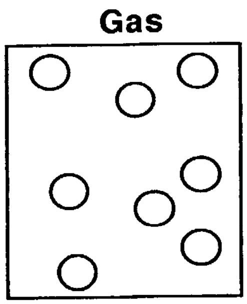
Note Packet # 6

Gases

As you already learned gases have **no definite shape** and **no definite volume**.
Gas particles completly fill any container they occupy. Gas particles are randomly spaced and far apart.



Units of gas pressure.
Gas pressure can be expressed as atmospheres (atms), kilopascals (kPa), millimeters of mercury (mmHg), and torr.

Gas Pressure is the result of gas particles colliding with the walls of the container.
Gas pressure in a container can be increased by:
1) increasing the number of gas particles in the container
2) increasing the temperature (kinetic energy)
3) decreasing the volume of the container

All of these result in more gas particle collisions with the container walls. More particle collisions result in more gas pressure.

STP means **standard temperature and pressure**. Since gas volume greatly changes with temperature or pressure we must have a standard when describing gas volume.

Standard Pressure is the normal atmospheric pressure at sea level and is recorded as
1 atm = 101.3 kPa = 760 mmHg = 760 torr

If you need to convert from one pressure unit to another, set up a ratio then cross multiply and divide to solve for the unknown.
Ex: How many mmHg are equal to 1.25 atm?
To solve: Start with the fact that 1 atm = 760 mmHg
Set up a ratio $\frac{1.25}{1} = \frac{x}{760}$ solve for x x = 950 mmHg

Standard Temperature is 273 Kelvin or 0°C

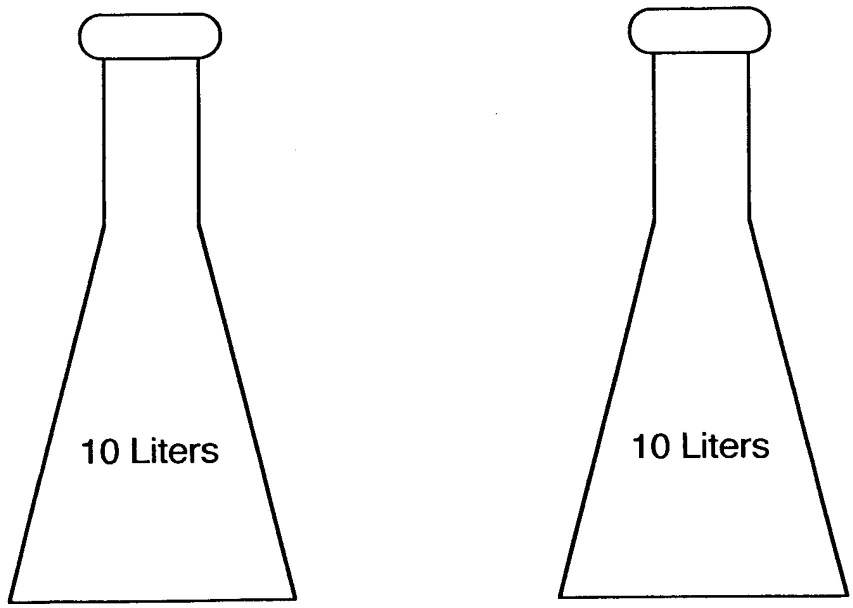
Constant Temperature means that temperature is unchanging.
Constant Pressure means that pressure is unchanging.

Ideal Gas is a model to explain behavior of gases. There are no actual ideal gases.
The **Kinetic Molecular Theory (KMT)** for an ideal gas states all ideal gas particles:
1) are in random, constant, straight line motion.
2) are separated by great distances compared to their size. The gas particles have no size (volume).
3) have no attractive forces between them.
4) have collisions that result in the transfer of energy between particles, but the total energy of the system remains constant.

Real gases are different from (deviate from) ideal gases because they;
a) don't travel in straight lines
b) do have some size
c) have some force of attraction for each other, This means they will stick together as a liquid when cooled.
Any **Real Gase** will behave most like an ideal gas at **low pressure** and **high temperature**. **Why?** Low pressure keeps them far apart. High temperature keeps them moving fast.
Gases with small particles (low mass) behave alot like an ideal gas. Gas particles with large particles (large mass) behave least like an ideal gas.
Use the periodic table to compare masses when choosing which gas acts most or least like an ideal gas.

Ex: Which gas behaves most like an ideal gas?
Which gas behaves the least like an ideal gas? Ar, Kr, Ne, or Rn.
To solve: Use the periodic table to compare masses.
Ne has the least mass. It acts the most like an ideal gas.
Rn has the most mass. it acts the least like an ideal gas.

Avagadro's Hypothesis Equal volumes of any gas at the same conditions of temperature and pressure contain an equal number of particles. These gases can exist with a large or small mass or can be monoatomic or a complex molecule.



Both of the above flasks are at equal temperature and pressure. They contain equal numbers of gas particles even though the two gases are very different. $He_{(g)}$ is a very light monoatomic gas and $SO_{2(g)}$ a heavy gas compound.

Kinetic Molecular Theory (KMT) describes the relationships of pressure, volume, temperature, velocity, and frequency and force of collisions among gas particles.

Boyle's Law states that as a gases pressure increases its volume decreases. Thsi is an inverse relationship.

$P_1V_1 = P_2V_2$

P_1 initial or first pressure
P_2 final or second pressure
V_1 initial or first volume
V_2 final or second volume

Remember! There are different units to express pressure. These include attmospheres (atms), kilopascals (kPa), millimeters of mercury (mmHg), and torr.

Ex: What will be the new volume of 200 mL of a gas if its pressure is increased from 1.5 atm to 4.5 atm if the temperature does not change.

To solve:

1. Apply Boyle's Law. $P_1V_1 = P_2V_2$
2. Determine the knowns and the unknown.

$P_1 =$ 1.50 atm
$P_2 =$ 4.50 atm
$V_1 =$ 200.0 mL
$V_2 =$?

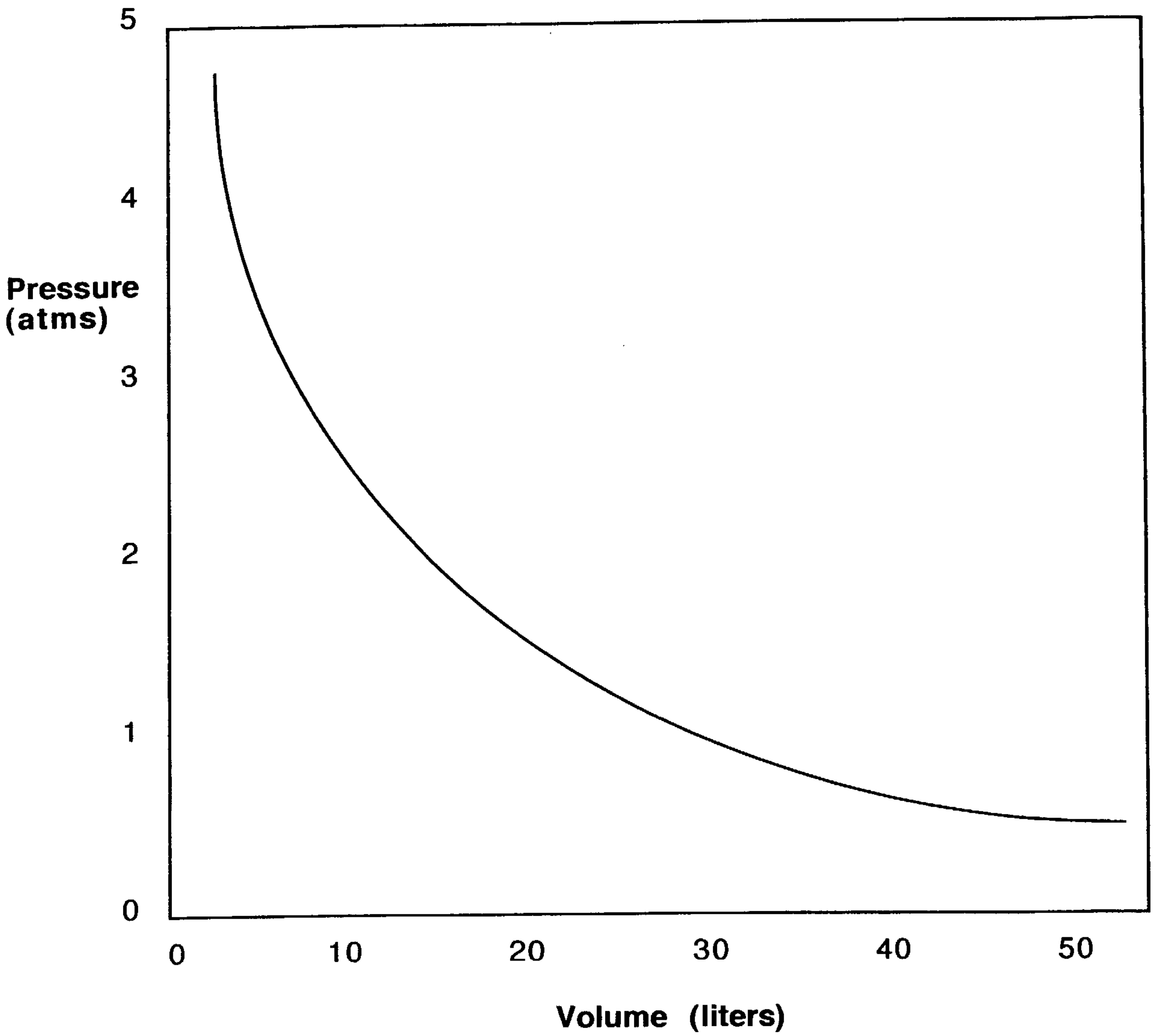
3. Insert the known information into Boyle's Law.
4. Solve for the unknown.

$1.50 \text{ atm} \times 200.0 \text{ mL} = 4.50 \times V_2$ $\qquad$ $300.0 = 4.50 \times V_2$

$V_2 = \frac{300.0}{4.50}$ $\qquad$ $V_2 = 66.7$ mL

Pages 5 & 6 exhibit how gas pressure and volume are related.

Boyle's Law
Relationship of Gas Pressure vs Volume

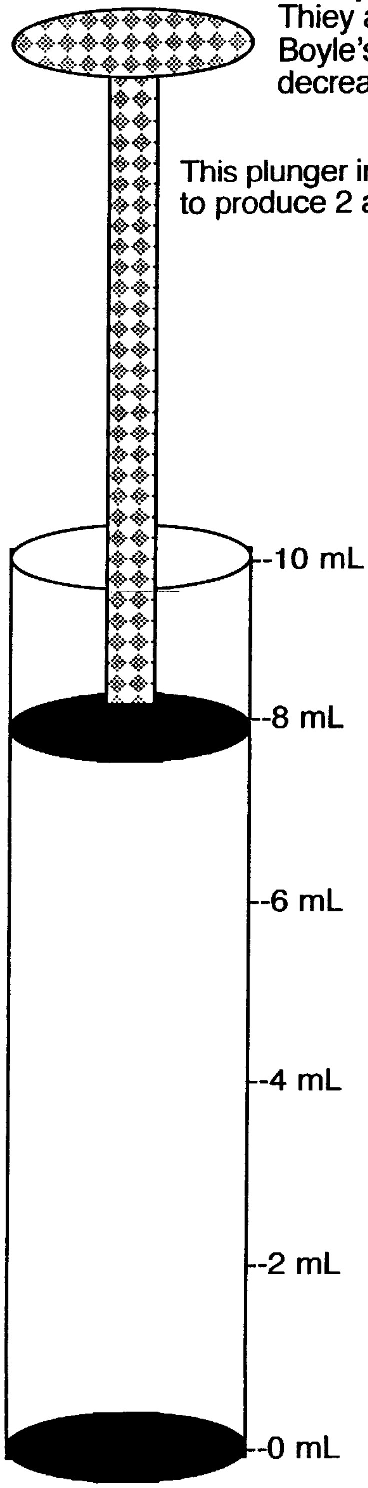


As gas pressure increases gas volume decreases.
As pressure increases the gas particles are squeezed closer together.
Boyle's Law displays an **inverse** relationship.

Remember! In an inverse relationship as one variable increases the other decreases.

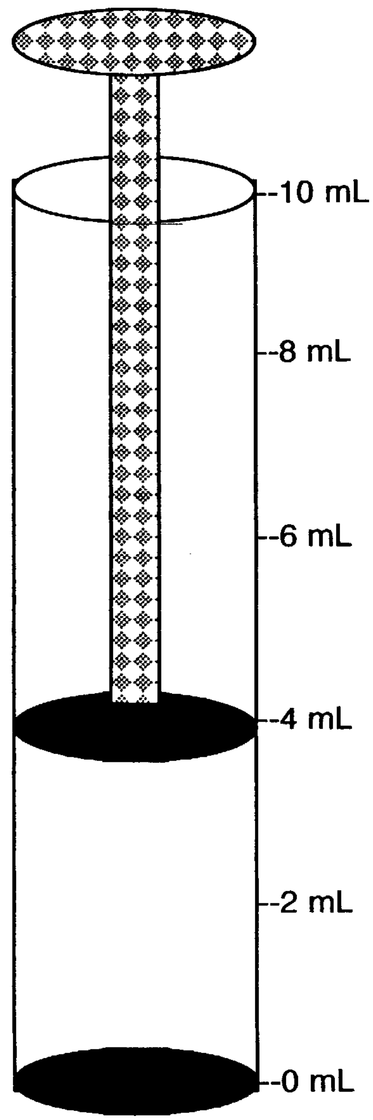
This page shows diagrams of pistons with a movable plunger.
Thiey are also known as Boyle's Law Apparattus.
Boyle's Law states that as gas pressure increases gas volume decreases.

This plunger in pushing down
to produce 2 atms of pressure.



Notice! Doubling the pressure halves the volume.

This plunger is pushing down to produce 4 atms of pressure.



Note Packet # 6

Charles Law states that as the temperature of a gas increases its volume increases.

This is a direct relationship.

Picture a party balloon that you buy at a store during the winter. If you walk outside with it, where it is cold, it begins to lose its shape. Its volume decreases. If you walk back inside with it,where it is warm, its volume increases and it regains its shape.

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

V_1 initial or first volume

V_2 final or second volume

T_1 initial or first Kelvin temperature

T_2 final or second Kelvin temperature

Remember! To convert ^{o}C to Kelvin use the formula $^{o}C + 273 = $ Kelvins

Ex: What is 45 ^{o}C in Kelvin?

To solve: 45 + 273 = 318 K

Ex: What will be the new volume of 500 mL of gas if its temp decreases from 546 K to 273 K?

To solve:

1. Apply Charles Law.

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

2. Determine the knowns and the unknowns.

V_1 = 500mL

V_2 = ?

T_1 = 546 K

T_2 = 273 K

3. Insert the knowns into Charles Law.

$$\frac{500mL}{546K} = \frac{V_2}{273}$$

4. Solve for the unknown (cross multiply and divide)

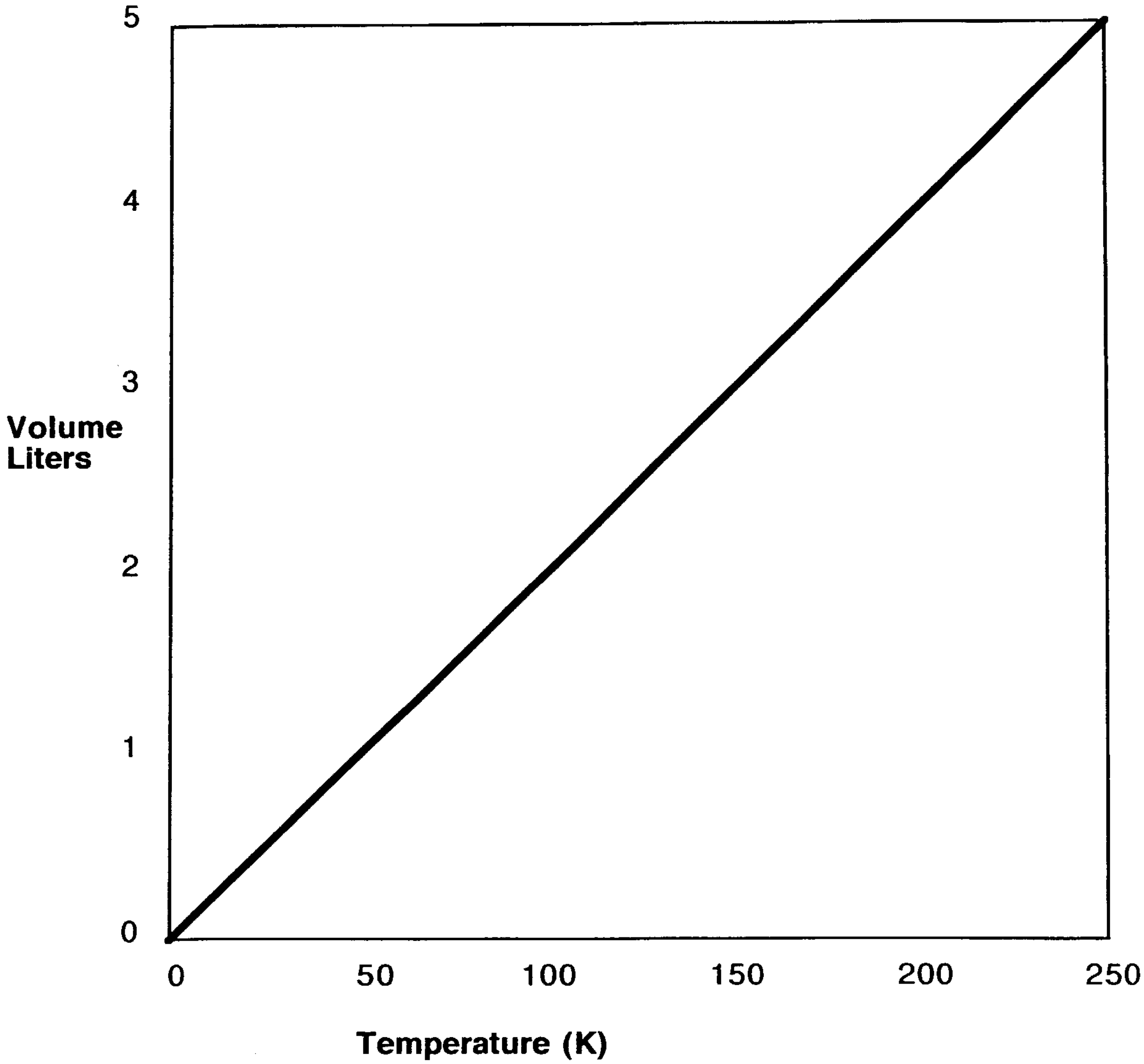
$136500 = 546 \times V_2$

$V_2 = \frac{136500}{546}$ $\quad$ V_2 = 250 mL

Pages 8 & 9 exhibit Charles Law.

Charles' Law

Relationship between Kelvin temperature and gas volume.



Kelvin temperature and volume have a **direct** relationship.
If the Kelvin temperature is doubled the gas volume doubles.
If the kelvin temperature is halved the gas volume is halved.

REMEMBER! Both variables increase in a direct relationship.

This balloon is warm. The gas expands. The volume is large. There is more space between the gas particles.

This balloon is cool. The gas contracts. The volume is small. There is less space between the gas particles.

Both of these balloons contain the same amount of gas particles.

Remember! Charles Law states that as gas temperature increases gas volume increases.

Note Packet # 6

Boyle's Law deals with pressure and volume, Charles law deals with temperature and volume. There are times when both the pressure and temperature of a gas changes. The **Combined Gas Law** deals with both a change of pressure and a change of temperature.

Combined Gas Law Formula

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

P_1 initial or first pressure
P_2 final or second pressure
V_1 initial or first volume
V_2 final or second volume
T_1 initial or first Kelvin temperature
T_2 final or second Kelvin temperature

Ex: What will be the new pressure of a gas if 250 L of gas at 101.3 kPa and 546 K changes volume to 125 L and the temperature changes to 819 K ?

To solve:
1. Apply the combined gas formula.

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

2. Determine the knowns and the unknowns.

P_1 = 101.3 kPa
P_2 = ?
V_1 = 250 L
V_2 = 125 L
T_1 = 546 K
T_2 = 819 K

3. Insert the knowns into the combined gas law.

$$\frac{101.3 \text{ kPa} \times 250 \text{ L}}{546 \text{ K}} = \frac{P_2 \times 125 \text{ L}}{819 \text{ K}}$$

4. Solve for the unknown.

20741175 = P_2 X 68250 $\qquad P_2 = \frac{20741175}{68250} \qquad$ P_2 = **303.9 kPa**

Note Packet # 6

VAPOR PRESSURE

We already know that gas pressure is the result of gas particle collisions with other gas particles and the walls of the container.

Gas pressure increases by:
1. Increasing the temp of the gas (kinetic energy)
2. Decreasing the volume of the gas (Boyle's Law)
3. Increasing the number of gas particles

If a liquid is in a sealed container as particles change from liquid to gas the gas pressure increases. This is because the number of gas particles in the container increases.

We already know:
Vaporization also known as boiling is the process by which a liquid changes to gas (vapor) at the boiling point of the substance

Vaporization occurs at the boiling point of a substance. Ex: Water boils at $100^{o}C$.

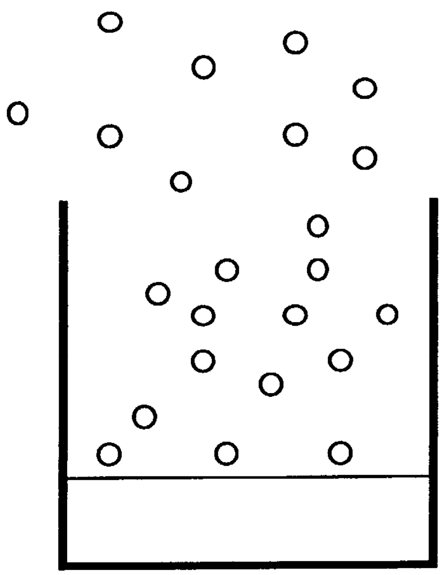
Evaporation is the process of liquid changing to gas or vapor at a wide range of temperatures. Ex: water left in an open glass will evaporate at room temperature.

What is the difference between vaporization (boiling) and evaporation?

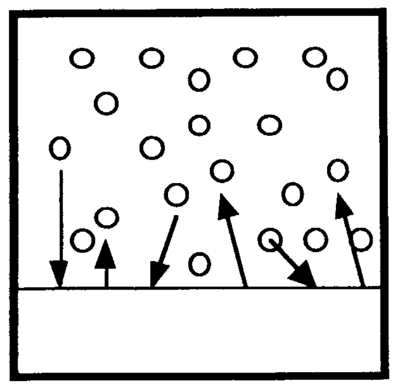
Factors that affect evaporation
1. **Temperature**: the higher the temperature the faster the evaporation rate.
   Ex: a towel on a wash line will dry faster on a warm day than a cold day.
2. **Surface area**: The larger the surface of the liquid the faster it will evaporate.
   Ex: water will evaporate faster from a pie plate than a test tube.
3. **Humidity**: The lower the humidity the faster the rate of evaporation.
   Ex: A towel will dry faster outdoors on a dry day than a damp one.
4. **Wind**: moving air increases the rate of evaporation.
   Ex: A hair dryer uses moving air to increase evaporation.

If evaporation occurs in a closed container the evaporation rate will eventually equal the rate of condensation. This is known as gas/liquid **equilibrium**. At this equilibrium the amount of liquid changing to gas equals the amount of gas changing to liquid.

OPEN CONTAINER



CLOSED CONTAINER



Boiling (vaporization) occurs when vapor pressure equals the surrounding pressure.
At 1 atm (101.3 kPa) water boils at $100^{o}C$.
Up to this point we have only discussed liquid changing to gas at normal pressure (1 atm).
However: **liquids vaporize (boil) at different temperatures according to the surrounding pressure.**
Ex: water will boil (vaporize) at the top of Mt. Everest at $80^{o}C$. compared to $100^{o}C$ at 1 atm.
Why does this occur?
The air pressure at the top of Mt. Everest is much lower than the air pressure at sea level.
Pressure is responsible for keeping liquid in the liquid state.

There are many possible pressures that a liquid can be exposed to. These pressures will determine the boiling point of the liquid.

Different liquids have different boiling points. These differences are due to the forces of attraction between the particles. If particles are strongly attracted to each other then they will hold together tightly and be less likely to change from liquid to gas resulting in low vapor pressure.
Ex: water molecules are highly attracted to each other and hold on to each other tightly resulting in low vapor pressure.
The opposite is also true. If the forces of attraction between particles are weak the particles only hold together loosely. They will easily change to gas result ing in high vapor pressure.
Ex: Propanone molecules are not attracted to each other very much and produce a high vapor pressure.

Liquids with high vapor pressures are called **volatile.**

Liquids with low vapor pressures are called **nonvolatile.**

Note Packet # 6

TABLE H SHOWS HOW THE VAPOR PRESSURE OF 4 DIFFERENT LIQUIDS VARIES WITH TEMPERATURE.

The vapor pressure of any liqiud increases as temperature increases.

Important Table H information

1. The horizontal dashed line represents standard pressure:
   101.3 kPa = 1 atm = 760 mmHg = 760 torr
   A liquids normal boiling point is determined using the dashed line.

2. A liquid's boiling point, vapor pressure, or temperature can be determined by finding its intersection point and locating the missing information.

3. Lowest boiling point --> Highest boiling point
   propanone ethanol water ethanoic acid

4. Lowest vapor pressure --> Highest vapor pressure
   propanone ethanol water ethanoic acid

5. Weakest intermolecular force --------------------------------->Strongest intermolecular force
   propanone ethanol water ethanoic acid

Examples:

a) What is propanone's normal boiling point?

To solve: determine where the curved line for propanone intersects the dashed line, then follow the line to the bottom to read the temperature.
Answer: 55^{o} C.

b) What is water's normal boiling point?
Answer: 100^{o} C.

c) What is the vapor pressure of ethanol at 90^{o} C ?

To solve: Determine where the curved line for ethanol intersects the line for at 90^{o} C, then follow to the left to read the vapor pressure in kilopascals.
Answer: 150 kPa

d) At what temperature will water boil at a pressure of 70 kPa?
To solve: Determine where the curved line for water intersects the line for 70 kPa, then follow the line to the bottom to read the temperature.
Answer: 90^{o} C

e) How many kPa are equal to 1.75 atm?

To solve: set up a ratio. $\frac{x}{101.3} = \frac{1.75}{1}$ next cross multiply and divide x = 177.3 kPa

Note Packet # 6

Answer the following problems. Use Table H

1. What is the vapor pressure of propanone at 75° C?

2. At what temperature will water boil when the pressure is 120 kPa?

3. What is ethanoic acid's normal boiling point?

4. Which Table H liquid has the strongest intermolecular forces?

5. Which Table H liquid has the weakest intermolecular forces?

6. Which Table H liquid has the highest boiling point?

7. Which Table H liquid has the lowest boiling point?

8. What does the horizontal dashed line represent?

9. How many kPa are equal to 1.5 atm?

10. How many atm are equal to 175 kPa?

11. At what temperature will ethanoic acid boil at 120 kPa?

12. What is the vapor pressure of water at 75° C?

Table H
Vapor Pressure of Four Liquids