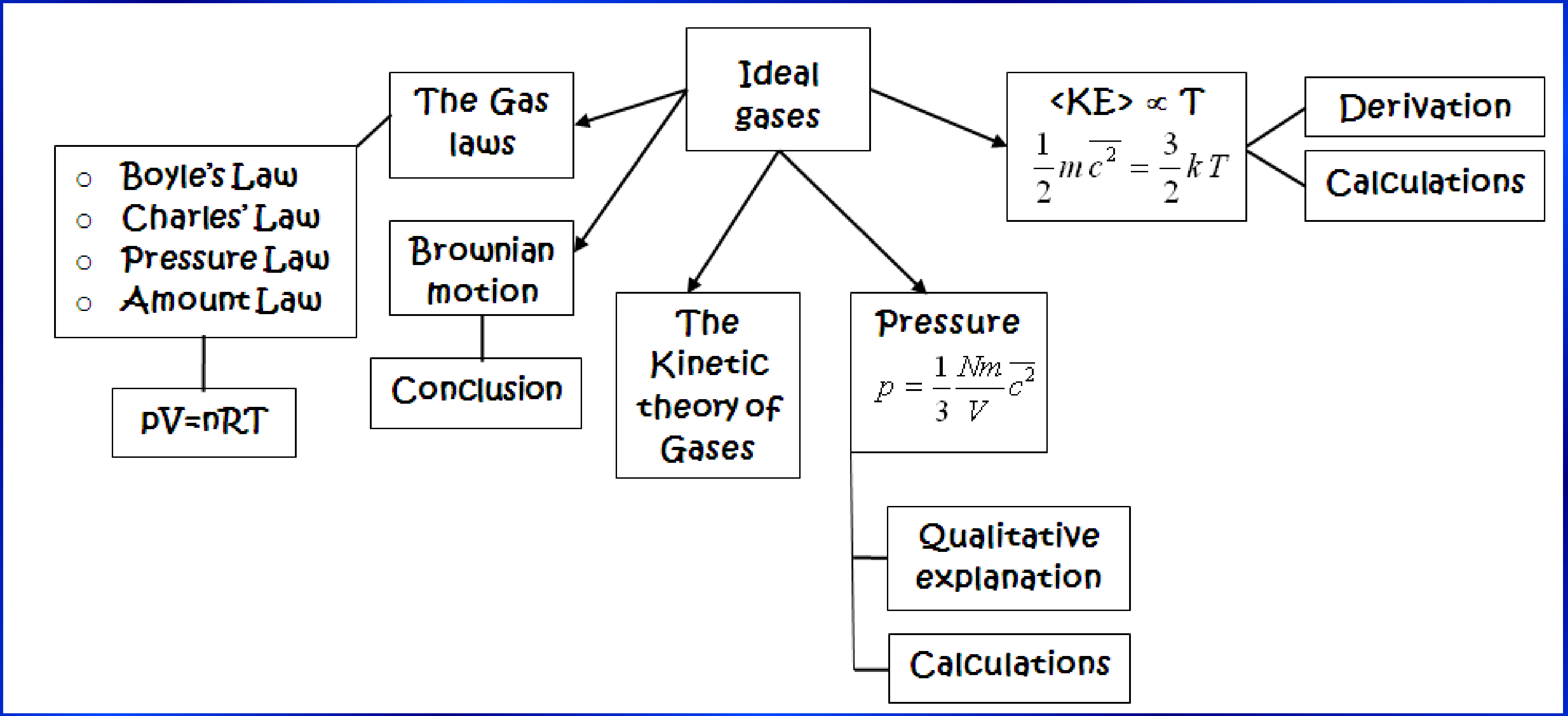
Chap. 11 Ideal Gases



limwh2012

The gas laws

- **Boyle's Law**

  $p \propto 1/V$ if T and n constant

- **Charles' Law**

  $V \propto T$ if p and n constant

- Pressure **Law**

  $p \propto T$ if V and n constant

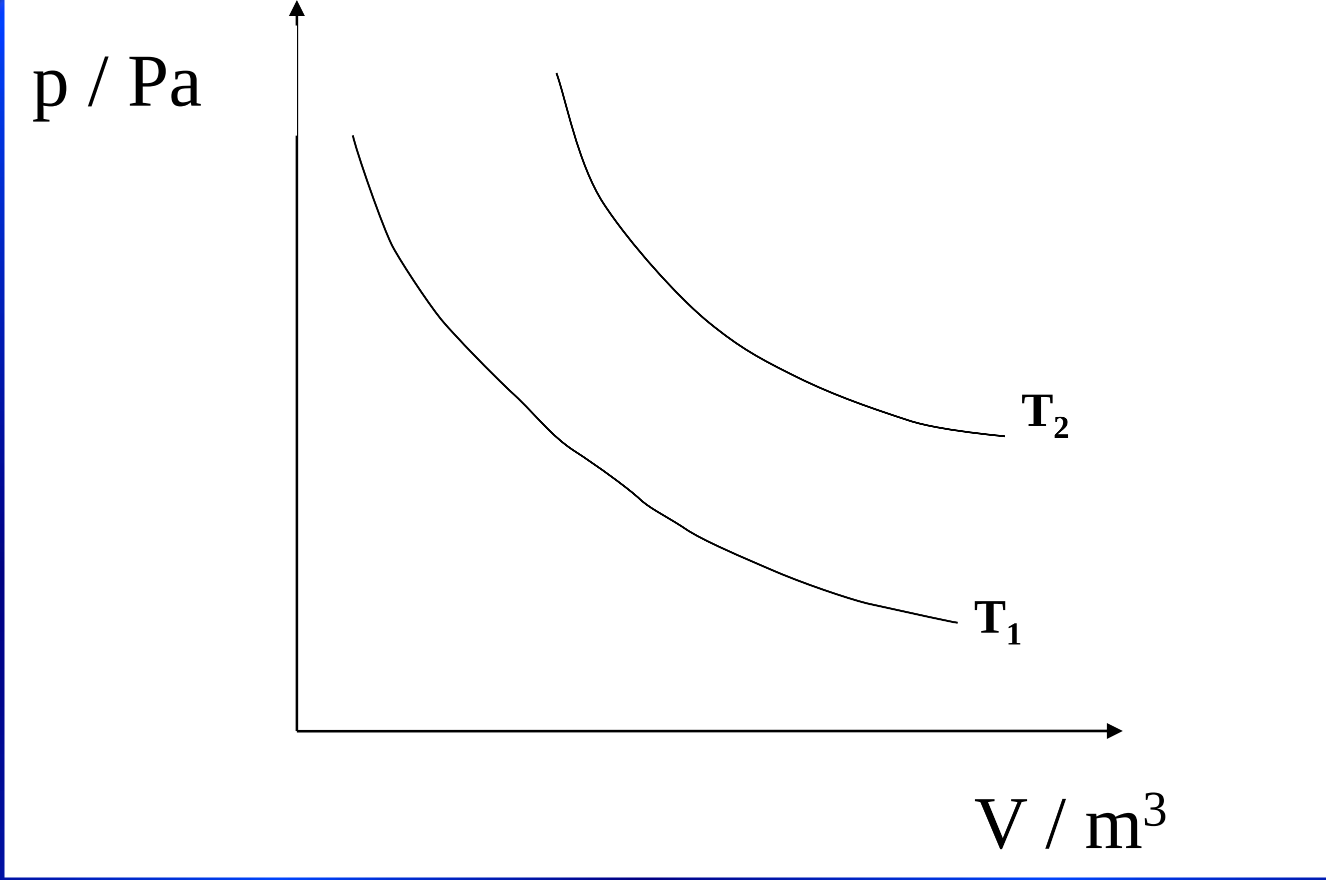
- **Amount Law**

  $p \propto n$ if T and V constant

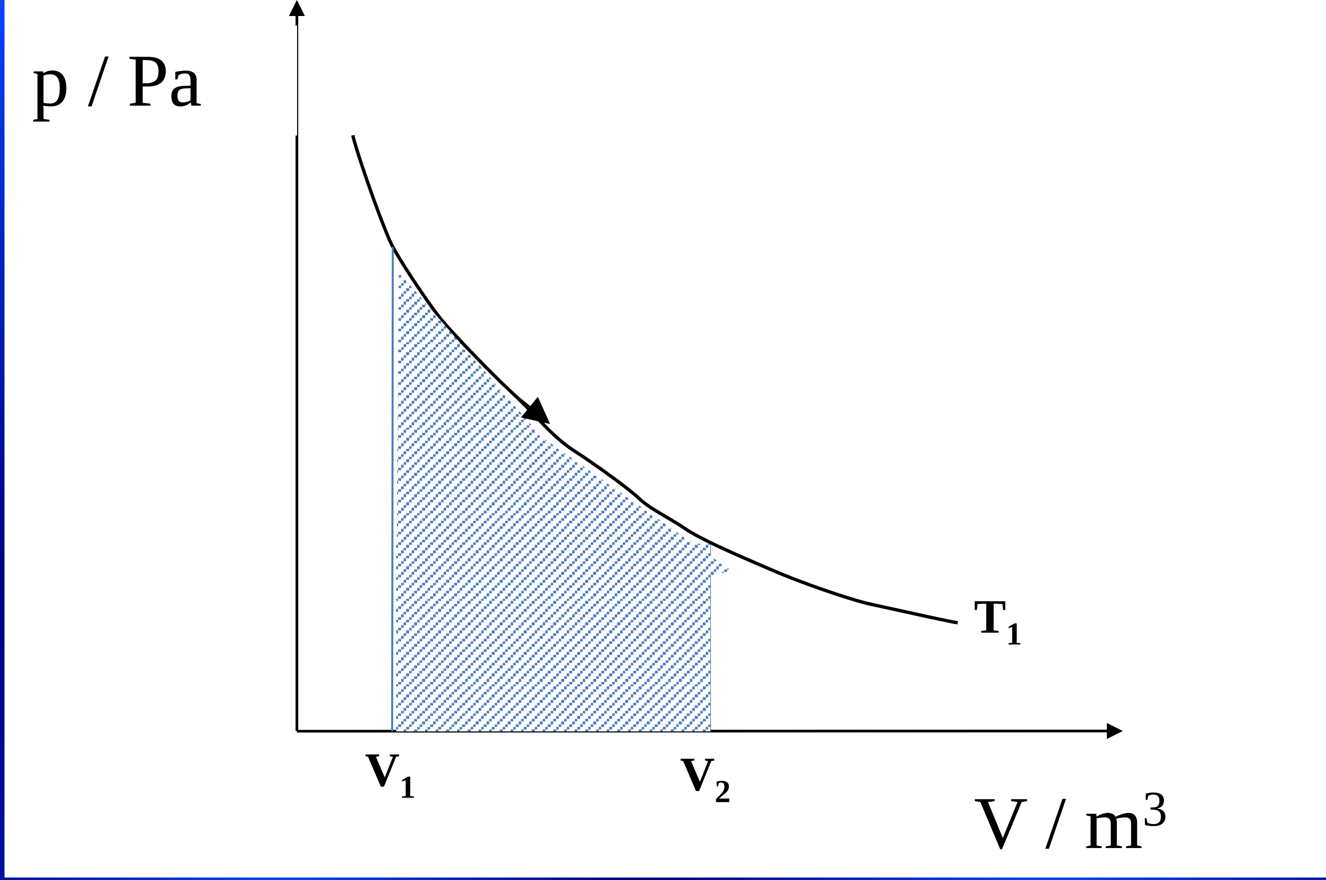
- Combining the four gas laws, as mentioned above, for an ideal gas,

$$pV \propto nT$$

- **pV = nRT**
- constant R is the universal molar gas constant $= 8.31 JK^{-1}mol^{-1}$
- For the same amount of substance, $\dfrac{p_1V_1}{T_1} = \dfrac{p_2V_2}{T_2}$



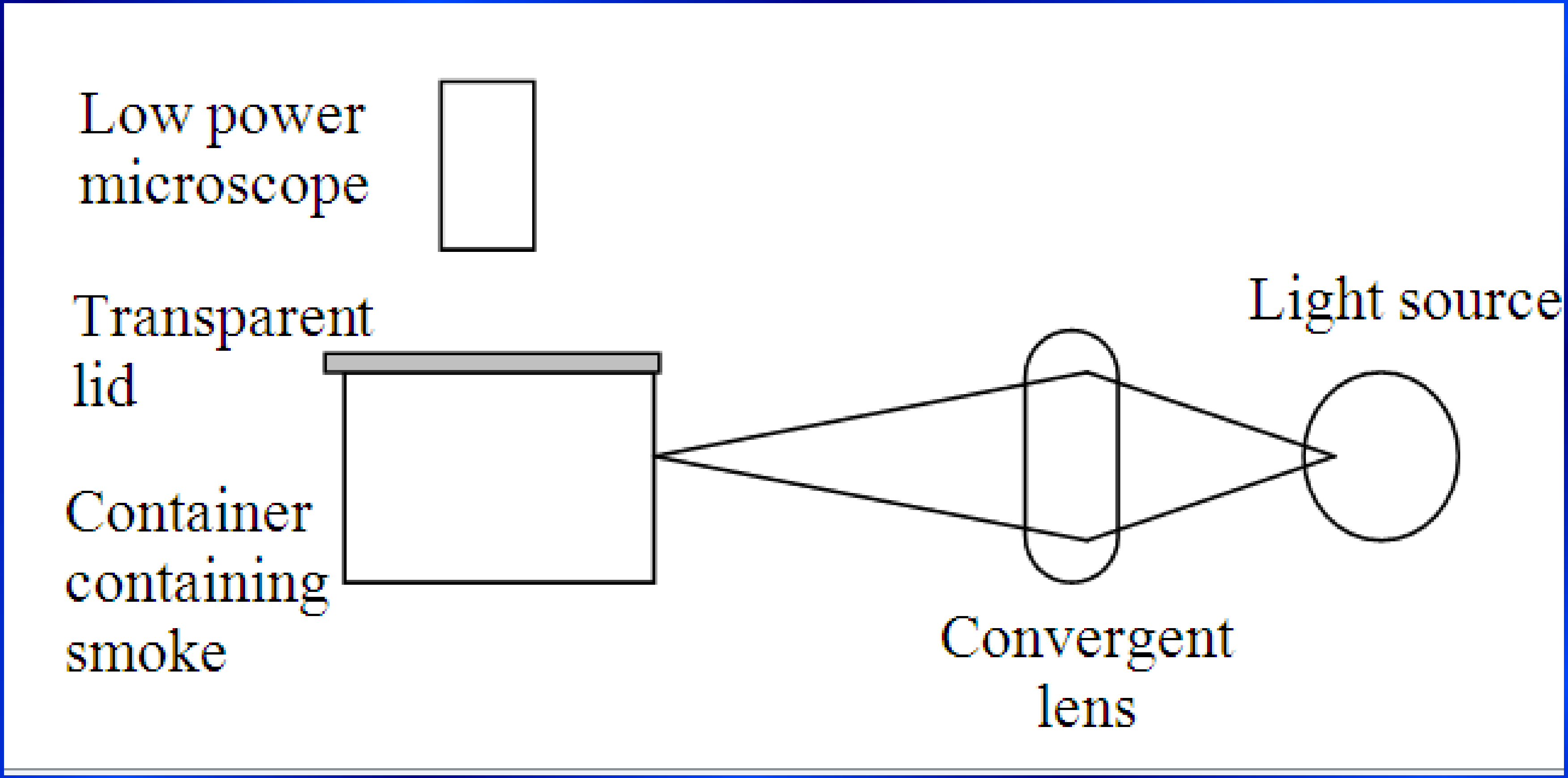
- **pV = nRT**
- P=(nRT)/V
- y=k/x
- p vs. V
- Each curve represents a process at a constant temperature where $T_2 > T_1$

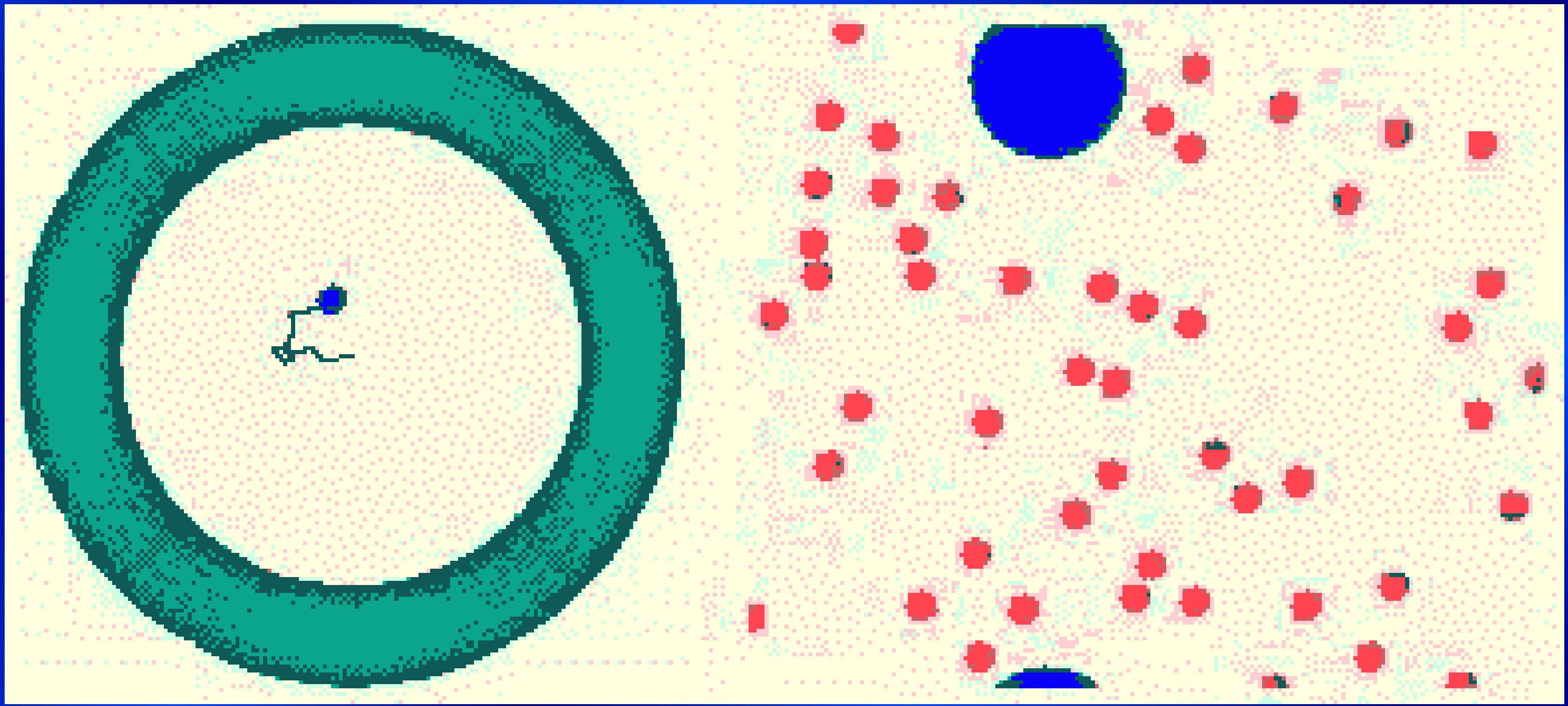


- Area under the graph represents work done, $W = p\,\Delta V$
- Work done on the gas, i.e. compression, W +ve
- Work done by the gas, i.e. expansion, W -ve

Questions related to $pV=nRT$ will be discussed in the class.

Describe an experiment to demonstrate Brownian Motion

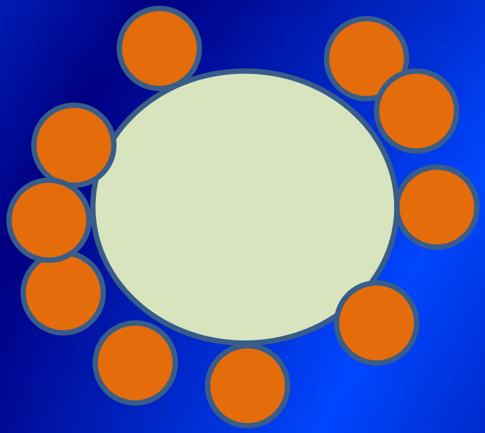




- Smoke particles are large in size and hence they reflect light which enables them to be seen as bright spots.
- In this experiment, we use the visible particles (smoke particles) to draw conclusions on the invisible particles (gas molecules)

smaller particles move faster
while large particles are less agitated

Large surface area
more collisions from all over directions
more likely to cancel out one another
less resultant movement, less random

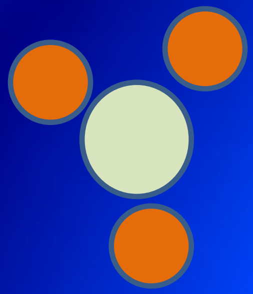


Smaller surface area

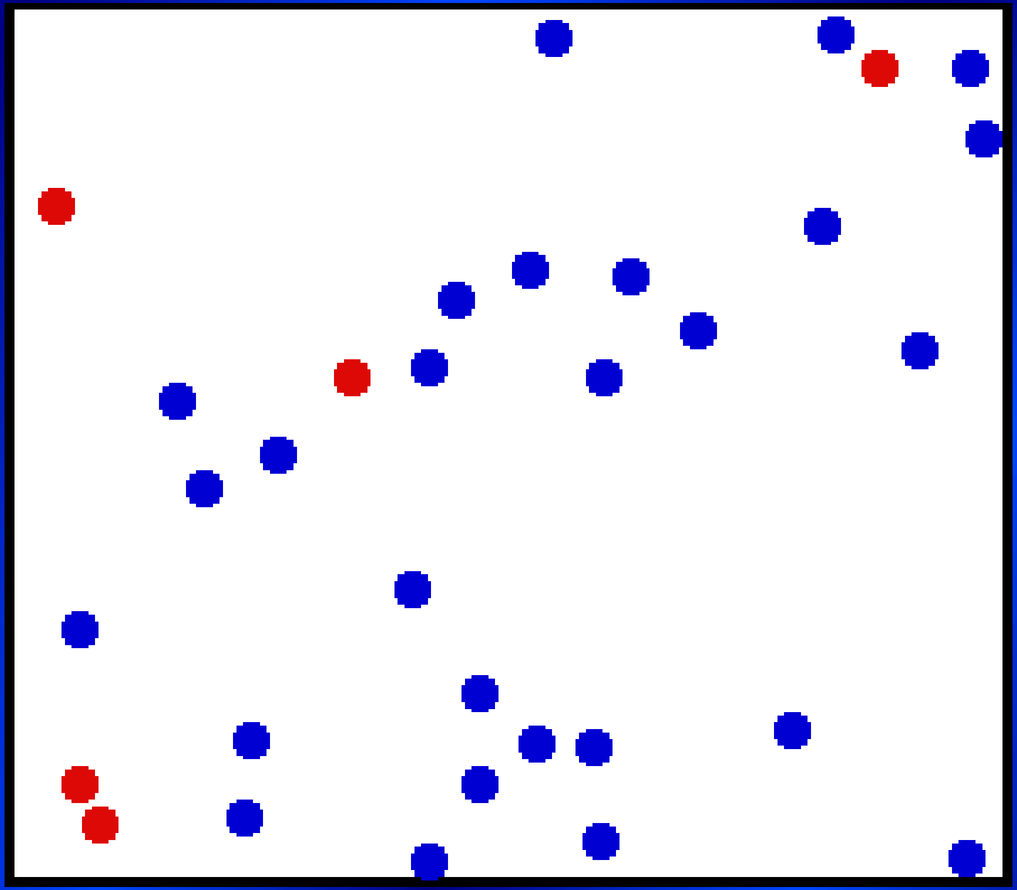
fewer collisions

less likely to cancel out one another

more resultant movement, more random



Smoke particles move faster when temperature increases

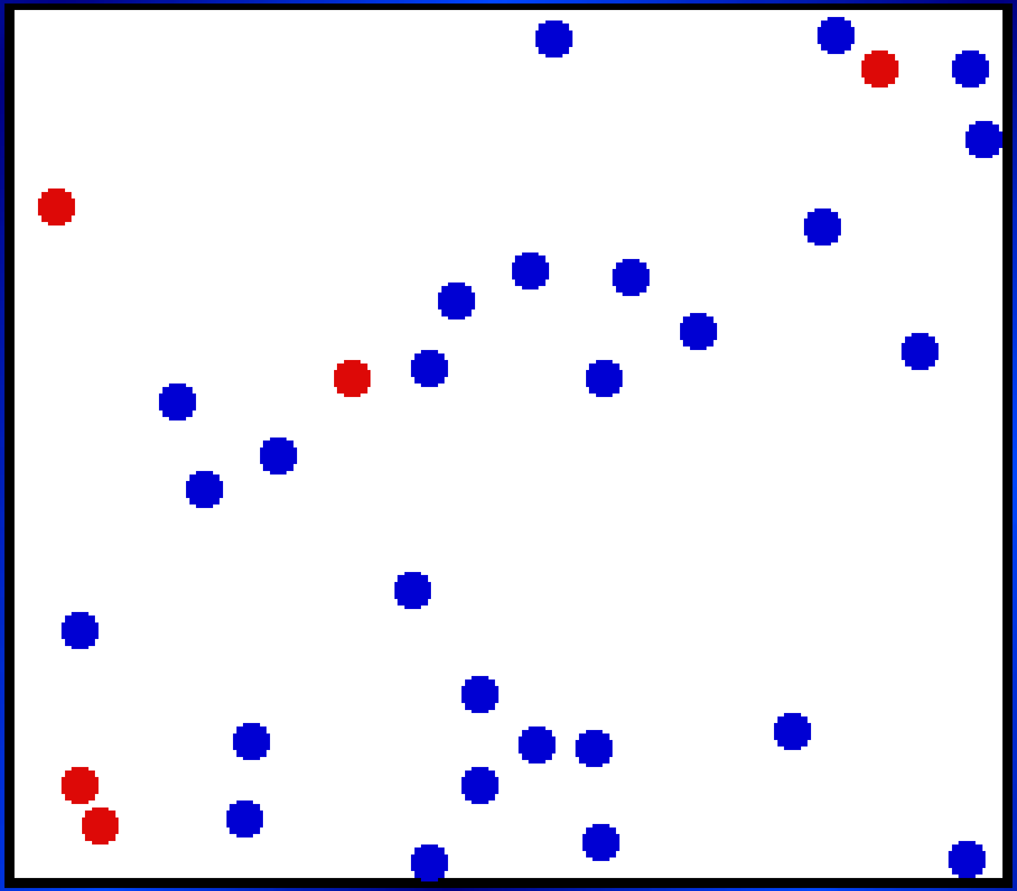


- temperature increases
- KE increases
- Frequency of unbalanced collisions increases
- Resultant force

The Kinetic theory of Gases

1. A sample of gas consists of a large number of atoms or molecules.
2. The gas molecules are constantly in haphazard and random motion. Newtonian mechanics may be applied to the motion of the gas molecules.
3. Gas molecules collide elastically with one another and the walls of the container. Atoms or molecules move with constant velocity between collisions. Gravity has no effect on molecular motion.
4. There is no intermolecular force except during collision.
5. The volume of the gas molecules is negligible compared to the volume of the container, which is also the volume of the gas.
6. The duration of collision is negligible compared to the time interval between collisions.

How does pressure arise?



1. Collisions
2. Change in momentum
3. Force = $\frac{\Delta p}{\Delta t}$
4. Total force
5. pressure

e) Pressure p exerted by N gas molecules, each of mass m, moving with a mean square speed $<u^2>$ in volume V is given by:

$$p = \frac{1}{3}\frac{Nm}{V} < u^2 >$$

where $< u^2 > = (u_1{}^2 + u_2{}^2 + \ldots + u_N{}^2) / N$

f) $p = \frac{1}{3}\frac{Nm}{V} < u^2 > = \frac{1}{3}\rho < u^2 >$ as $\frac{Nm}{V} = \rho$

where Nm : total mass of gas and V : total volume of gas

Q1: Three gas molecules in a sample are moving with speeds 40 ms^{-1}, 50 ms^{-1} and 60 ms^{-1}

a) The mean square speed $<u^2>$ of the sample is

$40^2 + 50^2 + 60^2 =$ <u>2570</u> m^2s^{-2}

b) The root mean square speed, $u_{rms} = 50.7\ ms^{-1}$

c) If the density of the sample is 0.3 kgm^{-3},

calculate the pressure exerted by the molecules.

p = 1/3 x 0.3 x 2566 = <u>257</u> Pa

Derivation for <KE> ∝ T

From the ideal gas: pV = nRT -- equation (1)

From kinetic theory, $pV = \frac{1}{3} Nm < u^2 >$ -- equation (2)

Equate (1) & (2)

$$\frac{1}{3} Nm < u^2 >= nRT$$

$$\frac{1}{2} m < u^2 >= \frac{3}{2} \frac{nR}{N} T$$

$$\frac{1}{2} m < u^2 >= \frac{3}{2} kT$$

$$\frac{nR}{N} = \frac{\mathrm{R}}{\mathrm{N_A}}$$

$\frac{\mathrm{R}}{\mathrm{N_A}}$ = k Boltzmann's constant = 1.38×10^{-23}

$$\frac{1}{2} m < u^2 > = \frac{3}{2} k T$$

$$<KE> = \frac{1}{2} m < u^2 >$$

$\frac{3}{2} k$ are constants

$<KE> \propto T$ (shown)

- <KE> of one molecule = $\frac{1}{2}m<u^2>=\frac{3}{2}kT$
- Total KE of n moles of molecules

  = n x N_A x <KE>
- For ideal gas, internal energy of n moles molecules = total KE

Q2: A sample, consists of 0.2 moles of hydrogen and 0.4 moles of helium, is held at 300 K. Assuming they behave ideally, determine:

a) <KE> of the sample = 3/2 kT = 1.5 x 1.38 x 10^{-23} x 300

= 6.21 x 10^{-21} J

b) Total KE of the sample = 0.6 x N_A x 6.21 x 10^{-21} = 2243 J

c) Internal energy of the sample =Σ KE = 2243J

More questions will be discussed in the class.