Matter

Phases of Matter

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Syllabus content

Section		AS	A2
III Matter	9. Phases of matter	✓	
	10. Deformation of solids	✓	
	11. Ideal gases		✓
	12. Temperature		✓
	13. Thermal properties of materials		✓

Section III: Matter

Recommended prior knowledge

Candidates should be able to describe matter in terms of particles, with a qualitative understanding of their behaviour.

Phases of matter

Content	Learning outcomes
9.1 Density 9.2 Solids, liquids, gases 9.3 Pressure in fluids 9.4 Change of phase	Candidates should be able to: *(a)* define the term density *(b)* relate the difference in the structures and densities of solids, liquids and gases to simple ideas of the spacing, ordering and motion of molecules *(c)* describe a simple kinetic model for solids, liquids and gases *(d)* describe an experiment that demonstrates Brownian motion and appreciate the evidence for the movement of molecules provided by such an experiment *(e)* distinguish between the structure of crystalline and non-crystalline solids with particular reference to metals, polymers and amorphous materials *(f)* define the term pressure and use the kinetic model to explain the pressure exerted by gases *(g)* derive, from the definitions of pressure and density, the equation $p = \rho g h$ *(h)* use the equation $p = \rho g h$ *(i)* distinguish between the processes of melting, boiling and evaporation.

Density

- The **mass density** or **density** of a material is its mass per unit volume.
- The symbol most often used for density is ρ (the lower case Greek letter rho).
- Mathematically, density is defined as mass divided by volume:

$$\rho = \frac{m}{V},$$

States of matter

Solid	Liquid	Gas
Fixed shape	No fixed shape • can flow • take the shape of container	No fixed shape • can flow • spread easily to fill any vessel • take the shape of vessel
Fixed volume	Fixed volume	No fixed volume • take the volume of vessel
Not compressible	Not compressible	Highly compressible

kinetic molecular model of matter

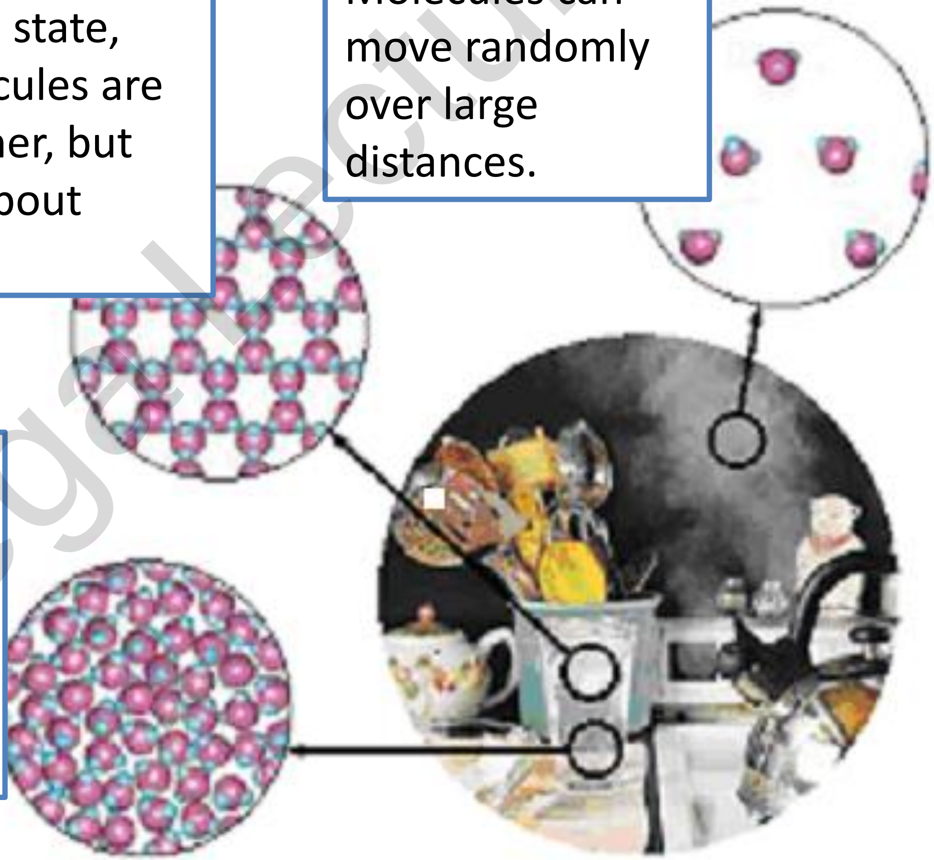
*The **kinetic theory of matter** states that all matter is made up of a large number of tiny atoms or molecules which are in continuous motion.*

Kinetic Molecular Model of Water

At 100°C, water becomes water vapor, a gas. Molecules can move randomly over large distances.

Between 0°C and 100 °C, water is a liquid. In the liquid state, water molecules are close together, but can move about freely.

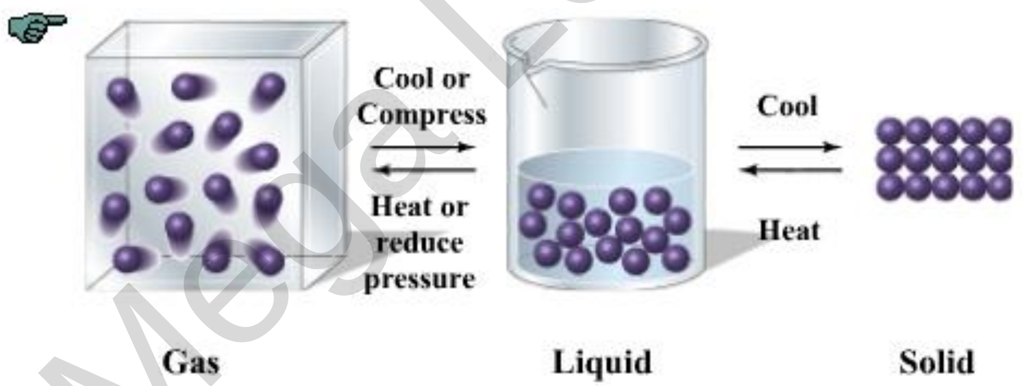
Below 0°C, water solidifies to become ice. In the solid state, water molecules are held together in a rigid structure.



Changing States

Changing states requires energy in either the form of heat.

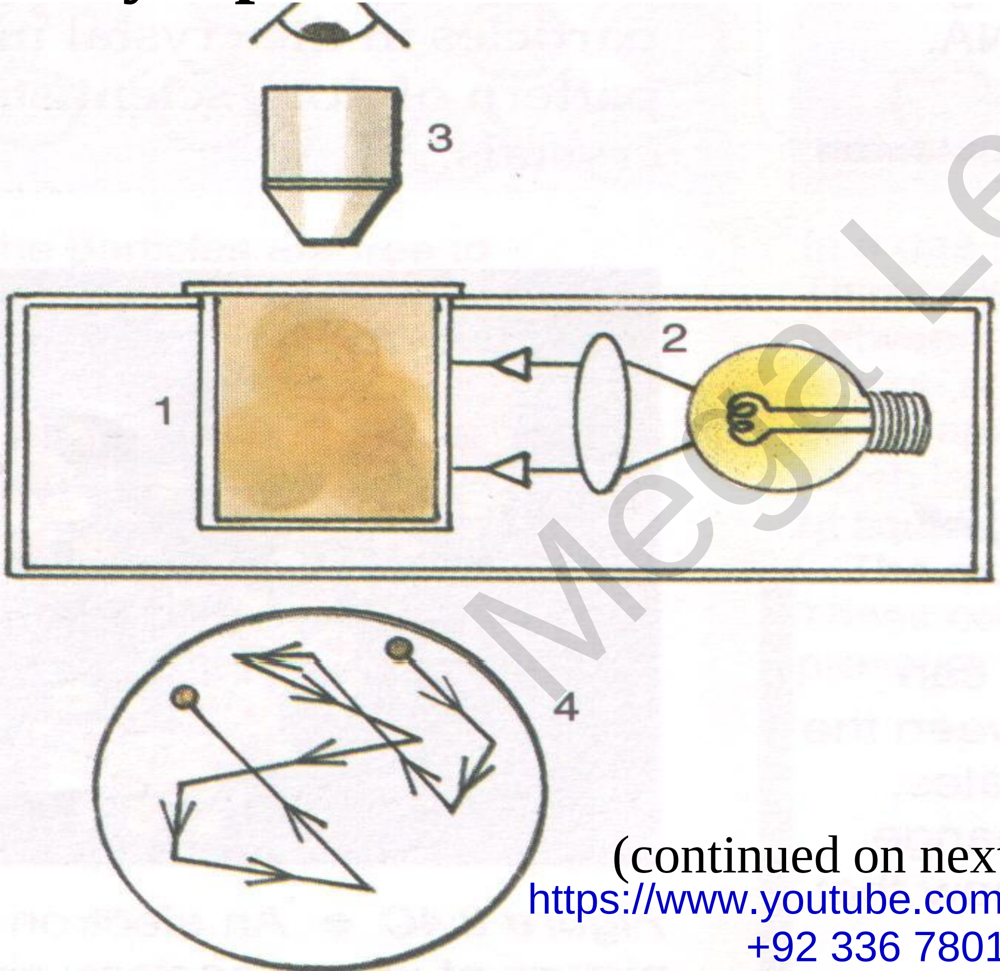
Changing states may also be due to the change in pressure in a system.



Brownian motion
is an evidence for
Kinetic molecular model of matter

Brownian Motion

Fig. shows a smoke cell and the erratic path followed by a particle of smoke.



1 A small glass cell is filled with smoke

2 Light is shone through the cell

3 The smoke is viewed through a microscope

4 You see the smoke particles constantly moving and changing direction. The path taken by one smoke particle will look something like this

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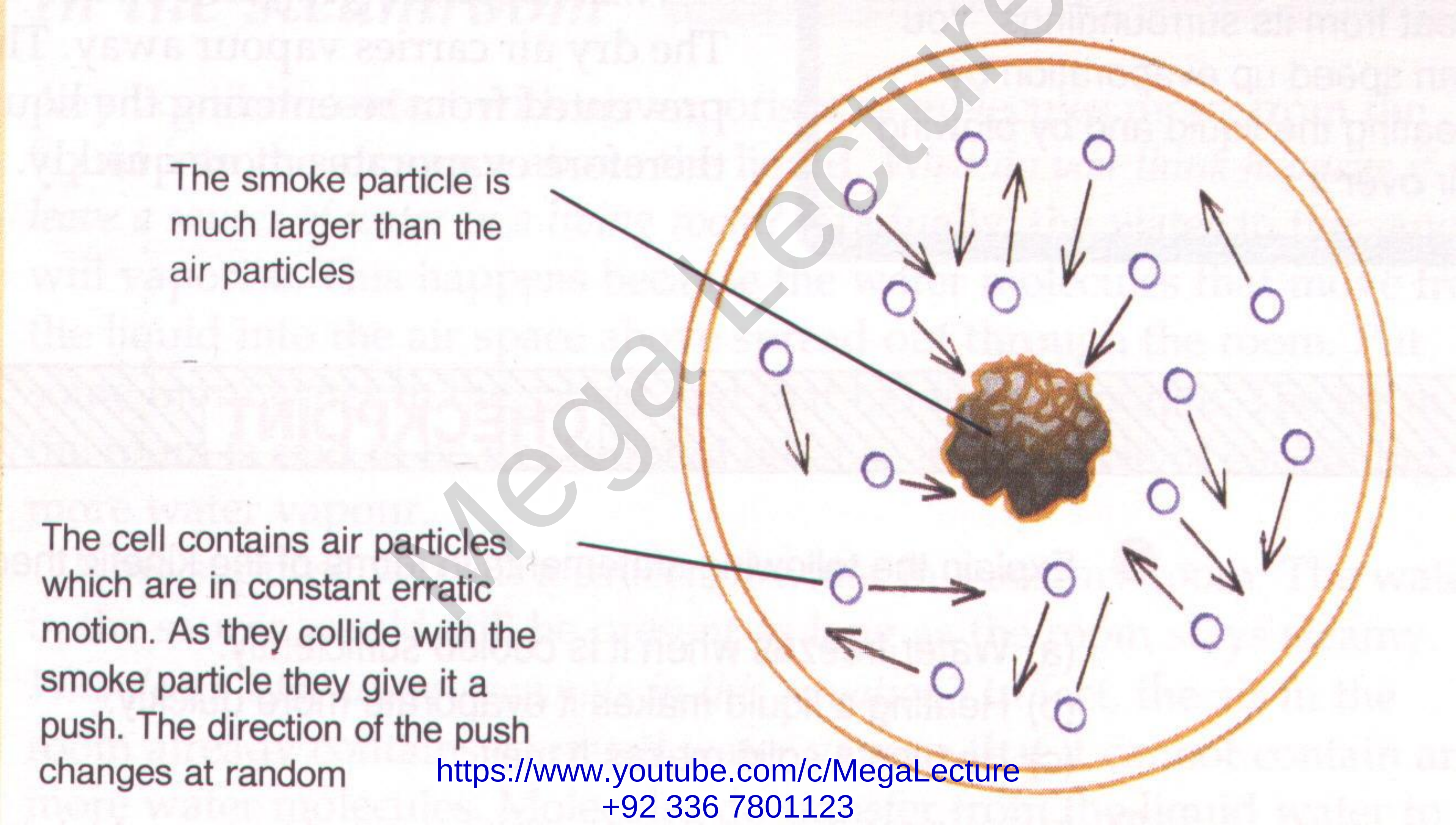
Brownian Motion



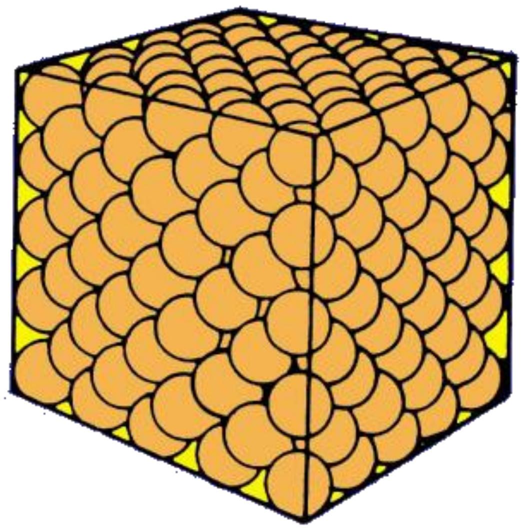
Explain what causes Brownian motion

- When the air molecule collide with a smoke particle
  - The molecules exert a force on the smoke particle
  - Continuous random collisions produce a random resultant force on the smoke particle
  - Cause the smoke particle to move randomly and continuously.

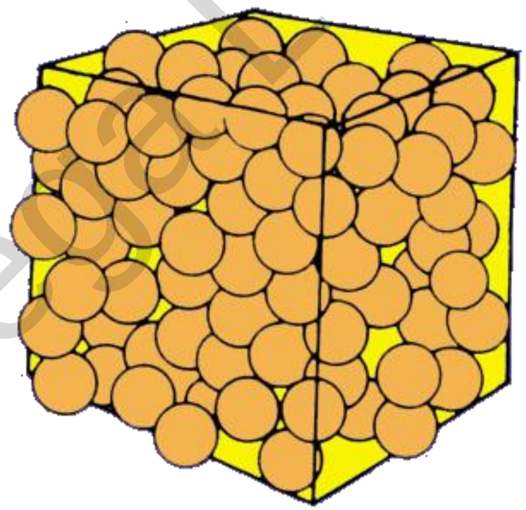
Explain how Brownian motion provides evidence for the kinetic molecular model of matter

- Brownian motion is observed by suspending small sized particles in a fluid.
- The random, continuous and jerky movement of the smoke particles suggests that
  - the small sized particles are continuously bombarded by random and continuously moving air particles or molecules.

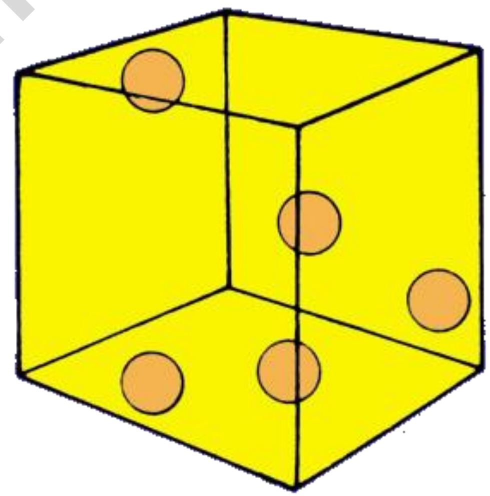
The molecular models of the three states of matter



molecular structure of a solid



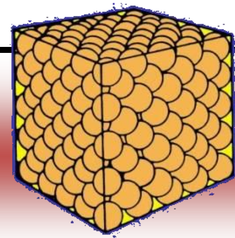
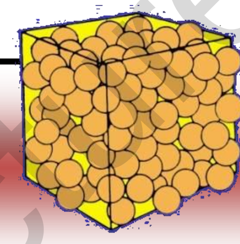
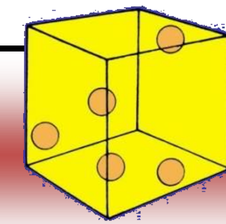
molecular structure of a liquid



molecular structure of a gas

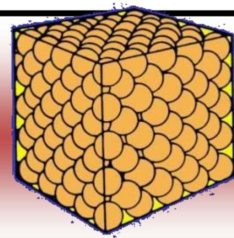
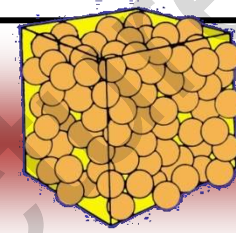
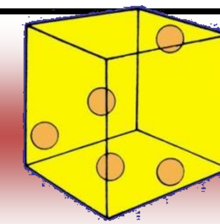
The molecular models of the three states of matter

Forces between molecules & Distance between molecules

	Solid 	Liquid 	Gas 
Forces between molecules	• balanced forces which hold molecules in fixed positions	• forces as strong as those in solid • molecules not held in fixed position, move among one another throughout liquid	• negligible • only at moments of collision, the intermolecular forces act
Distances between molecules	• arranged close together in a regular pattern	• not arranged in a regular pattern • slightly further apart than in solid	• far apart • mainly empty space between molecules

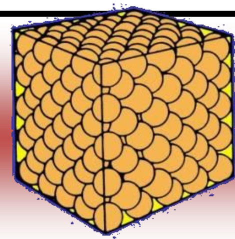
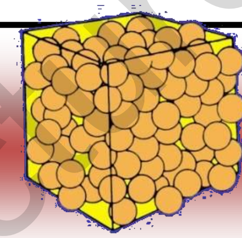
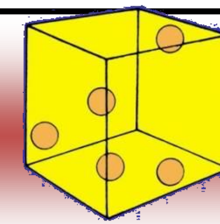
The molecular modes of the three states of matter

Motion of molecules & Compression

	Solid 	Liquid 	Gas 
Motion of molecules	• vibrate about fixed positions • alternately attracting and repelling one another	• vibrate to and fro • alternately attracting and repelling one another	• move randomly with high speed, colliding with one another and with the walls of the containers
Compress-ion	• cannot be compressed • molecules are arranged close together • little space between them	• cannot be compressed • molecules are still close together • little space between them	• can be easily compressed • far apart • mainly empty space between molecules

The molecular modes of the three states of matter

When heated…

	Solid 	Liquid 	Gas 
When heated	• molecules gain energy and vibrate more • separation between molecules increases slightly (solid expands)	• molecules vibrate and move about more vigorously • separation between molecules increases slightly (liquid expands)	• move even more randomly with higher speed, colliding with one another and with the walls of the containers (gas expands a lot)

Relationship between the motion of molecules and temperature

As temperature increases,

- surrounding air particles move faster and hit the particles move frequently and harder
- thermal energy is transferred to the molecules and the molecules gain kinetic energy causing molecules to move faster

Pressure exerted by a gas

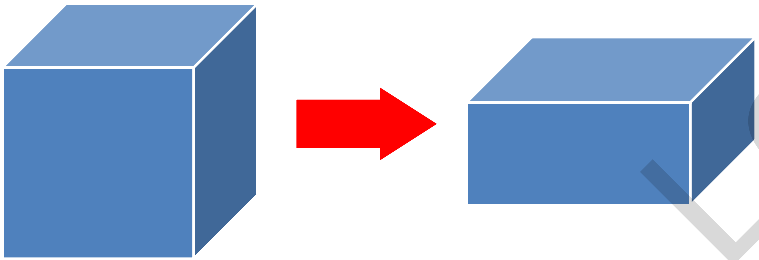
- The pressure of a gas is causes by collisions of the molecules with the walls of the container.
- **Gas pressure** results from the force exerted by a gas per unit surface area of an object.

Pressure exerted by a gas increases due to….

- a decrease in volume of a container, or (and)
- an increase in temperature

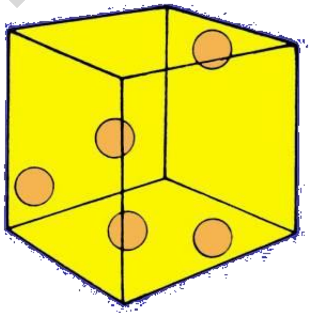
Pressure exerted by a gas

Pressure of a gas in terms of motion of its molecules



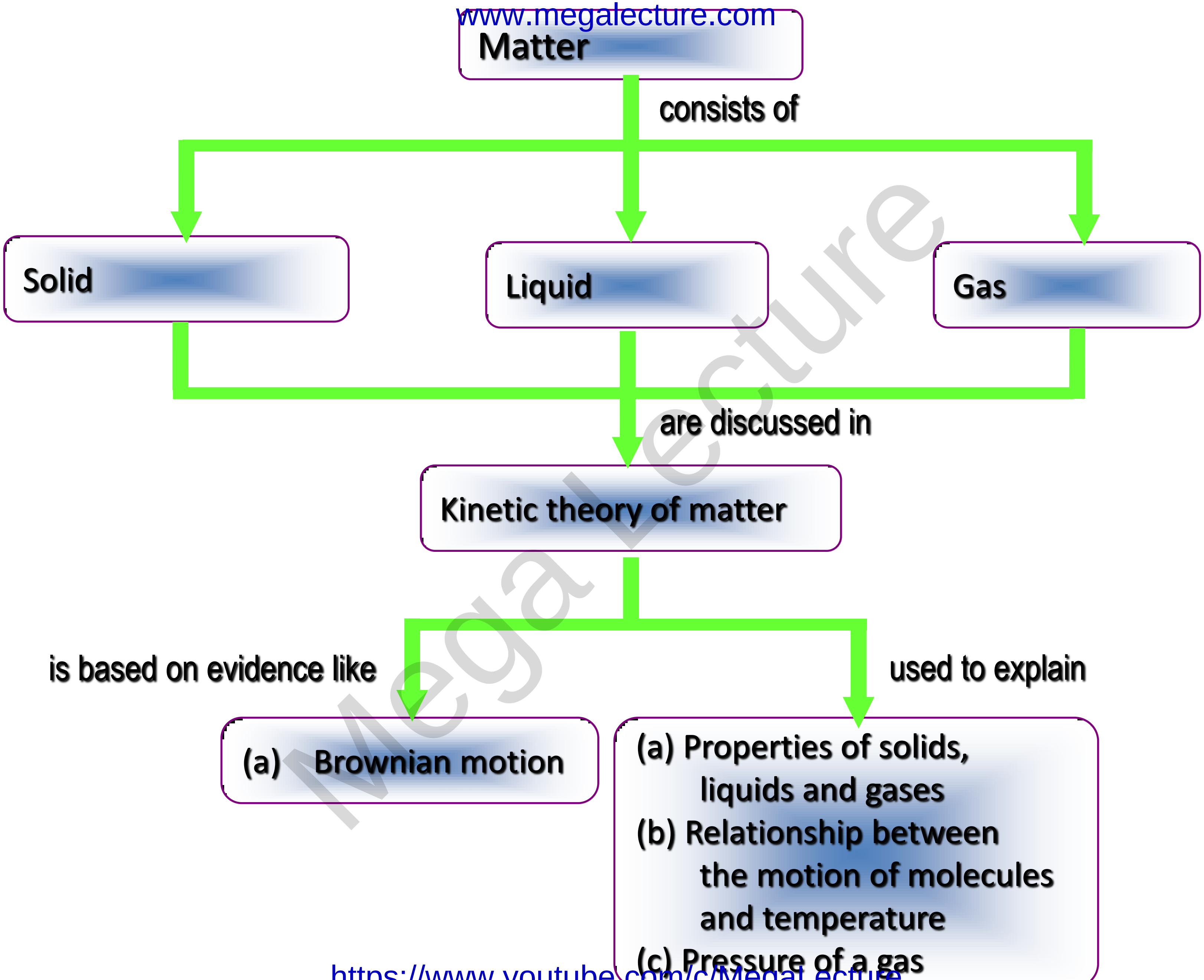
half the volume of container

- Number of gas molecules per cm^3 doubles
- Number of collisions of molecules with the wall in one second doubles
- Pressure doubles



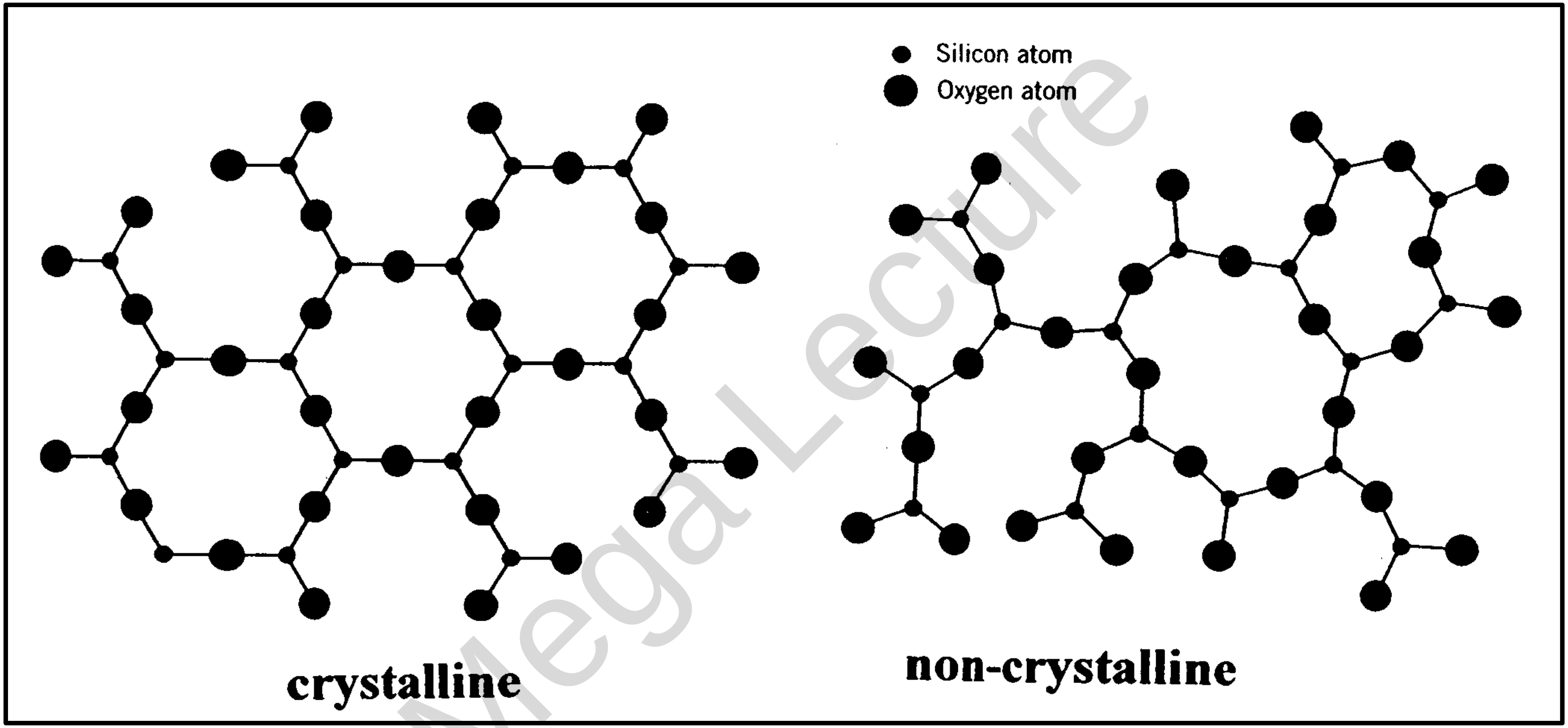
temperature of gas in container increases

- Molecules move faster
- Molecules hit the walls more frequently (with greater force)


Matter
consists of
Solid
Liquid
Gas
are discussed in
Kinetic theory of matter
is based on evidence like
(a) Brownian motion
used to explain
(a) Properties of solids, liquids and gases
(b) Relationship between the motion of molecules and temperature
(c) Pressure of a gas

Structure of crystalline and non-crystalline solids with particular reference to metals, polymers and amorphous materials

Reference link
http://www.youtube.com/watch?v=NNRxVE8yxg4


Silicon atom
Oxygen atom
crystalline
non-crystalline

Crystalline Solids - Metals

Pure metals are generally crystalline in structure. The atoms are arranged in a regular manner forming a three-dimensional lattice structure. With such ordered packing system, the largest number of atoms can be arranged within the smallest possible volume.

Crystalline solids have a very **high Young's Modulus**. They elongate and undergo **plastic deformation** under action of large forces.
Example : Copper.

Note : Young's modulus, also known as the **tensile modulus** or **elastic modulus**, is a measure of the stiffness of an elastic material and is a quantity used to characterize materials. It is defined as the ratio of the stress over the strain.

Polymers

Polymers consist of long chains of carbon atoms bonded to hydrogen or other atoms.

They have a very **low Young's Modulus** and they tolerate large strains while exhibiting **elastic behaviour**.
Example : Rubber

Note : Young's modulus, also known as the **tensile modulus** or **elastic modulus**, is a measure of the stiffness of an elastic material and is a quantity used to characterize materials. It is defined as the ratio of the stress over the strain.

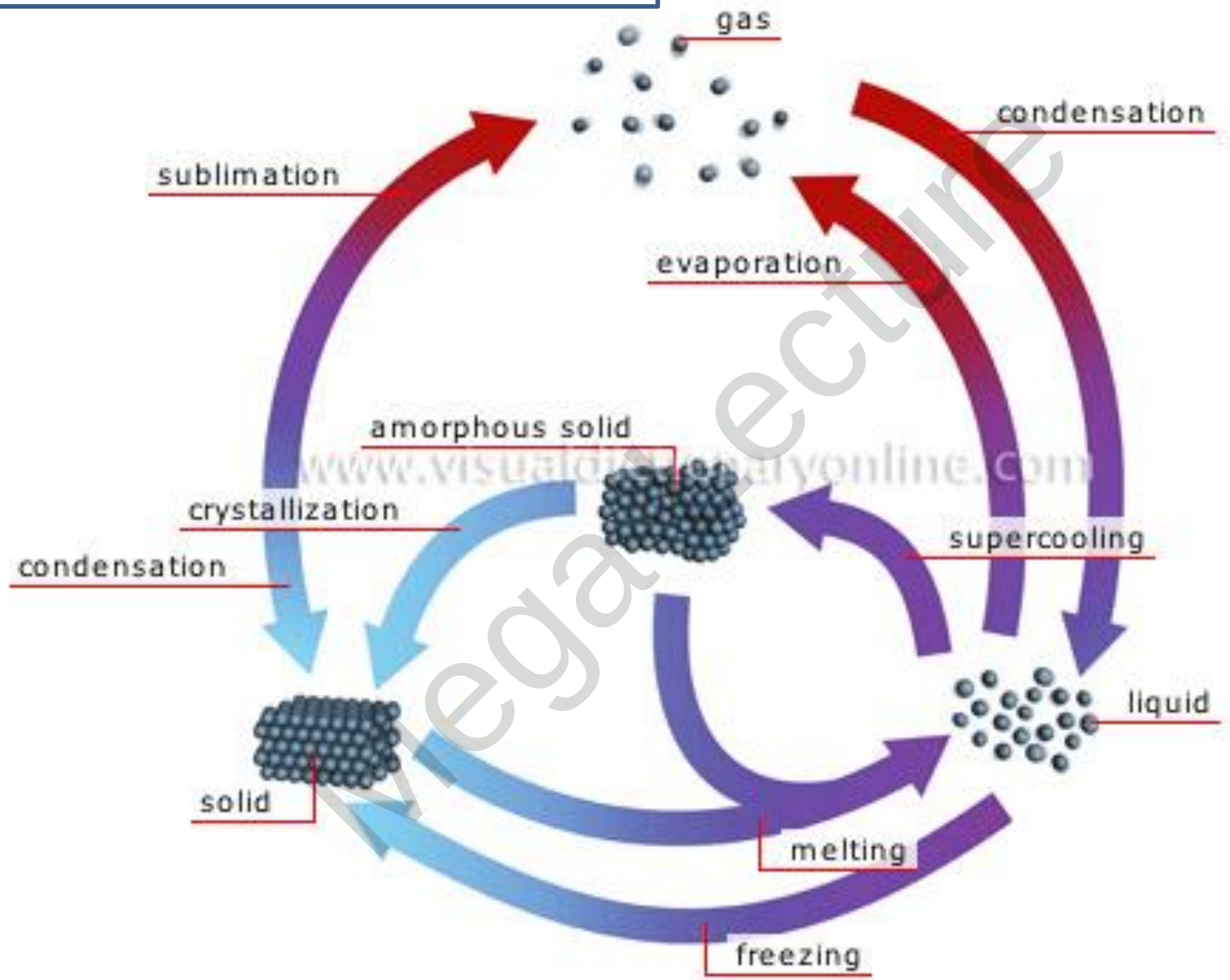
Amorphous Solids

Amorphous solids are solids obtained when a molten material is rapidly solidified and such that the disordered liquid structure is retained.

Amorphous solid have a very **high Young's Modulus** and generally they obey Hooke's law upto the breaking point.

Example : glass.

Not in syllabus , for your reference only

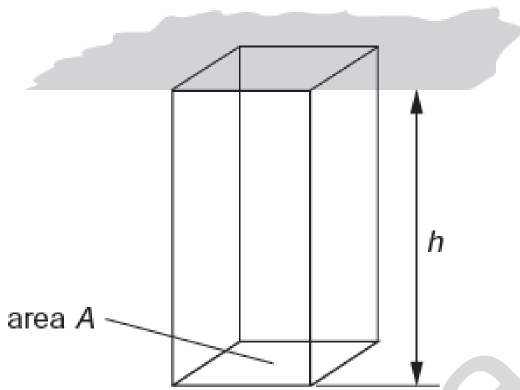


Derive from the definitions of pressure and density, the equation $p = \rho gh$

It is a well-known fact that pressure increases with depth of liquid. The relation between the pressure p due to a fluid (liquid or gas) at depth h is given by the equation

$$p = \rho gh,$$

where ρ is the density of the fluid and g is the acceleration of free fall. The equation can be derived as follows:



Consider a flat horizontal surface at a depth h in a fluid of density ρ. Then,

mass of fluid on area = density x volume

$= \rho Ah$

and weight of fluid on area $= \rho Ahg$.

This weight of fluid produces a pressure p on the area given by

$$\text{pressure } p = \frac{\text{force}}{\text{area}}$$

$$= \frac{\rho gAh}{A}$$

$$p = \rho gh.$$

Note that this equation allows the pressure due to the fluid to be calculated. It should be remembered that the actual pressure at depth h in a liquid would be given by

pressure = ρgh + atmospheric pressure at liquid surface

Sample problem 1

- Calculate the pressure on an inspection harch 7m diameter located on the bottom of a tank when it is filled with oil of density 875 Kgm^{-3} to a depth of 7 metres.

Solution

The Pressure at the bottom of the tank is given by $p = \rho g h$

ρ = 875 Kgm^{-3} , h = 7m, g = 9.8ms^{-2}

$p = \rho g h$

= 875 x 9.8 x 7

= 60.086 kPa

13.2

Evaporation

What is the relationship between evaporation and kinetic energy?

– During evaporation, only those molecules with a certain minimum kinetic energy can escape from the surface of the liquid.

Boiling Point

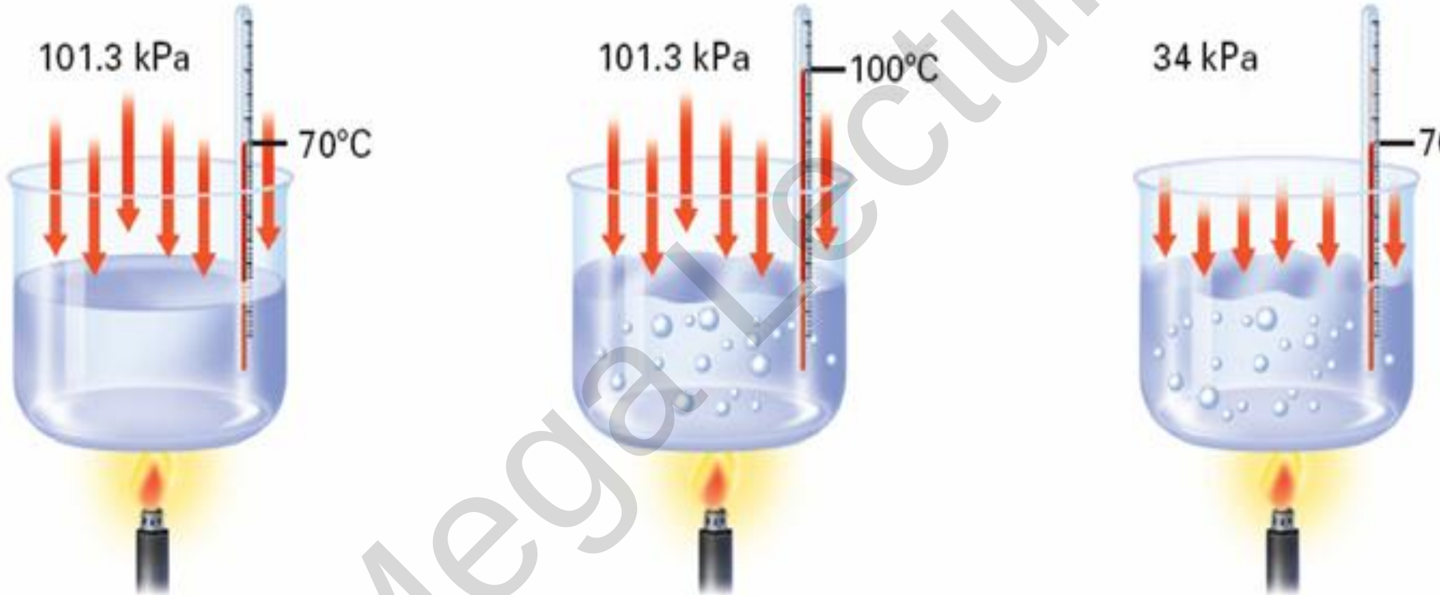
Under what conditions does boiling occur?

- When a liquid is heated to a temperature at which particles throughout the liquid have enough kinetic energy to vaporize, the liquid begins to boil.
  - The temperature at which the vapor pressure of the liquid is just equal to the external pressure on the liquid is the **boiling point.**
    - At a lower external pressure, the boiling point decreases.
    - At a higher external pressure, the boiling point increases.

Sea Level Atmospheric pressure at the surface of water at 70°C is greater than its vapor pressure. Bubbles of vapor cannot form in the water, and it does not boil.

Sea Level At the boiling point, the vapor pressure is equal to atmospheric pressure. Bubbles of vapor form in the water, and it boils.

Atop Mount Everest At higher altitudes, the atmospheric pressure is lower than it is at sea level. Thus the water boils at a lower temperature.



Melting point

- The general properties of solids reflect the orderly arrangement of their particles and the fixed locations of their particles
- **The melting point** is the temperature at which a solid changes into a liquid.