____ so molar absorptivity also remains

_____ so absorbance is the only proportional to

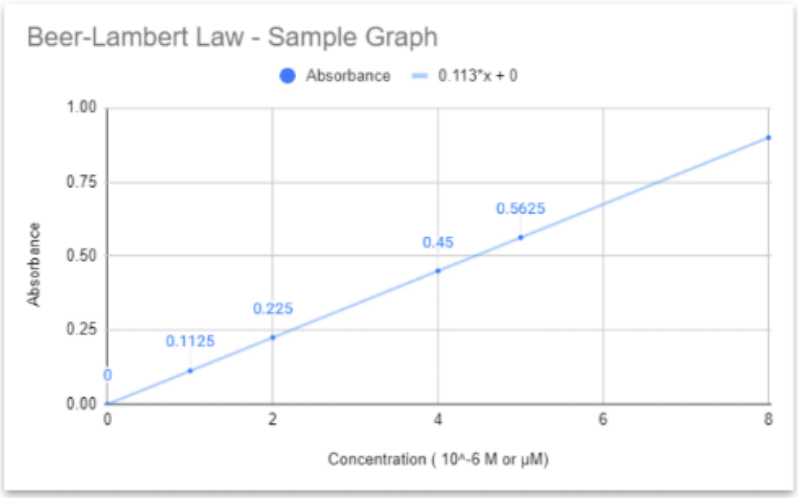
_____

E. Absorbance can be measured for an unknown substance and concentration can be determined from:

III. Practice:

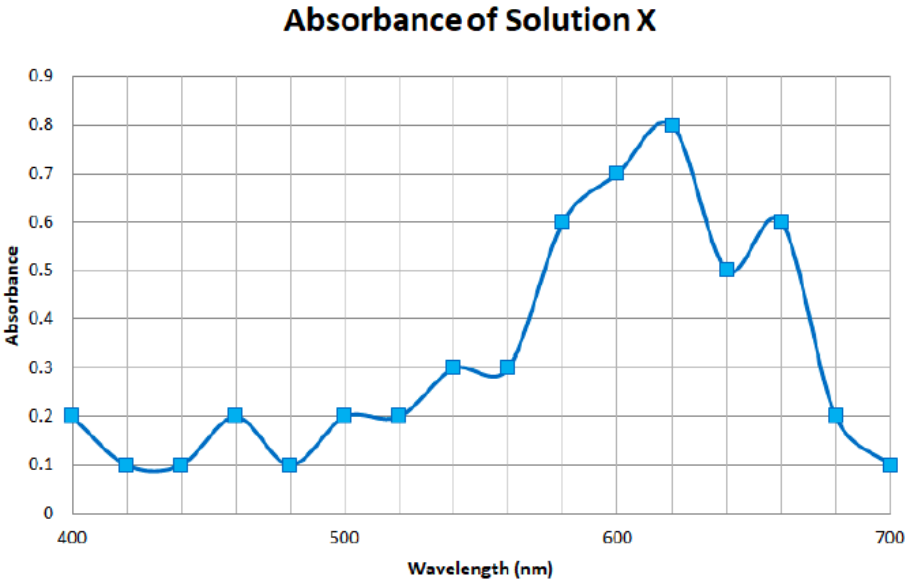
A. I Do:

1. Based on the provided calibration graph below, if the absorbance of an unknown concentration of the solution was 0.34, what was the M of the solution?



B. We Do:

SCAN ME

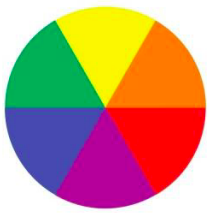


1. Solution X has an absorption spectrum shown on the graph.

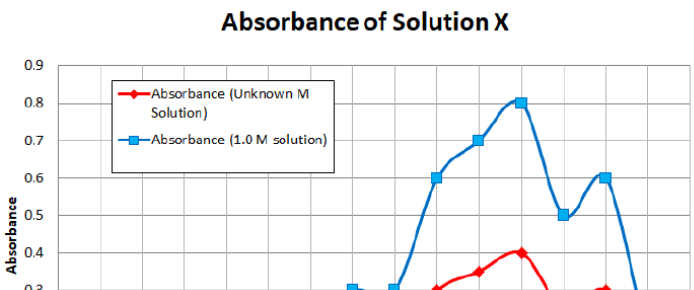
Color	Wavelength interval
Red	~ 700–635 nm
Orange	~ 635–590 nm
Yellow	~ 590–560 nm
Green	~ 560–520 nm
Cyan	~ 520–490 nm
Blue	~ 490–450 nm
Violet	~ 450–400 nm

a) What would be an appropriate wavelength to gather the absorption data?

b) What is the color of the light that is absorbed?



c) Predict the color of this solution.



d) A solution with an unknown amount of

the same solute, X, was prepared and graphed as shown. How is the new solution (unknown concentration) different from the first one? How is it the same?

C. You Do:

1. The diagrams below show the UV absorption spectra for two compounds. Diagram 1 is the absorption spectrum of pure acetone, a solvent used when preparing solutions for an experiment. Diagram 2 is the absorption spectrum of the solute for which the absorbance needs to be measured to determine its concentration. When the student reads the absorbance of the solution at 280 nm, the result is too high. Which of the following is most likely responsible for the error in the measured absorbance?

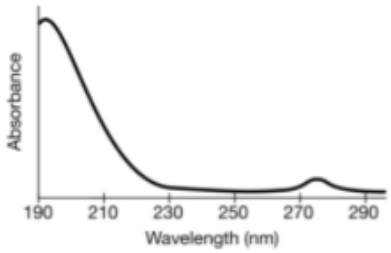


Diagram 1

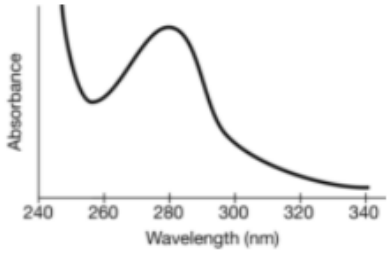
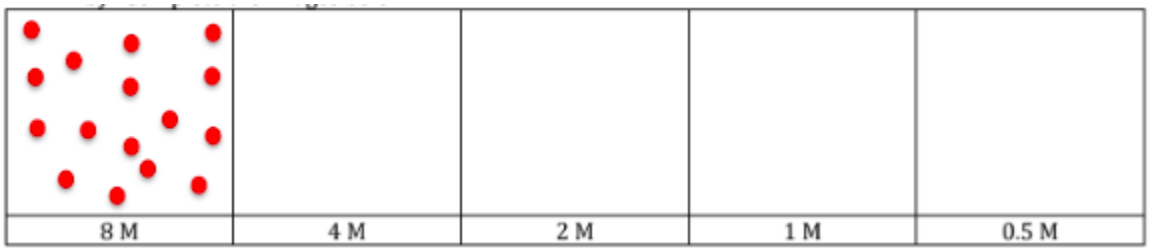


Diagram 2

   a) The student added too little solute to the acetone before measuring its absorbance
   b) The student rinsed the cuvette with the solution before filling the cuvette with the solution
   c) The student forgot to calibrate the spectrophotometer first by using a cuvette containing only acetone
   d) The wavelength setting was accidentally changed from 280 nm to 300 nm before the student made the measurement

2. Water is added to dilute an 8M solution of red dye.
   a) What happens to the concentration of a solution as water is added?

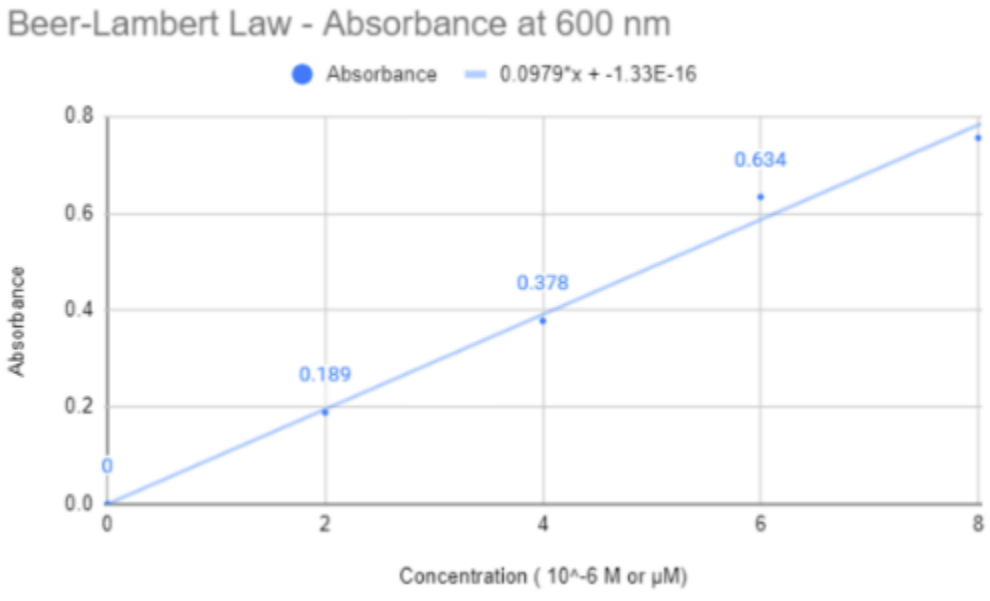
b) Complete the images below:



c) Explain why the absorbance of light decreases when the concentration of the solution decreases.

3. The standard size of a cuvette is 1 cm. How would the absorbance data be different if you used cuvettes that were twice that width? Illustrate to support your answer. (Assume constant concentration)

4. Given the following calibration curve for solution X



a) If you recorded an absorbance of 0.525, calculate the corresponding molarity of the solution. Mark this on the graph to check that your answer is reasonable.

b) If the molar mass of the dye used was 791.41 g/mol, how many grams of dye were dissolved in 10.0 mL of the solution measured in part a?

c) What is the calculated absorbance for a solution with a concentration of 1.5×10^{-6} M? Mark this on the graph to check that your answer is reasonable.

d) Propose a logical reason for the error that occurred with the data point at 6.0×10^{-6} M on the graph.