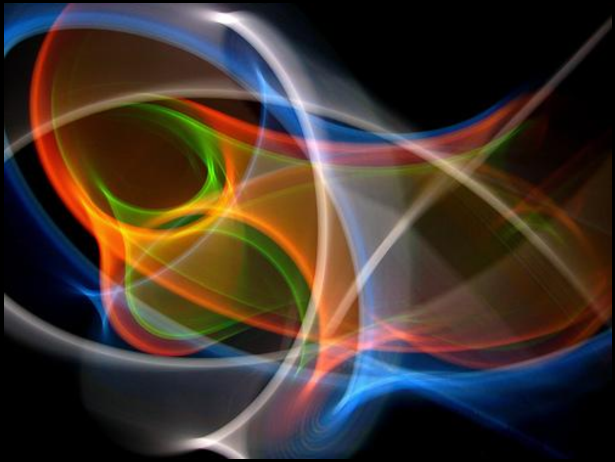
# Gases





LPT

# States of Matter - Gas (Vapor)

| | |
|---|---|
| Form | Fluid (Flows) |
| Compressibility | Very High |
| Shape | Variable (Fills Closed Container) |
| Volume | Variable (Fills Closed Container) |
| Particle Movement | Random, Independent |

Example: Steam



LPT

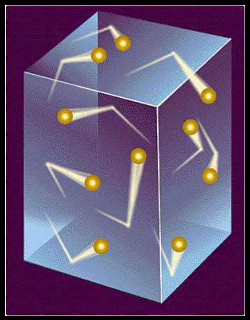
# Kinetic (Moving) Theory of Gases

Gases are composed of molecules in constant motion
Gas molecules move in random directions
Molecules of a gas collide frequently with each other & with vessel walls
(why gases mix to uniformity & fill all portions of the containment vessel)

Gas molecules move with an average velocity at a given temperature.
(the average energy of molecules in a gas is the same for all substances)

Distance between gas molecules >> than size of the individual molecules
(why gases can be compressed)

Molecules are perfectly elastic … no energy is lost when molecules collide
(If not-elastic, the temperature of a gas mix would always decrease with time)

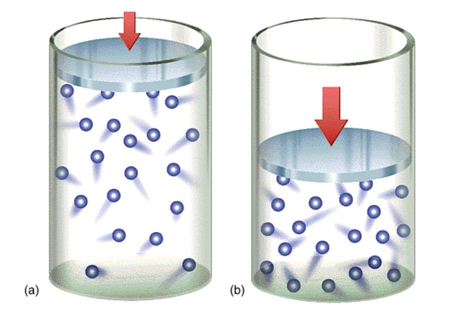


**Works for "Ideal" Gases:**

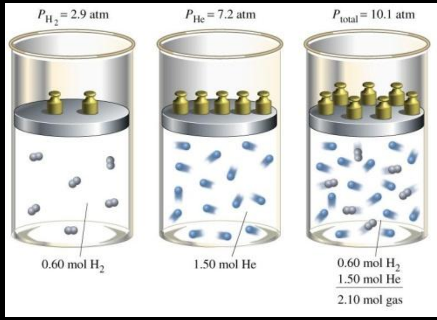
No molecular interactions 'cause of large separation
Volume of gas molecules insignificant

# Molecular Explanation of Gas Properties

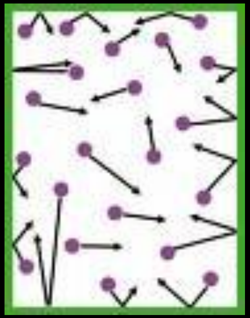
| Property | Gas Molecules: |
|---|---|
| Compressibility | Widely spaced |
| Low density | Widely spaced |
| Mixable | Widely spaced<br>In constant, random motion |
| Fills container | In constant, random motion |
| Uniform pressure | In constant, random motion<br>No energy loss collisions |




Compress



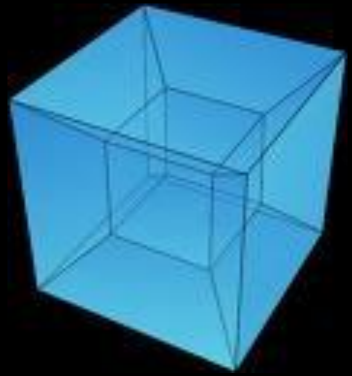

Mix



Fill



LPT



V

T

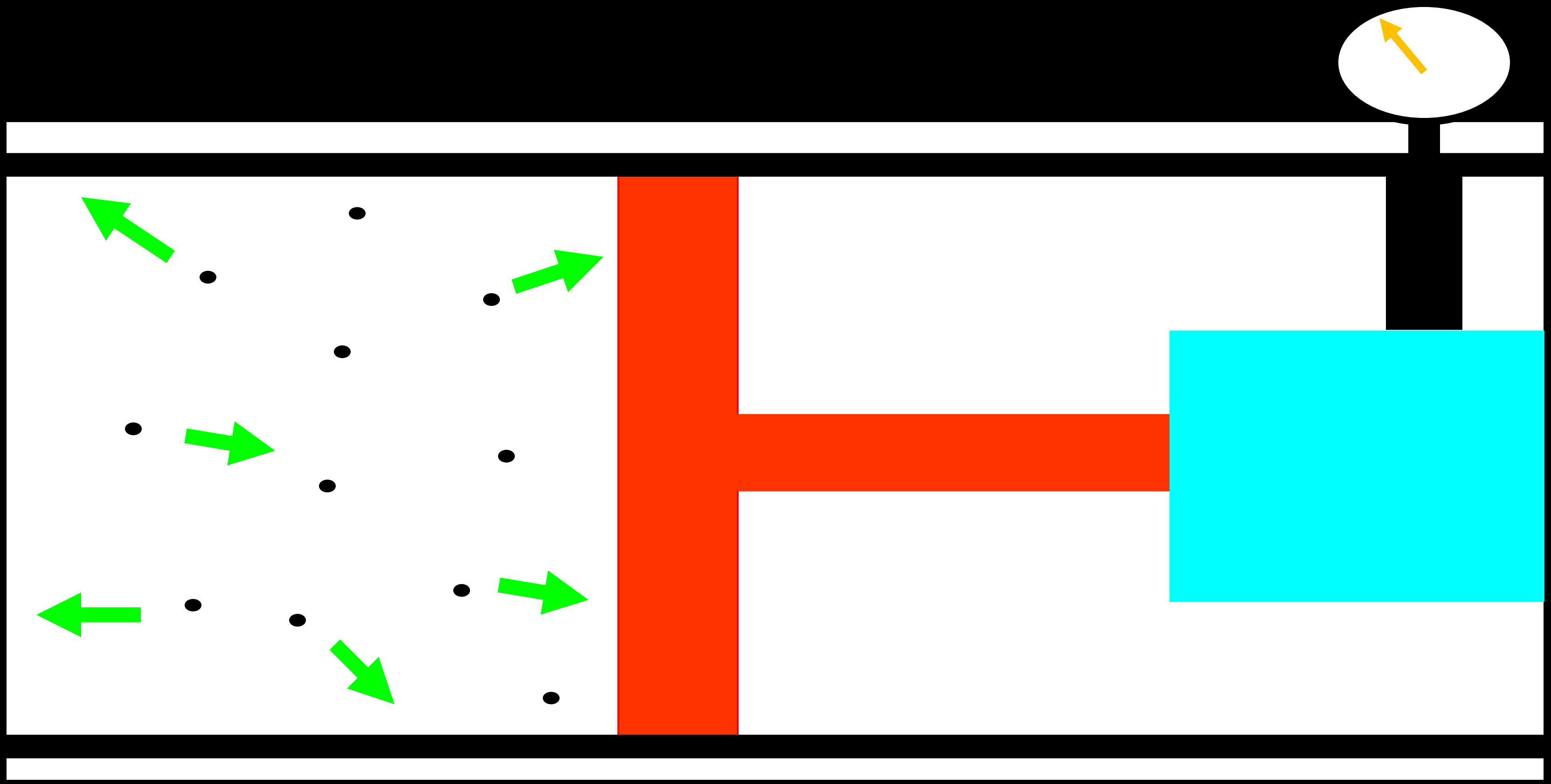
## Gas behavior is described in terms of:

| | |
|---|---|
| Volume | (V) |
| Pressure | (P) |
| Temperature | (T) |
| Quantity (moles) | (n) |

P

n

# Pressure: molecular impact on container walls

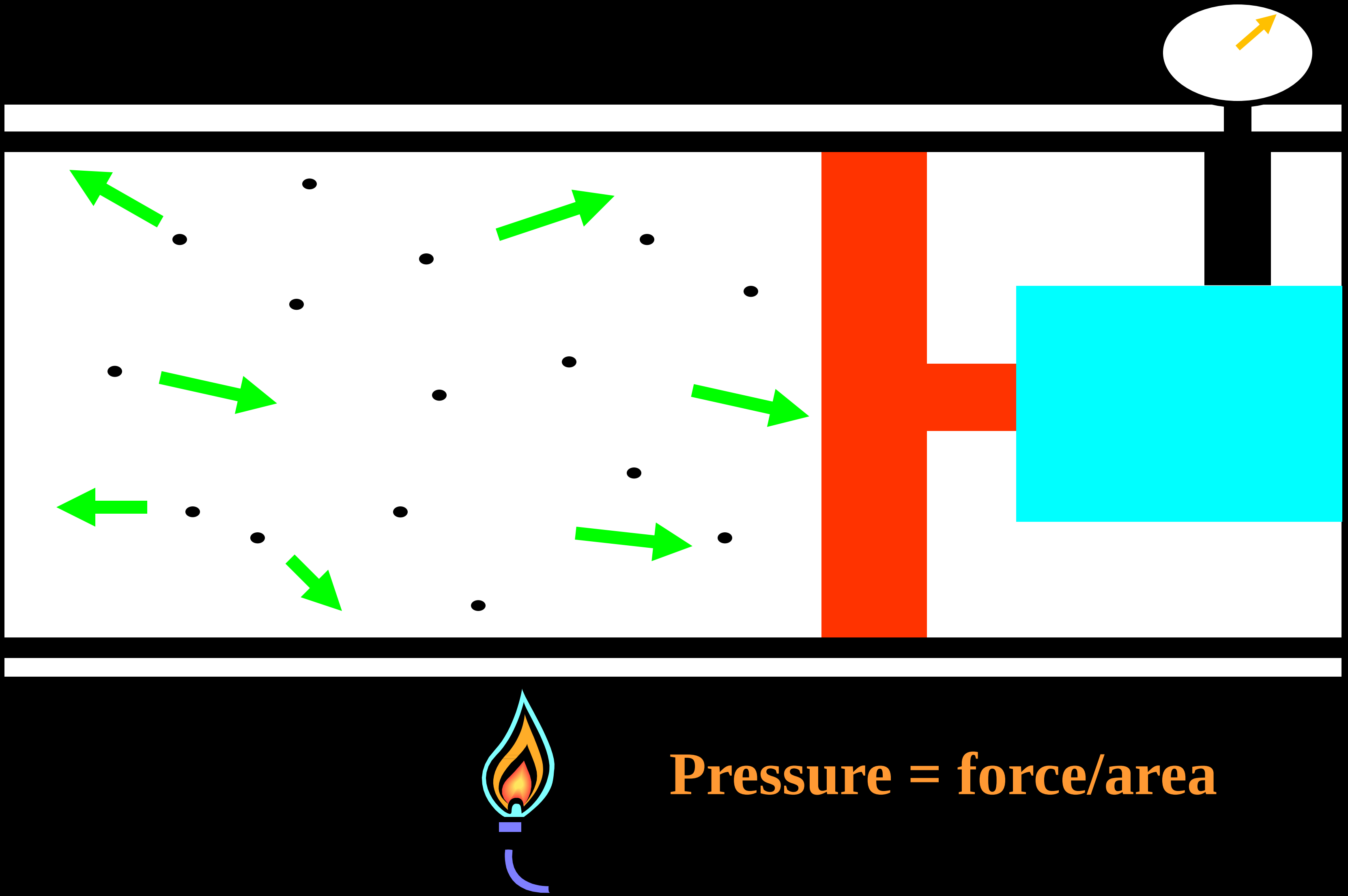


Pressure = force/area



LPT

# More impacts / time → Increased Pressure

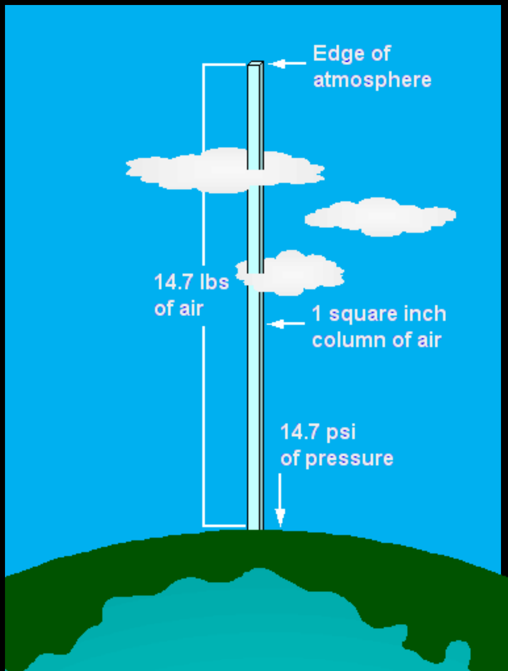


Pressure = force/area

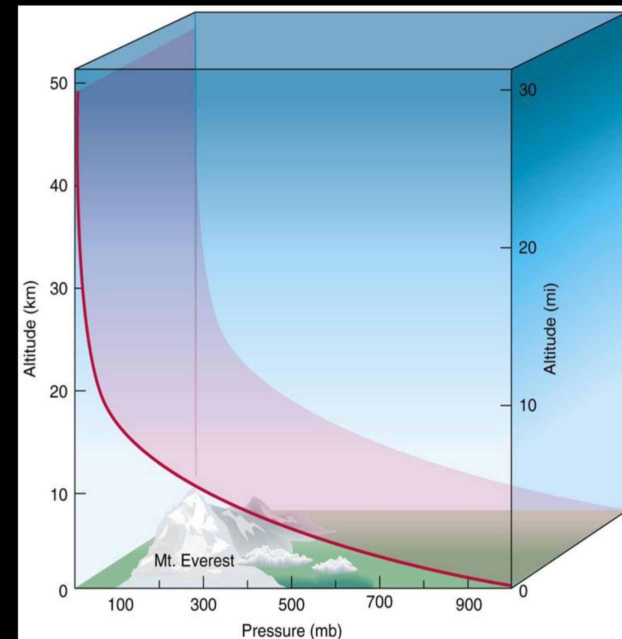


LPT

# Pressure = Force per Unit Area




## UNITS:




### Related to atmosphere

mm Hg (torr)
inches Hg
inches $H_2O$
bar (or millibar)
atm

### Related to force

psi (pounds / $in^2$ )
Pa ( Pascals: newtons / $m^2$)

Otto von Guericke 1654

### "Per" Expressions

1 torr = 1 mm Hg

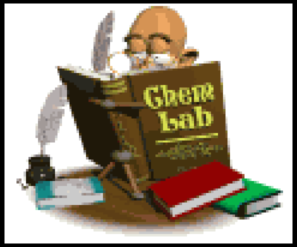
1 atm = 760 mm Hg
= 14.7 psi
= 1,013.25 millibars



LPT

# Complete Table

| mmHg | torr | atm |
|---|---|---|
| 465 | | |
| | | 2.41 |
| | 836 | |

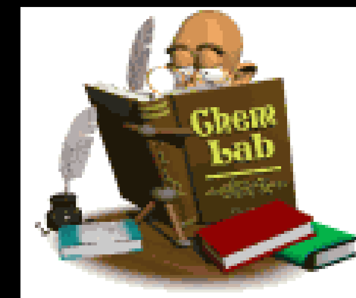





LPT

# Converting Pressures

$$465 \text{ torr} \times \frac{1 \text{ mmHg}}{1 \text{ torr}} = 465 \text{ mmHg}$$




$$836 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}} = 1.10 \text{ atm}$$

$$2.41 \text{ atm} \times \frac{760 \text{ torr}}{1 \text{ atm}} = 1830 \text{ torr}$$

$$465 \text{ mmHg} \times \frac{1 \text{ atm}}{760 \text{ mmHg}} = 0.612 \text{ atm}$$

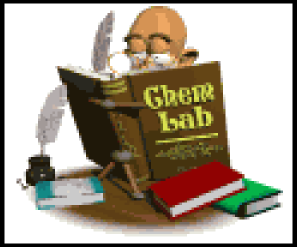
Let the units drive the solution



LPT

# Completed Table

| mmHg | torr | atm |
|---|---|---|
| 465 | 465 | 0.612 |
| 1830 | 1830 | 2.41 |
| 836 | 836 | 1.10 |





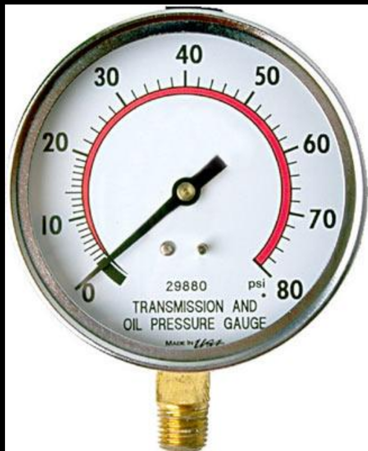

LPT

**NOAA reports barometric pressure in mm of mercury.**
**What is atmospheric pressure in inches of mercury?**

$$760.0 \text{ mm Hg} \times \frac{1 \text{ m}}{1000 \text{ mm}} \times \frac{100 \text{ cm}}{1 \text{ m}} \times \frac{1 \text{ in}}{2.54 \text{ cm}} = 29.92 \text{ in Hg}$$



LPT




# Gauge vs. Absolute Pressure

## Gauges have a zero point

## At gauge zero point = 1 atmospheric pressure

# Absolute Pressure

## Absolute pressure = pressure of gauge + atmospheric pressure
## Represents the actual (total) pressure on the system
## Gases respond to the absolute pressure

| DEPTH | ABSOLUTE PRESSURE | GAUGE PRESSURE | AIR VOLUME | SURFACE VOLUME EQUIVALENT | EXAMPLE |
|---|---|---|---|---|---|
| 0 | 1 ATM | 0 ATM | 1 | 1 | 60 |
| 10 | 2 ATM | 1 ATM | 1/2 | 2 | 30 |
| 20 | 3 ATM | 2 ATM | 1/3 | 3 | 20 |
| 30 | 4 ATM | 3 ATM | 1/4 | 4 | 15 |
| 40 | 5 ATM | 4 ATM | 1/5 | 5 | 12 |

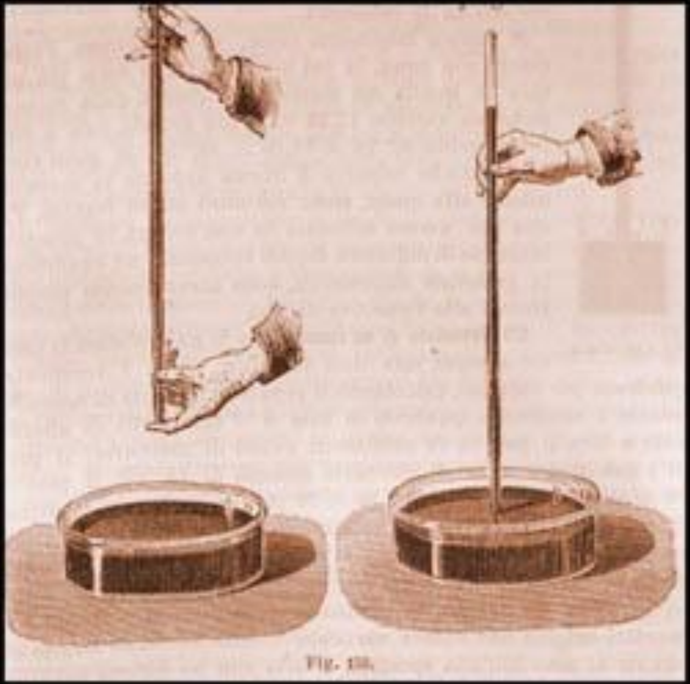


LPT

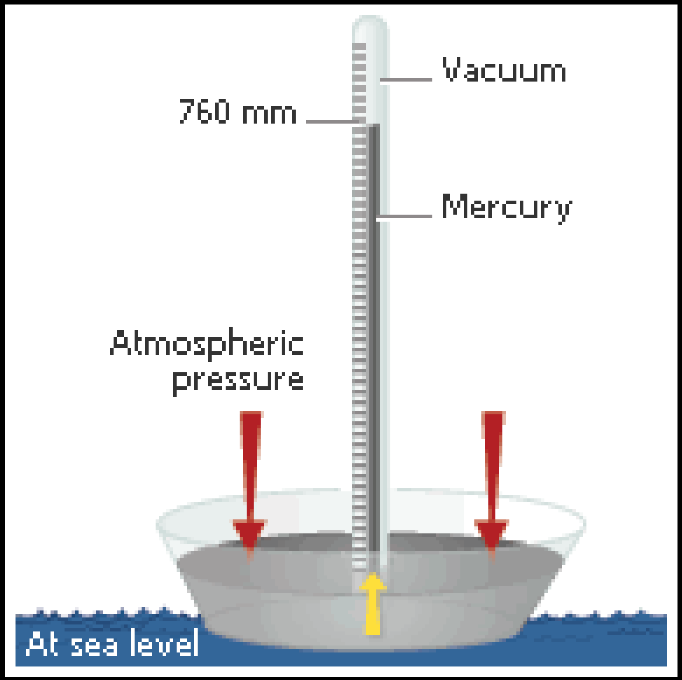
# Evangelista Torricelli

## Italian scientist
## Invented the barometer in 1644
## First to create a sustained vacuum

## Pressure unit torr in his honor










LPT

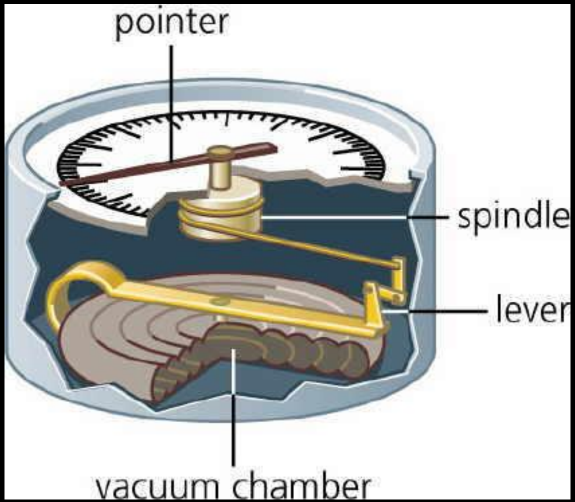
# Barometer

## Measures atmospheric pressure (weight)

**Mercury**


**Aneroid**

**(Without liquid)**



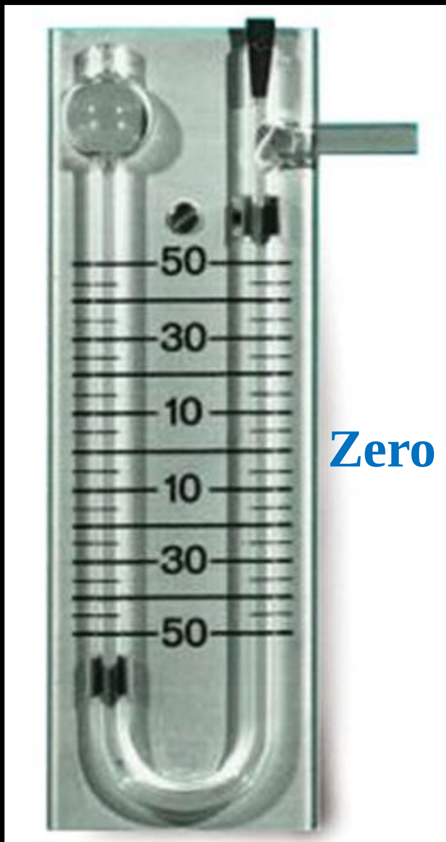

**Inverted Hg Filled Tube**

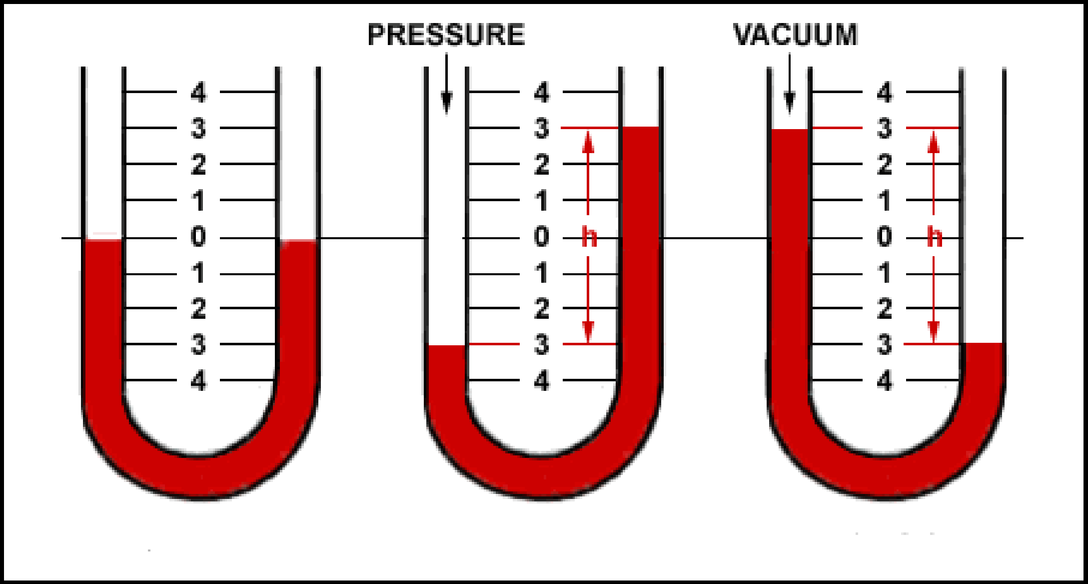
**Expanding Metal Chamber**

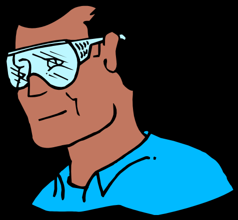


LPT

# Manometer



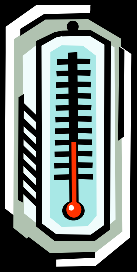
**U- Shaped tube connected to apparatus**
**Pressure = difference in column height**

# Temperature

## The *average* kinetic energy (K.E.) of molecules

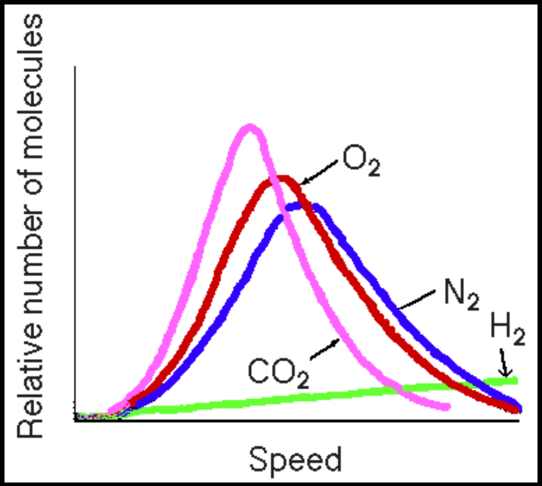
K.E. = energy of motion

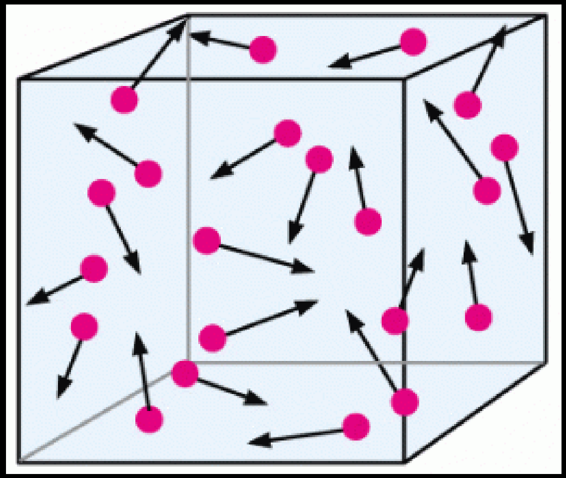
= 1/2 mass(velocity)$^2$



As velocity (speed) slows, K.E. decreases & temperature falls

At K.E. = 0, v = 0 (Absolute zero … no molecular movement)



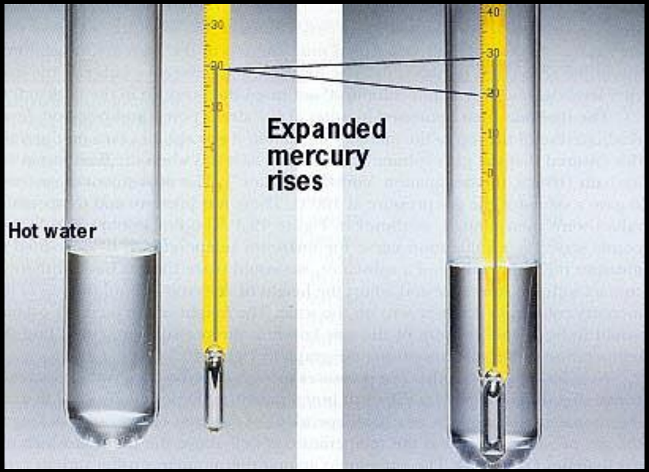
At constant temperature, larger molecules move slower



LPT

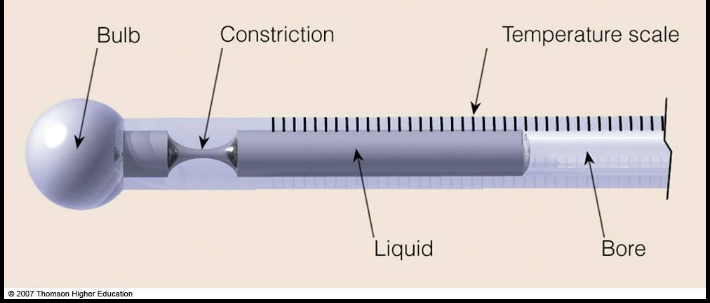
# Thermometer

## Device for measuring temperature




As liquid warms, it expands &
Amount of expansion is quantified

Clinical (Maximum Temperature):
Restriction Prevents Liquid Return to Bulb



# Temperature Scales

**Fahrenheit ($^{o}$F)** — **Daniel Fahrenheit**

Dutch scientist — 1724

Placed mercury in closed glass column

Used three points to define scale:

- 0 = coldest that could be reached with water, ice, sea salt slush
- 32 = water/ice
- 96 = arm pit temperature (used bisection to create scale)

| Ice/ Water Slush | Freezing Water | Human Arm Pit | Boiling Water |
|---|---|---|---|
|  |  |  |  |
| 0 $^{o}$F | 32 $^{o}$F | 96 $^{o}$F | 212 $^{o}$F |

**water: freezing and boiling points 180 units apart**



LPT

# Temperature Scales

**Celsius (Centigrade, $^{o}$C)** **Anders Celsius**

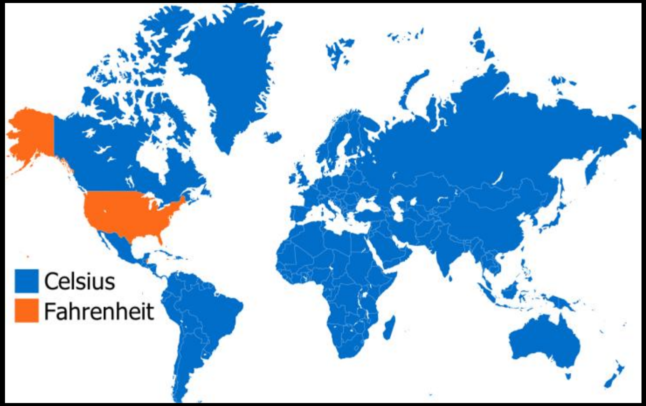
Swedish Astronomer 1742

International scientific scale

Used two points to define scale:

100 = freezing point of water

0 = boiling point of water




Freezing Water

100 $^{o}$C

Boiling Water

0 $^{o}$C

water: freezing and boiling points 100 units apart

**Carolus Linnaeus** 1744

Swedish Botanist

Reversed scale to set Freezing Point at 0 Degrees

# “Absolute” Temperature Scales

**William Thompson (Lord Kelvin) 1848**

**Proposed a scale based on absolute zero as zero point**

**Uses the Centigrade (1/273 gas volume change) degree**

**Makes all temperatures have positive value**

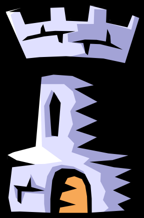
**$K = {}^oC + 273$     ${}^oC = K - 273$**

**William Rankine 1859**

**Proposed a scale based on absolute zero as zero point**

**Uses the Fahrenheit degree**

**${}^oR = {}^oF + 459$     ${}^oF = {}^oR - 459$**



**Gas laws must use absolute temperatures**

**Science uses Kelvin**

**American engineering (especially heating / cooling) uses Rankine**

# Temperature Conversions

**Zero point difference:**
**32 degrees**

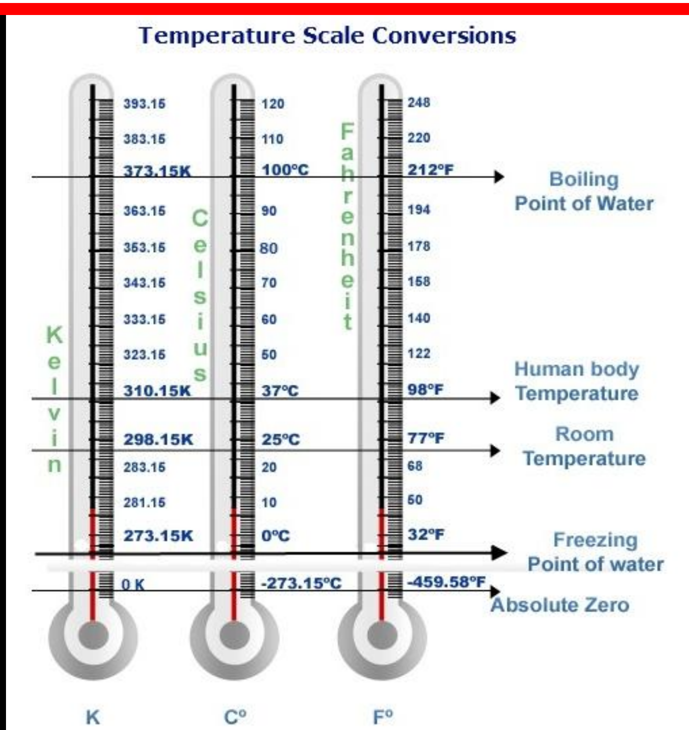
$$^{o}F = 9/5\ ^{o}C + 32$$

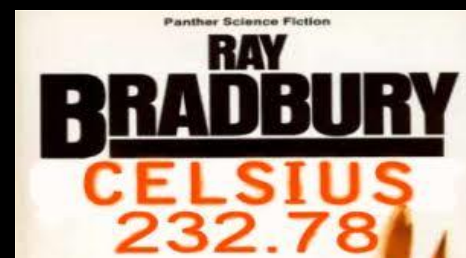
$$180/100 = 9/5$$

$$^{o}C = 5/9\ (^{o}F - 32)$$

**K = ºC + 273 (Kelvin, Absolute Celsius Scale)**

**By convention, there is no º symbol for degrees kelvin**








LPT

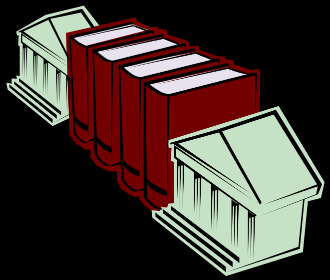
# Gas Behavior (Equations or Laws)

**Must use absolute temperature and pressure**

**We: Assume given pressure units = absolute**

**Convert given Celsius temperature to Kelvin**

**"Ideal" Gases**



**Described by Kinetic Theory of Gases**

**Behavior predictable by "Ideal Gas Laws"**

**Valid at low pressures & high temperatures**

**Not valid at compressed gas cylinder pressures**

**Need more complex "Real" Gas Equations**



LPT

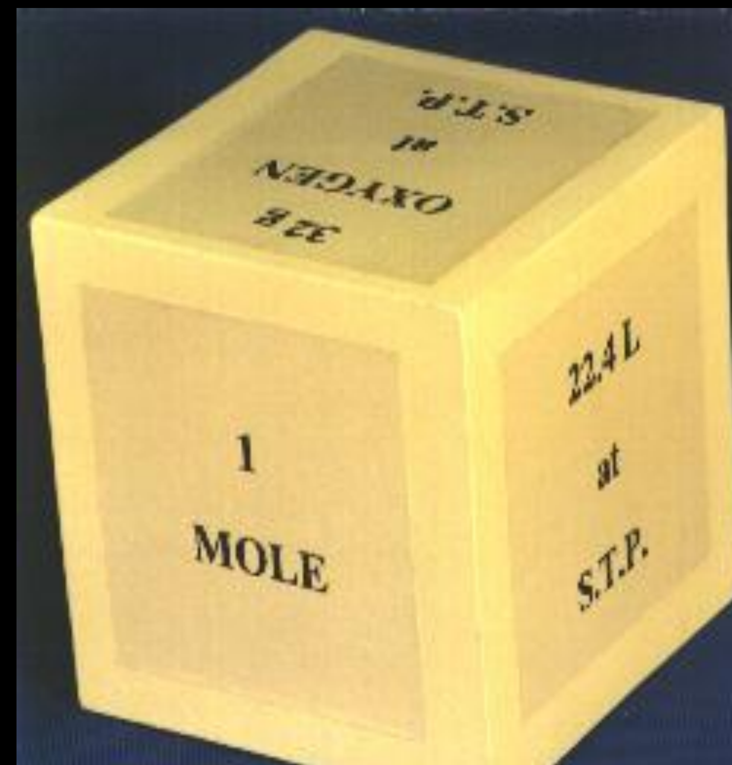
# STP
# Standard Temperature & Pressure

**Standard Temperature = 0° C (273 K )**
**Standard Pressure = 1 atm (760 torr)**

## At STP:

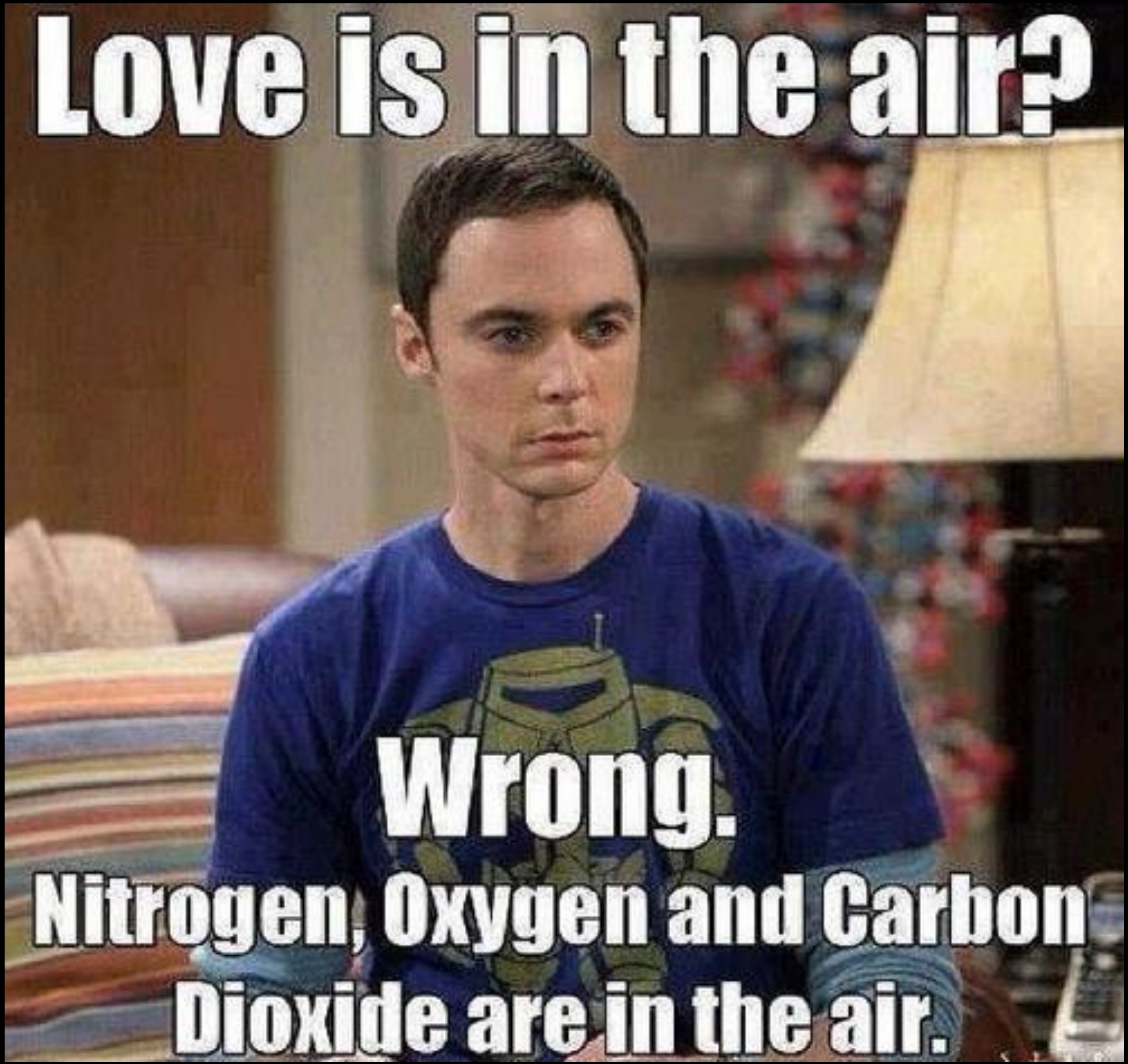
**22.4 L = 1 mole of any gas**

**22.4 L weighs Molar Mass**
**22.4 L contains $6.02 \times 10^{23}$ fu**






LPT


Love is in the air?
Wrong.
Nitrogen, Oxygen and Carbon Dioxide are in the air.

LPT