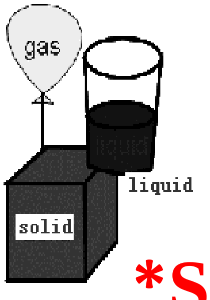


Physical Behavior of Matter

Physical Behavior of Matter

Unit 6

STUDENT

STUDENT

Unit Vocabulary:

- Absolute Zero
- Avogadro's Law
- Normal Boiling Point
- Compound
- Cooling Curve
- Deposition
- Energy
- Element
- Evaporation
- Heat
- Heat of Fusion
- Heat of Vaporization
- Heating Curve
- Heat Transfer
- Kinetic Energy
- Kinetic Molecular Theory (KMT)
- Lattice
- Matter
- Mixture
- Melting Point
- Potential Energy
- Sublimation
- Temperature
- Vapor Pressure

Unit Objectives:

At the completion of this unit you will be able to:

- Distinguish between the three phases of matter by identifying their different properties and representing them with particle diagrams
- Perform simple conversions between Celsius and Kelvin temperature scales
- Differentiate between exothermic and endothermic reactions/changes
- Identify phase changes, and understand how to read a heating or cooling curve
- Define heat, and understand how it varies from temperature
- Solve heat equations
- Solve gas law problems using the following laws: Avogadro's Law, Combined Gas Law, Dalton's Law of Partial Pressures
- State and understand the Kinetic Molecular Theory (KMT)
- Understand the relationship between temperature, volume, and pressure among gases using the following gas laws: Charles' Law, Boyle's Law, Gay Lussac's Law

Energy and Temperature definitions:

Energy: ____________ to do __________(ability of MATTER to do WORK)

Kinetic Energy (KE): energy of ______________________________

- associated with ________________ change

Potential (AKA Phase) Energy: energy of ____________ (____________ or ____________ energy)

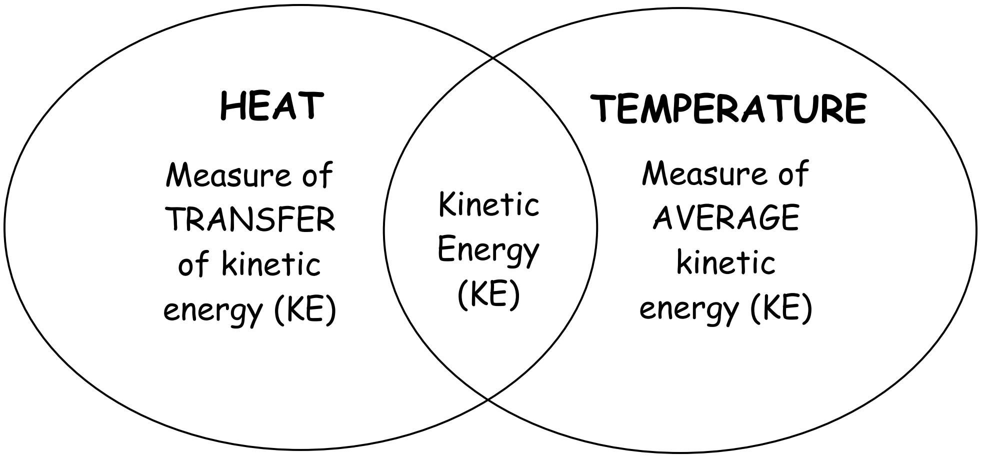
- associated with ____________ change, <u>NOT</u> TEMPERATURE change

Temperature: measure of the __________________________ of a substance's particles (Δ TEMP means Δ KE); does _____ depend on SAMPLE SIZE; measured in °C, °F, or K

Heat: quantity of ____________

- Cannot be measured directly (as opposed to temperature)
- Can only be measured as it's ____________ from one (HOTTER) object to another (COOLER) object
- ________ depend on SAMPLE SIZE (the larger the sample, the more heat needed to bring it to desired temp)
- measured in ____________ (J), ____________ (kJ) or ____________ (we will only use J or kJ in this class)

NOTE: Although there is a DIRECT RELATIONSHIP between TEMPERATURE and HEAT, they are NOT THE SAME THING!!!



Temperature Scales:

There are three common temperature scales:

1. Fahrenheit (°F)

2. Celsius (°C)

3. Kelvin (K)

- As chemists we use two of these scales: °C and K

ABSOLUTE ZERO = -273°C or 0 K; the temperature at which all PARTICLE MOTION ceases (http://www.news.wisc.edu/1184)

- The thermometer scales are calibrated by two fixed positions:

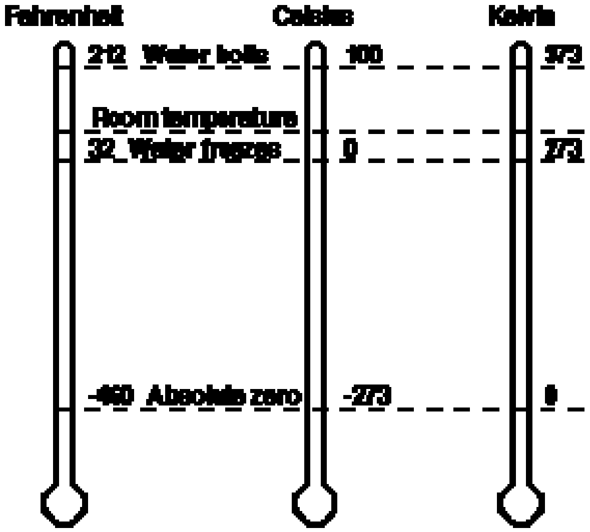
  1) The freezing/melting point of water = 0°C or 273 K

  2) The boiling point of water = 100°C or 373 K

- NOTE: There is a DIRECT CORRELATION between the KELVIN and CELSIUS scale which is what makes it very easy to convert from one to the other. They are to the same scale, only shifted.

- A change of 1°C is the same as a change of 1 K. Or, in equation form:

$$\Delta\ 1°C = \Delta\ 1\ K$$



Kelvin/Celsius Temperature Conversions:

Use formula in Table T →

K = °C + 273
or
°C = K - 273

1) What Kelvin temperature is equivalent to 35 °C?

2) The classroom has a temperature of 21°C, what is the temperature of the classroom in Kelvin?

3) When the temperature is 300K, what is the temperature in degrees Celsius? (Note: you must rearrange the formula!)

4) If something has a temperature of 5 K, what is this in °C?

5) A sample is heated and rises in temperature by 12°C. What is this temperature difference in Kelvin?

ΔT =

Practice:

Celsius	Kelvin
0 °C	
	20 K
50 °C	
	117 K
	0 K
-113 °C	
-74 °C	
	5 K
	99 K
31 °C	
-200 °C	
	37 K
	320 K
-0.5 °C	
	248 K

NOTICE**: It is possible to have a negative CELSIUS value, but ***never a negative KELVIN value! This is the main reason that chemists use the KELVIN scale.

Additional Questions to Ponder:

1. Different masses of copper and iron are found to have the same temperature. Compare the average kinetic energy of the copper atoms to the iron atoms. Explain your answer.

   Ans:

2. A student is examining two samples of ice. Sample A has a mass of 10 g while sample B has a mass of 1 g. Both samples are at their freezing point. Compare and contrast the two samples in terms of temperature and heat energy.

   Ans:

3. For the following scenarios, please indicate whether the average kinetic energy of water molecules is increasing, decreasing, or remaining the same.
   a) $H_2O(s)$ changes to $H_2O(l)$ at 0°C: Ans:
   b) $H_2O(l)$ changes to H_2O (s) at 0°C: Ans:
   c) $H_2O(l)$ at 10°C changes to $H_2O(l)$ at 20°C: Ans:
   d) $H_2O(l)$ at 20°C changes to $H_2O(l)$ at 10°C: Ans:

4. When the temperature of an object changes by 100°C, how much does it change in Kelvin?

   Ans:

5. What are the two fixed points on the thermometer (please state the names and temperature values for both?

   Ans:

6. When you look at a solid, it does not seem to be moving at all. Since the particles are *not* at absolute zero, explain how it is possible for the particles to be moving.

   Ans:

7. A temperature probe in a plant reads -298°C. Is this temperature possible? Explain.

   Ans:

Phases of Matter:

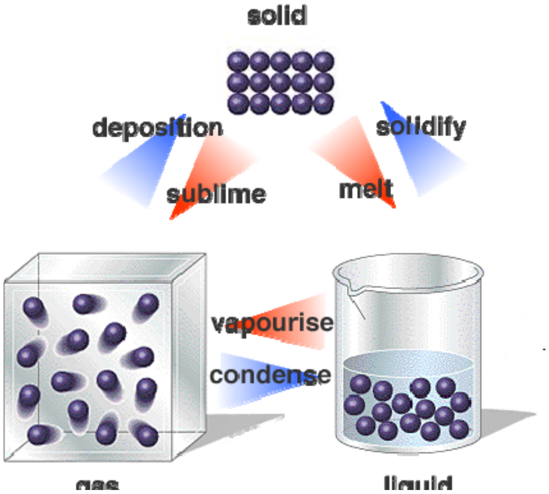
Matter exists in three forms at _____ (**S**tandard **T**emperature & **P**ressure)

**See Table A*

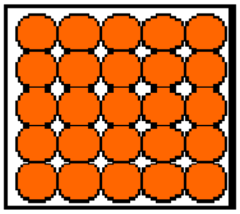
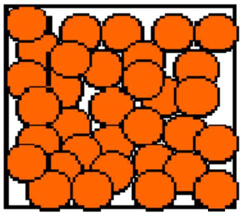
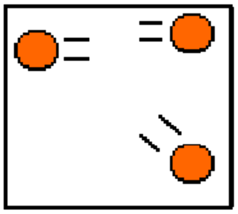
1. ______________ (s)
2. ______________ (ℓ)
3. ______________ (g)
4. ______________ =

(http://electronics.howstuffworks.com/plasma-display.htm)

*______________ = A SOLID DISSOLVED IN WATER (SOLUTION) (This is a STATE, but not a PHASE)

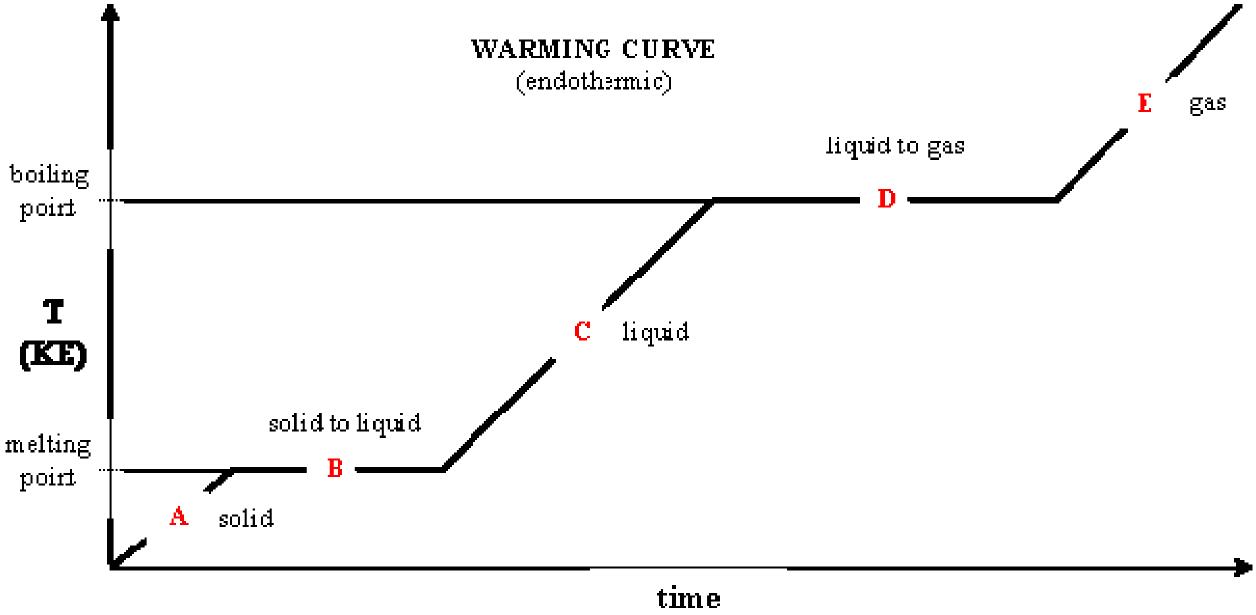


http://www.harcourtschool.com/activity/states_of_matter/

Properties	SOLID	LIQUID	GAS
SHAPE	DEFINITE SHAPE	TAKES SHAPE (of container)	TAKES SHAPE (of container)
VOLUME	DEFINITE VOLUME	DEFINITE VOLUME	TAKES VOLUME (of container)
PARTICLE MOVEMENT	Vibrates about a FIXED point	Vibrates about MOVING points	FREE TO MOVE (most freedom)
DENSITY Distance between particles	HIGH DENSITY (SMALL DISTANCE)	HIGH DENSITY (SMALL DISTANCE)	LOW DENSITY (LARGE DISTANCE)
INTERMOLECULAR FORCES (IMF's) Attraction between particles	(@ room temp.) STRONG	(@ room temp.) STRONG	(@ room temp.) WEAK
PARTICLE DIAGRAM Using a "o" to represent a single particle			

Heating and Cooling Curves: Changes in Matter Physical State

Heating Curves: TEMPERATURE vs. TIME is graphed while a substance is being HEATED at a constant rate.

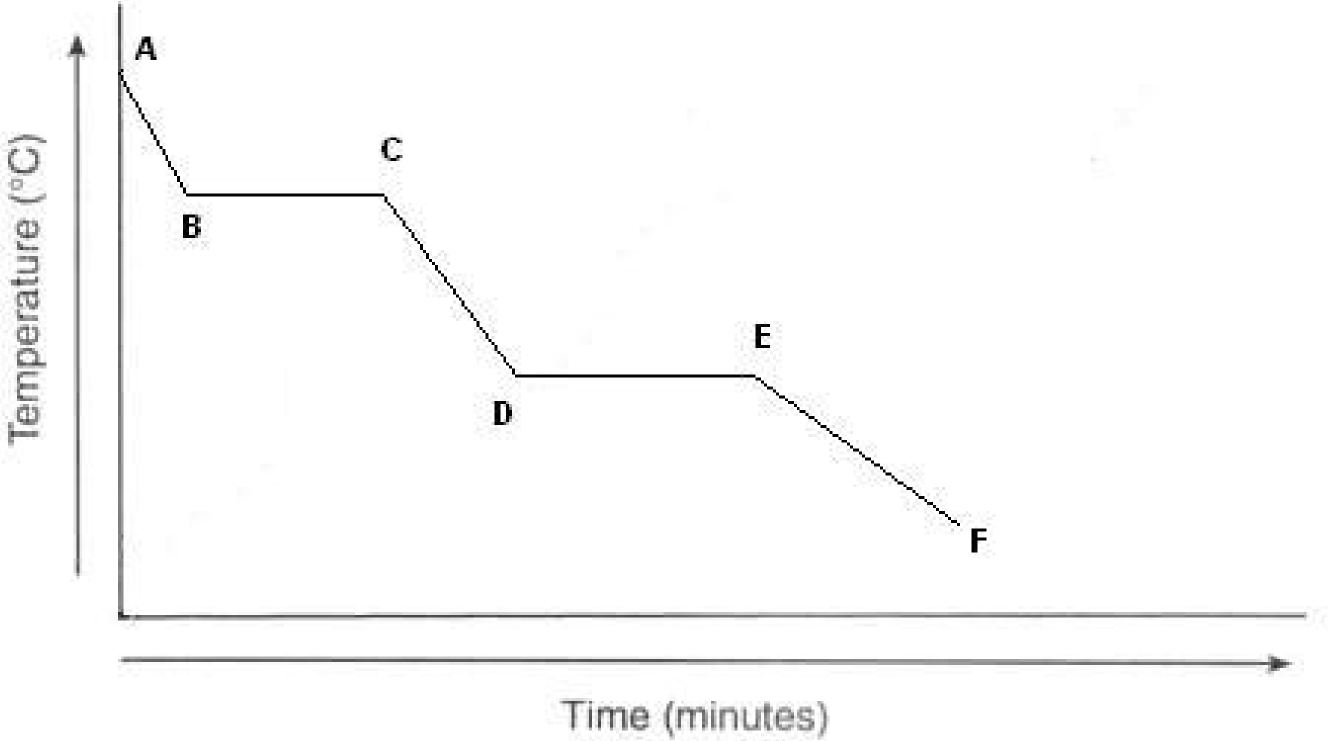


*While Kinetic Energy (KE) is changing, Potential Energy (PE) remains constant

*While Potential Energy (PE) is changing, Kinetic Energy (KE) remains constant

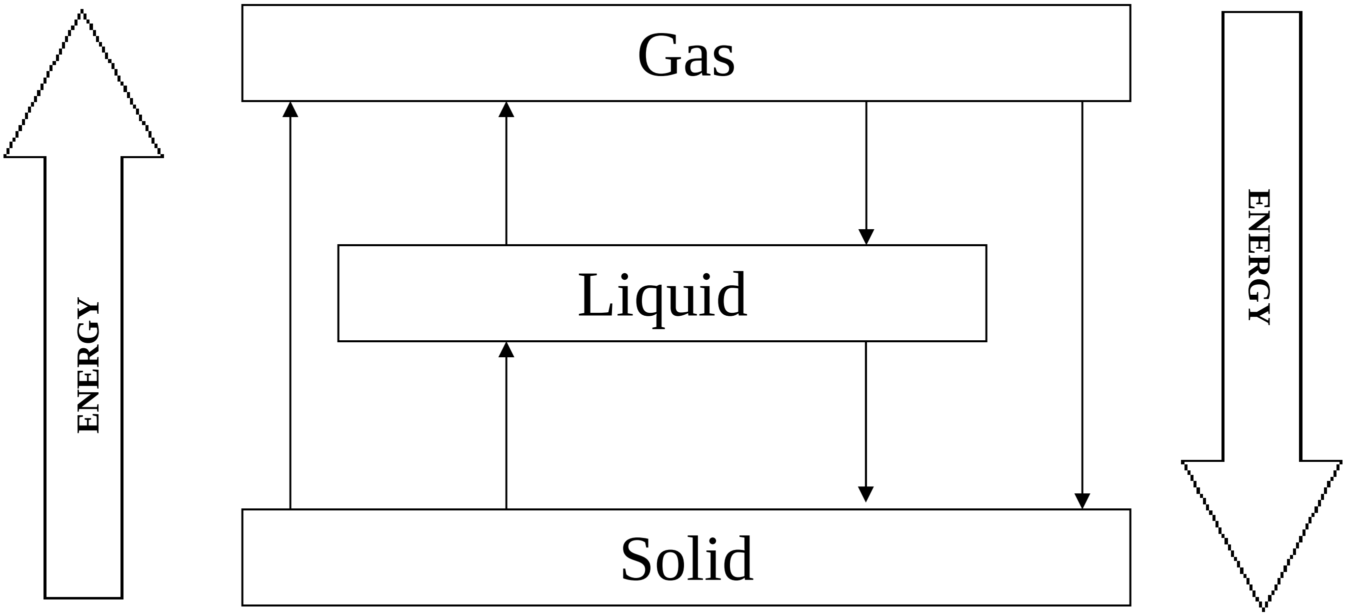
Section	Phases (# and Name)	Δ T	Δ KE	Δ PE
A				
B				
C				
D				
E				

Cooling Curves: TEMPERATURE vs. TIME is graphed while a substance is being COOLED at a constant rate.



Section	Phases (# and Name)	Δ T	Δ KE	Δ PE
AB				
BC				
CD				
DE				
EF				

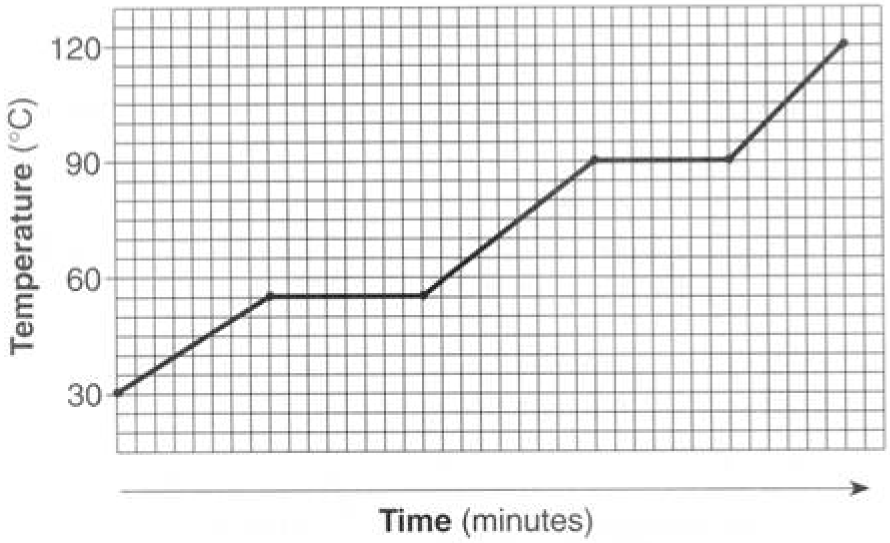
Phase Changes:



Phase Changes are classified as ENDOTHERMIC or EXOTHERMIC.

ENDOTHERMIC = **system absorbs or takes in heat energy**
EXOTHERMIC = **system gives off heat energy**

Use the graph below to answer the questions that follow:



At what temperature will this substance boil? __________

At what temperature will this substance become a liquid? __________

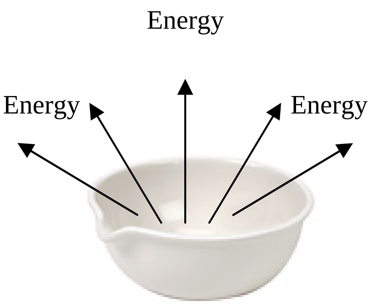
Between 55°C and 90°C, the kinetic energy of the substance is ________________

At 90°C, the potential energy of the substance is ________________

Definition

system RELEASES or GIVES OFF heat energy

Characteristics



EXOTHERMIC

Examples

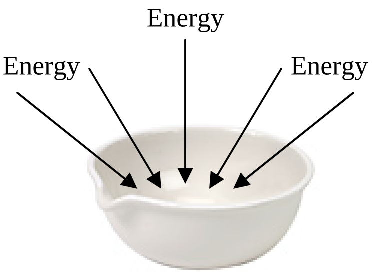
FREEZING
CONDENSATION

Non-examples

Definition

system ABSORBS or GAINS heat energy

Characteristics



ENDOTHERMIC

Examples

MELTING
BOILING

Non-examples

Measurement of Heat Energy:

HEAT = Energy transferred due to a difference in temperatures

The amount of heat LOST or GAINED in a physical or chemical reaction can be calculated using the following equation (**found in Table T**):

$q = mc\Delta T$

q = heat (units = Joules or J)
m = mass of sample
c = heat capacity of sample (see Table B for H_2O)
ΔT = change in temperature

Example 1: How many joules are absorbed when 50.0 g of water are heated from 30.2°C to 58.6°C?

q =
m =
c =
ΔT =

Practice Problems:

1. What is the specific heat of silver if a 93.9 g sample cools from 215.0°C to 196.0°C with the loss of 428 J of energy?

2. If 100.0 J are added to 20.0 g of water at 30.0°C, what will be the final temperature of water?

3. The temperature of a sample of water in the liquid phase is raised 30.0°C by the addition of 3762 J. What is the mass of water?

Why can't we use the equation $q = mc\Delta T$ to calculate the heat involved in melting or boiling a substance?

Heat of Fusion (H_f): the amount of heat (or PE) required to change a substance from a solid to a liquid (see Table B)

Heat of Fusion Equation (see Table T):

$$q = mH_f$$

Example: How many joules are required to melt 255 g of ice at 0°C?

Practice Problems:

1. What is the total number of kilojoules of heat needed to change 15.0 g of ice to water at 0°C?

2. 1.0×10^5 J of heat is needed to melt ice at 0°C, what was the mass of the sample?

3. In question 1 is heat being absorbed or released? Is this process endothermic or exothermic?

Heat of Vaporization: the amount of heat required to change a substance from a liquid to a gas (see Table B)

Heat of Vaporization Equation (see Table T):

$$q = mH_v$$

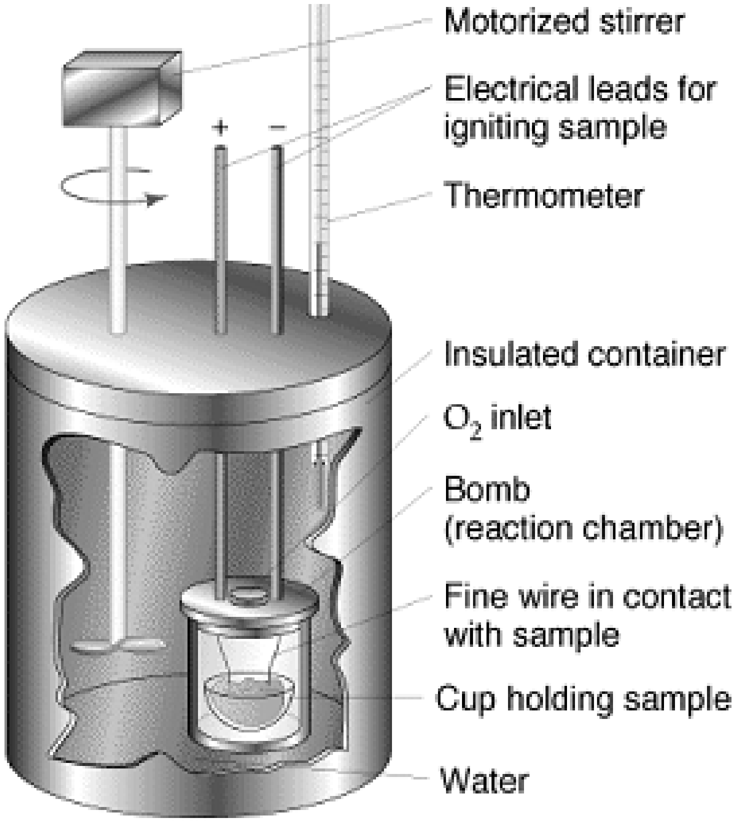
Example: How many kilojoules of energy are required to vaporize 423 g of water at 100°C?

Practice problems:

1. What is the total number of kilojoules required to completely boil 100. g of water at 100°C.

2. At 1 atmosphere of pressure, 25.0 g of a compound at its normal boiling point are converted to a gas by the addition of 34,400 J. What is the heat of vaporization for this compound?

A device known as a BOMB CALORIMETER can be used to measure the amount of heat given off in a reaction. The reaction takes place in the reaction chamber and the heat released by the reaction is absorbed by the surrounding water. The HEAT given off by the reaction can be calculated by measuring the TEMPERATURE INCREASE of the WATER.



SOLIDS & LIQUIDS:

LIQUID: the phase of matter characterized by its constituent particles appearing to VIBRATE about MOVING POINTS.

1. **Evaporation:** the process by which SURFACE PARTICLES of LIQUIDS escape into the VAPOR state (PHASE CHANGE from LIQUID to GAS)

   Can a liquid evaporate if its temperature is below its normal boiling point? Give an example.

   Ans: ____

Vapor Pressure (Table H): the UPWARD pressure exerted by a vapor in equilibrium with its liquid

What happens if the vapor pressure of a liquid is equal to the atmospheric pressure? **Ans:** ______________________________

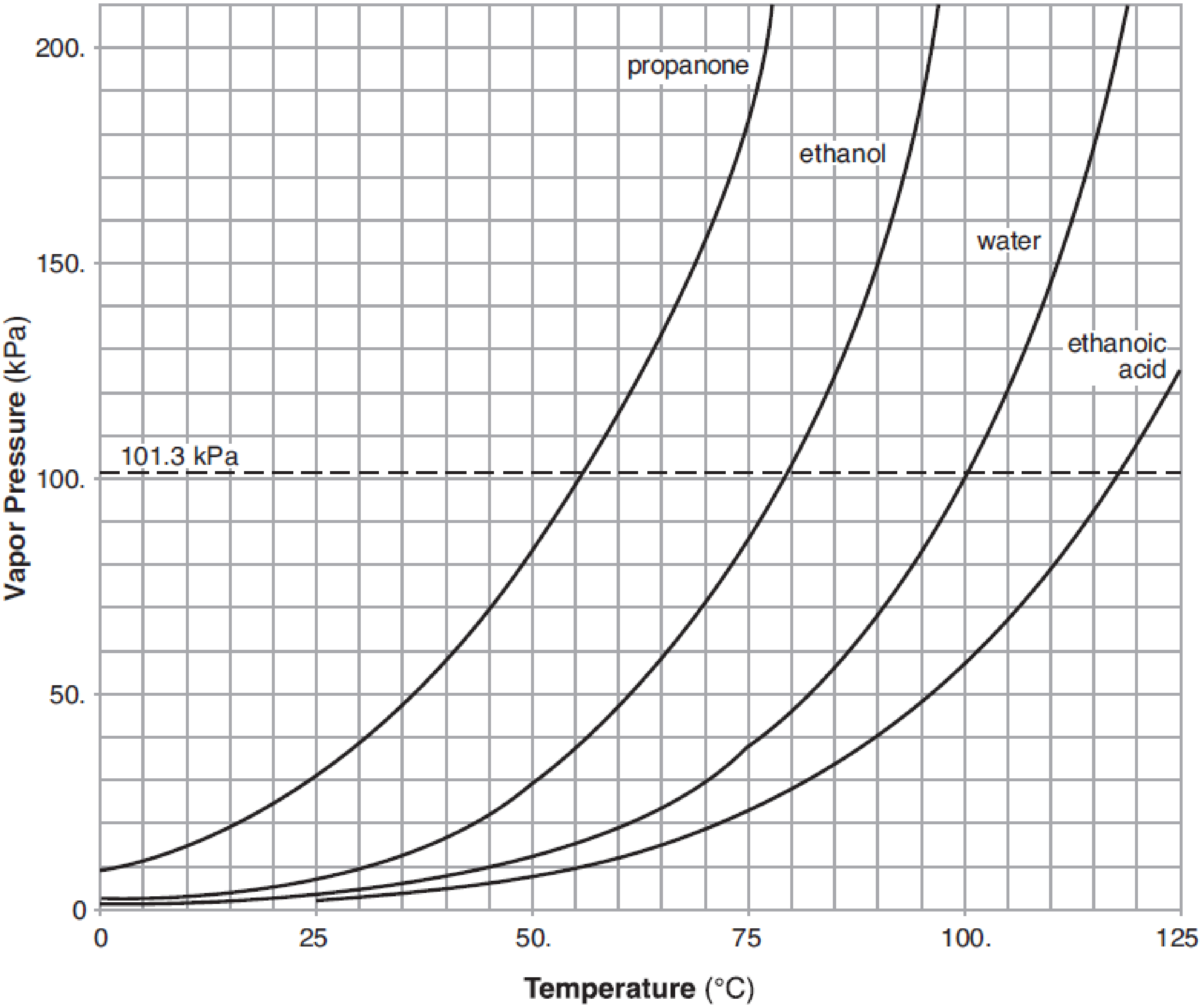
SOLID: the phase of matter characterized by particles that appear to VIBRATE about FIXED POINTS.

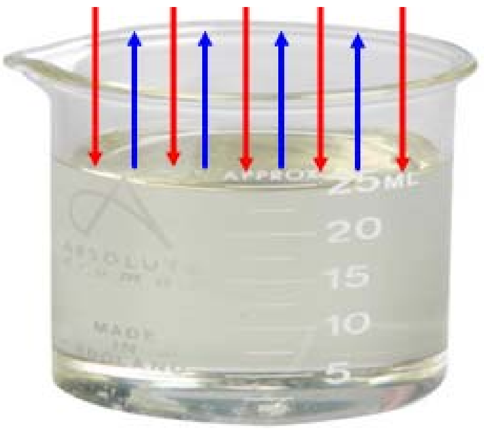
- As the TEMPERATURE of a liquid is LOWERED, the FORCES OF ATTRACTION between the particles become STRONGER
- Attractive forces ARRANGE particles in an ORDERLY fashion
- The MOTION of the particles becomes severely RESTRICTED (particles VIBRATE in place)
- The temperature at which a substance becomes a solid is its MELTING POINT (m.p.) or FREEZING POINT (f.p.)
- All true solids have a structure called a CRYSTAL LATTICE

Graphite Crystal Lattice Structure
http://departments.kings.edu/chemlab/animation/angraph.avi

Diamond Crystal Lattice Structure
http://departments.kings.edu/chemlab/animation/andiamond.avi

Table H
Vapor Pressure of Four Liquids





↑ = ________________________ pressure

↓ = ________________________ pressure

VAPOR PRESSURE PRACTICE

1. According to Reference Table *H*, what is the boiling point of ethanoic acid at 80 kPa?

   A) 28°C B) 125°C
   C) 111°C D) 100°C

2. Water will boil at 50°C if the pressure on the surface of the water is

   A) 12 kPa B) 3 kPa
   C) 101.3 kPa D) 50 kPa

3. What is the normal boiling point of ethanoic acid?

   A) 117.9°C B) 101.3°C
   C) 52°C D) 55°C

4. As the atmospheric pressure increases, the temperature at which water boils in an open vessel

   A) decreases B) increases
   C) remains the same

5. The strongest intermolecular forces of attraction exist in a liquid whose heat of vaporization is

   A) 100 J/g B) 200 J/g
   C) 300 J/g D) 400 J/g

6. A liquid would boil at the lowest temperature at a pressure of

   A) 1 atmosphere B) 2 atmospheres
   C) 50 kPa D) 101.3 kPa

7. The boiling point of a pure substance is defined as the temperature at which

   A) the vapor pressure equals the external pressure
   B) the liquid phase can be completely evaporated
   C) the kinetic energy of the molecules begins to increase
   D) the molecules of the substance break apart

GASES:

Kinetic Molecular Theory (KMT): A MODEL USED TO EXPLAIN THE BEHAVIOR OF GASES IN TERMS OF THE MOTION OF THEIR PARTICLES

Major Assumptions of KMT:

1. Gas particles HAVE NO VOLUME (take up no space)
2. The gas particles DO NOT ATTRACT each other (NO IMF's)
3. The gas particles move in RANDOM, CONTINUOUS motion.
4. The gas particles are perfectly ELASTIC—lose no SPEED after they COLLIDE w/ one another or w/ the walls of the container.

- KMT is based on the CONCEPT or MODEL of an IDEAL GAS
- An IDEAL GAS is THEORETICAL and is used to PREDICT the behavior of REAL GASES (O_2, H_2, He, etc.)
- The ASSUMPTIONS above are not true of REAL GASES

Problems for REAL gases fitting KMT:

1. ______________________________ (big particles have high IMF's)
2. ___________ movements are subject to more IMF's
3. _________________ containers mean _________________

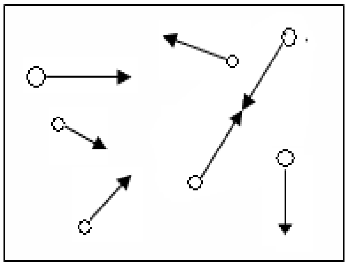
Real gases follow KMT best under the following conditions:

1. _________________ (NONPOLAR)
2. _________________
3. _________________
4. _________________ (FAST MOVING)
5. _________________

Q: What is the most ideal gas on the planet? Explain.

A: ____

Collision Theory: In order for a reaction to occur, particles must COLLIDE with the proper amount of ENERGY and with the proper ANGLE and POSITION.



Gas Laws:

http://hyperphysics.phy-str.gsu.edu/Hbase/Kinetic/vappre.html

Avogadro's Law: GASES at the same TEMPERATURE, PRESSURE, & VOLUME have the same number of MOLECULES or PARTICLES

CO_2 100 torr 5.0 L 800 K	H_2 100 torr 5.0 L 800 K	Ar 100 torr 5.0 L 800 K

1. Which one has more gas particles? Explain.
   Ans:

2. Which one will behave the most ***ideally***? Explain.
   Ans:

3. Which one has the most atoms? Explain.
   Ans:

Combined Gas Law: (use for GASES ONLY when all THREE VARIABLES for a gas are CHANGING – nothing remains constant in this type of problem)

From Reference Table T:

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

P_1 = Initial Presure	V_1 = Initial Volume	T_1 = Initial Kelvin Temperature
P_2 = Final Pressure	V_2 = Final Volume	T_2 = Final Kelvin Temperature

****NOTE:** You MUST use Kelvin (not °C) for the calculation to work!

Sample Problem 1: A gas has a volume of 100. mL at a temperature of 20.0 K and a pressure of 760. mmHg. What will be the new volume if the temperature is changed to 40.0 K and the pressure to 380. mmHg?

Sample Problem 2: An ideally behaving gas occupies 500. mL at STP. What volume does it occupy at 546 K and 980. KPa?

*Both Avogadro's Law and the Kinetic Molecular Theory can be used to explain the relationship between pressure, temperature, and volume of a gas.

Ideal Gas Equation: $\boxed{PV = nRT}$

Where *P* is pressure, *V* is volume, *n* is # moles, *R* is the universal gas constant (don't worry about this one) and *T* is temperature

Solve for any one of the variables and see how would be affected by changing any of the others (and we'll ignore the pesky *n* and *R*):

$$P = \frac{T}{V} \qquad V = \frac{T}{P} \qquad T = PV$$

Here's an easy way to remember the relationship between pressure, temperature, and volume. NOTICE how the variables are written from left to right in alphabetical order. Place your finger on whatever variable remains constant, then rotate the variable you want to change up or down. Watch what happens to the third variable as a result.

P T V

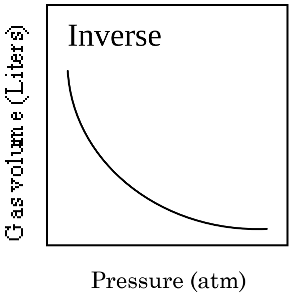
a. If PRESSURE DECREASES at CONSTANT TEMPERATURE, the VOLUME INCREASES.

b. If TEMPERATURE INCREASES at CONSTANT PRESSURE, the VOLUME INCREASES.

c. If TEMPERATURE INCREASES at CONSTANT VOLUME, the PRESSURE INCREASES.

****Does this all sound logical?***

When either P, T, or V is held constant for a gas:

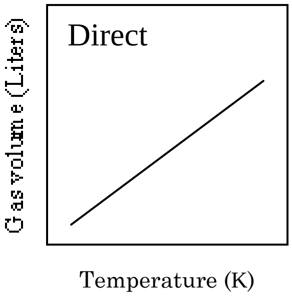


- Boyles Law (Constant Temperature):

Example: The volume occupied by a gas at STP is 250 L. At what pressure (in atm) will the gas occupy 1500 L, if the temperature is constant?

$P_2 = 0.167$ atm

Example: decreasing P on marshmallow will increase V

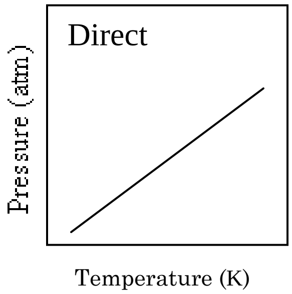


- Charles Law (Constant Pressure):

Example: The volume of an ideally behaving gas is 300 L at 227°C. What volume will the gas occupy at 27°C when pressure remains constant?

$V_2 = 35.7$ L

Example 2: Aerosol cans with gases under high pressure can't be near high temp or contents will expand and the bottle will explode



- Gay Lussac's Law (Constant Volume)

Example: The pressure exerted by an ideally behaving gas is 700 KPa at 200 K. What pressure does the gas exert at 500 K when volume remains constant?

$P_2 = 1750$ kPa

Some Gas Law Problems to Try:

1. A gas has a volume of 75.0 mL at a temperature of 15.0 K and a pressure of 760. mm Hg. What will be the new volume when the temperature is changed to 40.0 K and the pressure is changed to 570. mm Hg?

2. The volume of a sample of a gas at 273°C is 200.0 L. If the volume is decreased to 100.0 L at constant pressure, what will be the new temperature of the gas?

3. What will be the new volume of 100. mL of gas if the Kelvin temperature and the pressure are both doubled?

4. A gas occupies a volume of 400. mL at a pressure of 330. torr and a temperature of 298 K. At what temperature will the gas occupy a volume of 200. mL and have a pressure of 660. torr?

Dalton's Law of Partial Pressure: in a mixture of GASES, the TOTAL PRESSURE of the mixture is the SUM of the PARTIAL PRESSURES of each component gas.

$$P_{total} = P_1 + P_2 + P_3 + \ldots$$

Example: The total pressure of three gas components in a mixture is 550 torr. If the pressure of gas A is 200 torr and the pressure of gas B is 75 torr, what is the partial pressure of gas C?

Partial Pressure Problems:

1. A mixture of oxygen, nitrogen, and hydrogen gases exerts a total pressure of 74.0 kPa at 0°C. The partial pressure of the oxygen is 20.0 kPa and the partial pressure of nitrogen is 40.0 kPa. What is the partial pressure of hydrogen in this mixture?

2. A cylinder is filled with 2.00 moles of nitrogen, 3.00 moles of argon, and 5.00 moles of helium. If the gas mixture is at STP, what is the partial pressure of the argon?

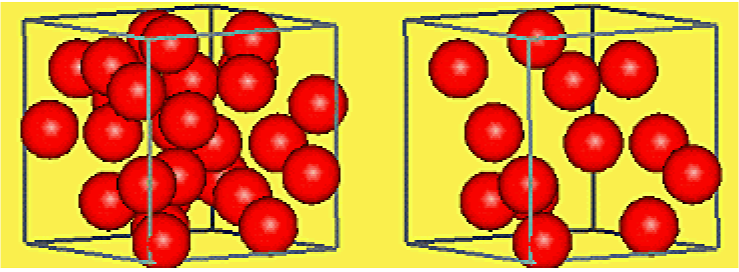
3. If 4.00 moles of oxygen gas, 3.00 moles of hydrogen gas, and 1.00 moles of nitrogen gas are combined in a closed container at standard pressure, what is the partial pressure exerted by the hydrogen gas?

DENSITY: the quantity of matter in a given unit of volume

D = mass/volume

Take a look at the two boxes below. Each box has the same volume. If each ball has the same mass, which box would weigh more? Why?

Ans: The box on the left would weigh more because it has more balls in the same amount of space.



The box that has more balls has more MASS per unit of VOLUME. This property of matter is called density. The density of a material helps to distinguish it from other materials. Since mass is usually expressed in grams and volume in cubic centimeters, density is expressed in **grams/cubic centimeter (g/cm^3).**