ASPIRE HUB

EDUCATION

Secondary 3 Physics

Kinetic Particle Model of Matter (Brownian Motion)

NAME:

DATE:

OBJECTIVE:

Kinetic Particle Model of Matter (Brownian Motion)

1. Infer from a Brownian motion experiment the evidence for the random movement of molecule in a liquid or gas.

2. Relate the rise in temperature of a body to the increase in average kinetic energy of all the particles in the body.

3. Explain the pressure of a gas in terms of the motion of its molecules.

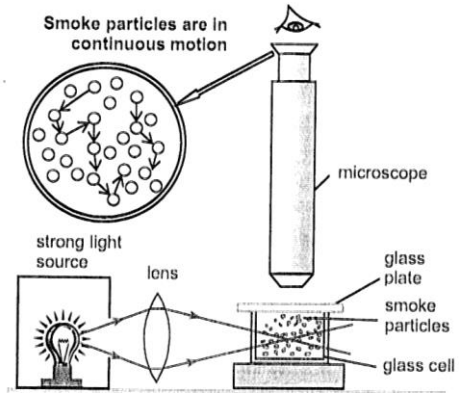
Kinetic Particle Model

The kinetic particle model states that all matter is made up of tiny particles (e.g. atoms, ions or molecules) which are in continuous, random motion.

1. Brownian Motion

Brownian motion provides clear evidence for the kinetic particle model which states that matter is comprised of tiny particles that are in **continuous random** motion, with a range of speeds in **all directions** and kinetic energies.

Experiment:



Procedure:

- The glass cell is a transparent container containing smoke particles.
- The glass cell is brightly illuminated and a microscope is used to focus on the smoke particles.

Observations:

- The smoke particles are seen moving around in a jerky, random motion.
- They do not often collide with each other, but rather appear to be knocked about by some other invisible particles.

Conclusion:

- Motion of smoke particles shows that surrounding air molecules are also moving.
- Random motion of smoke particles is due to **random and uneven collisions with surrounding air molecules.** Therefore, it demonstrates that air molecules (or rather, microscopic particles) **move randomly in all directions** with a **range of speeds** and kinetic energies, known as **Brownian motion**.

Brownian motion can also be demonstrated by placing tiny graphite particles onto water.

2. Relationship between motion of particles and temperature

- **Temperature** increases with the **average kinetic energy** of the particles and vice versa.

Experiment:
As temperature increases, smoke particles **move more vigorously,** implying that the surrounding air molecules are also moving **more vigorously**. Hence, it means that the **average kinetic energy of the particles increases**.

3. Relationship between motion of particles and pressure

- Gaseous particles collide with one another and with the inner walls of the container.
- With each collision, a force is exerted on the inner wall by the particle.
- The large number of collisions produces an average force on the walls.
- This force exerted on the area of the wall is the pressure of the gas.

Pressure of a gas directly depends on the **frequency of collision** with the container walls and the **force each particle** exerts on the walls.

4. Example

A fixed volume of gas is enclosed in a container. Use kinetic particle model to explain how:

a. the pressure on the wall of the container is produced by the gas;
b. an increase in temperature would affect the pressure;
c. reducing the volume of the container would affect the pressure.

(Assume that all other factors remain constant.)

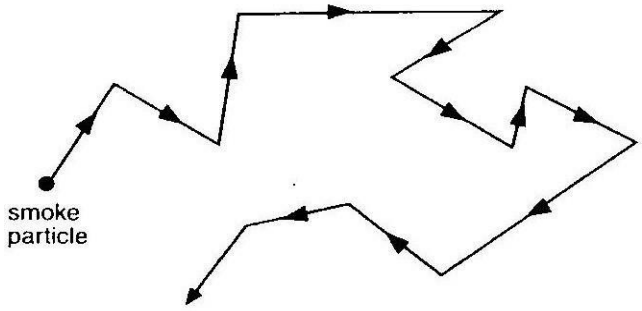
Solution:

a. Gaseous molecules are constantly moving in random motion at high speed. Therefore, they collide continuously with the inner walls of the container, exerting an average force per unit surface area of the walls - which is pressure.
b. An increase in temperature means an increase in kinetic energy and speed of the gaseous molecules. The rate of collision with the inner walls of the container increases, causing the average force exerted per unit surface area to increase.
c. A decrease in volume increases the density of molecules. This in turn increases the rate of collision with the inner walls of the container, causing the average force exerted per unit surface area to increase.

Kinetic Model of Matter 1 (Brownian Motion)

Multiple Choice Questions

1 Smoke particles suspended in the air are viewed through a microscope. What causes the random jerky path of the smoke particle?



A Air molecules colliding with the smoke particle
B Convection currents in the air
C Small change of pressure in the air
D Small changes of temperature of the air

( )

2 The size of a balloon increases if the pressure inside it increases. The balloon will get bigger if it is left in the heat of the Sun. Why does this happen?

A Number of air molecules inside it increases
B Air molecules inside it are all moving outwards
C Air molecules inside it are bigger when they are heated
D Air molecules inside it move faster when they are heated

( )

3 The volume of a fixed mass of gas in a cylinder is increased at constant temperature. The pressure exerted by the gas molecules decreases because

A density of gas decreases
B gas molecules collide with each other less frequently
C there is a larger area of the cylinder in contact with the gas
D gas molecules strike the cylinder walls less frequently

( )

4 In a Brownian motion experiment involving smoke particles in the air, heavy particles settle quickly but very small particles remain suspended for long periods of time. This is because

A air pressure has a greater effect on smaller particles
B random bombardment by air molecules keeps the particles suspended
C Earth's gravitational field does not act on very small particles
D small smoke particles have the same density as air

( )

5 When air is pumped into a bicycle tyre at a constant temperature, the pressure increases because

A more molecules are hitting the tyre
B the molecules are closer together
C the molecules are moving faster
D the molecules have more kinetic energy

( )

6 Diagram A below shows an experiment to observe the movement of smoke particles. The result of the movement is shown in the diagram B.

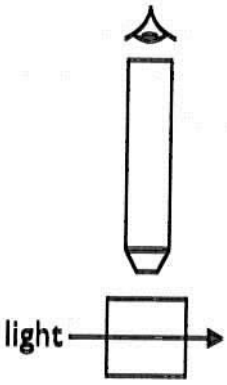


diagram A


diagram B

What conclusion can be made from the experiment?

A Smoke particles always move at high speed
B Light causes the movement of smoke particles to be random
C Smoke particles always move randomly in all directions
D The atmospheric pressure causes the smoke particles to move

( )

7 A container filled with a gas is heated without changing its volume. Which of the following statements is true?

A The average kinetic speed of the gas particles decrease
B The force exerted on the surface area on the wall increases
C There is no change in pressure exerted on the walls of the container
D The temperature causes the gas particles to expand in size

( )

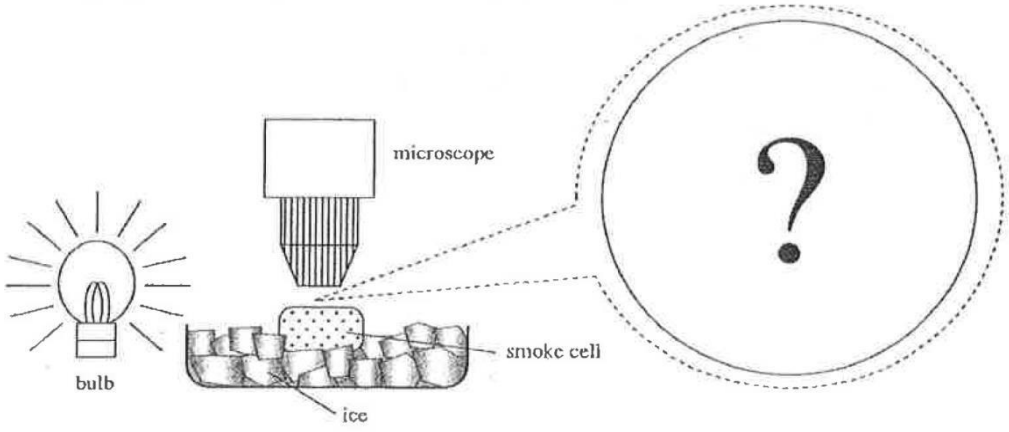
8 Which of the following statements explains the Brownian motion of smoke particles?

A It is due to the collision between the smoke particles
B It is due to the collision between the smoke particles and the walls of the container
C It is due to the collision between the smoke particles and air particles
D It is due to the collision between the smoke particles and light particles

( )

9 In an experiment conducted at room temperature of 20°C, smoke particles are observed to be moving about quickly and randomly in a transparent cell, as viewed from a microscope.

Subsequently, the smoke cell is then placed in a container of ice as shown in the figure. What will be observed?



A The smoke particles more about more quickly than before, while their motion remains random
B The smoke particles more about more quickly than before, but in an orderly manner
C The smoke particles more about more slowly than before, while their motion remains random
D The smoke particles stop moving

( )

10 Which one of the following correctly describes the strength of the forces between the molecules in a solid, and the type(s) of motion the molecules can have?

	Strength of forces	Type(s) of motion
A	Very weak	Vibrational only
B	Very strong	Rotational and translational
C	Very weak	Vibrational and rotational
D	Very strong	Vibrational only

( )

11 In a Brownian motion experiment, the motion of smoke particles of various sizes is observed. It is seen that while the larger particles settle down quickly, the smaller particles continue to move about randomly for a longer period of time. Which of the following statement best explains this observation?

A As the smaller particles are lighter, random bombardment by air molecules is able to keep them suspended in a state of motion

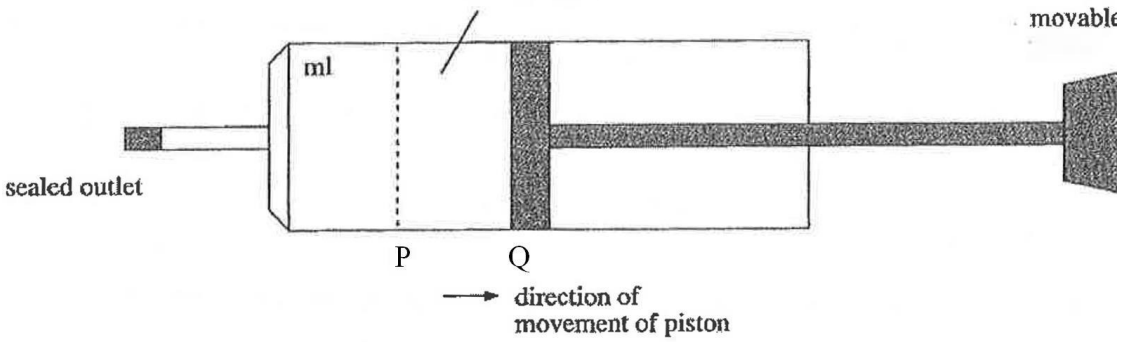
B The smaller particles have the same density as the air, allowing them to move about randomly just like the air molecules

C The smaller smoke particles have no mass

D The larger smoke particles are heavier than the smaller particles

( )

12 A fixed amount of nitrogen gas is kept in a container with a movable piston. The piston is moved from position P to Q while the temperature is kept constant. How will this affect the following properties of gas?



	Average molecular distance apart	Frequency of collision with walls of container	Average speed of molecules
A	Increases	Decreases	Decreases
B	Decreases	Increases	Increases
C	Increases	Decreases	No change
D	Increases	Increases	Decreases

( )

13 On the spray containers of insecticide, one can always find a warning label saying that it is dangerous to dispose of the container, even when empty, in fire. Why is that so?

A When the can is heated, the gas molecules inside the empty can will expand and the pressure within the container will build up until the can explodes

B When the can is heated, the gas molecules inside the empty can will move faster and the pressure within the container will build up until the can explodes

C When the can is heated, the gas molecules inside the can will absorb thermal energy from the fire very quickly and catch fire

D The can is not fire-proof and will catch fire easily

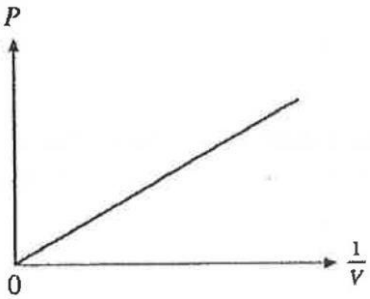
( )

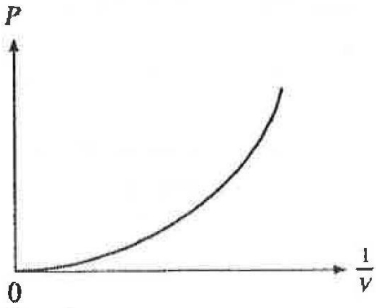
14 What happens when a fixed mass of gas is heated under constant pressure?

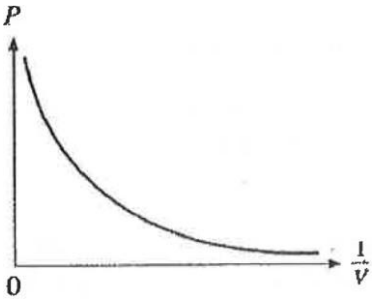
A Average separation between the gas molecules decreases
B Volume of the gas molecules increases
C Average speed of the gas molecules decreases
D Average kinetic energy of the gas molecules increases

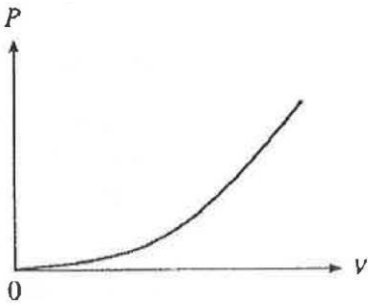
( )

15 For a fixed mass of gas at constant temperature, which of the following correctly shows the relationship between its pressure P and volume V?

A 

B 

C 

D 

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16 What happens to a fixed mass of gas when its temperature increases while its pressure is kept constant?

A Volume of the gas molecules increases
B Density of the gas decreases
C Frequency of collision between the gas molecules decreases
D Temperature of the gas increases at an increasing rate with its increase in volume

( )

Structured Questions

1 In an experiment to study the Brownian motion of very small particles suspended in a gas, the particles seem to be moving in an irregular way and are always in motion.

(a) State what the above description indicates about the gas molecules.

(b) Explain why a large particle suspended in the gas would show no detectable Brownian motion.

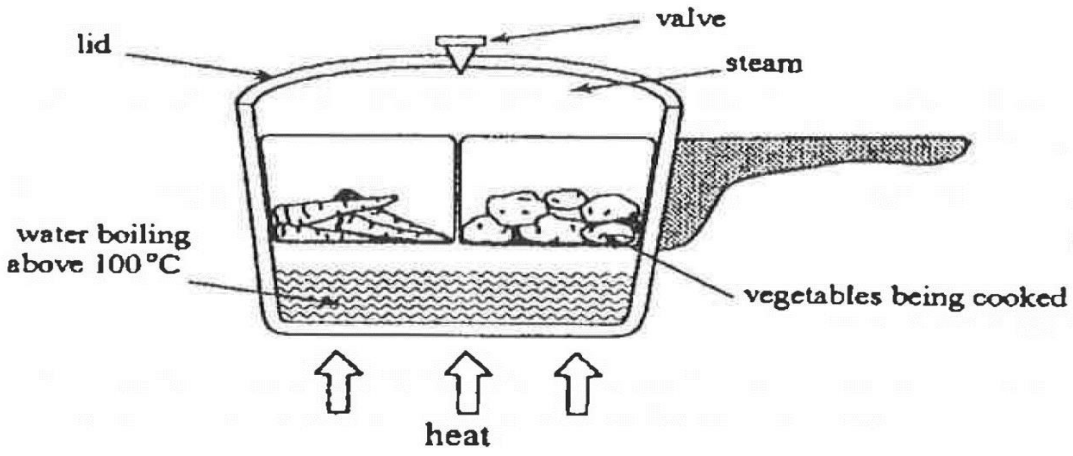
2 John blows a balloon under the shade. The air in the balloon exerts a pressure on the walls of the balloon. Use the kinetic particle model to answer the following questions.

(a) (i) When placed under the Sun, how does the motion of the air molecules in the balloon change?

(ii) State and explain how (a)(i) affects the pressure exerted by the air molecules on the balloon.

(b) Subsequently, the balloon increases in size. How does this increase in volume affect the change in pressure?

3 The figure shows a simple pressure cooker.



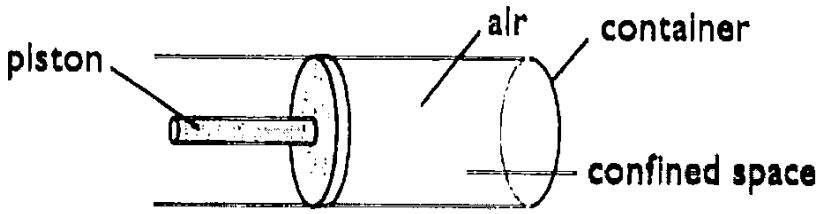
(a) (i) How does the separation of molecules in the water differ from that of the molecules in the steam?

(ii) How do the forces of attraction between the water molecules differ from those between the steam molecules?

(b) How do the steam molecules exert a pressure on the lid of the container?

(c) The use of a heavier valve allows the water to boil at a higher temperature. State the effect that it will have on the **speed** of the steam molecules and on the **pressure** exerted by the steam molecules on the lid?

4 A piston is **pushed** in a confined container as shown below.



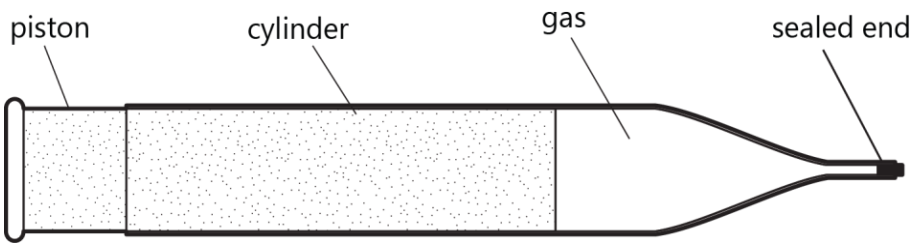
(a) Explain, in terms of the motion of the air molecules, why pressure increases.

(b) State what happens when the container is flexible.

5 A dust particle is floating in the air.

(a) Draw on the diagram the path the particle is most likely to travel.
(b) Explain why the dust particle move in as in (a).

6 The figure shows a syringe that contains gas at the same pressure as the air outside. The piston moves freely along the cylinder without any friction. No gas escapes.



As the syringe is heated from 20 °C to 100 °C, the piston moves outwards. It stops moving when the temperature is steady. State how the value of each of the following quantities compares at 100 °C, after the piston stops, with its value at 20 °C.

For each quantity you should write *greater, same* or *less*.

the average distance between the gas molecules	
the pressure of the gas after the piston stops	
the average speed of the gas molecules	
the frequency of the collisions between the gas molecules and the piston	

7 A fully inflated balloon with an initial volume of 2.0 m3 is tied to a lead ball and dumped into a lake with a depth of 20 m. The atmospheric pressure at the surface of the lake is 1.0 x 105 Pa. (The gravitational field strength is 10N/kg.)

(a) Predict and explain briefly what will happen to the size of the balloon as it sinks to the bottom of the lake.

_____

(b) Given that the density of water is 1000kg/m^3, calculate the pressure acting on the balloon at the bottom of the lake by the water.

_____

(c) Using your answer in (b) and consider the relationship between pressure and volume, calculate the volume of the balloon at the bottom of the lake.

_____

8 A gas syringe is filled with argon gas, with the outlet of the syringe sealed to prevent the gas from escaping.

(a) Explain how the argon gas exerts pressure on the syringe in terms of the motion of molecules.

(b) State two reasons why argon gas can be easily compressed.

(c) The initial position of the movable plunger of the syringe is at the 100ml mark. State whether the following quantities have *increased*, *decreased* or *remains unchanged* when the plunger is

(i) pulled to the 200 ml mark while the temperature is kept constant.

Quantity	Change (if any)
Number of argon atoms	
Number of argon atoms per ml	
Mass of argon gas	
Pressure of argon gas	
Kinetic energy of argon gas	

(ii) pushed to the 50 ml mark while the temperature is kept constant.

Quantity	Change (if any)
Number of argon atoms	
Number of argon atoms per ml	
Mass of argon gas	
Pressure of argon gas	
Kinetic energy of argon gas	