The Kinetic Molecular Model

The kinetic molecular model states that everything is made up of lots of tiny identical molecules...

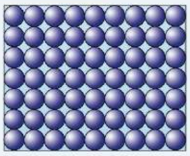
You can Describe the States of Matter Using the Molecular Model

1) In the kinetic molecular model, all matter is made up of molecules. You can think of the molecules as being tiny balls.

The kinetic molecular model is also sometimes called 'kinetic theory' or 'the particle model'.

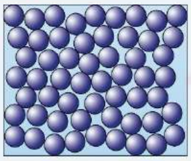
2) The three states of matter are solid (e.g. ice), liquid (e.g. water) and gas (e.g. water vapour).
3) You can explain the ways that matter behaves in these states using the kinetic molecular model.

Solids



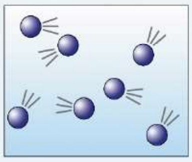
1) The molecules are held very close together in a fixed, regular arrangement.
2) The molecules can't move past each other — they only vibrate about their fixed positions. They have much less energy than molecules in other states of matter.
3) There are strong forces that act between the molecules. These forces stop the molecules from moving much and keep them in their fixed arrangements. The forces between molecules are also known as bonds.

Liquids



1) The molecules are close together, but further apart than in a solid.
2) The molecules can move past each other, and form irregular arrangements.
3) This is because the forces between the molecules are weaker than in a solid.
4) The molecules have more energy than molecules in a solid, and move around each other in random directions at low speeds.

Gases



1) Gas molecules are mostly far apart from each other. They have more energy than the molecules in a solid or a liquid.
2) The molecules move in random directions and at high speeds.
3) The molecules are able to move so freely because there are almost no forces between the molecules in a gas.

Liquids and gases are both fluids. A fluid is any substance that can flow.

You can use the Molecular Model to Explain Properties of Matter

Shape and Flow

Solids can't flow. They have a fixed size and shape.

Liquids and gases can flow, so they will always take the shape of the container they're in. Liquids and gases can flow because their molecules can move past each other.

The molecules in a solid can't move past each other because the forces between them are much stronger.

Compressibility

Gases can be compressed, but liquids and solids cannot.

This is because gas molecules are so far apart, they can easily be pushed closer together. Liquid and solid molecules are already so close together that they can't be pushed closer.

Volume

Solids and liquids have a fixed volume, but gases will expand to have the same volume as the container they're in.

This is because the strong forces between molecules in a solid or liquid keep the molecules close together. There are almost no forces between gas molecules.

Density

Solids are generally more dense than liquids, and liquids are generally more dense than gases.

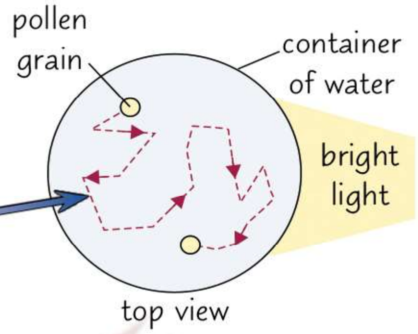
Remember, density is mass per unit volume (p.6). The distances between the molecules in a liquid are larger than in a solid, so there will be fewer molecules in a particular volume. This is true when you compare a gas to a liquid too — the molecules are further apart in a gas than a liquid, so there is less mass per unit volume.

Brownian Motion

You can see the effects of the kinetic molecular model in action with Brownian motion...

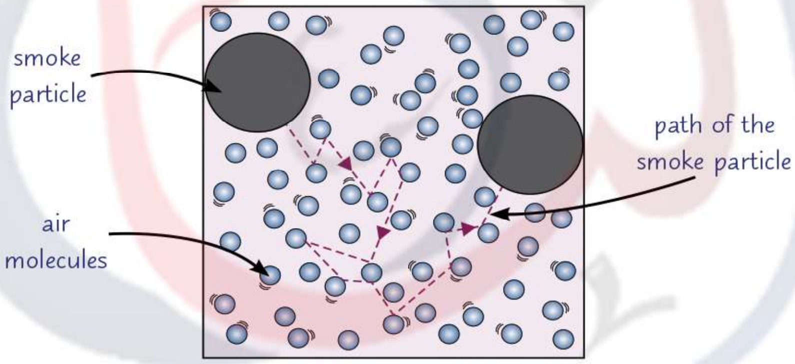
Particles Suspended in a Fluid Move in Random Directions

1) Small particles of a solid can become suspended in a fluid — this means they are mixed throughout the fluid. For example, pollen grains can become suspended in water, and smoke particles can become suspended in the air.
2) The solid particles move within the fluid, even when the fluid itself isn't moving. The solid particles move in random directions, taking a zigzag-shaped path.
3) Using a microscope and a bright lamp you can see pollen grains suspended in water moving in this way.
4) You'll see the pollen grains as spots of bright light, because they reflect the light from the lamp.



Brownian Motion Provides Evidence for the Molecular Model

1) The kinetic molecular model can be used to explain the zigzag motion of the suspended particles.
2) According to the model, a fluid is made up of many small molecules. These molecules are so small that you can't see them, even with a standard microscope.
3) When larger, more massive solid particles are suspended in a fluid (e.g. pollen grains in water), the fluid molecules collide with the solid particles. These collision may change the speed and direction of the larger solid particles, making them move in random directions. This is Brownian motion.
4) For example, here's the path of a smoke particle suspended in air:



Supplement

Brownian Motion Involves Changes in Momentum

1) Small, light fluid molecules are able to move a solid particle much more massive than themselves.
2) This is because the fluid molecules have a large speed, which means they have a relatively large momentum.
3) When they collide with a solid particle, they undergo a large change in momentum. This means that they apply a large force to the particle (p.22) — it's this force that causes the particle to move.

Need to remind yourself about momentum? Have a look on page 21.

Supplement

Random, zigzag motion is a sign that everything's made of molecules...

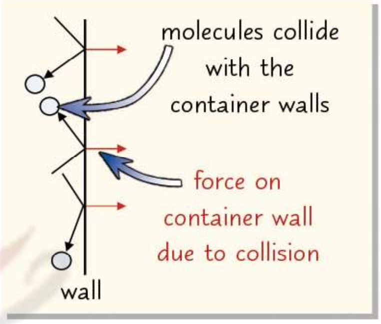
So, Brownian motion gives evidence to support the kinetic molecular model, because if matter wasn't made from molecules, particles suspended in fluids wouldn't be bombarded by anything and so wouldn't change direction. For them to move in random directions there must be molecules to give them a push.

Gas Pressure

Handily, you can explain pressure (see page 43) in terms of the kinetic molecular model of matter too...

Pressure is Created when Molecules Collide with Container Walls

1) Imagine a gas trapped inside a sealed container of a fixed size. The gas molecules collide with the container walls and exert a force on them, creating pressure (p.43).
2) The gas pressure is the total force exerted by all the molecules in the gas on a unit area of the container walls.
3) When a molecule hits a container wall, it rebounds and changes direction. This means the momentum of the molecule also changes.
4) During the collision, the wall exerts a force on the molecule to change its momentum. As this happens the molecule applies an equal and opposite force on the surface.
5) The faster a molecule is travelling when it collides with the wall, the larger its momentum change will be, and the larger the force it will exert on the wall.



At a Constant Volume, Gas Pressure will Increase with Temperature

1) Increasing the temperature of a gas will mean the gas molecules move faster (see p.51).
2) For a gas with a constant volume (e.g. in a sealed, rigid container), the total force exerted on the container walls by the gas will increase because:
   - the molecules will collide more often with the walls of the container.
   - they will each exert a larger force on the container. This is because their momentum change will be larger.
3) Pressure is the force per unit area, so this also means the pressure will be higher.
4) Similarly, if you decrease the temperature, the molecules move slower and the pressure decreases.

At a Constant Temperature, Decreasing Volume will Increase Pressure

1) Decreasing the volume of a container of gas means that the gas molecules have less room to move. The molecules will therefore collide with the container walls more often.
2) That means there will be a greater overall force exerted on the walls and the pressure will increase.
3) You can use this equation to find changes in volume and pressure at a constant temperature:

If you increase the volume, the molecules will collide with the wall less often and the pressure will decrease.

$$pV = \text{constant}$$

Where p = pressure, V = volume.

EXAMPLE:

A gas has a pressure of 200 kPa and a volume of 0.08 m³. The pressure is increased to 500 kPa, while the temperature is constant. What is the gas's new volume?

1) Since pV = constant, you can equate pV in the initial conditions (p_1V_1) to pV in the final conditions (p_2V_2).
2) Then just substitute in the values, and rearrange for V_2.

$$p_1V_1 = p_2V_2$$
$$200 \times 0.08 = 500 \times V_2$$
$$16 = 500 \times V_2$$
$$V_2 = \frac{16}{500} = 0.032 \text{ m}^3$$

More molecule collisions means a higher gas pressure...

REVISION TIP

When you're revising this, try to picture what is happening to the gas molecules whizzing around their container. Remember — the number of collisions and the force of the collisions is what causes the total force on the container. The higher the total force, the higher the pressure will be.