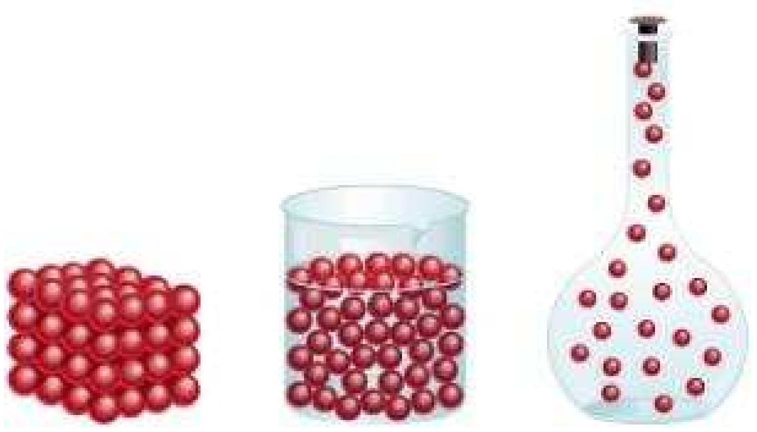
6. States of matter

Solids, liquids, & gases can be easily recognized by their different properties



The Gaseous State

Particles have sufficient energy to overcome all forces of attraction

Particles completely separated from others

Results in low densities
Gases completely fill their containers

Observed Properties of Matter

Solids, liquids, & gases can be easily recognized by their different properties

DENSITY mass divided by volume

SHAPE is it fixed or take container's shape

COMPRESSIBILITY if pressure applied, does voume change?

THERMAL EXPANSION how does volume change if heated?

	State		
Property	**Solid**	**Liquid**	**Gas**
DENSITY	high	high	low
SHAPE	fixed	takes container's shape	expands to fill container
COMPRESSIBILITY	small	small	large
THERMAL EXPANSION	very small	small	moderate

The Solid State

At room temperatures, solids:

are not compressible

commonly have repeating regular units

Two types of solids are known

Crystalline **have definite melting points**
ionic covalent molecular metallic

Amorphous **no definite melting points or regular repeating units**

Liquid state

Compared to solids, liquids
are free to move around
at random, but still touch

Since the particles are still close, liquids have
densities similar to solids

Take on the shape of container

Viscosity resistance to flow

World's most viscous liquid ?

Liquid state

The forces that hold a liquid together result in several properties ....

Viscosity resistance to flow

Vapor Pressure ability for molecules to escape from the surface of a liquid

Boiling Point when vapor pressure equals atmospheric pressure

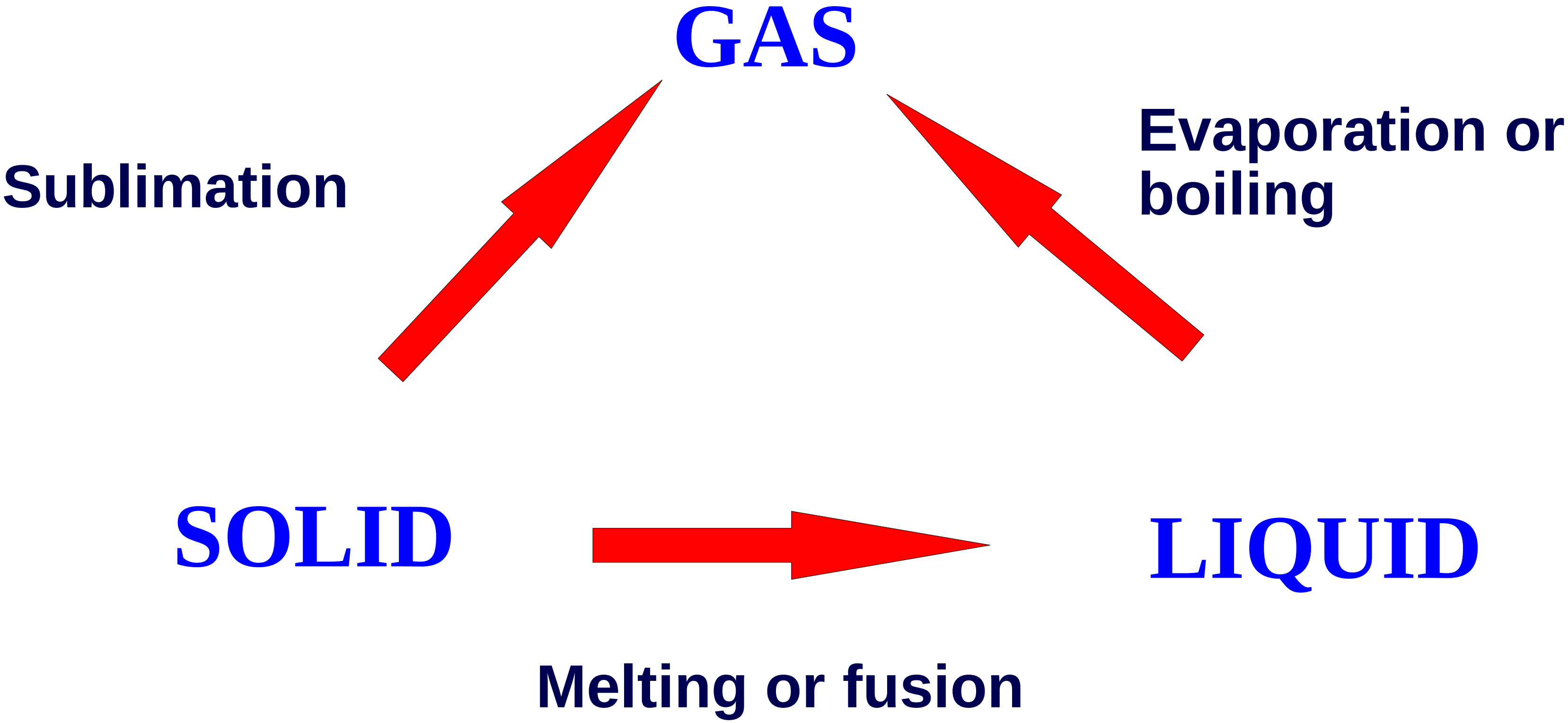
Gaseous state

Particles have sufficient energy
to overcome all forces that
attract them to each other

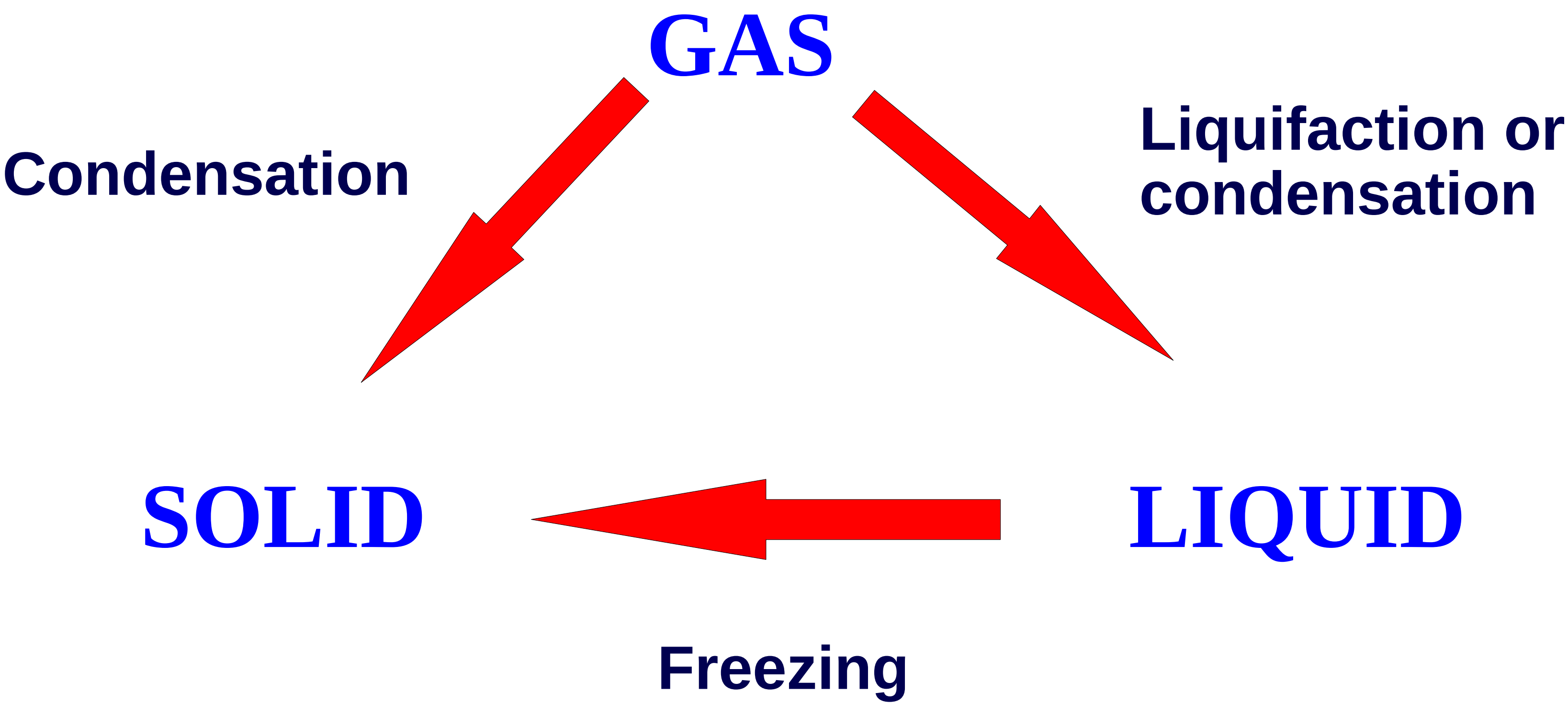
Particles completely separated from each other

Low densities
Gases completely fill their containers

Change of state



Change of state



Chemicals in the home

Chemicals are everywhere in the home

Many are toxic and/or corrosive

Paints, detergents, insecticides, medicines, bleaches, baking soda, disinfectants, cleaners, soaps..........

A lot of chemistry occurs in the kitchen

Chemistry in the Kitchen

Example

Homemade baking powder:

cream of tartar (½ tsp)
baking soda (¼ tsp)
cornstarch (¼ tsp)

acid + base 6 CO_2

Chemistry in the Kitchen

Cooking and Heat

Anthropologists:
fire 6 separate humans from other animals

Chemistry in the Kitchen

A. Why do we cook food ?

- enhance/intensify/alter the flavor/aroma/color
- softening (chewable & digestible)
- firming (coagulating proteins)
- destroy pathogenic microorganisms

B. Generating Heat

- gas
- electricity
- microwaves
- wood/coals

C. Heat Transferral

- radiation
- convection
- conduction

Radiation

Examples: toaster, broiler
heated directly
no need for air/water

Convection

Examples: boiling, roasting heat transfers through air or water

Conduction

Example: pan fry
heat pan ° heat oil ° heat food
heat by direct contact (slow)
also internal heating

D. Cooking Methods

Some important chemical principles at work during boiling

Boiling

B.P. 100EC or 212EF at sea level

B.P. constant regardless of rate

B.P. decreases with altitude

Due to lower pressure

TABLE 6.6 Variations in the boiling point of water with elevation

Location	Elevation (feet above sea level)	Boiling point of water (°C)
San Francisco, CA	Sea level	100.0
Salt Lake City, UT	4,390	95.6
Denver, CO	5,280	95.0
La Paz, Bolivia	12,795	91.4
Mount Everest	20,028	76.5

Boiling

Water boils 1EC or 2EF lower for each 1000' of elevation

B.P 95EC in Denver

Boiling

Adding salt elevates b.p.

Boiling point elevation

1 teaspoon salt per quart water

B.p. increases by 1EC ↵

Boiling - advantages

Adds no fat

Fast

Easy & clean

Tenderize vegetable cellulose

Boiling - disadvantages

Leaches nutrients from food

Danger of burns

Discolor food (vegetables)

Texture

Boiling - discoloring

Caused by heat + acid

Denature chlorophyll

Cook uncovered

Add baking soda: $NaHCO_3$

Cooking Meat Maillard reaction

Most foods will turn brown at temperatures above 154E C

Meat cooked in boiling water can never exceed more than around 100E C

Cooking Meat

sugars (in carbohydrates) and amino acids (in proteins) combine to form new chemicals having the exotic aromas and flavors that gives food its appeal

Heats of Reaction

Heat is released or absorbed during a chemical change (reaction)

heat released: exothermic reaction

heat absorbed: endothermic reaction

How is Heat Measured ?

energy units: calorie or joule (metric)

1 calorie = 4.18 joule

Definition: one calorie is heat required to raise temperature of one gram of water by 1EC

1,000 calories = 1 Kilocalorie

= 1 Calorie

Specific Heat (s)

Heat required to raise temperature of 1 g of a substance by 1^{o}C

A physical property, constant units: J/g.^{o}C

For water: s = 4.18 J/g.^{o}C

Heat Capacity(C)

Heat required to raise temperature of X g of a substance by 1^{o}C

includes mass term

C = specific heat × mass of substance
(units: J/^{o}C)

To Calculate C

need mass and specific heat

C = m x s

J/EC **gram** **J/gEC**

Calculating total heat (q)

For any substance $q = m \times s \times)T$

$$)T = T_{final} - T_{initial}$$

How can this equation be used?

1. **calculate heat needed to warm matter**
2. **calculate heat lost when matter cools**

Bath Time

How much heat energy is required to heat 100,000 grams bath water from 25.0 to 55.0 EC ?

q = c x m x)T

q = 4.18 x 100,000 x 30

= 1.25×10^{7} J

Remember !

density of water = 1.0 g/mL

for water only: mass = volume

100 g water same amount as 100 mL water

Another Example

A 500.0 g block of aluminum cools from 100.0 to 50.0EC.
How much heat is lost ?

q = c x m x)T

$c_{(Al)}$ = 0.900 J/g.EC

q = 0.900 x 500.0 x 50.0
= 2.25 x 10^4 J

Energy Rich Compounds

methane CH_4

acetylene C_2H_4

sugars $C_6H_{12}O_6$ $C_{11}H_{22}O_{12}$

energy stored in chemical bonds

Enthalpy (H)

Heat content of a substance

high heat content: oil, gasoline, wood

low heat content: water

Heat released during chemical reaction =
heat of reaction = $) H = H_{products} - H_{reactants}$

Thermochemical Equations

Show heat evolved during a reaction

$$2\,H_2 + O_2 \rightarrow 2\,H_2O$$

$$2\,H_2 + O_2 \rightarrow 2\,H_2O + 570\ kJ$$

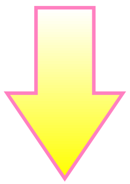
$$2\ \text{moles}\ H_2 + 1\ \text{mole}\ O_2 \rightarrow 570\ kJ$$

$$2\,H_2 + O_2 \rightarrow 2\,H_2O \quad \Delta H = -570\ kJ$$

Show heat evolved during a reaction

....combustion of octane

$2\ C_8H_{18} + 25\ O_2$ ¸ $16\ CO_2 + 9\ H_2O + 1.10 \times 10^4$ kJ



2 moles octane or 228 g

How much heat would 1 g of octane produce?

set up ratio

$$\frac{228\ \text{g octane}}{1.10 \times 10^{4}\ \text{kJ}} = \frac{1\ \text{g octane}}{?\ \text{kJ}}$$

$$?\ \text{kJ} = \frac{1.10 \times 10^{4}\ \text{kJ}}{228\ \text{g}} = 48.2\ \text{kJ}$$

The Gas Laws

The effect of T, P and V on gases has been extensively studied

The relationships between temperature, pressure, volume and moles are called the **gas laws**

To understand the relationships, a few concepts need to be introduced

Pressure

Gases exert pressure on any container they are in

Pressure is defined as force per unit area

pressure = force/area

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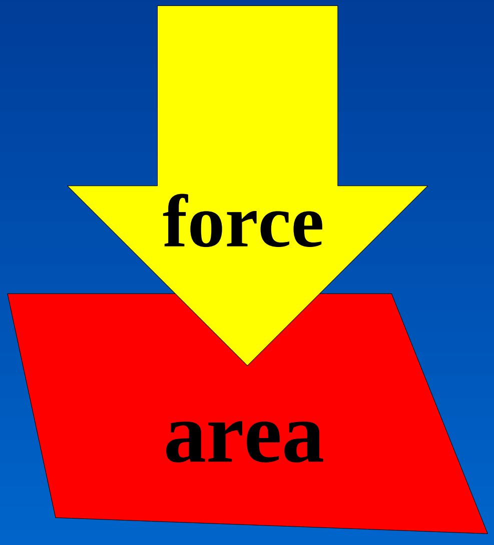
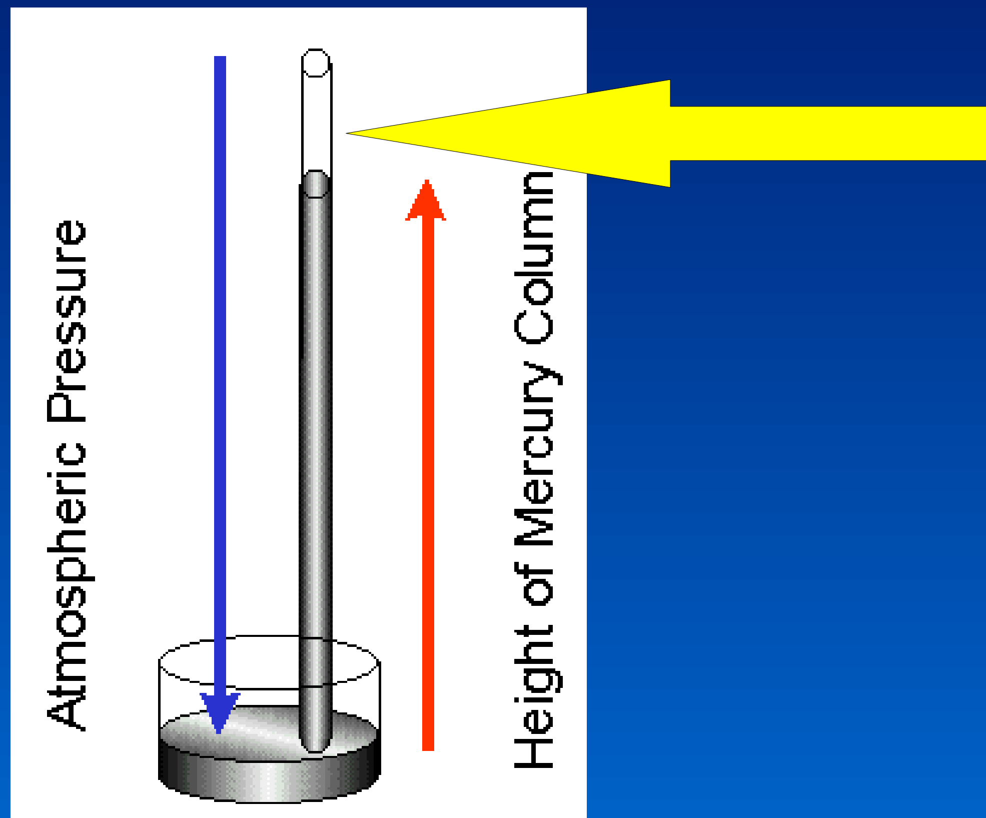


Barometer

Device used to measure atmospheric pressure



vacuum

Units of Pressure

1 atmosphere =

760 torr
760 mm Hg
29.9 in Hg
15 lb/in^2
101,325 Pa

Units for Other Properties

Volume | Temperature | Moles

Volume → Liters

Temperature → Kelvin
no negative temperatures

Moles → Amounts in moles

The Gas Laws

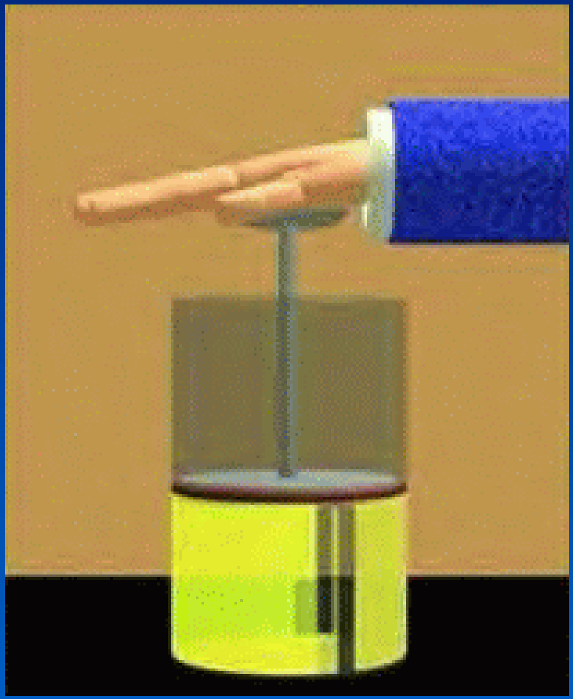
Laws that show the relationship between volume and other properties of gases

Boyle's law
Charles' law
Avodagro's law

The Ideal Gas law combines all of these into one law

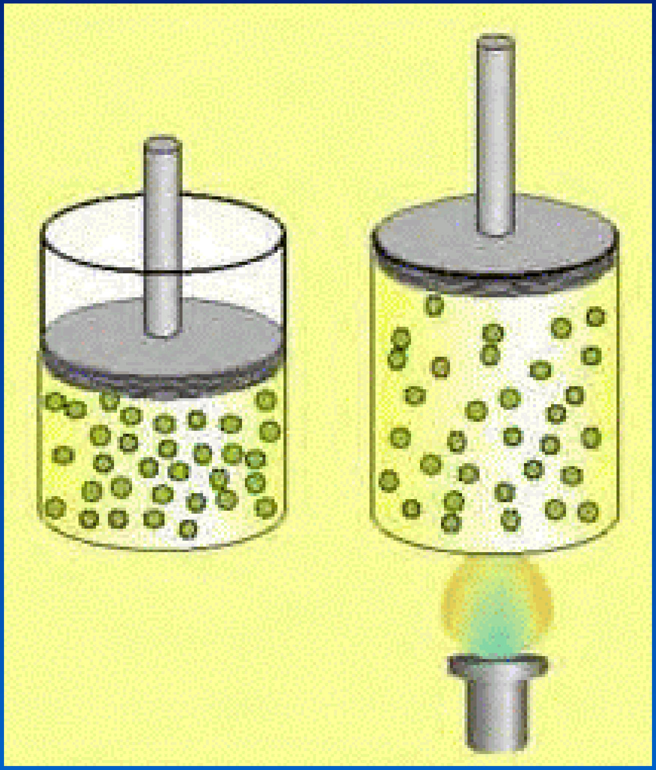
Boyle's law

Increasing pressure ° decreases volume



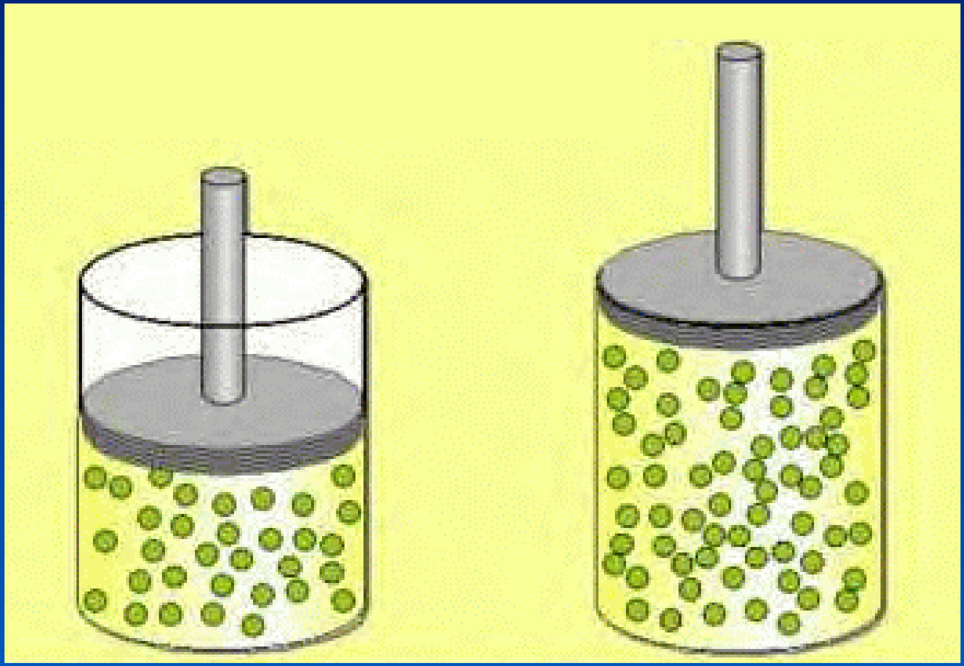
Charles' law

Increasing temperature ° increases volume



Avogadro’s law

Increasing molecules º increases volume



The Ideal Gas Law

A combination of Boyle's, Charles' and Avogadro's laws

$$PV = nRT$$

R called gas law constant
= 0.082 L.atm/mol.K

Example

What is the volume of 2.0 moles of gas, at 3.50 atm and 310 K?

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$$PV = nRT$$

$$V = \frac{nRT}{P}$$

Example

What is the volume of 2.0 moles of gas, at 3.50 atm and 310 K?

$$PV = nRT$$

$$V = \frac{nRT}{P}$$

$$= \frac{2.0 \times 0.082 \times 310}{3.50} = 14.5 \text{ L}$$

Changes in State

A substance can usually be changed to different states by adding or removing energy from a system

If energy added change is endothermic

If energy given off change is exothermic

As we saw earlier, these terms also apply to chemical reactions