Kinetic Particle Theory

- Comment on the different states of matter that you can observe in this photograph.

- Identify essential similarities and differences in their properties.

Kinetic Particle Theory – Models

Kinetic Particle Theory – Models

By the end of this topic you should be able to…

- Describe the solid, liquid and gaseous states of matter and explain their interconversion in terms of the kinetic particle theory and of the energy changes involved.
- Describe and explain evidence for the movement of particles in liquids and gases.
- Explain everyday effects of diffusion in terms of particles, *e.g.* the spread of perfumes and cooking aromas; tea and coffee grains in water.
- State qualitatively the effect of (relative) molecular mass on the rate of diffusion and explain the dependence of rate of diffusion on temperature.

Singapore Examinations and Assessment Board
University of Cambridge International Examinations
Ministry of Education, Singapore

Kinetic Particle Theory – Models

What is "matter"?
How does kinetic particle theory describe "matter"?

Kinetic Particle Theory – Models

Matter is defined as any substance that has ______ and ________.

The *kinetic particle theory* states that all matter is composed of _____ _________ that are in a _________ state of ________ _______.

Kinetic Particle Theory – Models

Matter is defined as any substance that has _mass_ and _volume_.

The *kinetic particle theory* states that all matter is composed of _tiny_ _particles_ that are in a _constant_ state of _random_ _motion_.

Kinetic Particle Theory – Models

The motion of the particles in a substance increases as the ____________ of the substance increases.

As the motion of the particles in a substance increases, the _________ _______ energy of the particles also increases.

Therefore, as the ____________ of a substance increases, the _________ _______ energy of the particles in the substance also increases.

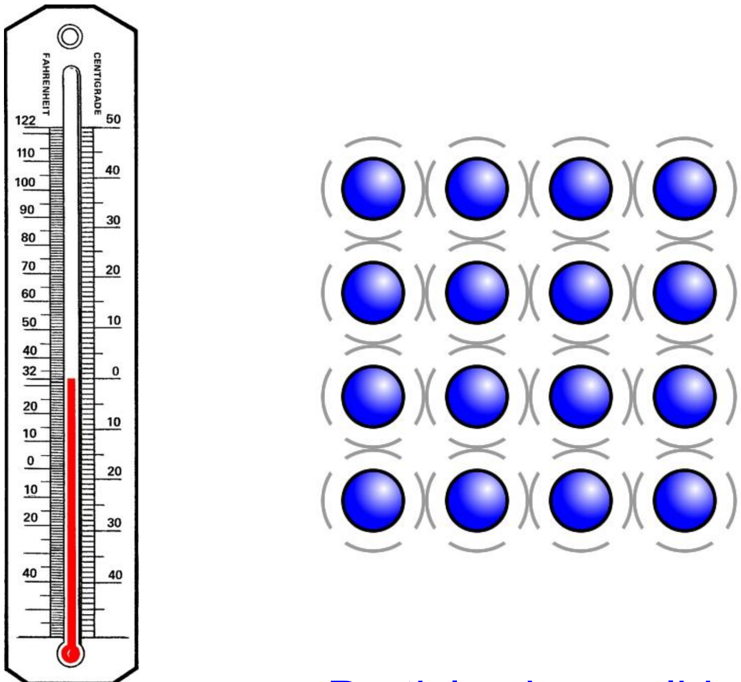
Kinetic Particle Theory – Models

The motion of the particles in a substance increases as the temperature of the substance increases.

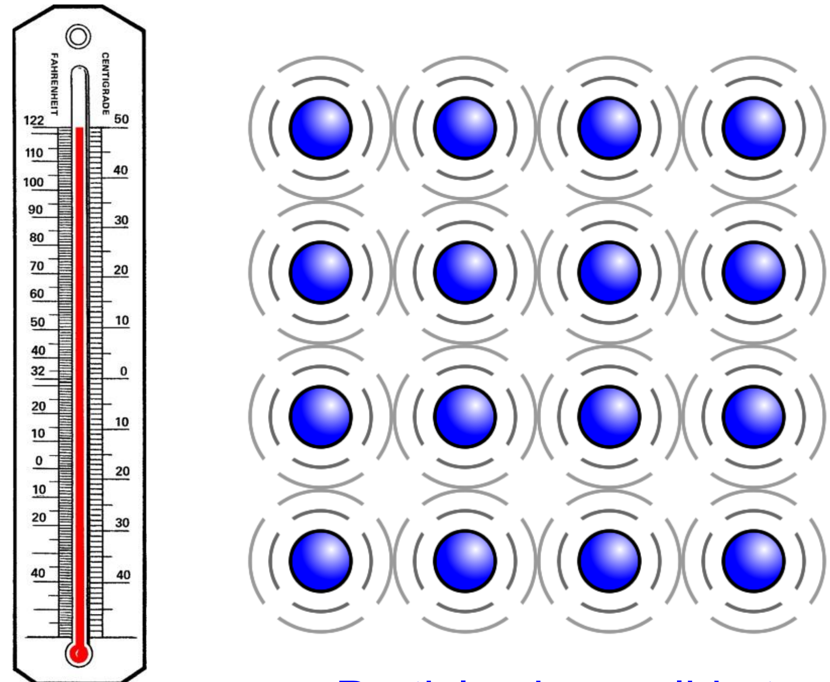
As the motion of the particles in a substance increases, the average kinetic energy of the particles also increases.

Therefore, as the temperature of a substance increases, the average kinetic energy of the particles in the substance also increases.

Kinetic Particle Theory – Models



- Particles in a solid at *low* temperature.



- Particles in a solid at *high* temperature.

- The particles in a substance at a *low temperature* have a relatively *small average kinetic energy*. The particles in a substance at a *high temperature* have a relatively *large average kinetic energy*. *Temperature is an indicator of the particles average kinetic energy*.

Kinetic Particle Theory – Models

If a substance is cooled to a very low temperature, will the particles stop moving?

Kinetic Particle Theory – Models

If a substance is cooled to a very low temperature, will the particles stop moving?

- If a substance were cooled to the extremely low temperature of −273 °C (also known as *zero Kelvin* or *absolute zero*) its particles would stop moving.

Kinetic Particle Theory – Models

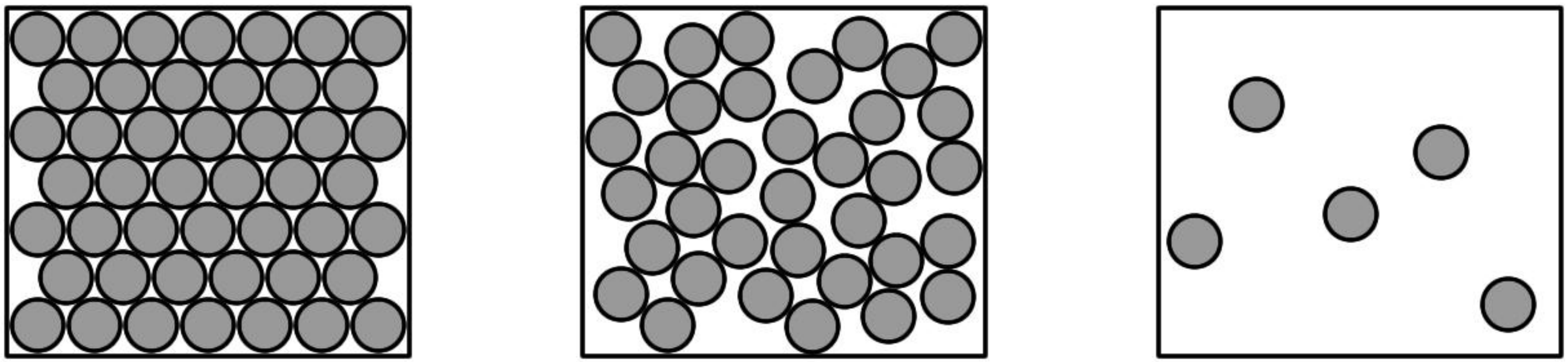
How are the particles arranged in solids, liquids and gases?

What are the properties of solids, liquids and gases?

Kinetic Particle Theory – Models

States of Matter

The three different states of matter are…

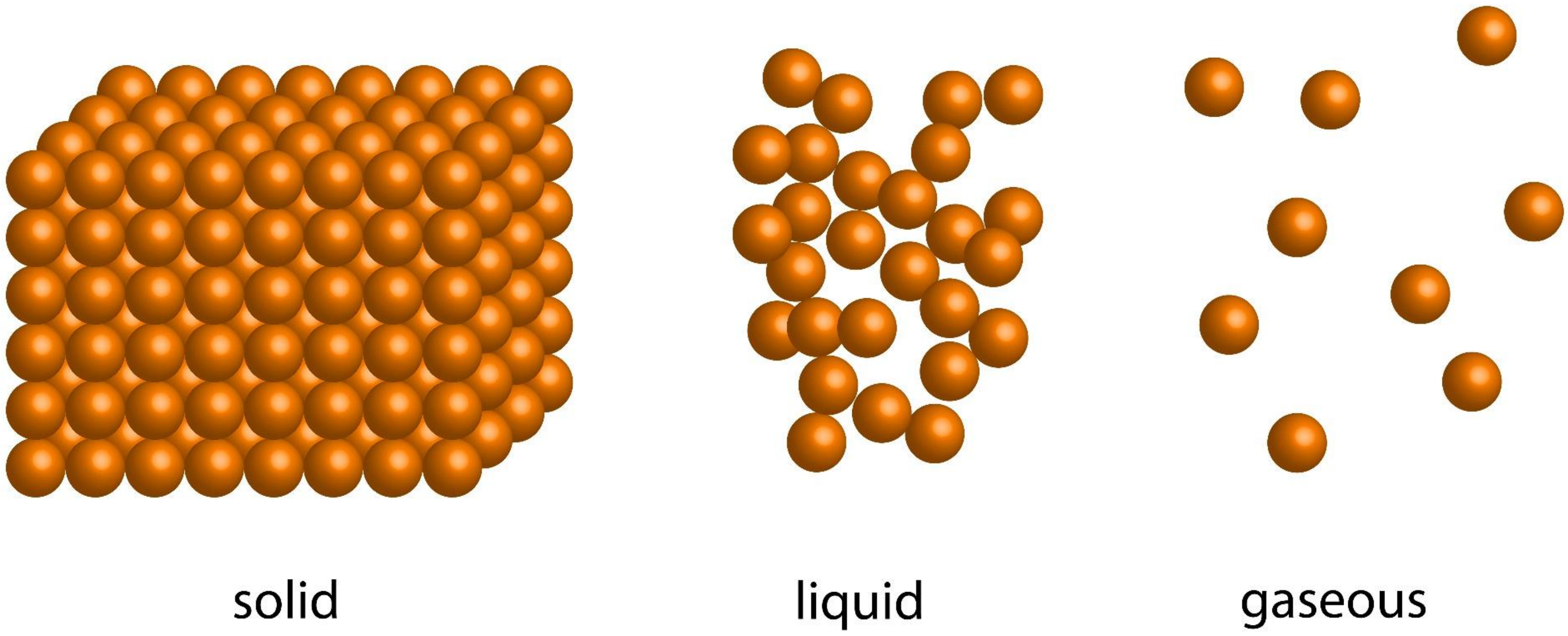


Solid Liquid Gas

Kinetic Particle Theory – Models

States of Matter

The three different states of matter are…



Kinetic Particle Theory – Models

States of Matter

	Solid	Liquid	Gas
Element			
Compound			

Kinetic Particle Theory – Models

States of Matter

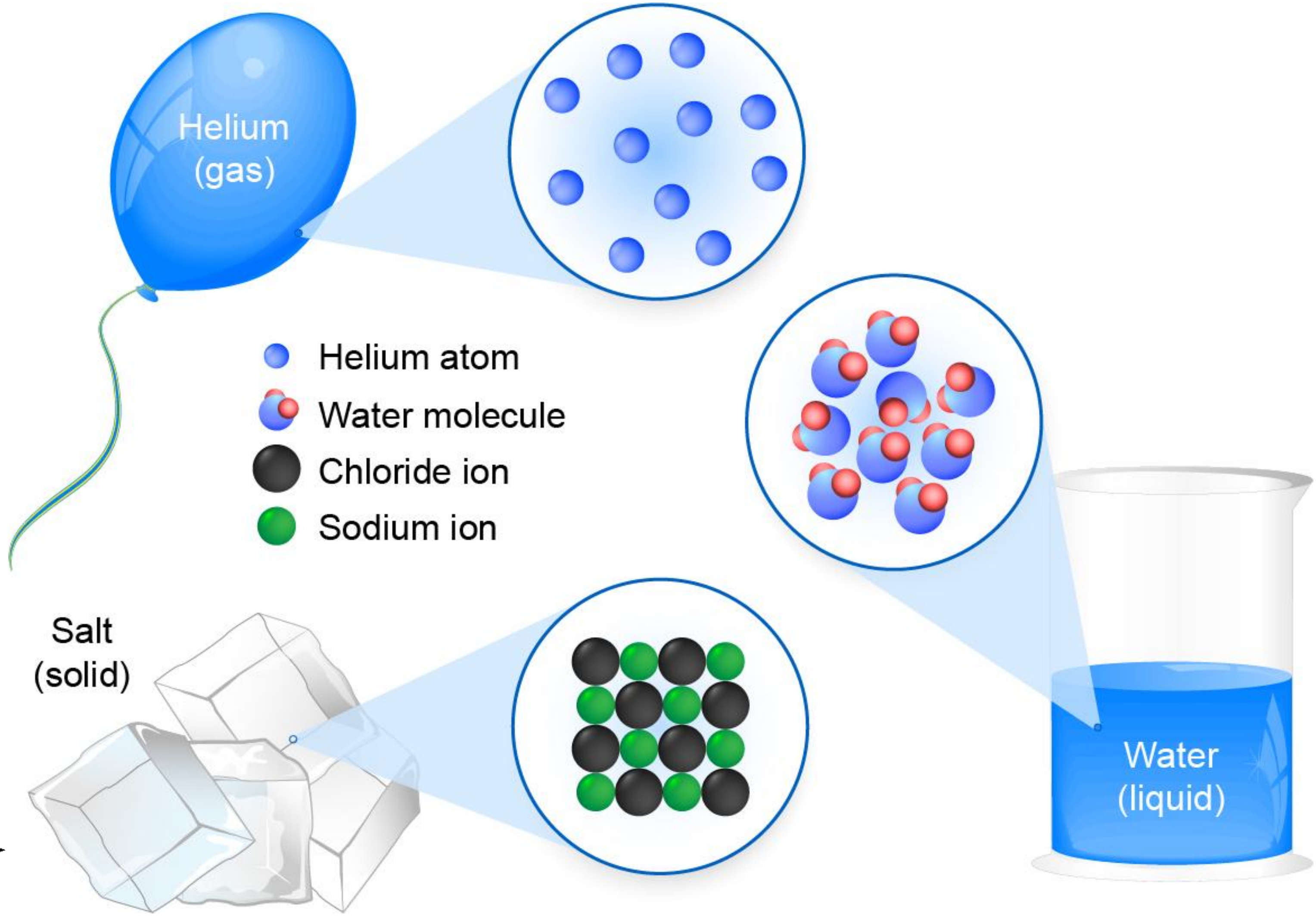
	Solid	Liquid	Gas
Element	Copper – Cu Iron – Fe Sulfur – S	Bromine – Br_2 Mercury – Hg	Argon – Ar Hydrogen – H_2 Oxygen – O_2
Compound	Sodium chloride – $NaCl$ Glucose – $C_6H_{12}O_6$	Water – H_2O Ethanol – C_2H_5OH	Carbon dioxide – CO_2 Ammonia – NH_3

Blue = Metal

Green = Non-metal

Kinetic Particle Theory – Models

States of Matter

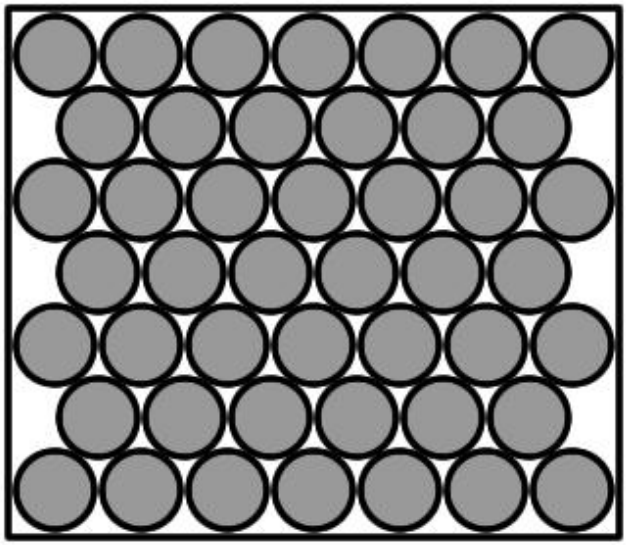


Kinetic Particle Theory – Models

PHET Simulation – States of Matter

Kinetic Particle Theory – Models

States of Matter



Solid

- The particles in a *solid* are very closely packed together…

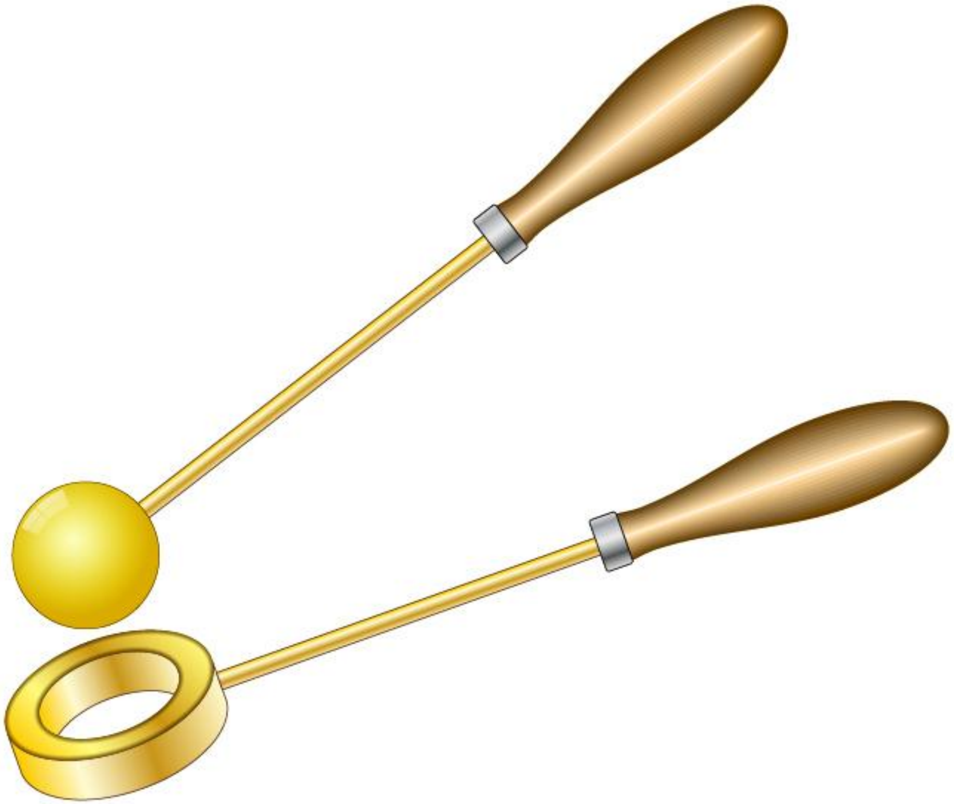
…in an ordered / lattice arrangement…

…in which they vibrate and rotate about fixed positions (low average kinetic energy).

- Forces of attraction between the particles are strong.

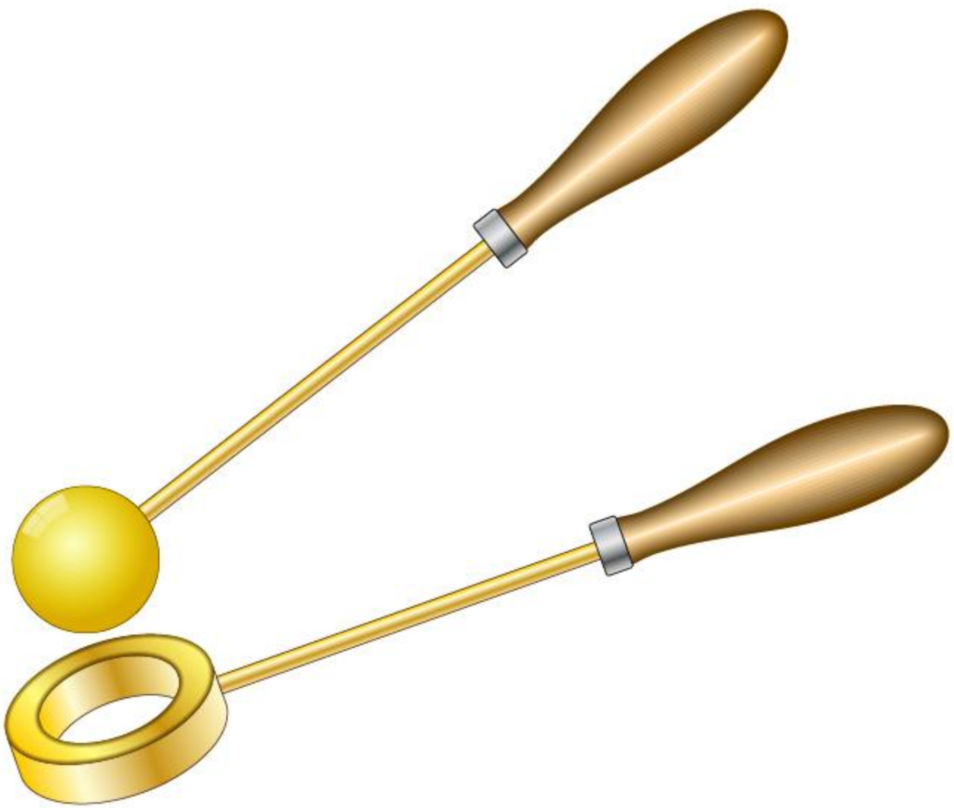
- The *solid* has a fixed volume and fixed shape. It cannot be compressed and does not expand very much when heated.

Kinetic Particle Theory – Models



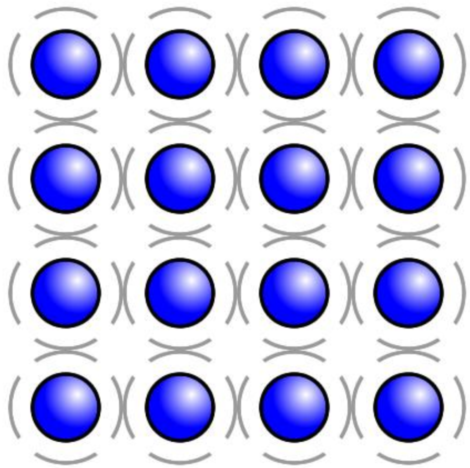
- Solids expand slightly on heating. This phenomenon is known as *thermal expansion*.
- Thermal expansion of a solid can be demonstrated by a simple experiment using a metal sphere and a metal ring.

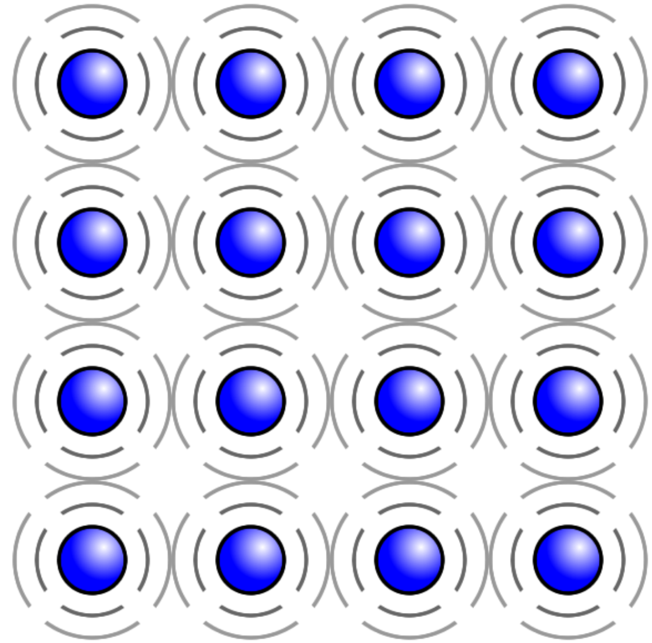
Kinetic Particle Theory – Models



- At room temperature, the metal sphere is exactly the right size to fit through the metal ring.
- After heating the metal sphere to a high temperature in a Bunsen burner flame, the sphere expands to a point where it is too large to fit through the metal ring.

Kinetic Particle Theory – Models

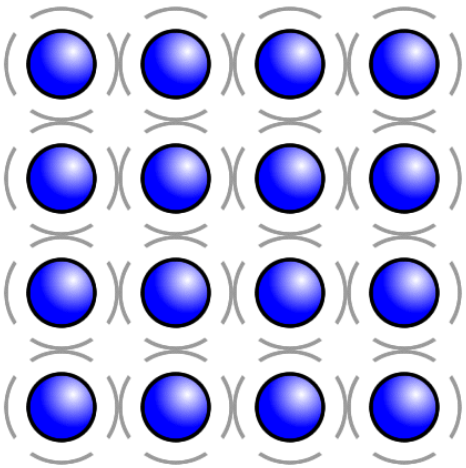


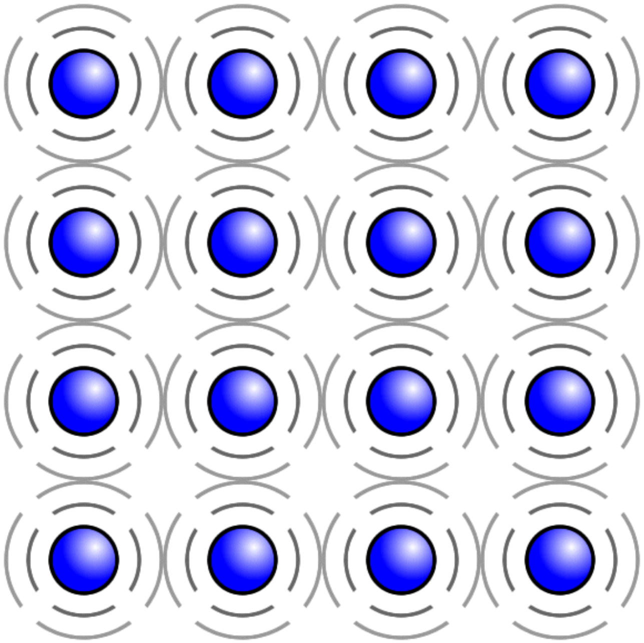


- Particles in a solid at *low* temperature.
- Particles in a solid at *high* temperature.

- When a solid is *heated*, the *average kinetic energy* of the particles *increases*, *i.e.* the particles vibrate more vigorously about their fixed positions. This increased vibration causes the average separation of the particles to increase slightly, causing the solid to *expand*.

Kinetic Particle Theory – Models





- Particles in a solid at *low* temperature.
- Particles in a solid at *high* temperature.

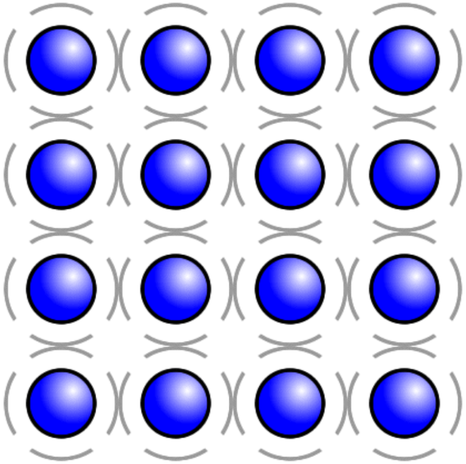
- When a solid undergoes thermal expansion, the mass of the solid remains the same, but the density of the solid decreases.

density = mass ÷ volume

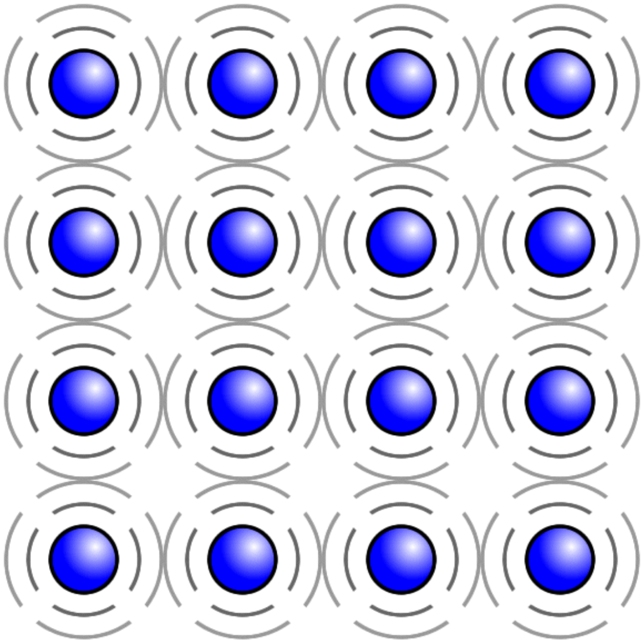
mass remains the same while volume increases

therefore density decreases

Kinetic Particle Theory – Models



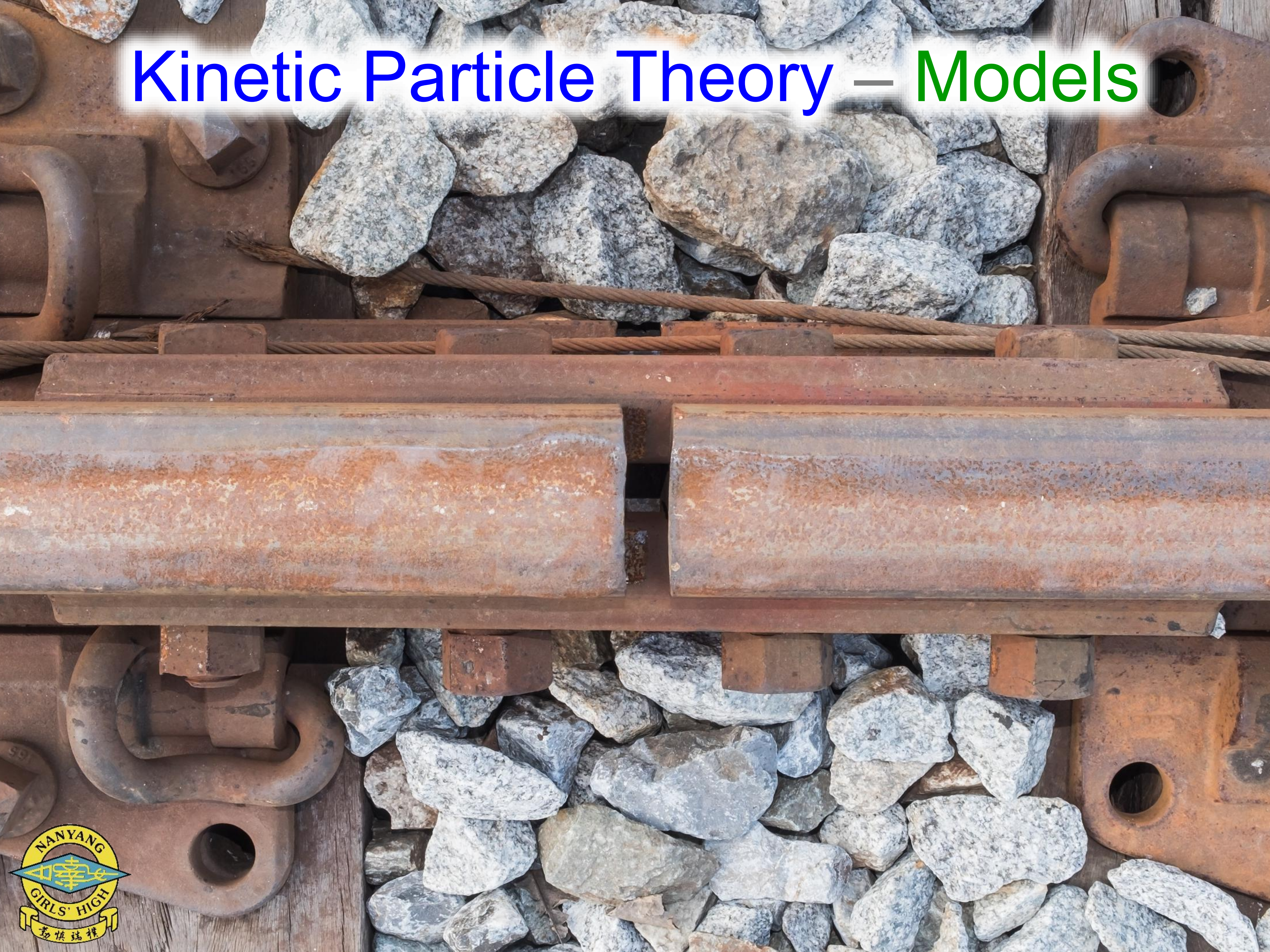
- Particles in a solid at *low* temperature.



- Particles in a solid at *high* temperature.

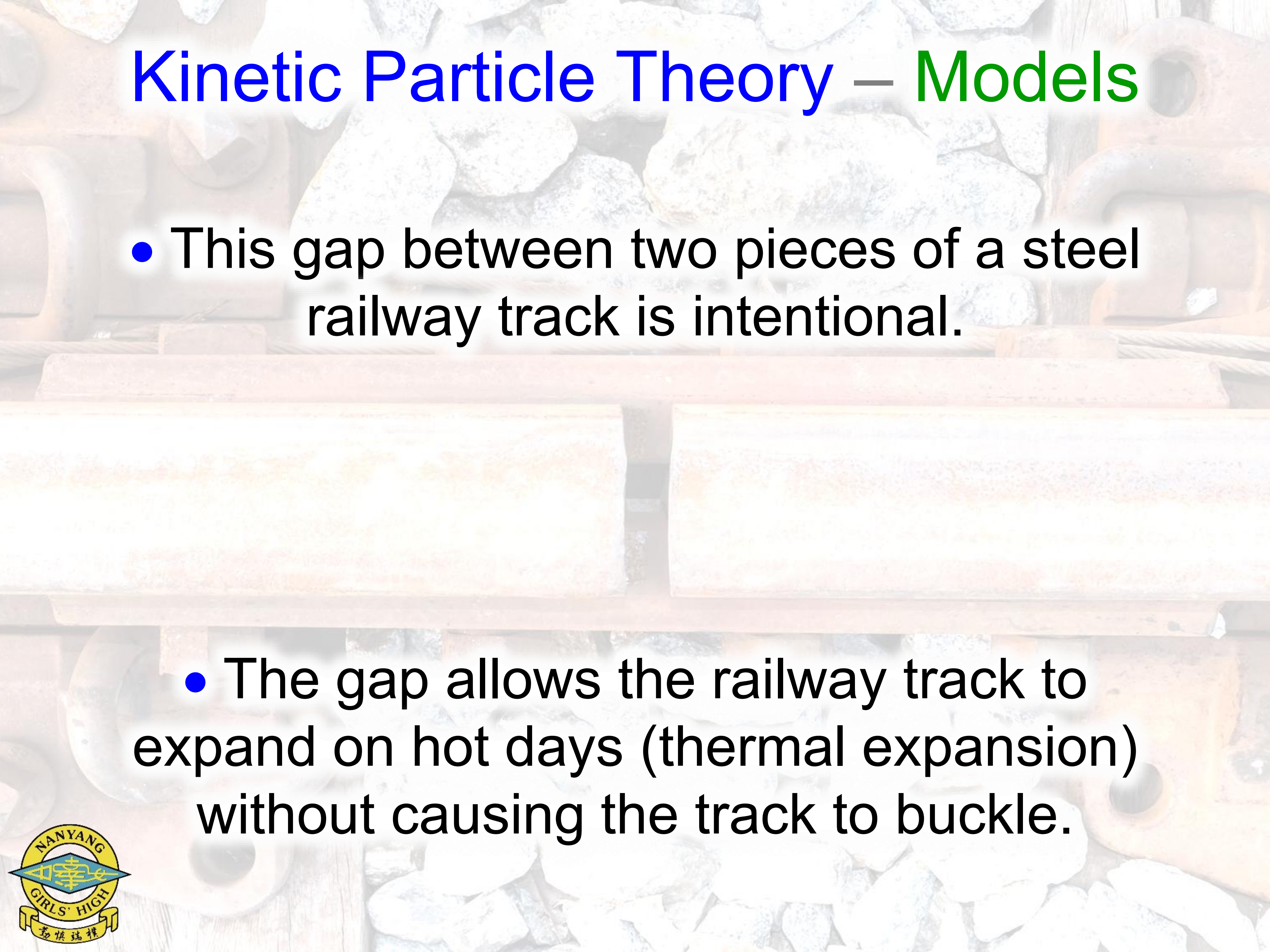
- **Note:** The *particles do not expand* when they are heated, and the *particles do not contract* when they are cooled. The particles always remain the same size, regardless of temperature – they just move further apart (when heated) or closer together (when cooled).

Kinetic Particle Theory – Models



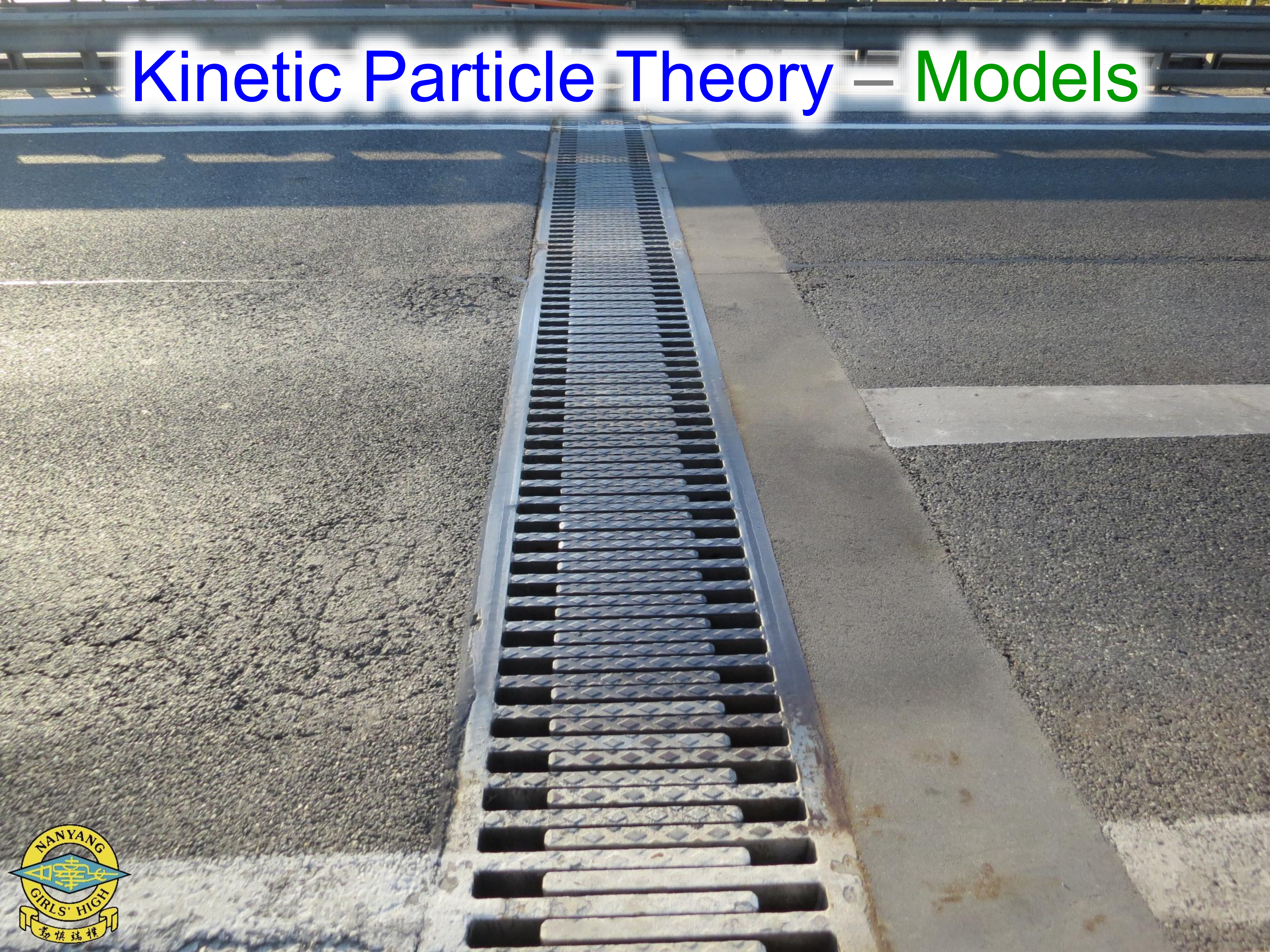
Kinetic Particle Theory – Models

- This gap between two pieces of a steel railway track is intentional.

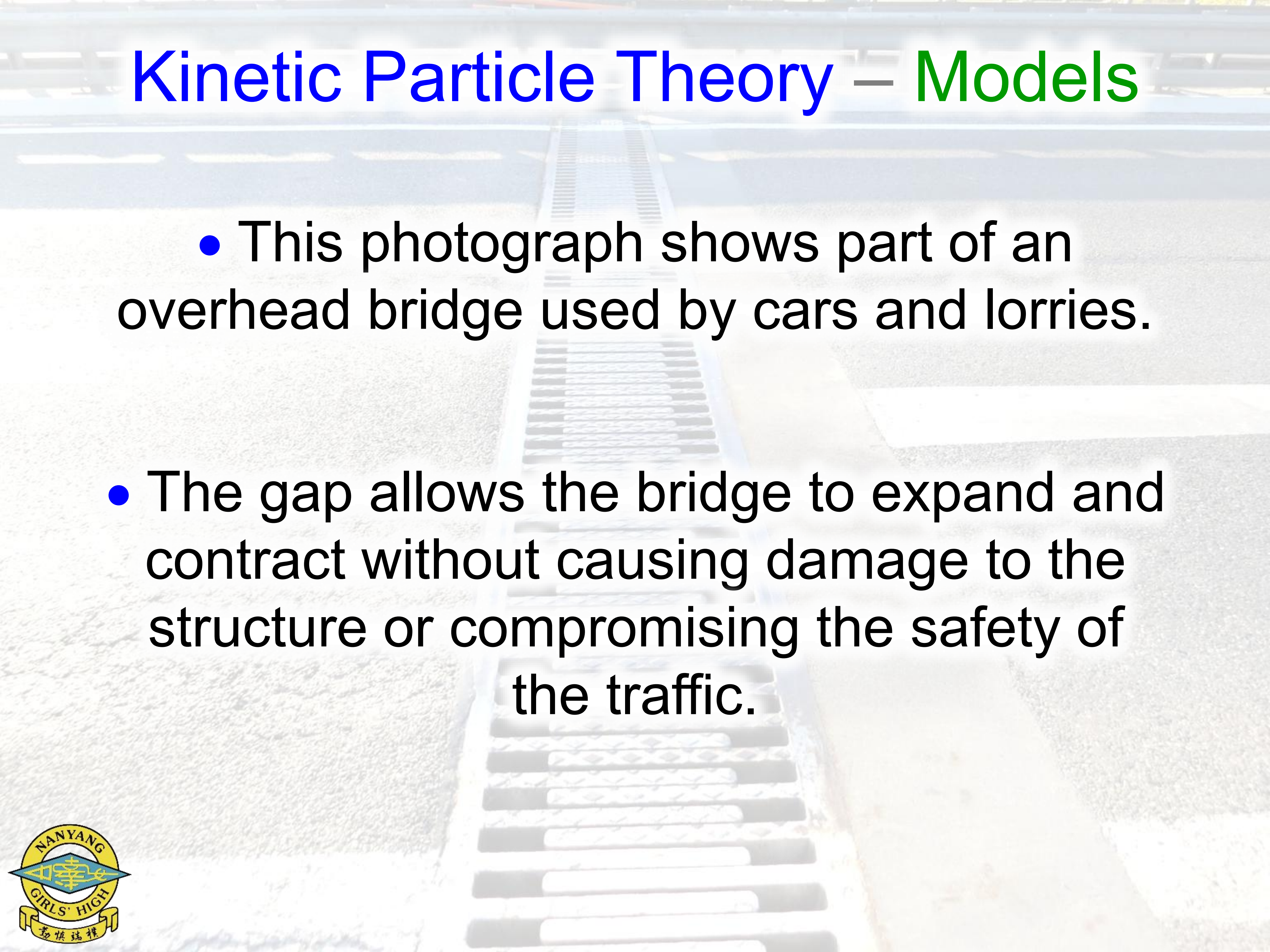


- The gap allows the railway track to expand on hot days (thermal expansion) without causing the track to buckle.

Kinetic Particle Theory – Models



Kinetic Particle Theory – Models

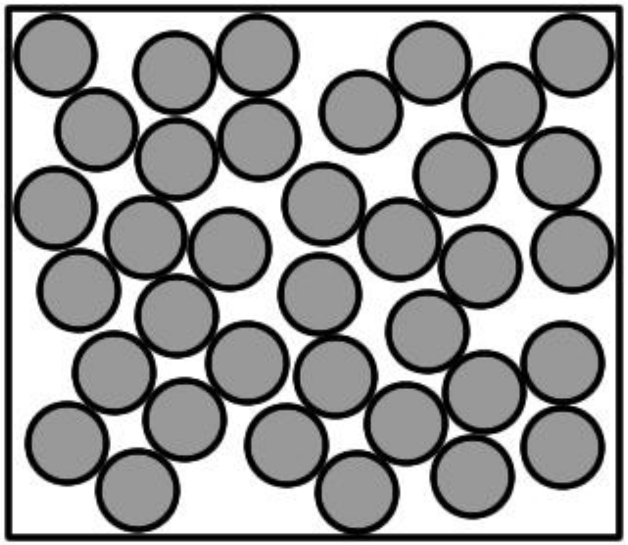


- This photograph shows part of an overhead bridge used by cars and lorries.

- The gap allows the bridge to expand and contract without causing damage to the structure or compromising the safety of the traffic.

Kinetic Particle Theory – Models

States of Matter



Liquid

- The particles in a *liquid* are closely packed together…

…in a random arrangement…

…in which they travel short distances by slipping and sliding over each other.

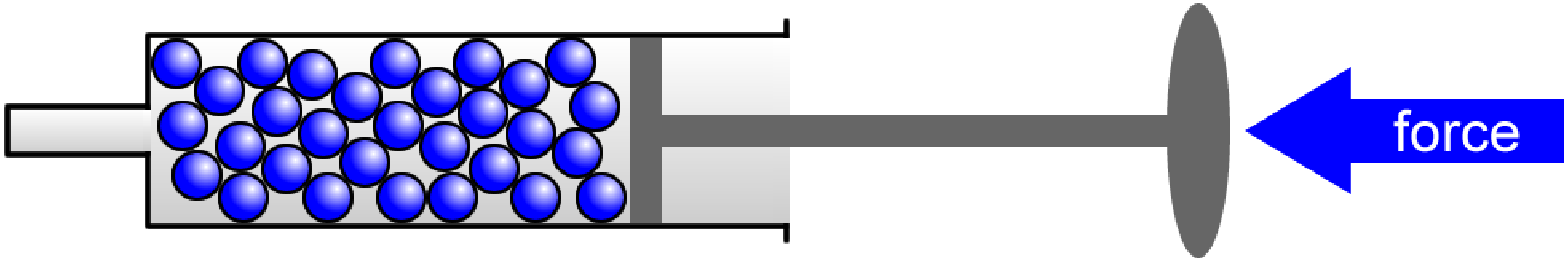
- Forces of attraction between the particles are quite strong.

- The *liquid* has a fixed volume but no fixed shape. It cannot be compressed and does not expand very much when heated.

Kinetic Particle Theory – Models

- Solids and liquids *cannot* be compressed.

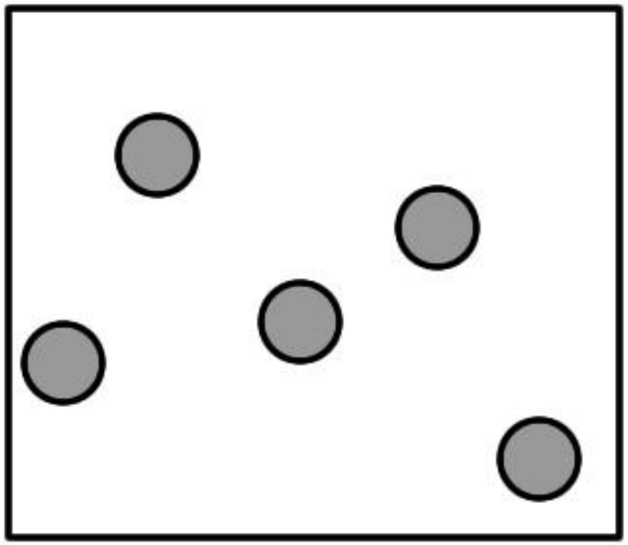
- A liquid in an air-tight syringe cannot be compressed into a smaller volume when a force is applied on the plunger.



- The particles in the liquid are naturally closely packed together. There are no significant spaces between the particles, so when a force is applied on the plunger, the average separation of the particles cannot be reduced any further and the liquid occupies the same volume.

Kinetic Particle Theory – Models

States of Matter



Gas

- The particles in a *gas* are separated far apart from one another…

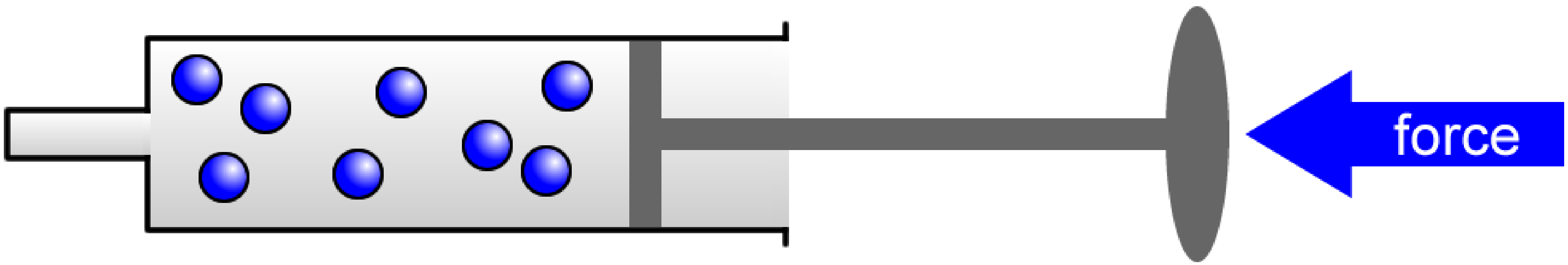
…in a very random / chaotic arrangement…

…in which they move about rapidly in all directions (high average kinetic energy).

- Forces of attraction between the particles are negligible.
- The *gas* has no fixed volume and no fixed shape. It can be easily compressed and rapidly expands when heated.

Kinetic Particle Theory – Models

- Unlike solids and liquids, gases *can* be compressed.
- A gas in an air-tight syringe can be compressed into a smaller volume when a force is applied on the plunger.



- There is naturally a large separation between particles in the gas phase. When a force is applied on the plunger, the average separation between the gas particles is reduced as the particles are forced closer together. The same number of gas particles occupy a smaller volume because their average separation has been reduced.

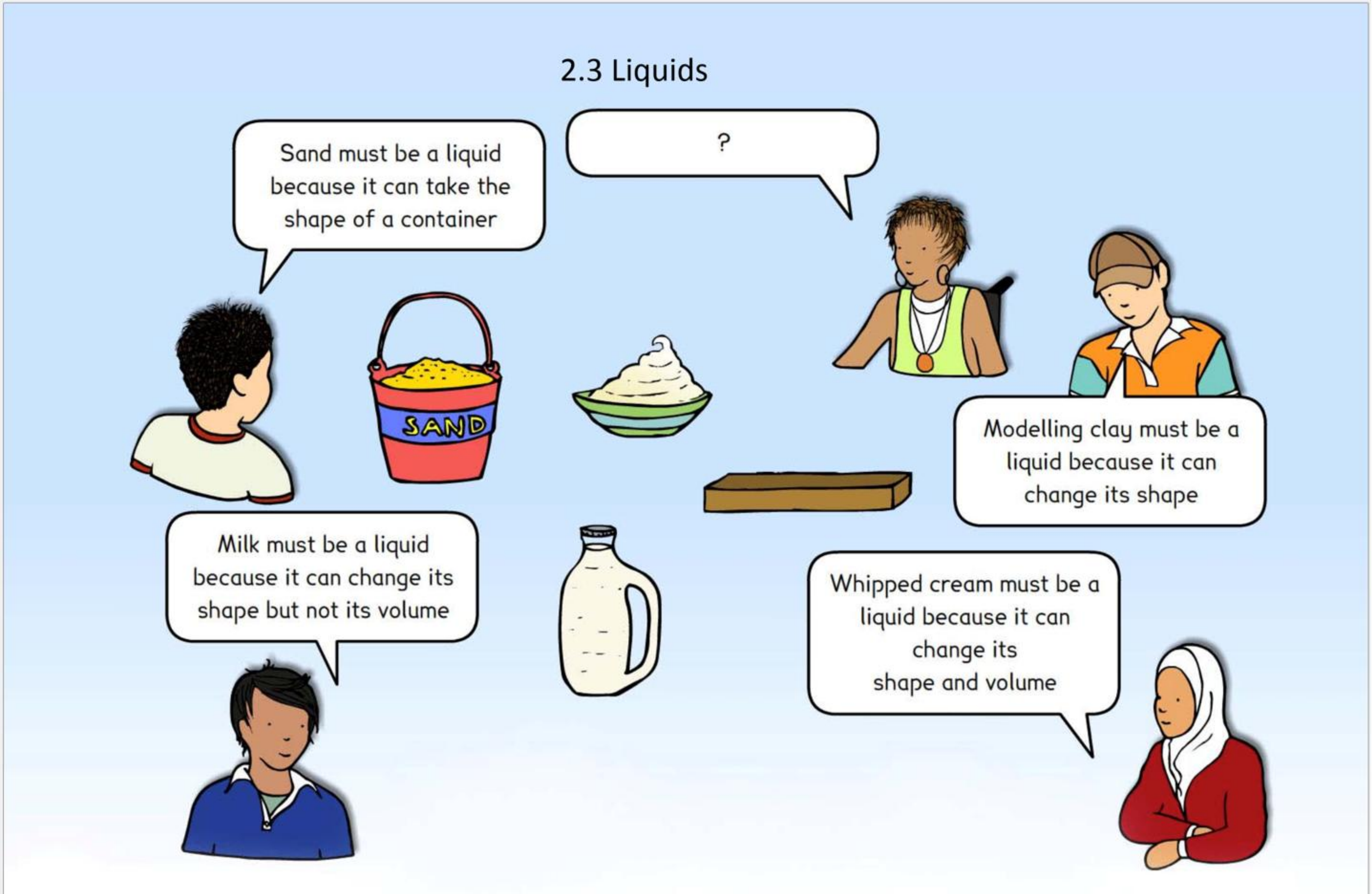
Kinetic Particle Theory – Models

- Unlike solids and liquids, gases *can* be compressed.

- A gas in an air-tight syringe can be compressed into a smaller volume when a force is applied on the plunger.

- There is naturally a large separation between particles in the gas phase. When a force is applied on the plunger, the average separation between the gas particles is reduced as the particles are forced closer together. The same number of gas particles occupy a smaller volume because their average separation has been reduced.

Kinetic Particle Theory – Models

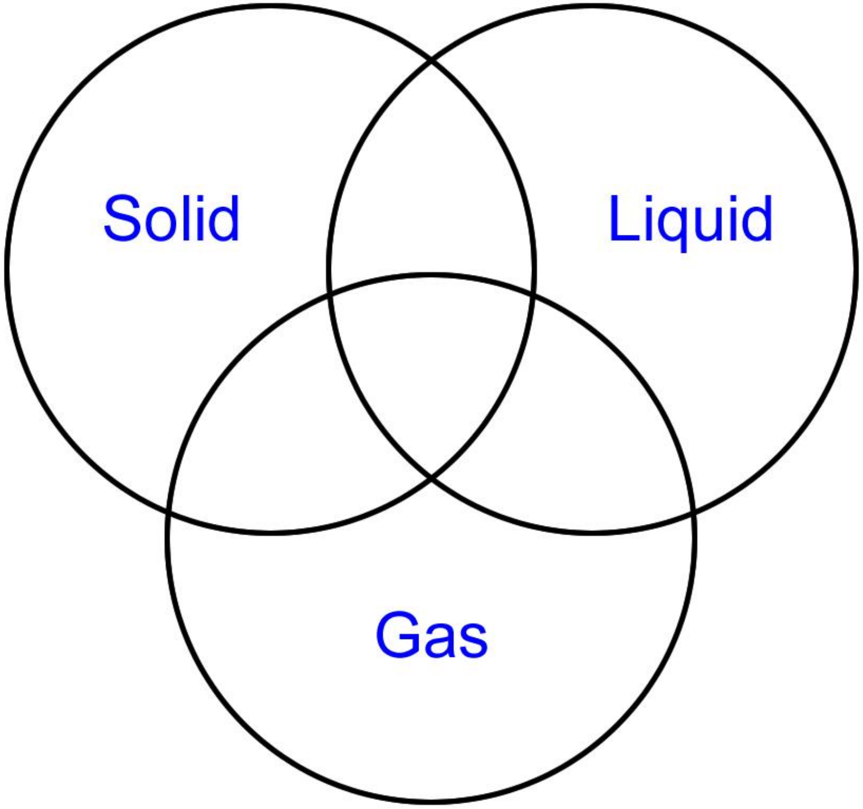


Kinetic Particle Theory – Models

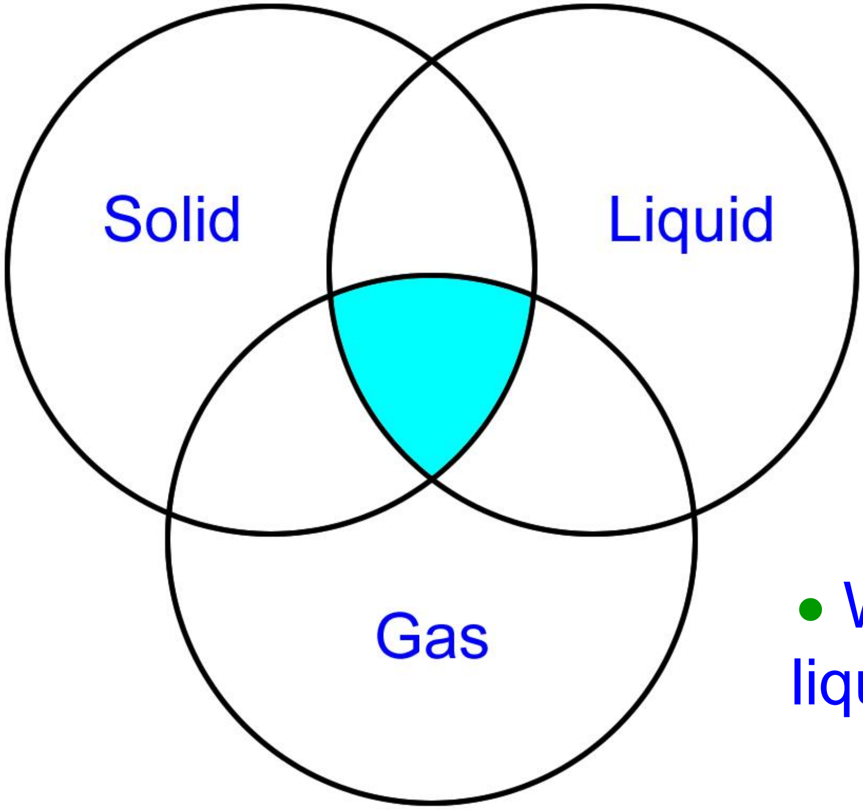
What are the essential similarities and differences between solids, liquids and gases?

- For example, in which state of matter is the force of attraction between the particles strongest?
- For example, in which state of matter do the particles have the greatest average kinetic energy?

Kinetic Particle Theory – Models

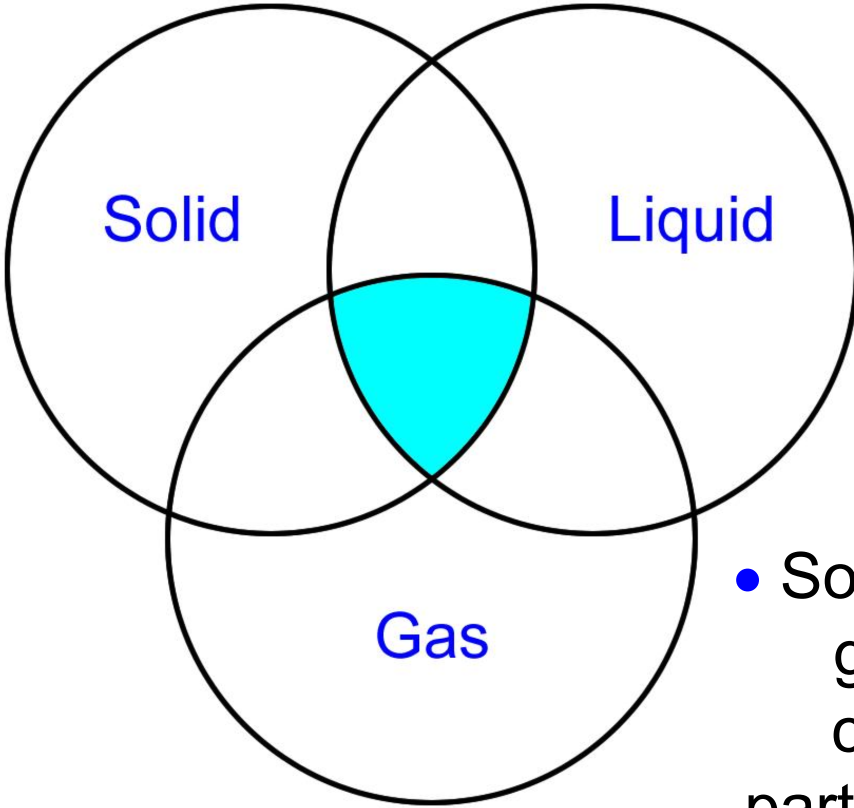


Kinetic Particle Theory – Models



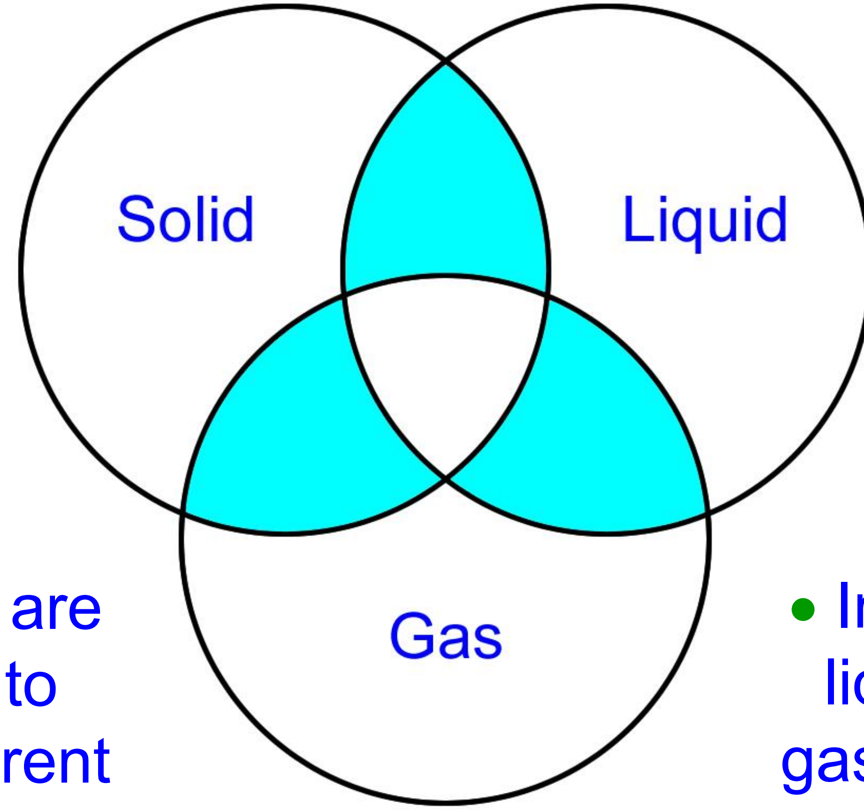
- What do solids, liquids and gases all have in common?

Kinetic Particle Theory – Models



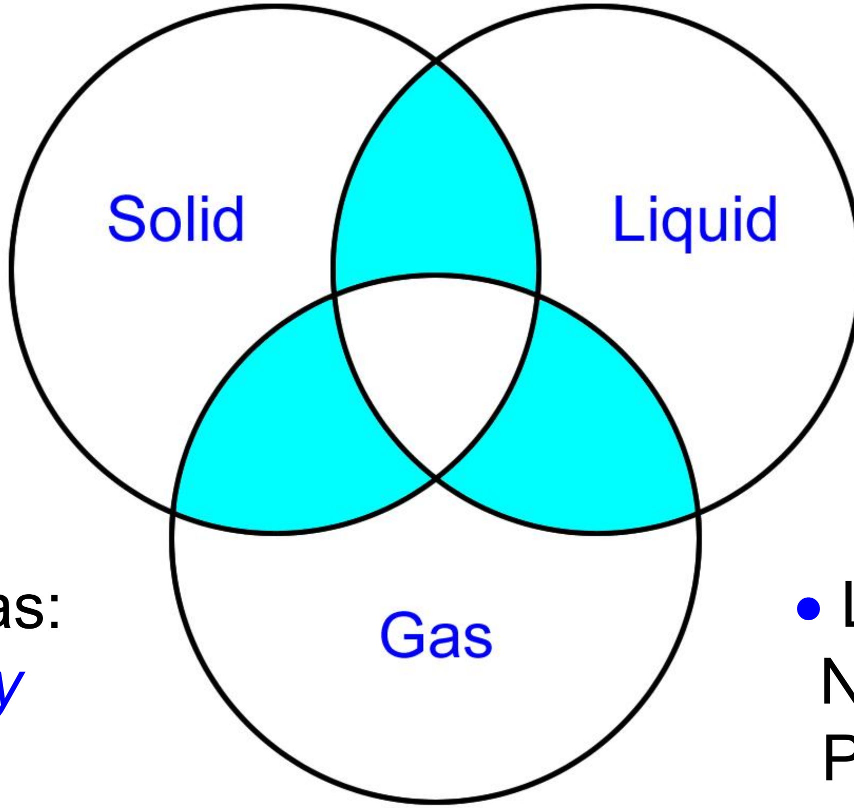
- Solids, liquids and gases are all composed of particles that are in a constant state of motion.

Kinetic Particle Theory – Models



- In what ways are solids similar to liquids, but different from gases?
- In what ways are solids similar to gases, but different from liquids?
- In what ways are liquids similar to gases, but different from solids?

Kinetic Particle Theory – Models



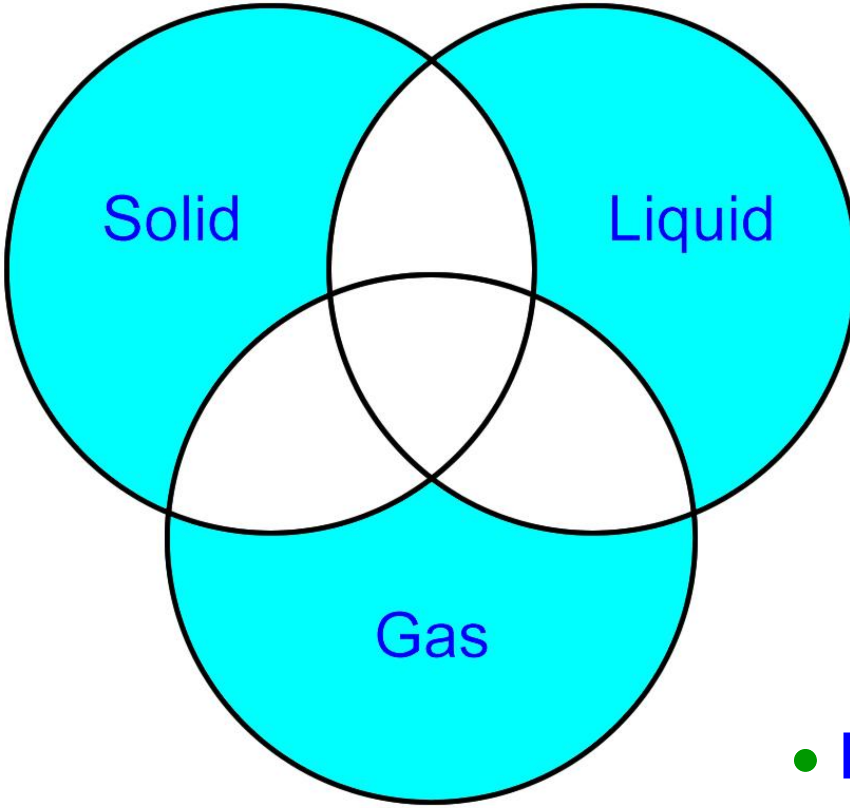
- Solid and Liquid: Fixed volume. Cannot be compressed.

- Solid and Gas: Are there *any* similarities?

- Liquid and Gas: No fixed shape. Particles do not have a fixed position.

Kinetic Particle Theory – Models

- In what ways are solids different to liquids and gases?

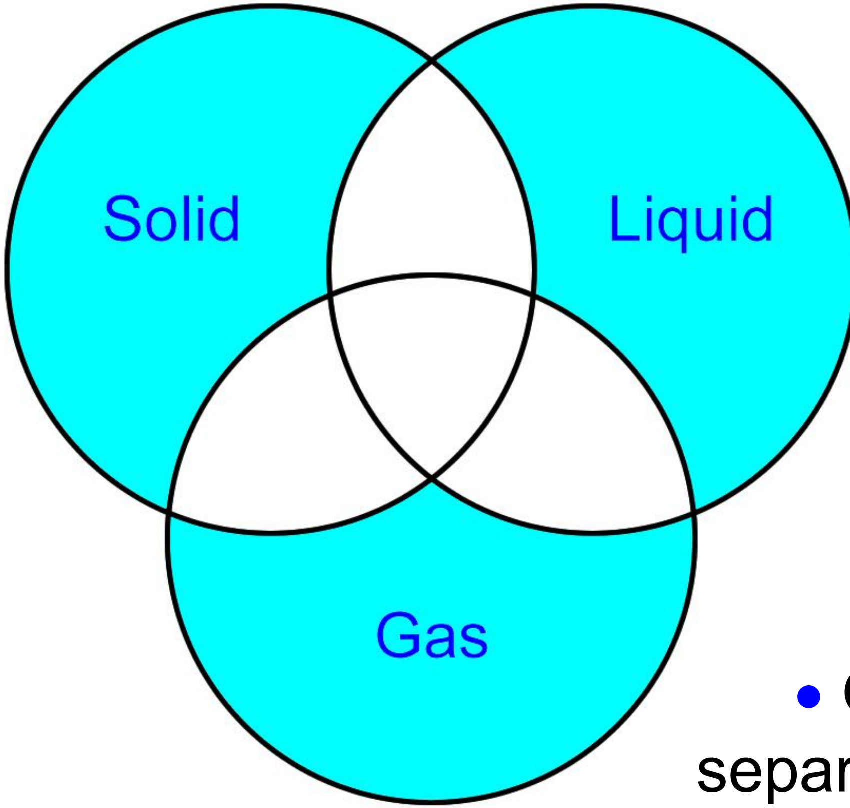


- In what ways are liquids different to solids and gases?

- In what ways are gases different to solids and liquids?

Kinetic Particle Theory – Models

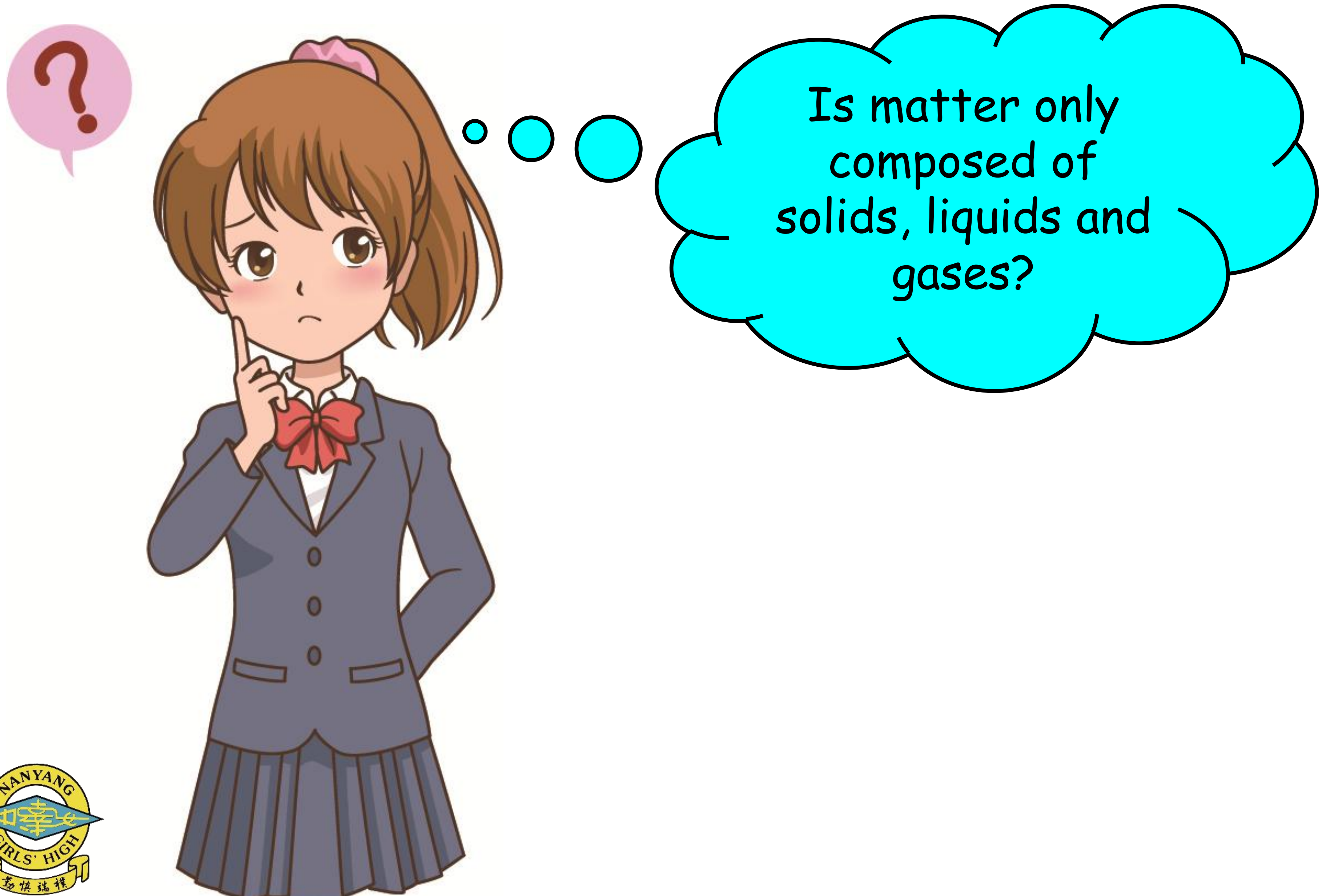
- Solid: Fixed shape. Particles are in a regular arrangement vibrating about fixed positions.



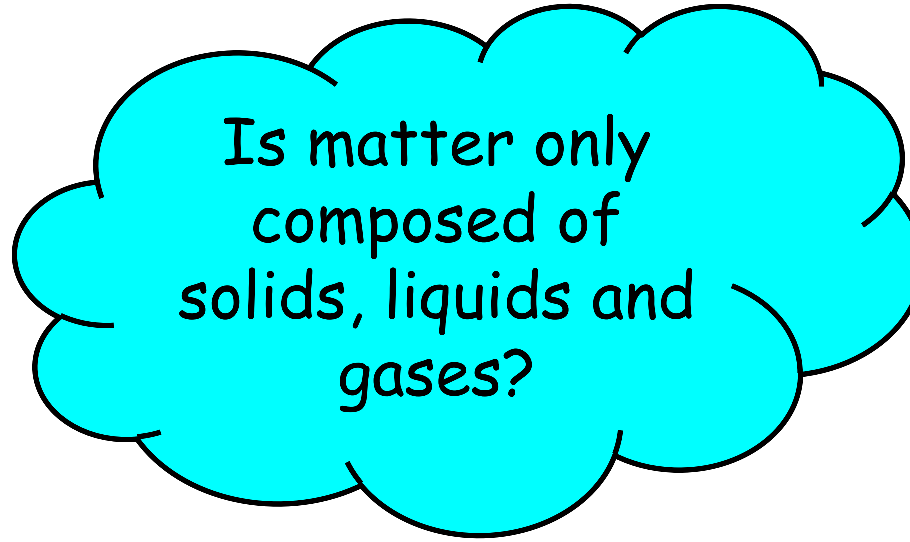
- Liquid: Particles slide over each other, travelling short distances.

- Gas: Large separation between particles. Particles move in a chaotic manner.

Kinetic Particle Theory – Models

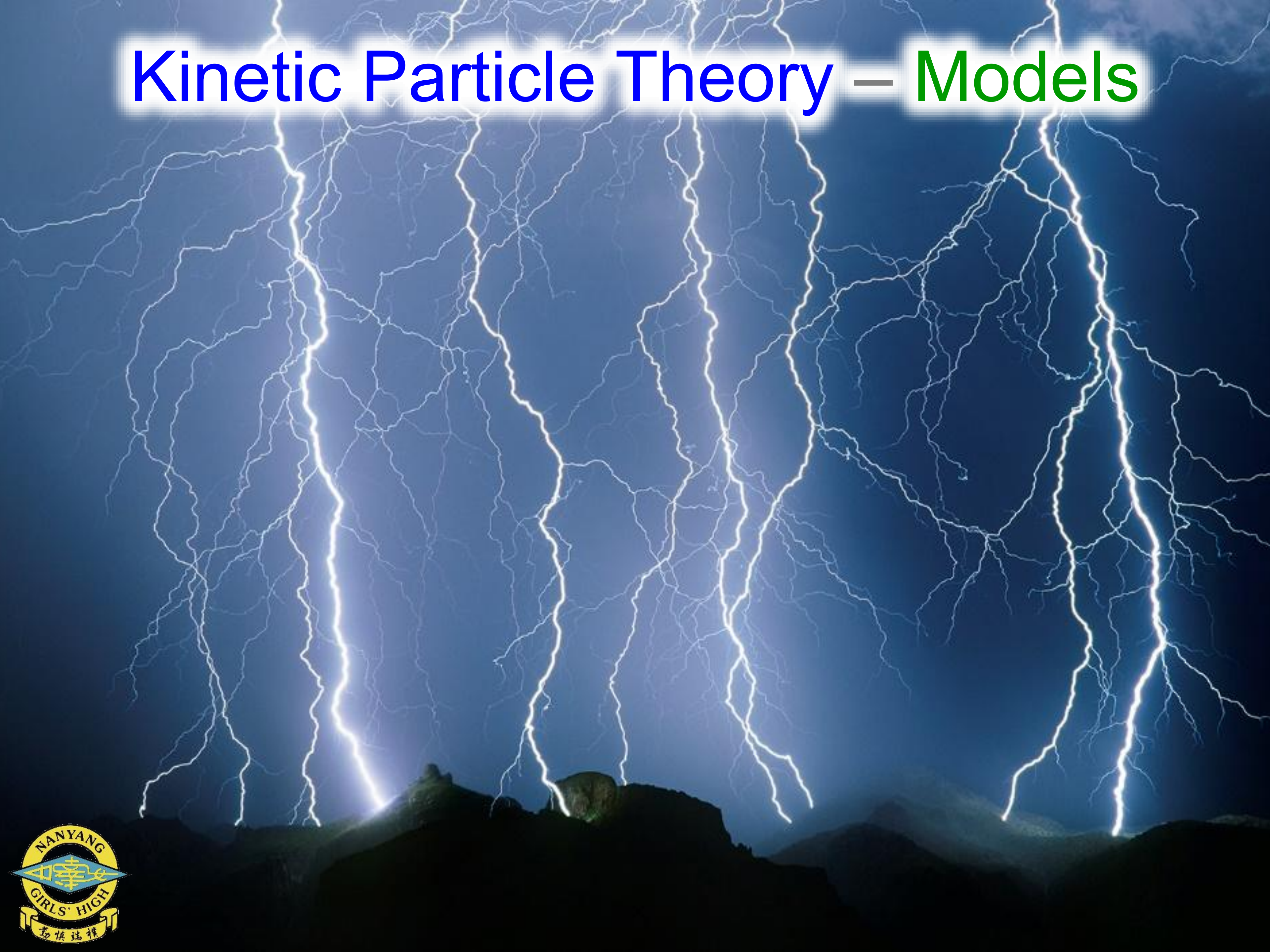


Kinetic Particle Theory – Models



- More exotic states of matter include *plasmas* and *Bose-Einstein Condensates*.

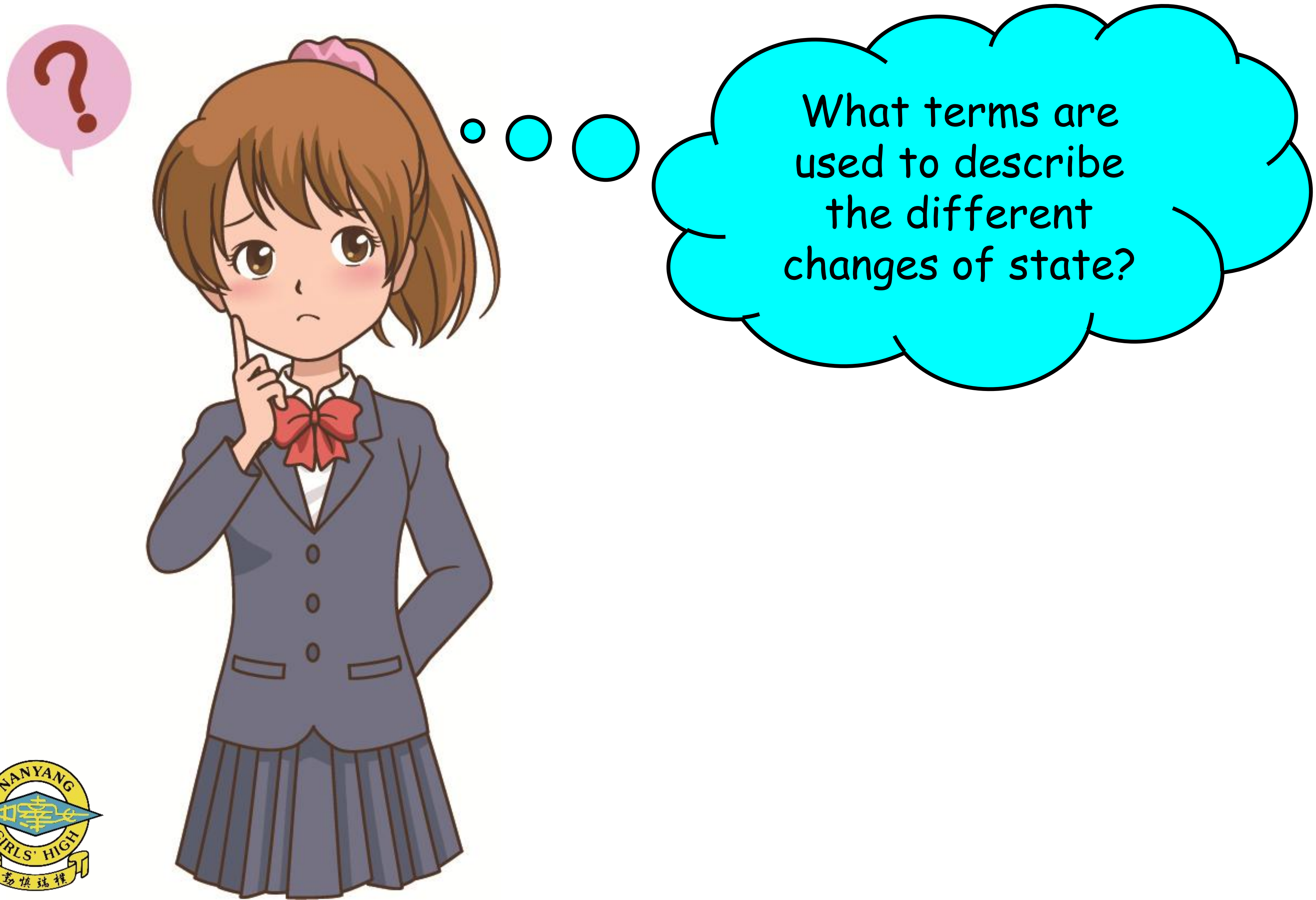
Kinetic Particle Theory – Models



Kinetic Particle Theory – Models

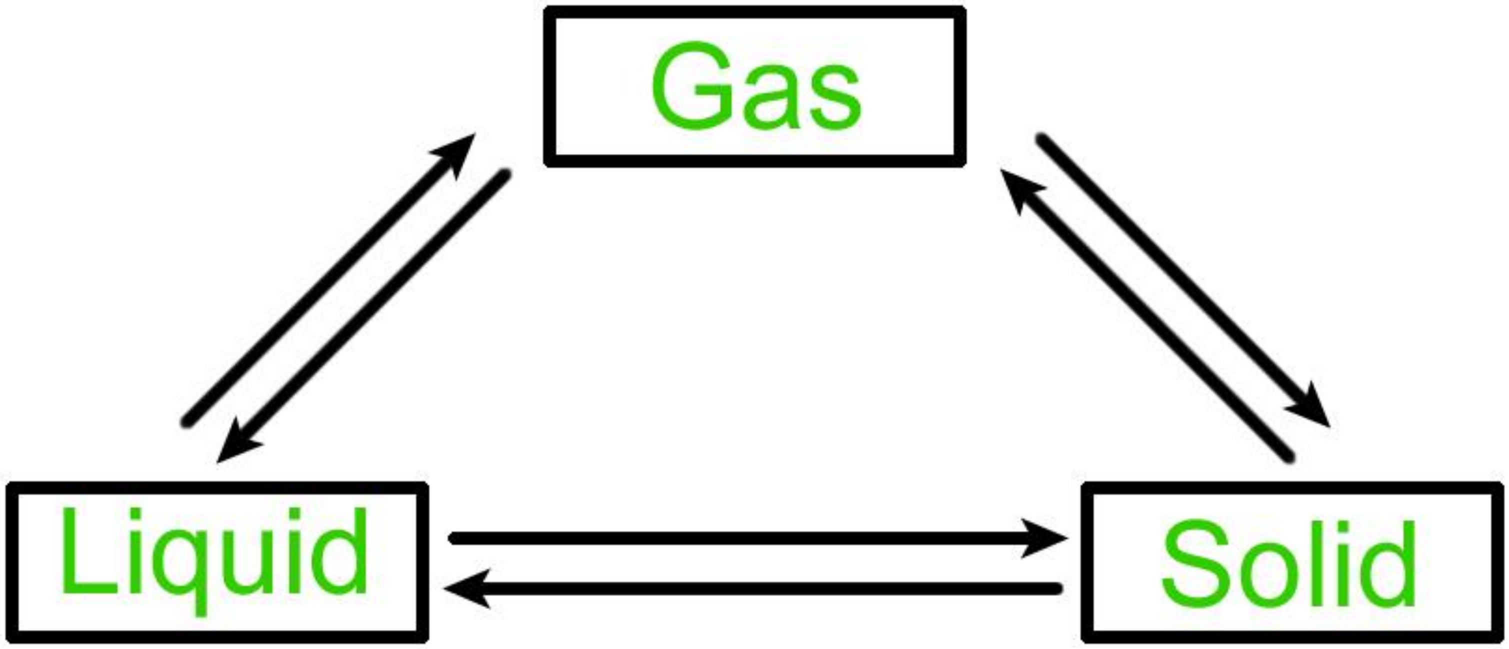
- A *plasma* is an *ionised gas*.
- Plasmas are more common than you might imagine, for example, *lightning* is a plasma.
- Lightning is formed when a large potential difference between the clouds and ground splits electrons away from nitrogen (N_2) and oxygen (O_2) molecules in the air – a process called *ionisation*.
- When the electrons return to the ionised molecules in the air – a process called *recombination* – energy is released in a flash of heat and light.

Kinetic Particle Theory – Models



Kinetic Particle Theory – Models

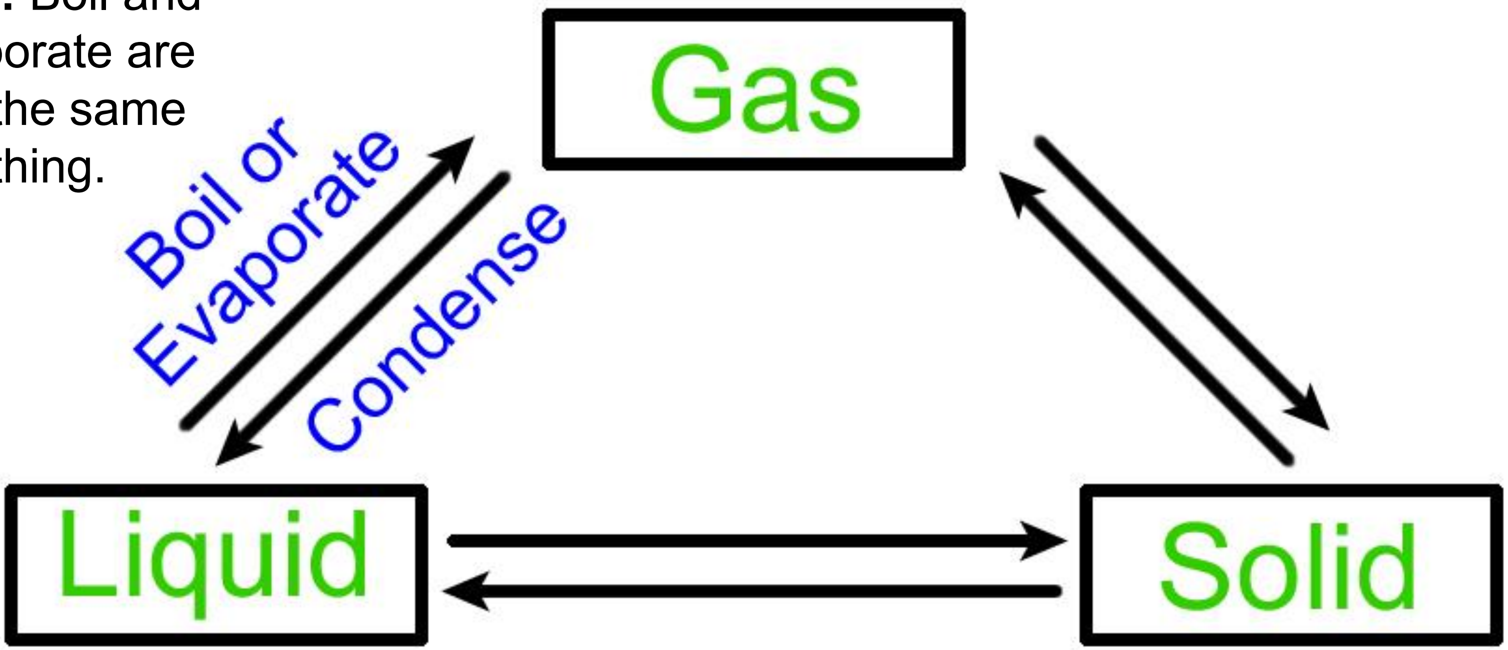
Change of State



Kinetic Particle Theory – Models

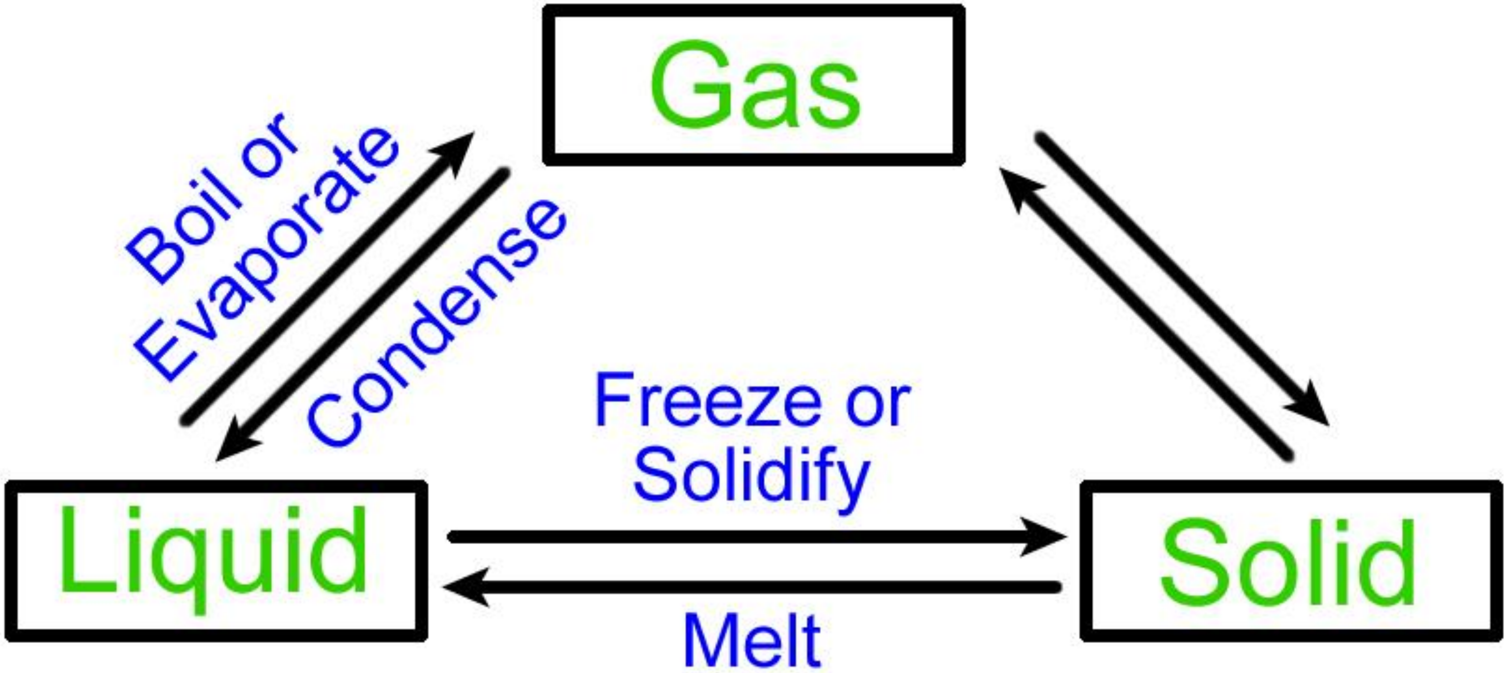
Change of State

Note: Boil and evaporate are *not* the same thing.



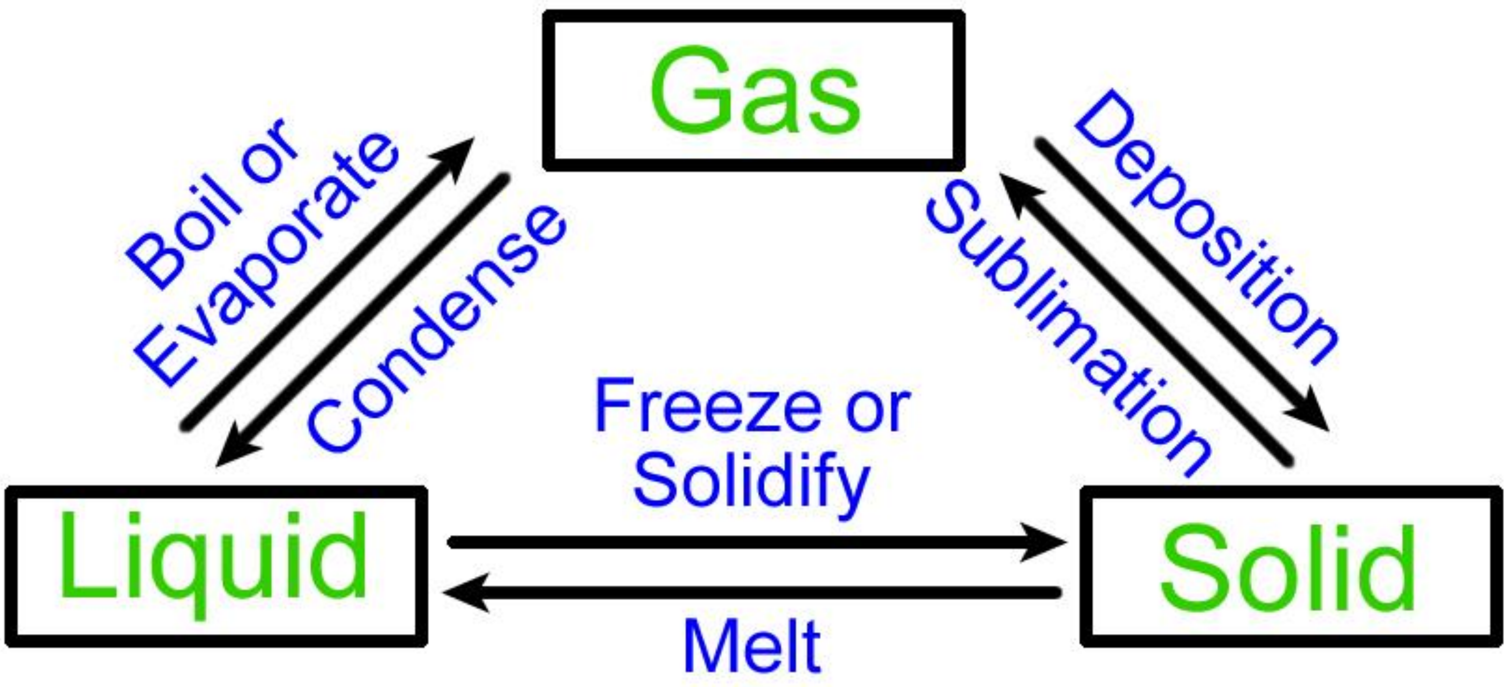
Kinetic Particle Theory – Models

Change of State



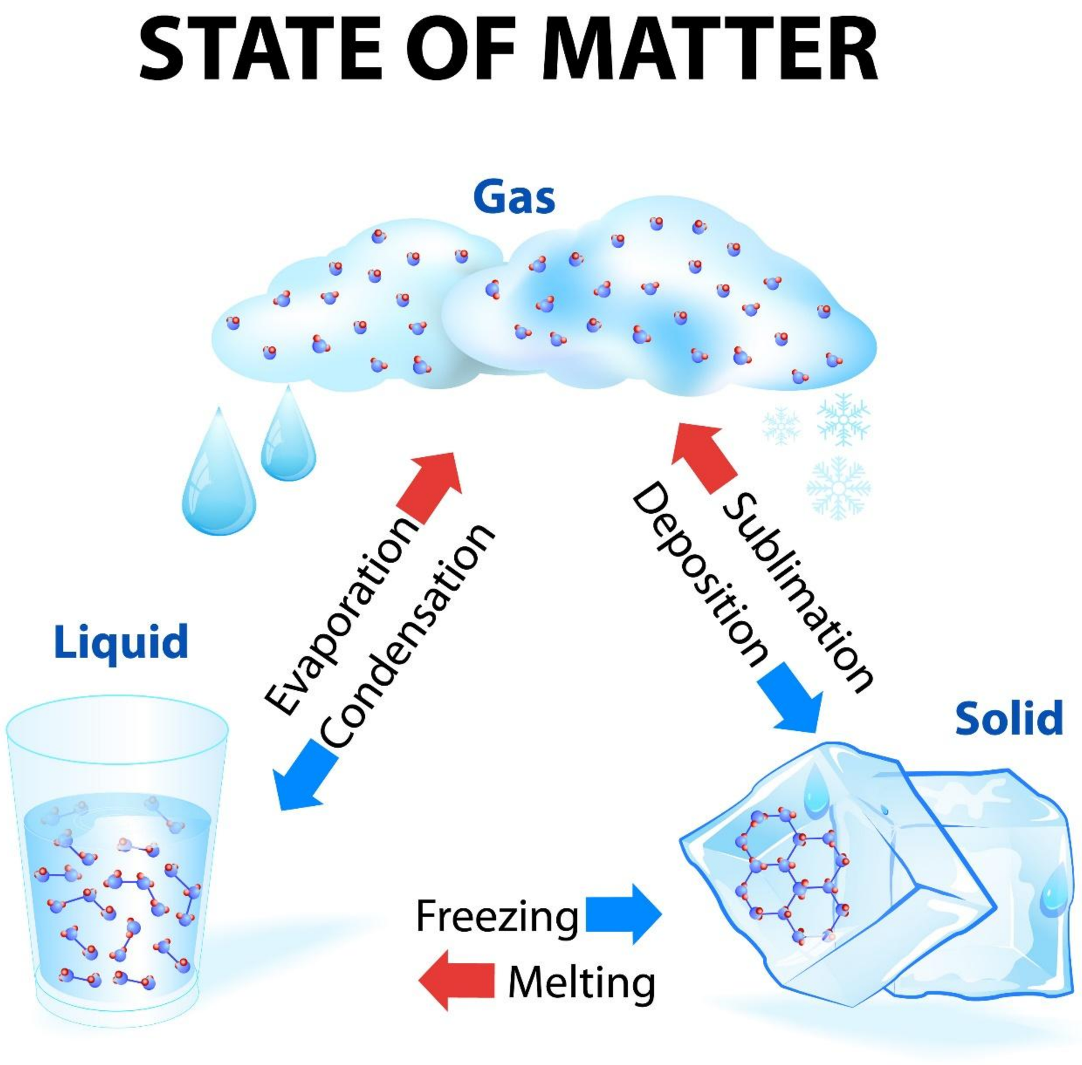
Kinetic Particle Theory – Models

Change of State



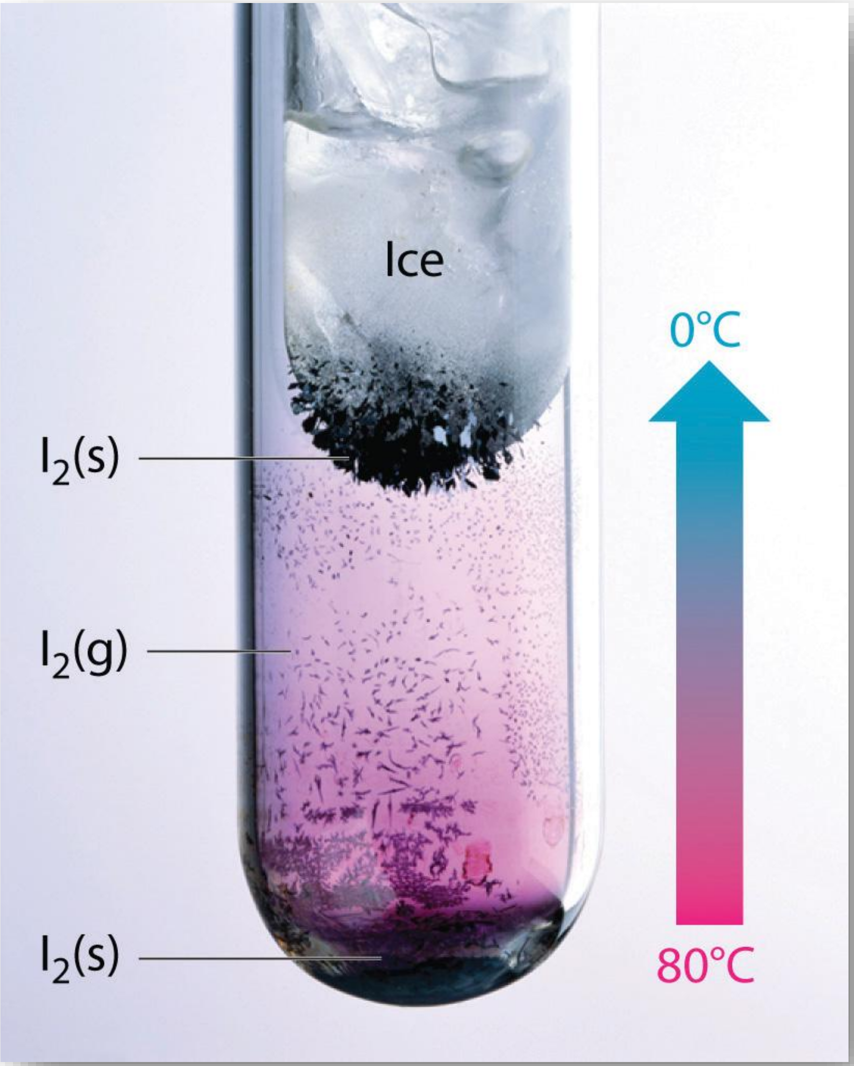
Note: Changes of state are classified as *physical changes* (not *chemical changes*) because they can be easily reversed.

Kinetic Particle Theory – Models



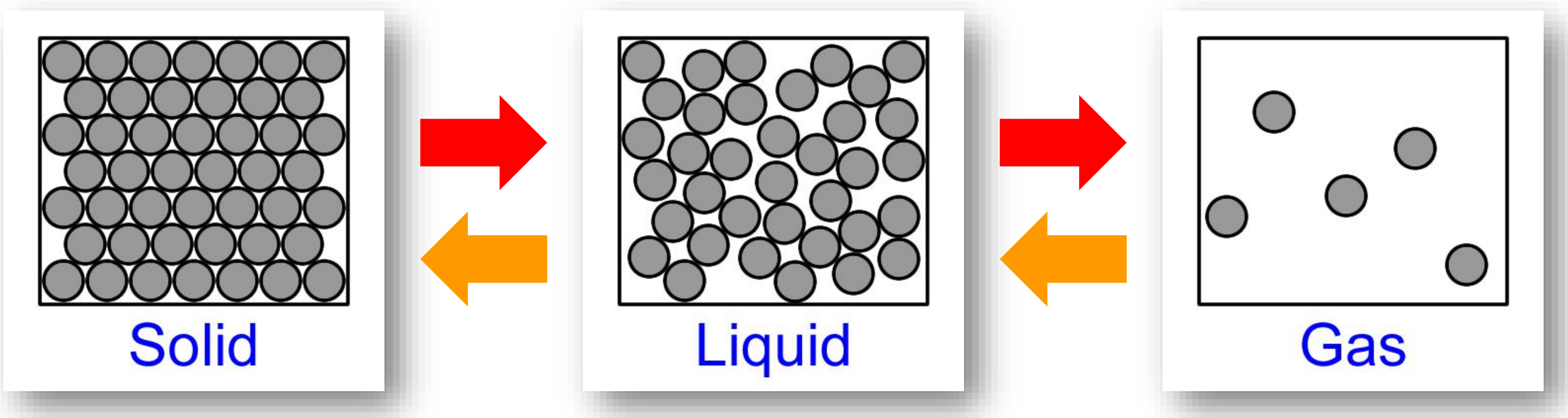
Kinetic Particle Theory – Models

- The sublimation and deposition of iodine.



Kinetic Particle Theory – Models

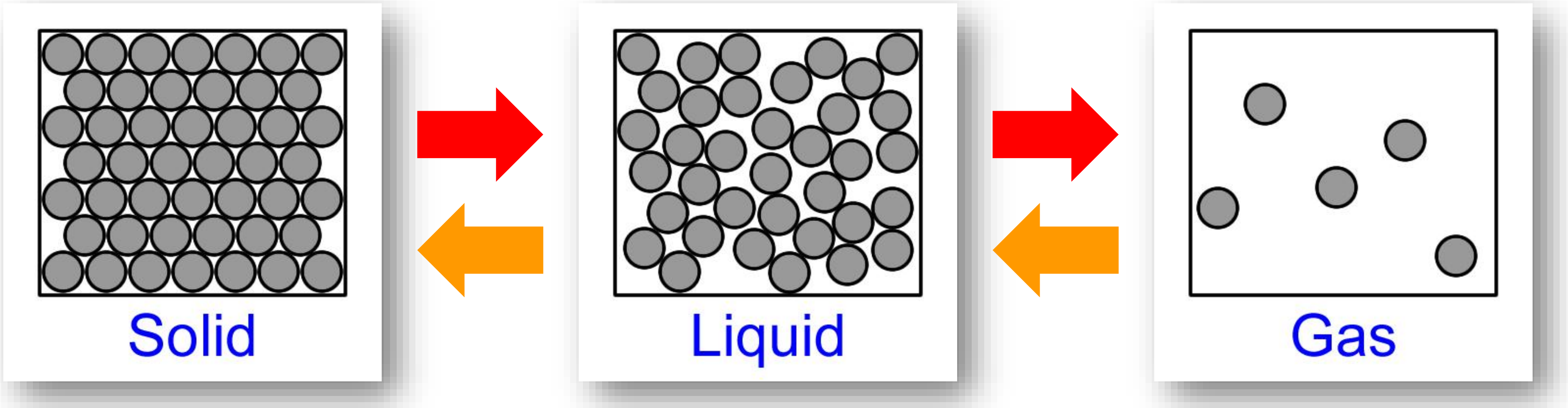
- **Melting and boiling**: Energy moves *into* the system to increase the average kinetic energy of the particles and weaken / overcome the force of attraction between them (*endothermic*).



- **Condensing and solidifying**: Energy moves *out* of the system as the particles' average kinetic energy decreases and the force of attraction between them increases (*exothermic*).

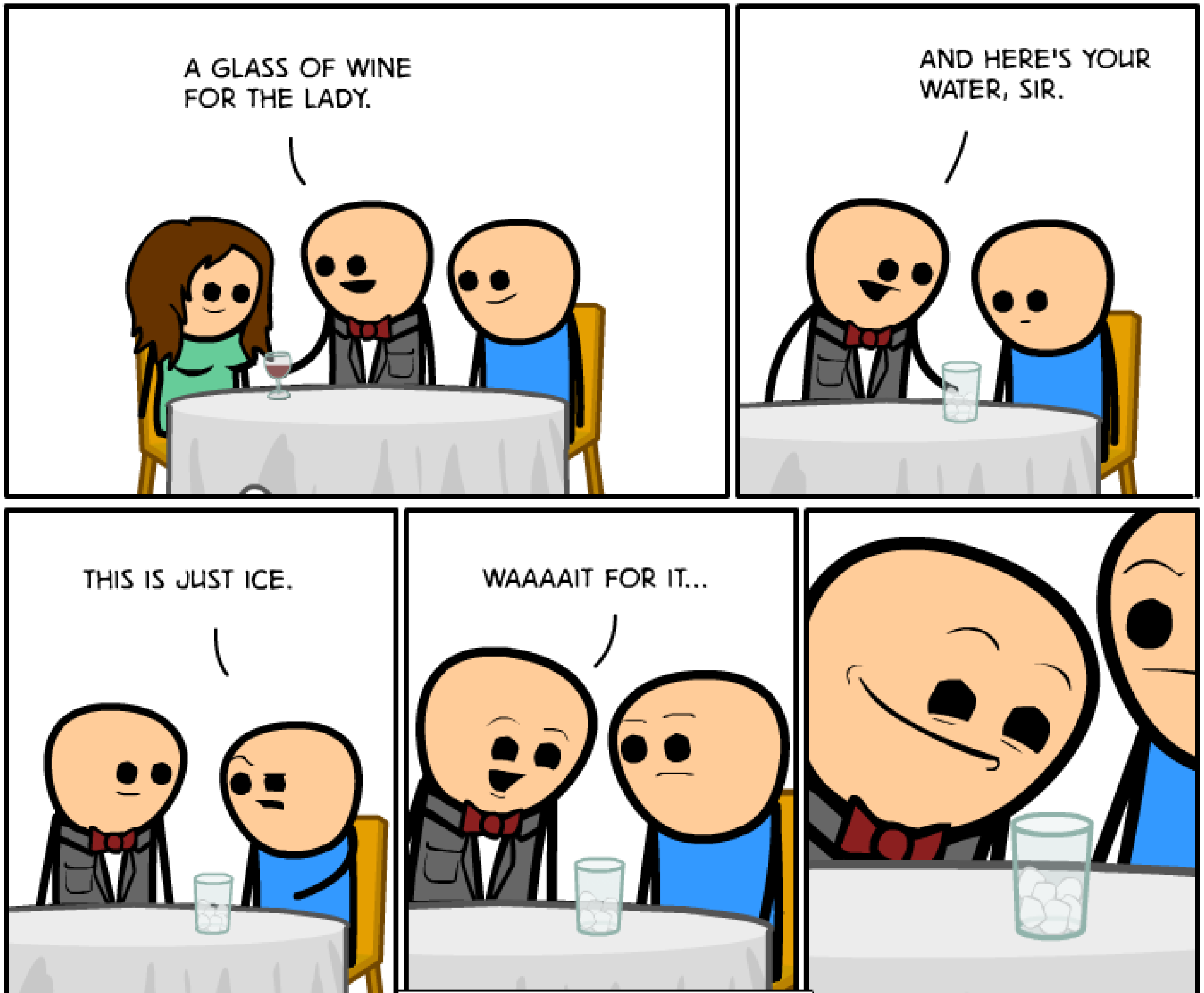
Kinetic Particle Theory – Models

- **Example**: When a doctor wipes an alcohol swab on your arm, your arm feels cold. This is because the alcohol absorbs energy from your skin as it evaporates.



- **Example**: If your hand comes into contact with steam from a kettle of boiling water, your hand will be scalded. This is because the steam releases energy as it condenses on your skin.

Kinetic Particle Theory – Models



Cyanide and Happiness

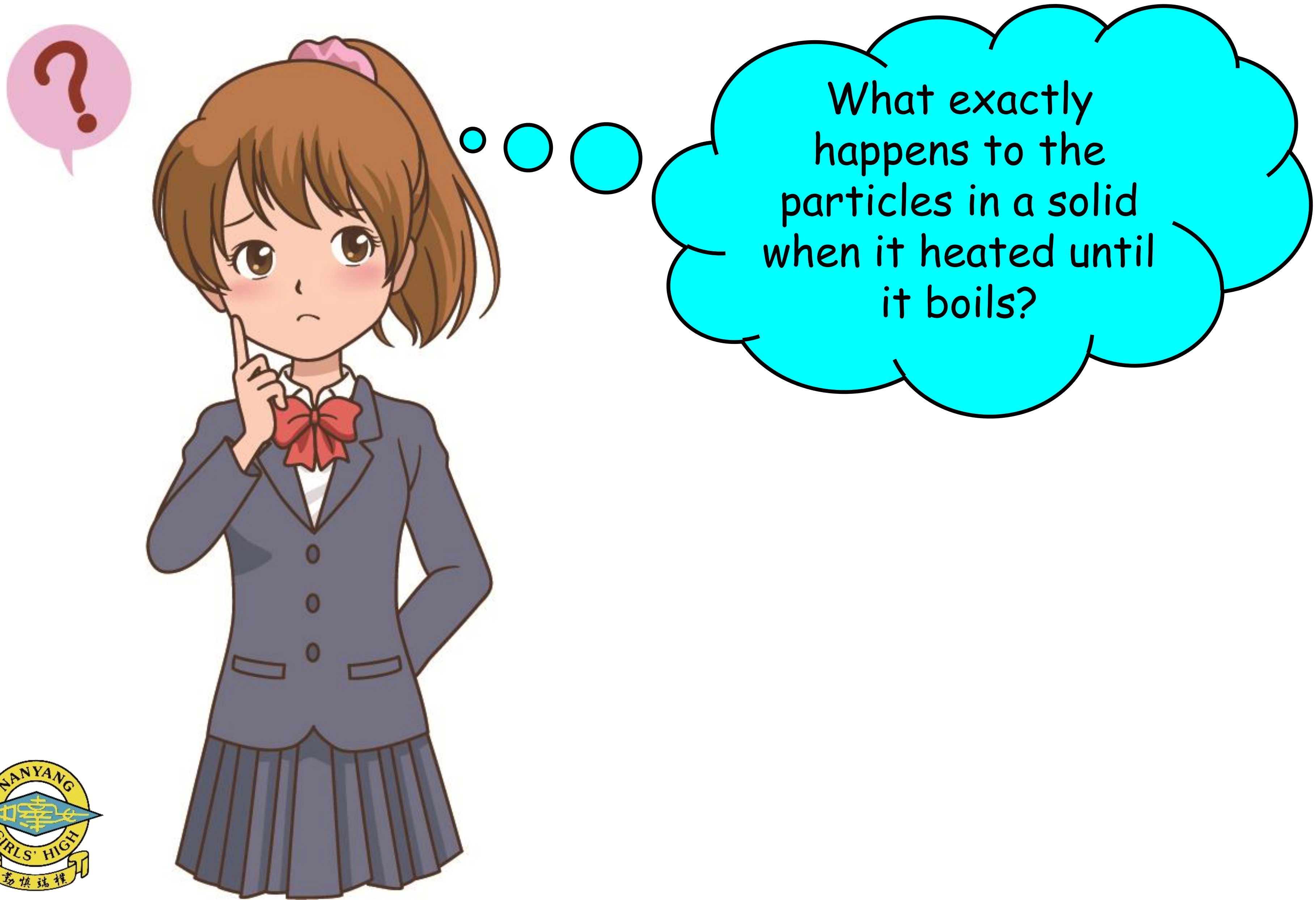
Kinetic Particle Theory – Models

Are boiling and evaporating the same?

Kinetic Particle Theory – Models

- Boiling and evaporation are *both* physical changes that involve a liquid changing into a gas.
- Boiling and evaporation *both* absorb energy from the surroundings as the relatively low energy molecules in the liquid state change into relatively high energy molecules in the gaseous state.
- *Evaporation* occurs from the surface of the liquid and can occur at any temperature between the melting point and boiling point of the chemical.
- *Boiling* occurs throughout the bulk of the liquid and occurs at a specific temperature (boiling point) at atmospheric pressure.

Kinetic Particle Theory – Models



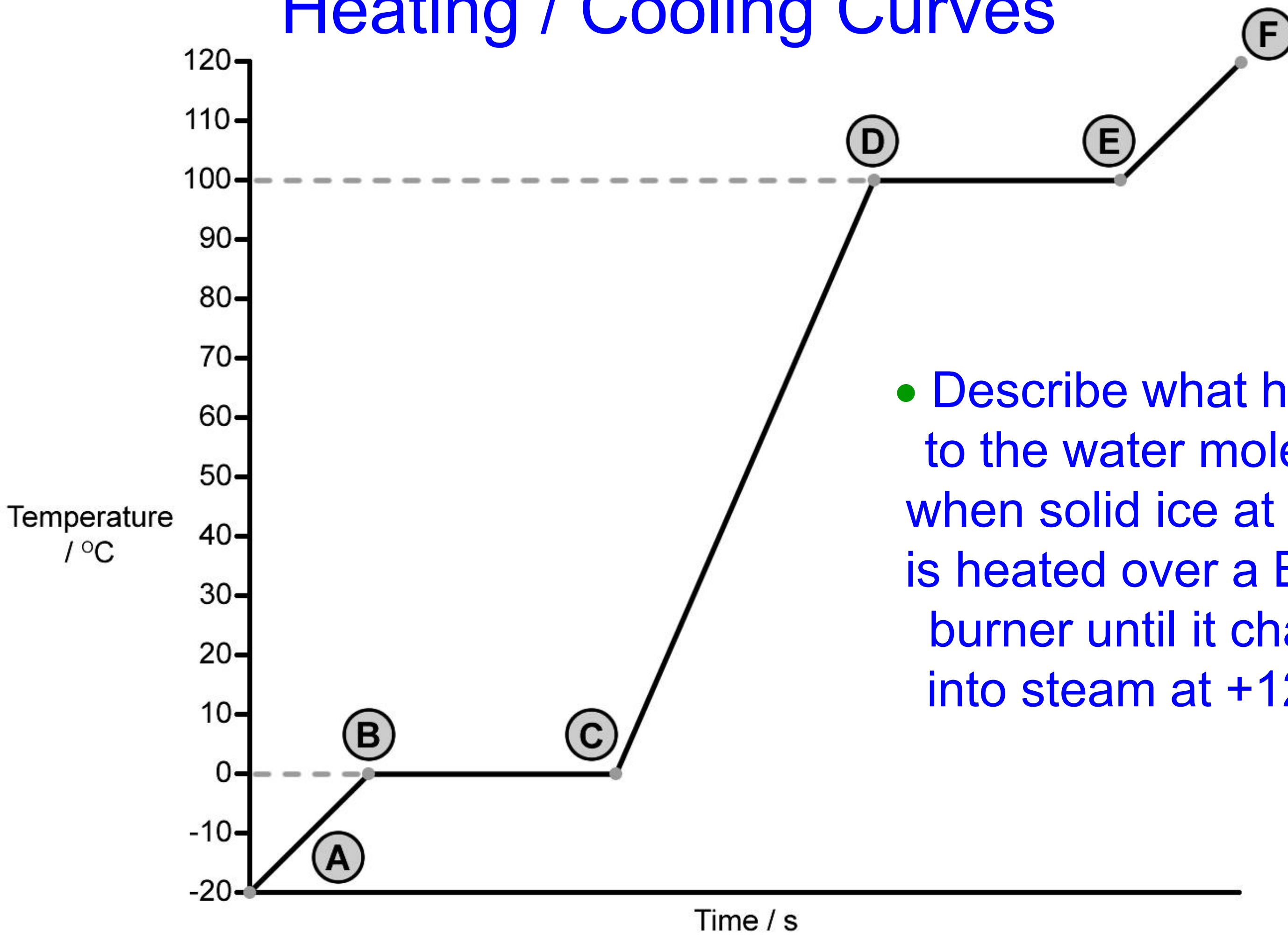
Kinetic Particle Theory – Models

Kinetic Particle Theory – Models

- Imagine heating ice over a Bunsen burner.
- The temperature of the ice increases from –20 °C until it has completely changed into steam at +120 °C.
- What is the heat energy from the Bunsen burner used to do? What changes does it cause to happen?
- What changes happen to the average kinetic energy of the H_2O molecules and the forces of attraction between them?

Kinetic Particle Theory – Models

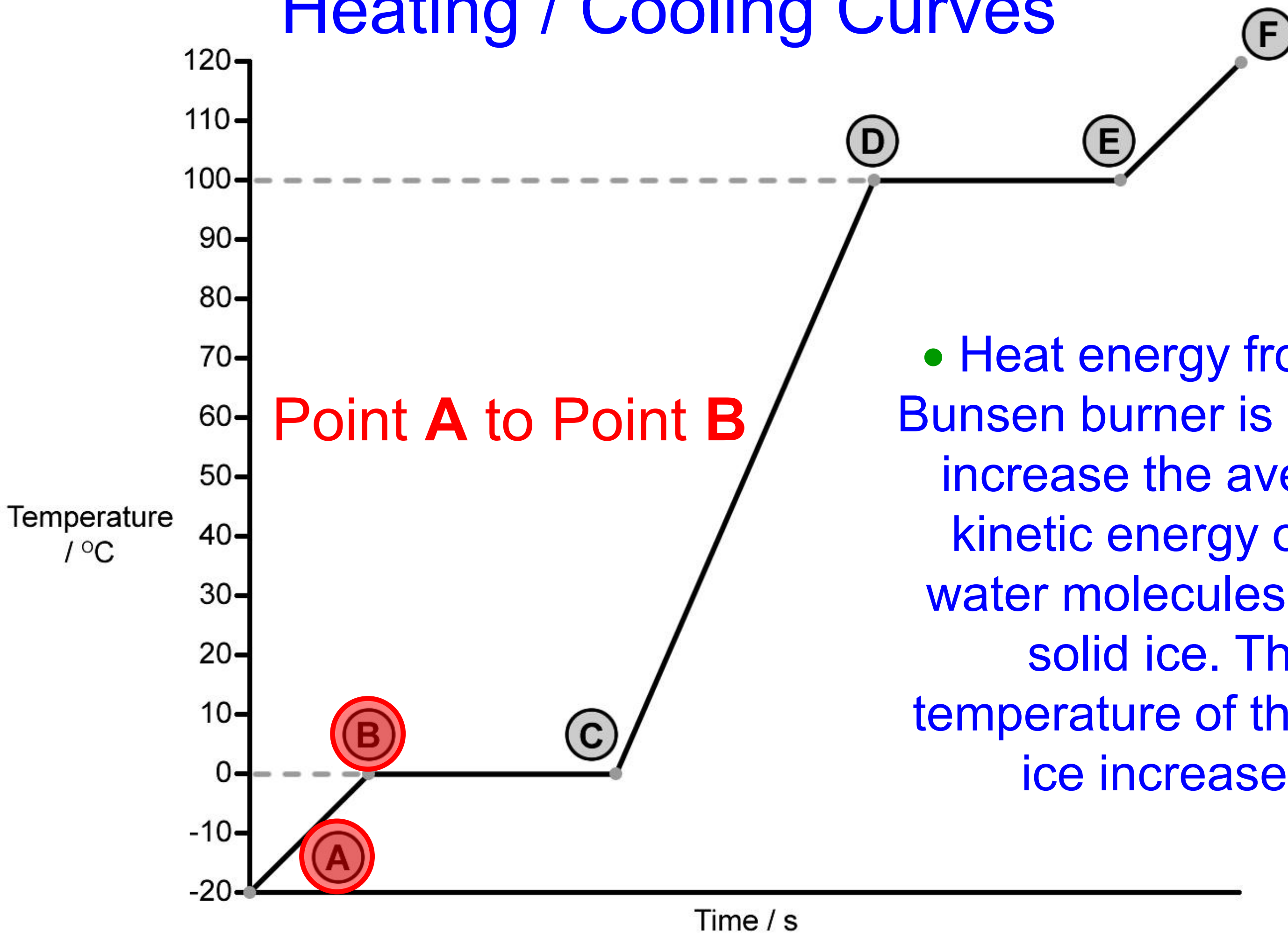
Heating / Cooling Curves



- Describe what happens to the water molecules when solid ice at −20 °C is heated over a Bunsen burner until it changes into steam at +120 °C.

Kinetic Particle Theory – Models

Heating / Cooling Curves

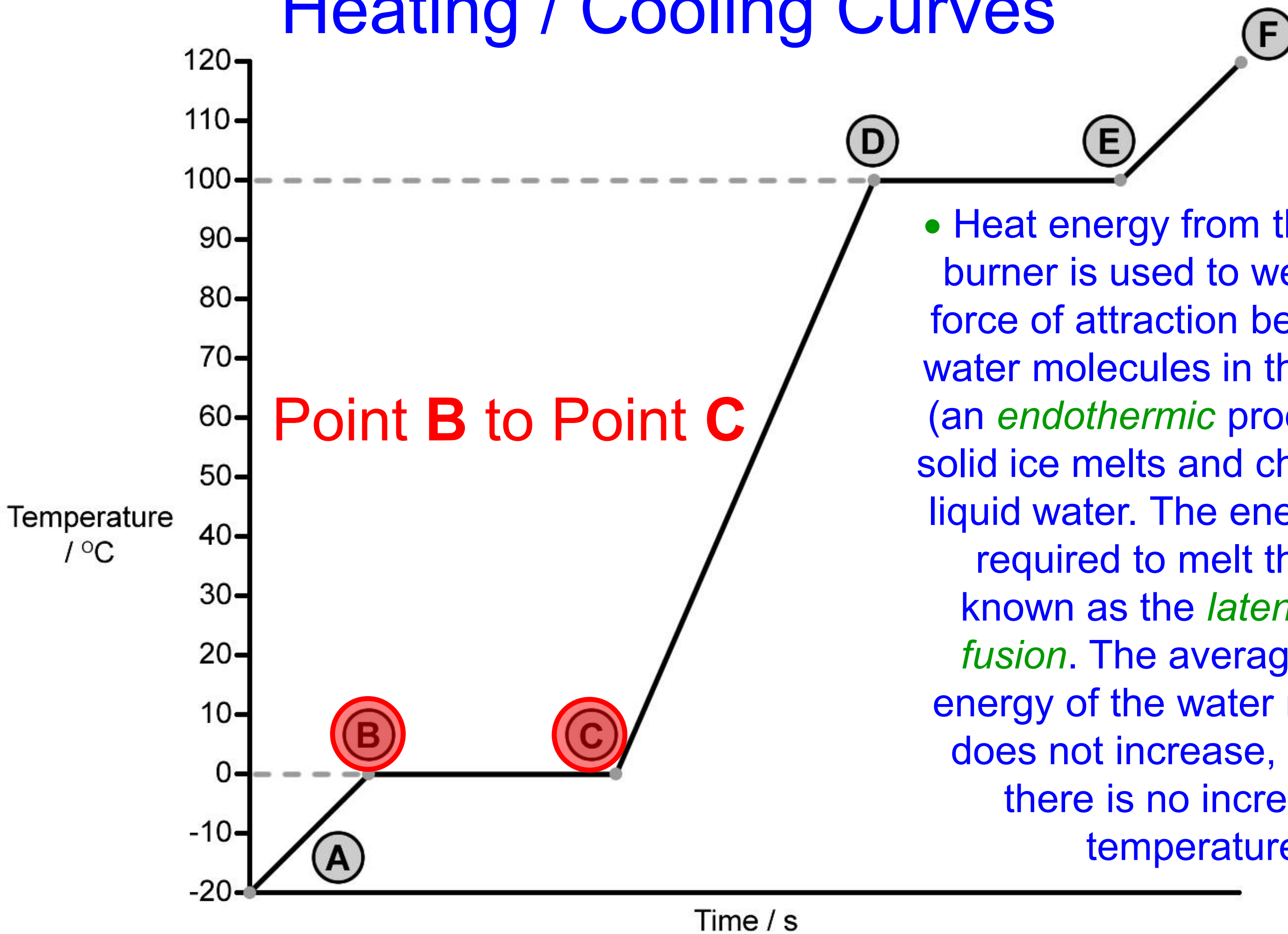


Point **A** to Point **B**

- Heat energy from the Bunsen burner is used to increase the average kinetic energy of the water molecules in the solid ice. The temperature of the solid ice increases.

Kinetic Particle Theory – Models

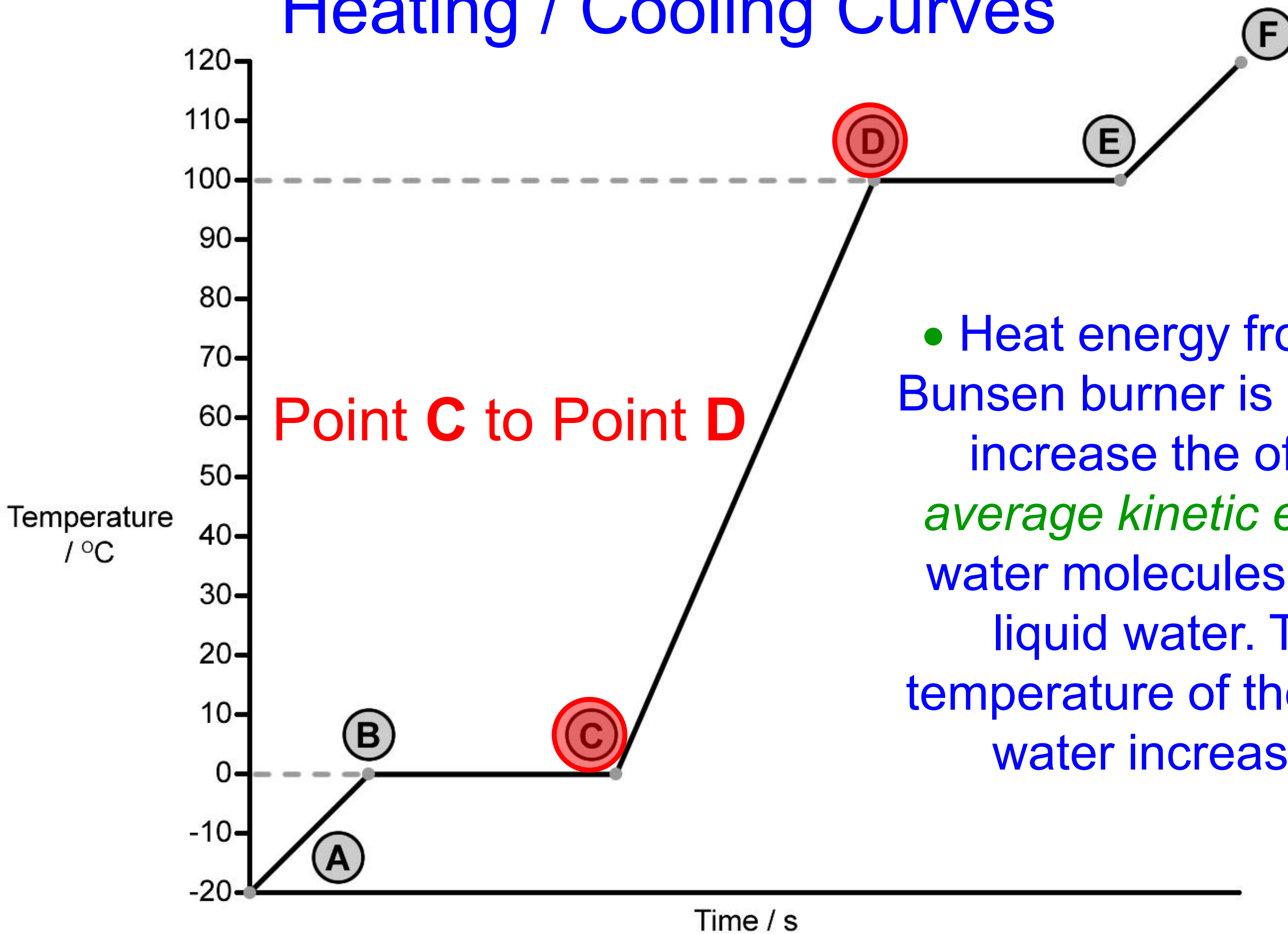
Heating / Cooling Curves



- Heat energy from the Bunsen burner is used to weaken the force of attraction between the water molecules in the solid ice (an *endothermic* process). The solid ice melts and changes into liquid water. The energy that is required to melt the ice is known as the *latent heat of fusion*. The average kinetic energy of the water molecules does not increase, therefore there is no increase in temperature.

Kinetic Particle Theory – Models

Heating / Cooling Curves

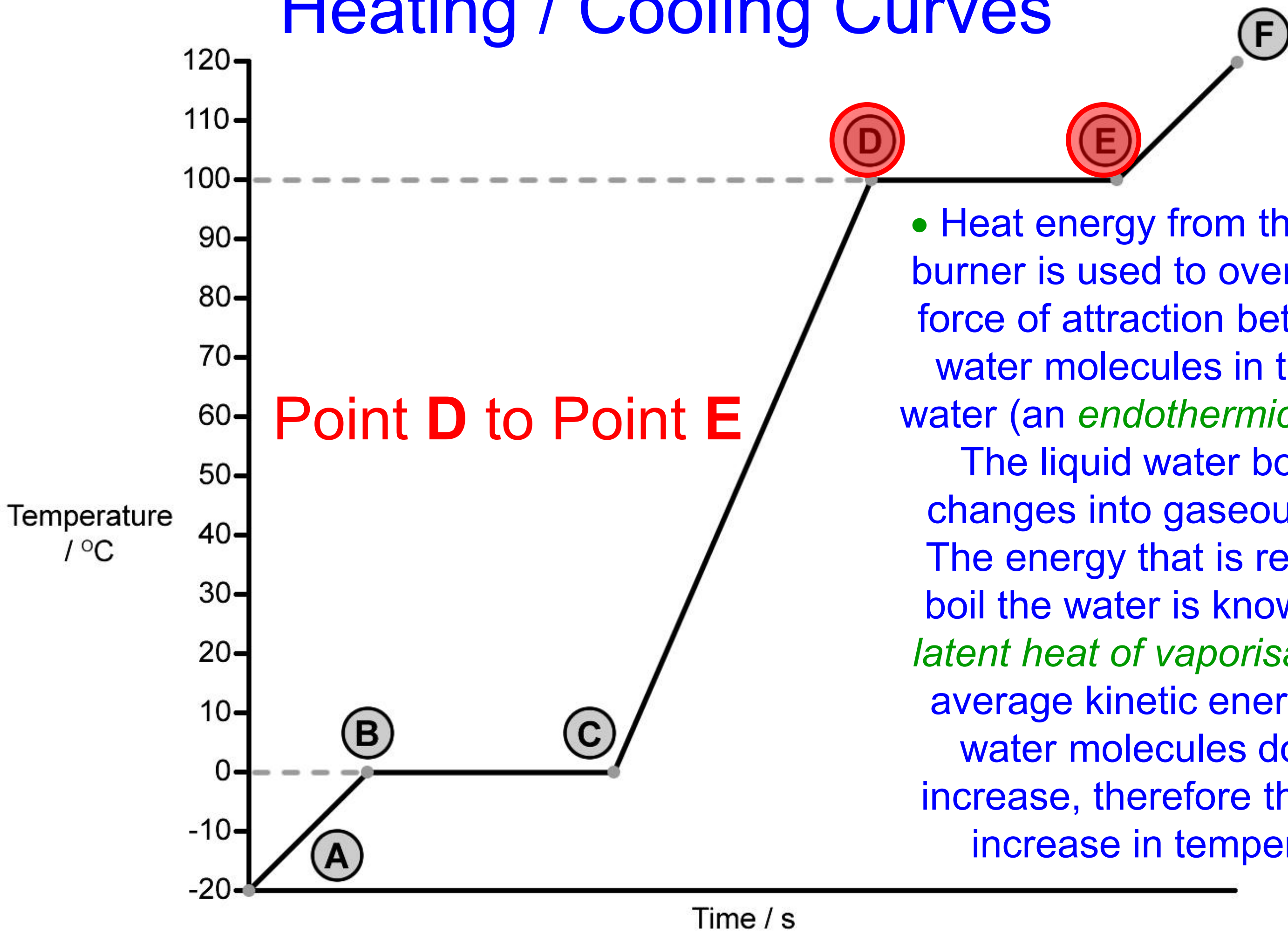


Point **C** to Point **D**

- Heat energy from the Bunsen burner is used to increase the of the *average kinetic energy* water molecules in the liquid water. The temperature of the liquid water increases.

Kinetic Particle Theory – Models

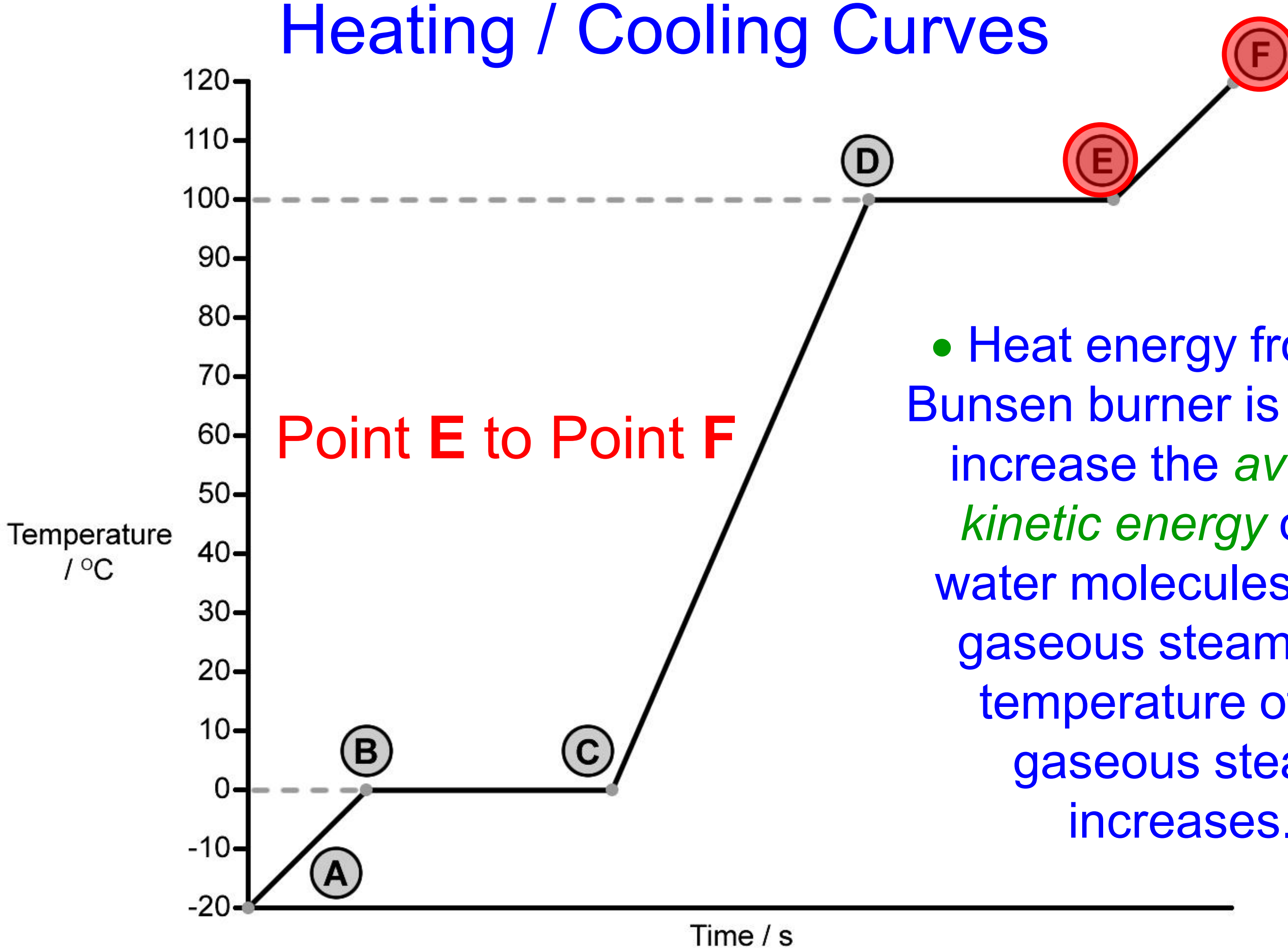
Heating / Cooling Curves



- Heat energy from the Bunsen burner is used to overcome the force of attraction between the water molecules in the liquid water (an *endothermic* process). The liquid water boils and changes into gaseous steam. The energy that is required to boil the water is known as the *latent heat of vaporisation*. The average kinetic energy of the water molecules does not increase, therefore there is no increase in temperature.

Kinetic Particle Theory – Models

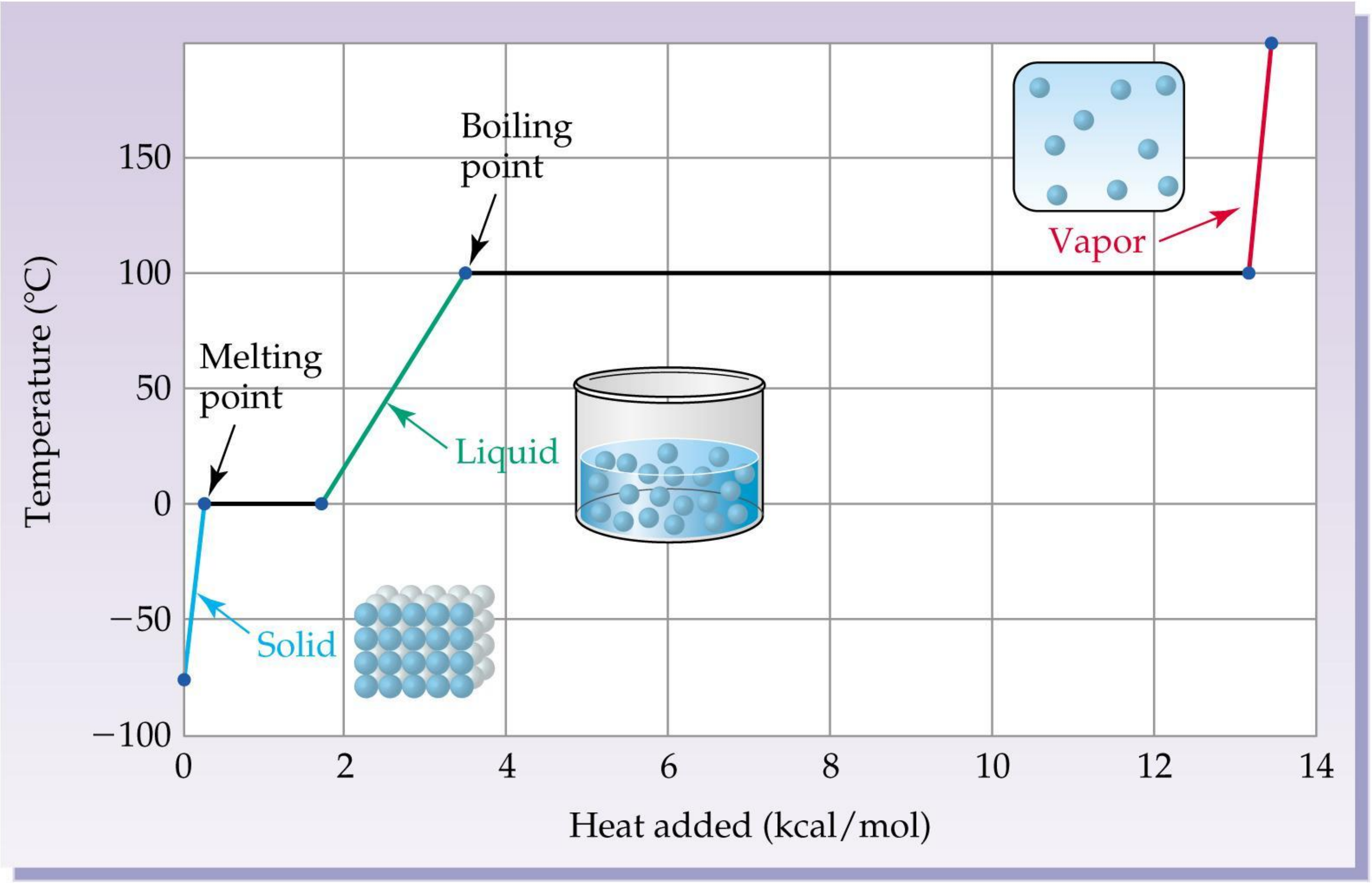
Heating / Cooling Curves



- Heat energy from the Bunsen burner is used to increase the *average kinetic energy* of the water molecules in the gaseous steam. The temperature of the gaseous steam increases.

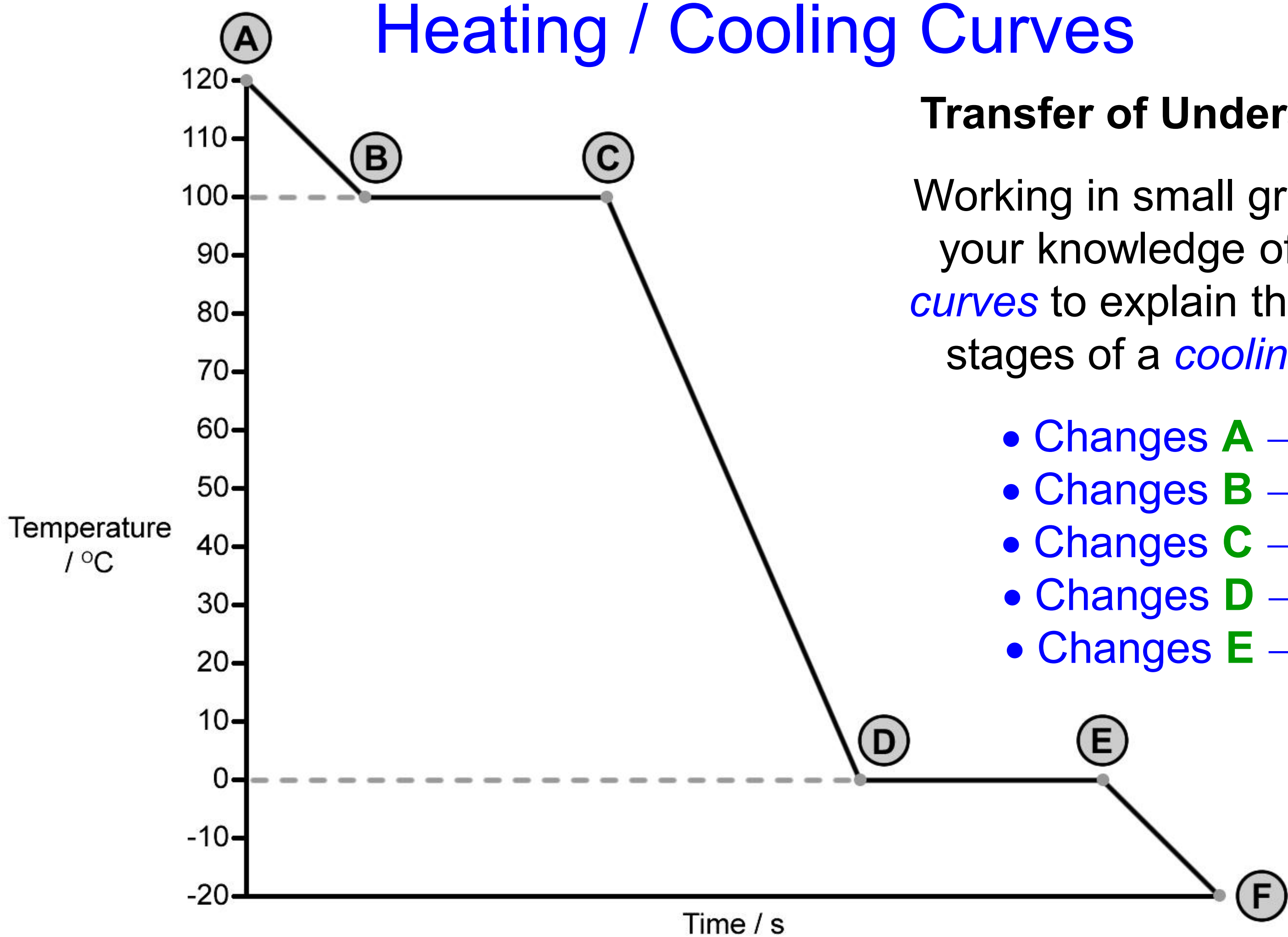
Kinetic Particle Theory – Models

Heating / Cooling Curves



Kinetic Particle Theory – Models

Heating / Cooling Curves



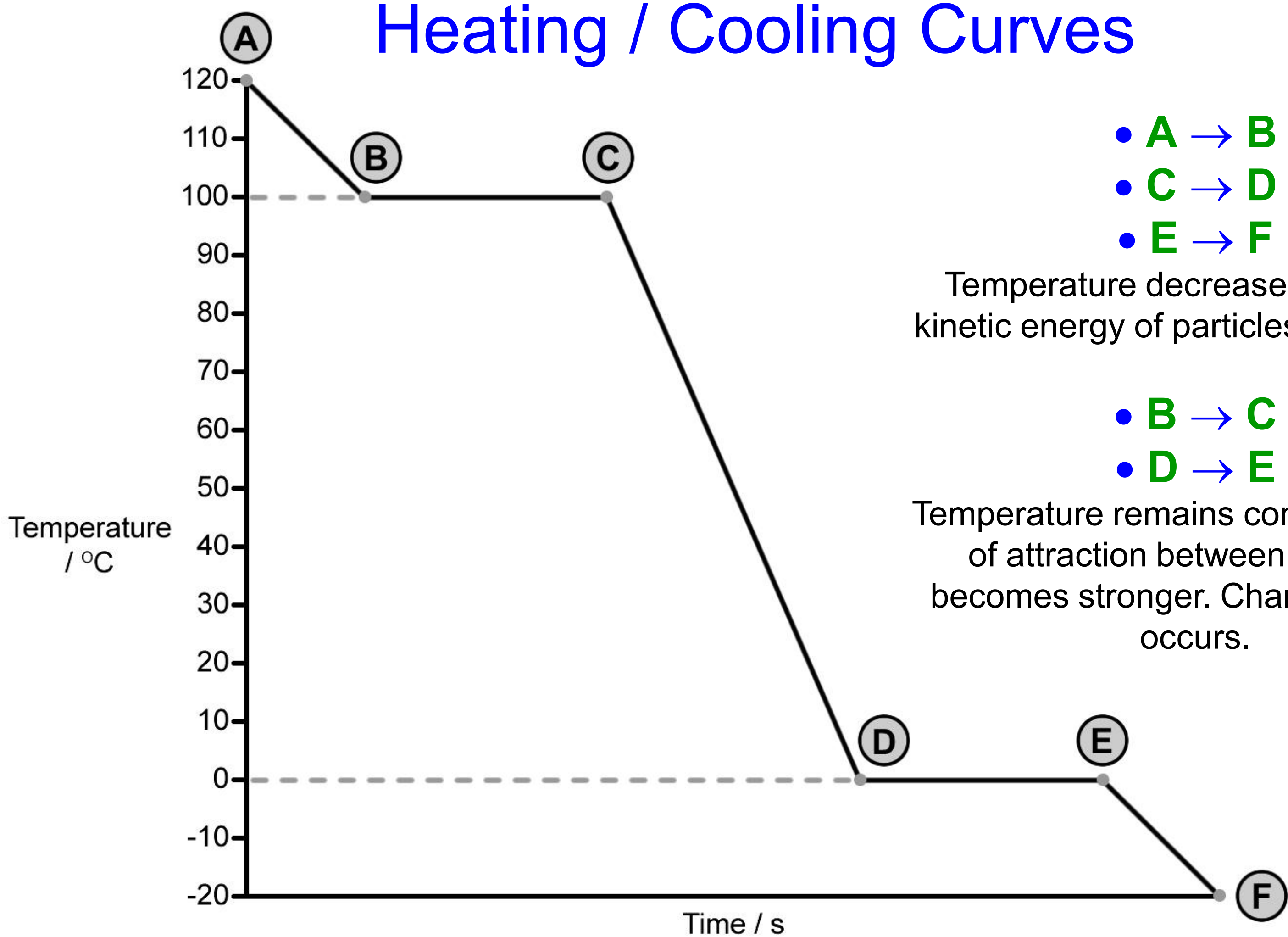
Transfer of Understanding

Working in small groups, use your knowledge of *heating curves* to explain the different stages of a *cooling curve*.

- Changes **A** → **B** ?
- Changes **B** → **C** ?
- Changes **C** → **D** ?
- Changes **D** → **E** ?
- Changes **E** → **F** ?

Kinetic Particle Theory – Models

Heating / Cooling Curves



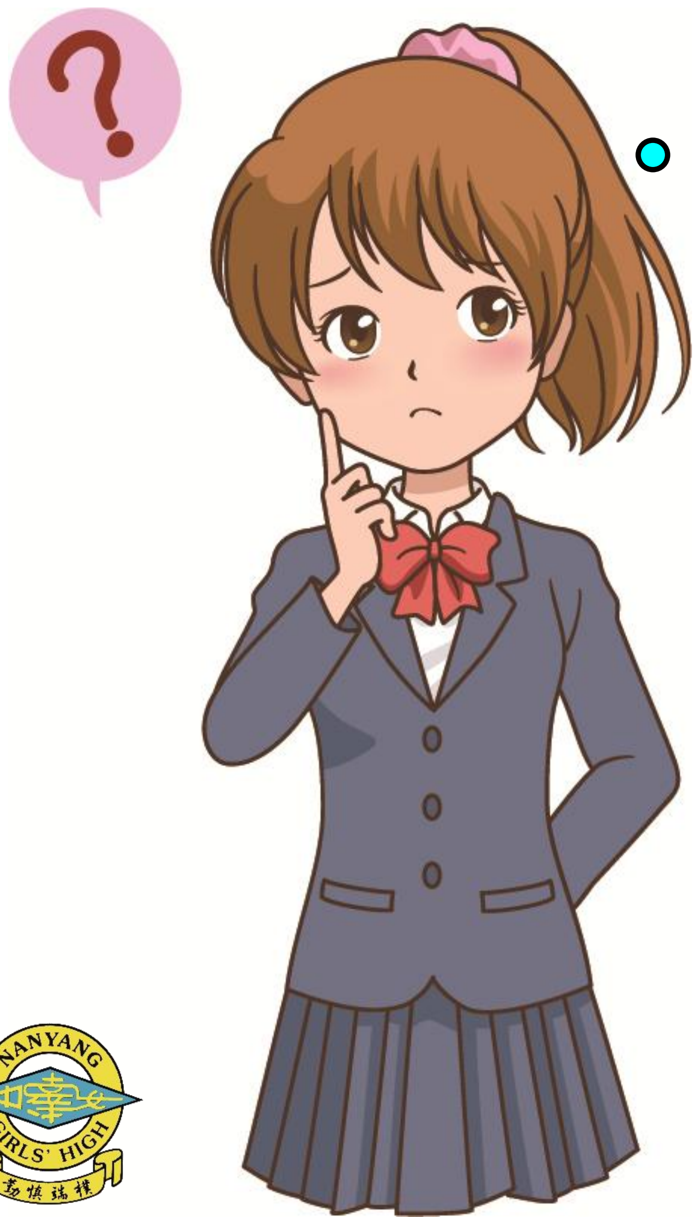
- A → B
- C → D
- E → F

Temperature decreases. Average kinetic energy of particles decreases.

- B → C
- D → E

Temperature remains constant. Force of attraction between particles becomes stronger. Change in state occurs.

Kinetic Particle Theory – Models



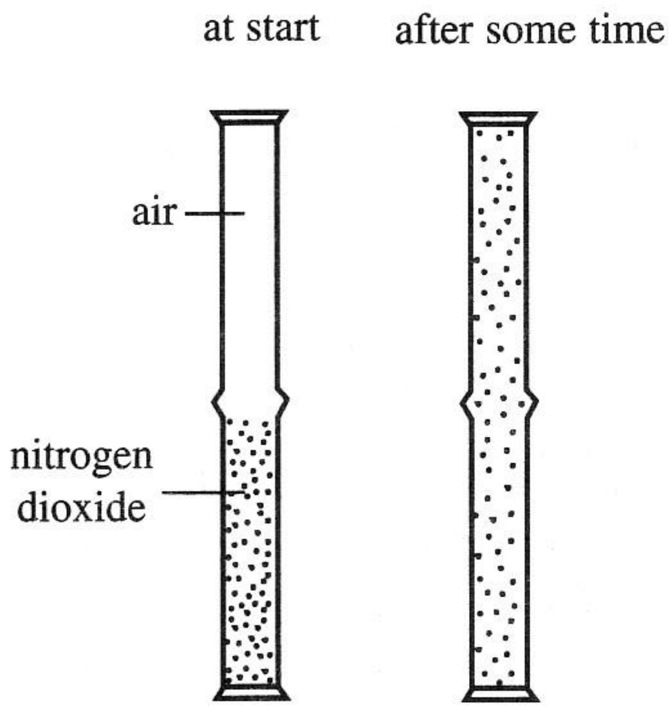
What is diffusion?

What are some examples of diffusion?

Kinetic Particle Theory – Models

Diffusion

- *Diffusion* is the *net movement* of a gas (or chemical in solution) from a region of *higher concentration* to a region of *lower concentration*.



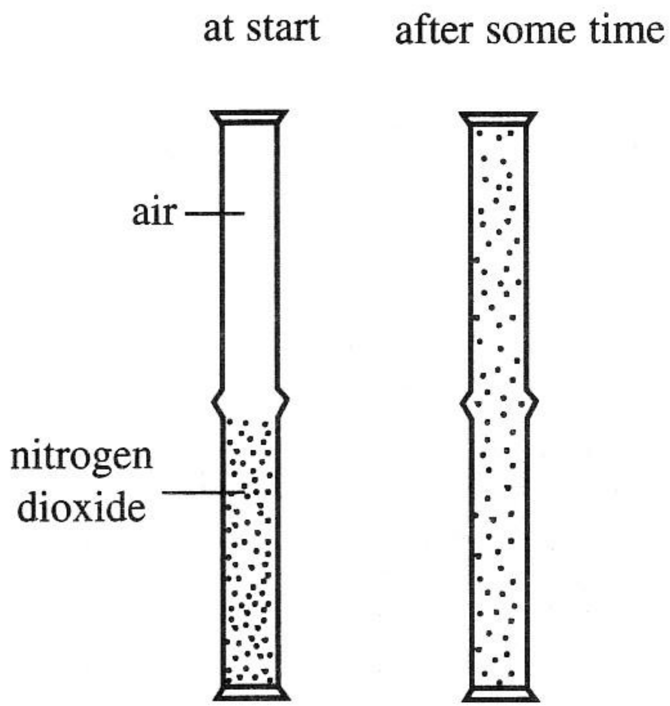
- *Diffusion* occurs due to the constant random movement of the gas particles.

- *Diffusion* is often cited as evidence that matter is composed of tiny particles in a constant state of motion.

Kinetic Particle Theory – Models

Diffusion

- *Diffusion* occurs until a system reaches *equilibrium*, and there are no longer any *concentration gradients*, *i.e.* no regions of high concentration and no regions of low concentration.



- When the system reaches *equilibrium*, and there are no longer any *concentration gradients*, then the system is said to be *homogeneous*, *i.e.* it has the same composition throughout. **Note**: Particles are still in a state of constant random motion.

Kinetic Particle Theory – Models

Kinetic Particle Theory – Models

- Reddish-brown bromine can be seen to diffuse from the gas jar at the bottom into the gas jar at the top.

- Note that the diffusion of bromine is not instantaneous because the gas jar at the top contains air (nitrogen and oxygen). The molecules of bromine collide with the molecules of nitrogen and oxygen, which obstructs and slows the movement of the bromine molecules.

Kinetic Particle Theory – Models

PHET Simulation – Diffusion

Kinetic Particle Theory – Models

- The aroma of a perfume spreading across a room is one example of *diffusion*.

Kinetic Particle Theory – Models

- What other examples of *diffusion* can you think of?
- In addition to *diffusion*, what other empirical evidence is there that all matter is composed of tiny particles that are in a constant state of motion?

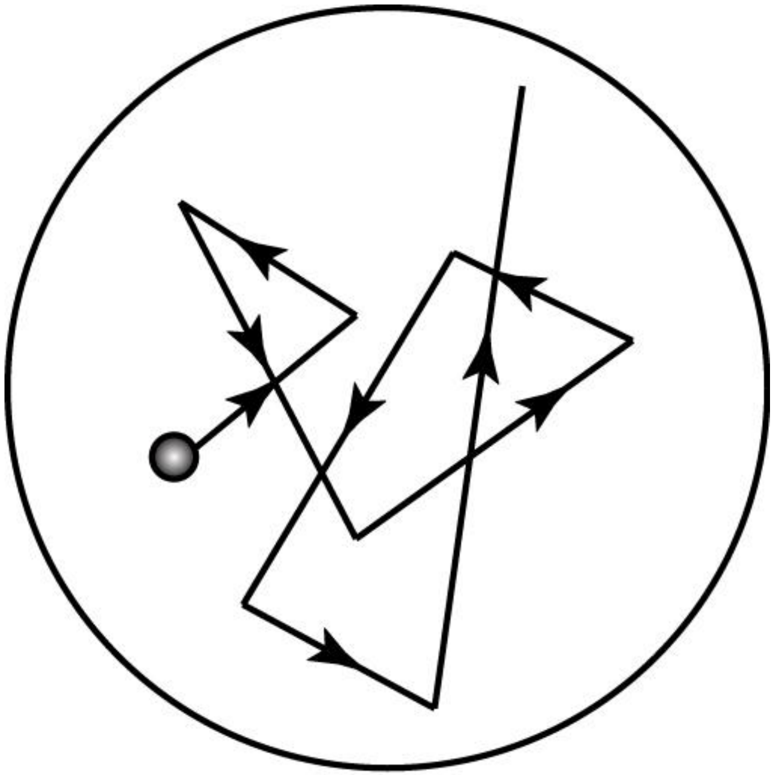
Kinetic Particle Theory – Models

- Detecting the aroma of fresh coffee from the kitchen when you are sitting in the living room is another example of *diffusion*.

Kinetic Particle Theory – Models

- The coloured chemicals present in tea (pheophytins) can be seen to *dissolve* and then *diffuse* into a cup of hot water, until the colour is *homogeneous* throughout.

Kinetic Particle Theory – Models



Brownian Motion

- *Brownian Motion* is further evidence that particles are in a *constant state* of *random motion*.
- The phenomenon is named after the botanist Robert Brown, who in 1827, used a microscope to observe pollen grains suspended on the surface of a water droplet.

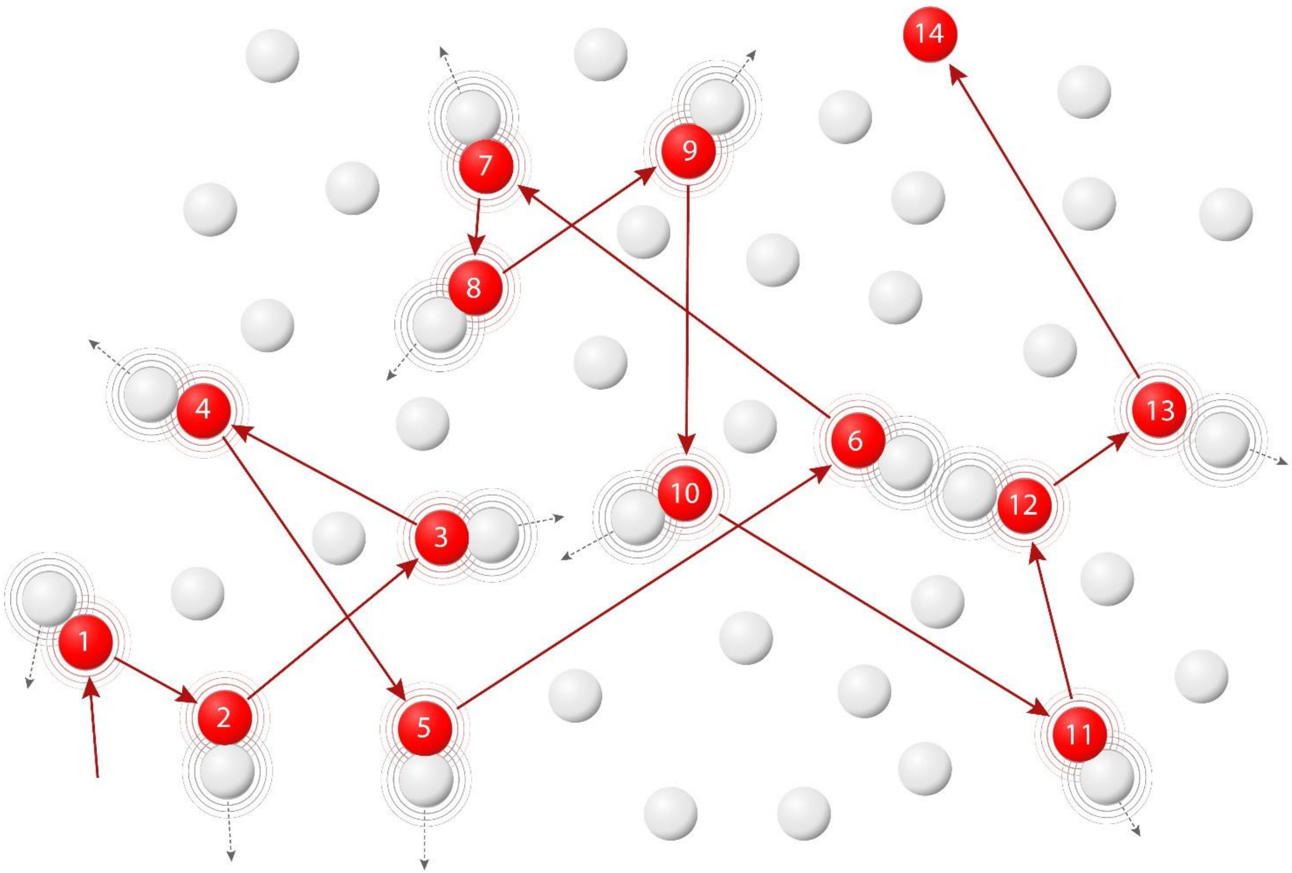
Kinetic Particle Theory – Models

- Robert Brown was frustrated that the pollen grains did not remain stationary on the surface of the water droplet, but were *constantly moving* in a *random manner*.

- This is evidence that water molecules are in a *constant state* of *random motion*. When the water molecules *collide* with the pollen grains, they exert a force on the pollen grains and “push” them around in a random manner.

Kinetic Particle Theory – Models

Brownian motion



Kinetic Particle Theory – Models

- Why are durians banned on Singapore's buses and trains?

Kinetic Particle Theory – Models

Kinetic Particle Theory – Models

- Some people have a deep appreciation for the smell of the durian, which they describe as sweet and fragrant. Others find the aroma overpowering and revolting.
- The fragrant molecules that are responsible for the durian's smell *diffuse* from a *region of high concentration* to a *region of lower concentration*, *i.e.* throughout the bus or train carriage.
- The consequence is that everybody on the bus or train will eventually be able to smell the durian, whether they like the aroma or not.

Kinetic Particle Theory – Models

Do all gases diffuse at the same rate?

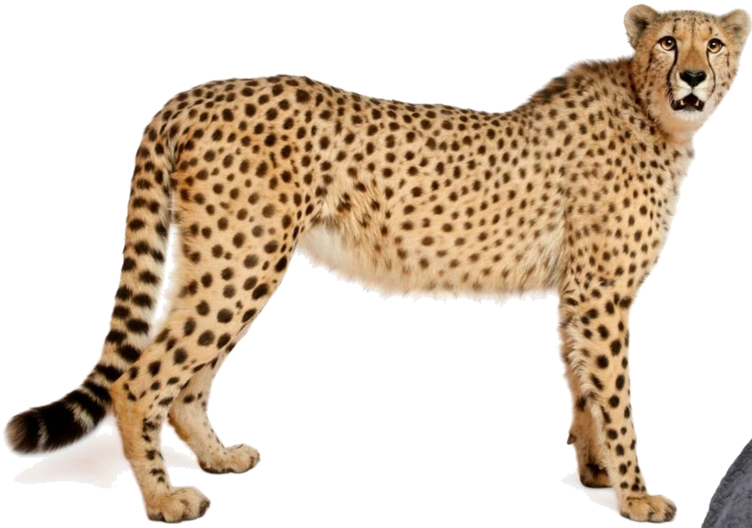
- Consider the information on the following slides to help you decide.

Kinetic Particle Theory – Models

Which one is the *fastest*?

Explain your reasoning.

Kinetic Particle Theory – Models



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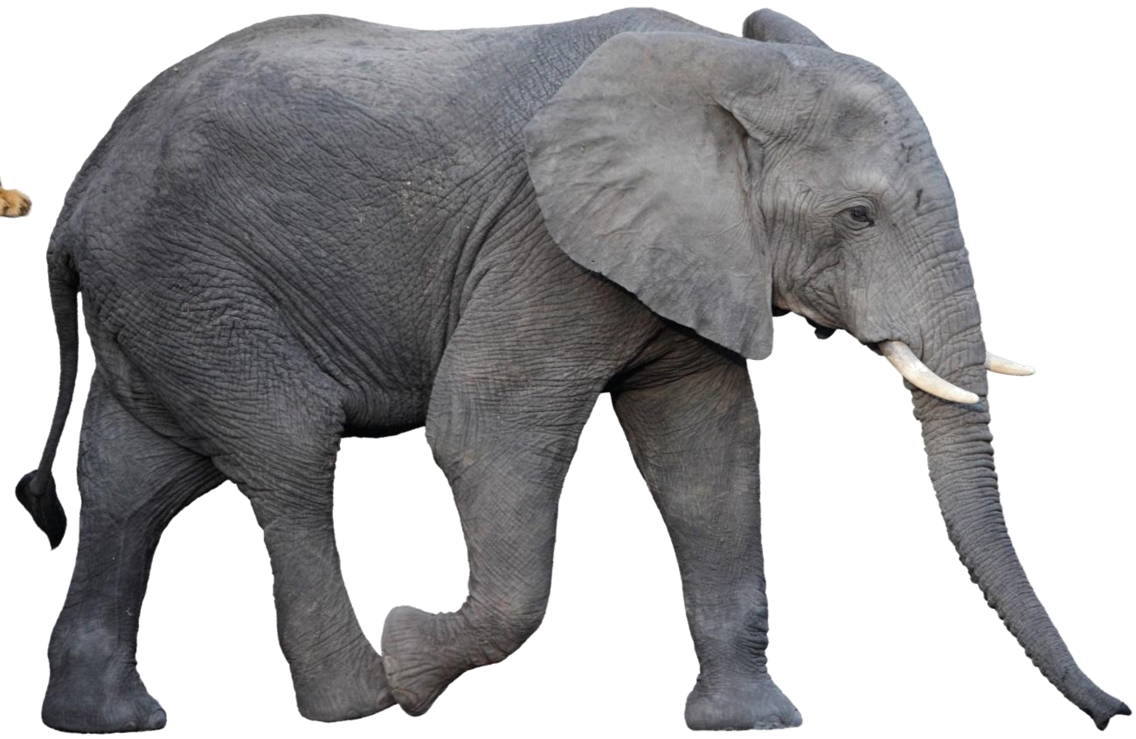
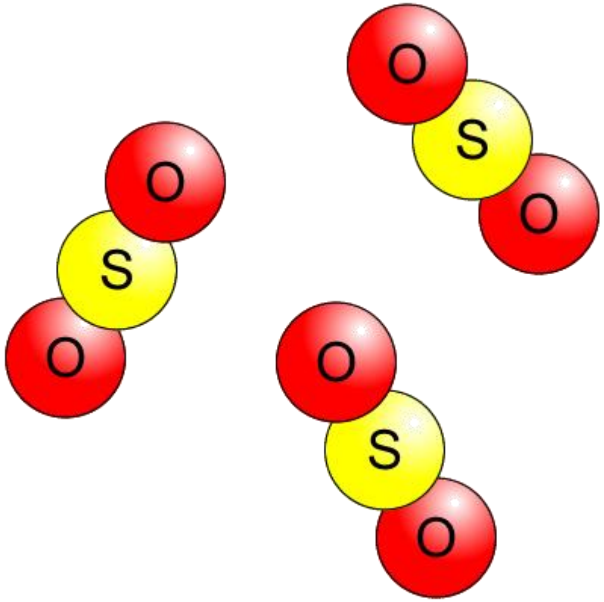
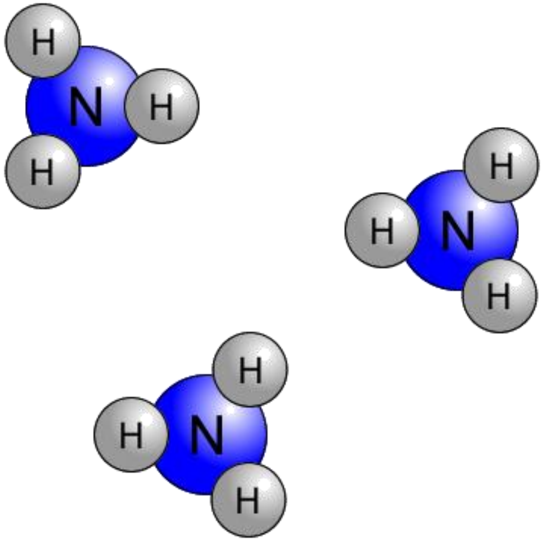


Kinetic Particle Theory – Models

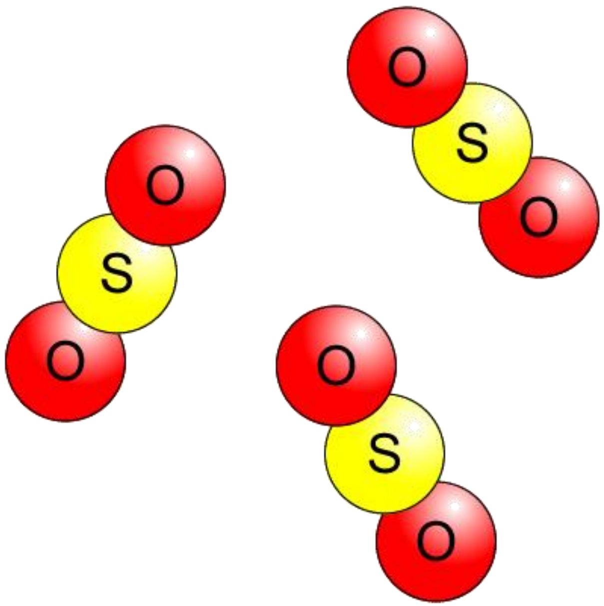
Which one is the *fastest* ? Explain your reasoning.

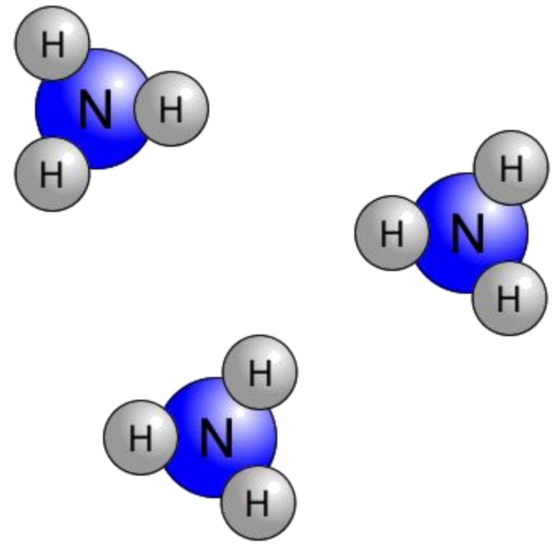




Kinetic Particle Theory – Models

Which one is the *fastest* ? Explain your reasoning.





Hint: The relative molecular mass (M_r) of sulfur dioxide (formula: SO_2) is…

$M_r = A_r[S] + A_r[O] + A_r[O]$

$M_r = 32.0 + 16.0 + 16.0 = \mathbf{64.0}$

Hint: The relative molecular mass (M_r) of ammonia (formula: NH_3) is…

$M_r = A_r[N] + A_r[H] + A_r[H] + A_r[H]$

$M_r = 14.0 + 1.0 + 1.0 + 1.0 = \mathbf{17.0}$

Note: A_r is the *relative atomic mass* of the chemical element. The value is taken from the Periodic Table. *Relative molecular mass* or M_r is a dimensionless unit that is used to represent the mass of a molecule or one mole of molecules.

Kinetic Particle Theory – Models

- The *greater* the relative molecular mass of a gas, the *slower* the rate at which the gas will diffuse.
- The *smaller* the relative molecular mass of a gas, the *faster* the rate at which the gas will diffuse.
- Place the following three gases in the order in which they will diffuse, from the *fastest* to the *slowest*.

- Chlorine – Cl_2
- Hydrogen – H_2
- Methane – CH_4

- A_r [C] = 12.0
- A_r [C*l*] = 35.5
- A_r [H] = 1.0

Kinetic Particle Theory – Models

- The *greater* the relative molecular mass of a gas, the *slower* the rate at which the gas will diffuse.
- The *smaller* the relative molecular mass of a gas, the *faster* the rate at which the gas will diffuse.
- Place the following three gases in the order in which they will diffuse, from the *fastest* to the *slowest*.

← Fastest → ← Rate of Diffusion → ← Slowest →

- Hydrogen – H_2
  $2 \times 1 =$ **2**
- Methane – CH_4
  $12 + (4 \times 1) =$ **16**
- Chlorine – Cl_2
  $2 \times 35.5 =$ **71**

Kinetic Particle Theory – Models

- *Graham's Law* allows us to compare the rates at which two different gases diffuse at the same temperature.

$$\frac{rate\ of\ diffusion\ gas\ 1}{rate\ of\ diffusion\ gas\ 2} = \frac{\sqrt{relative\ molecular\ mass\ gas\ 2}}{\sqrt{relative\ molecular\ mass\ gas\ 1}}$$

- For example, compare the rates at which H_2 gas (M_r = 2) and O_2 gas (M_r = 32) diffuse.

$$\frac{rate\ H_2}{rate\ O_2} = \frac{\sqrt{32}}{\sqrt{2}} = \frac{\sqrt{16}}{\sqrt{1}} = \frac{4}{1}$$

- Therefore H_2 gas diffuses *four* times faster than O_2 gas.

Kinetic Particle Theory – Models

Fastest?

Sulfur Dioxide – $SO_{2(g)}$

Water Vapour – $H_2O_{(g)}$

Carbon Dioxide – $CO_{2(g)}$

Oxygen – $O_{2(g)}$

Ammonia – $NH_{3(g)}$

Chlorine – $Cl_{2(g)}$

Nitrogen Dioxide – $NO_{2(g)}$

Hydrogen – $H_{2(g)}$

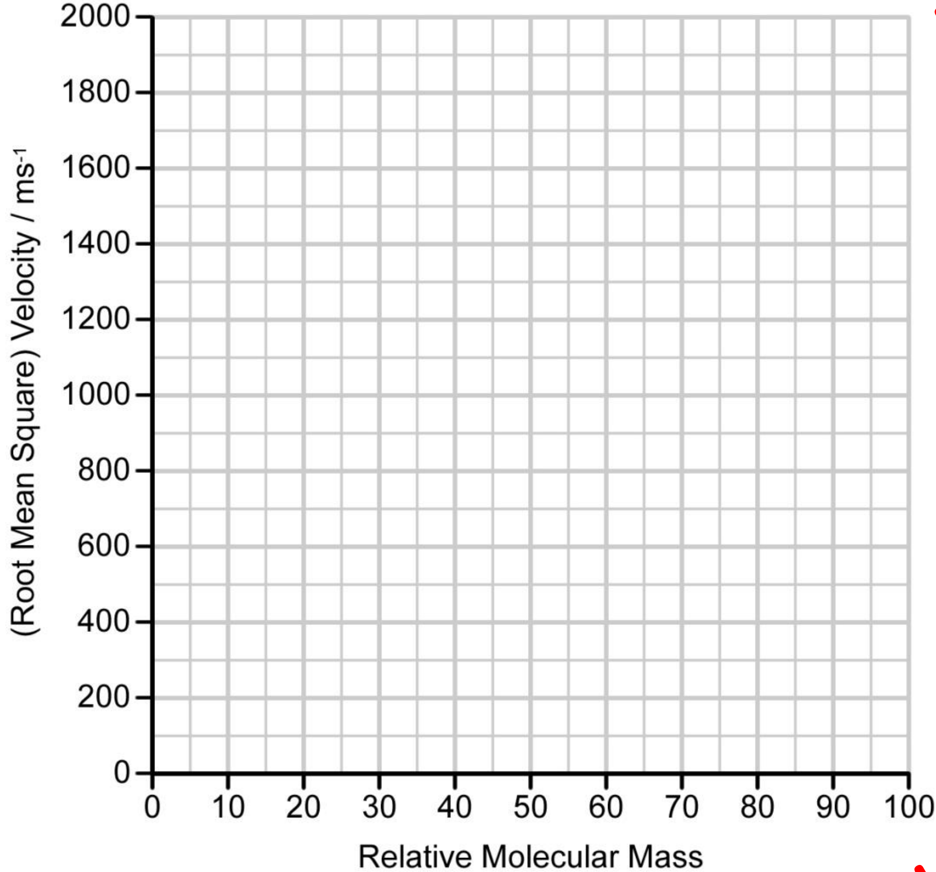
Methane – $CH_{4(g)}$

Nitrogen – $N_{2(g)}$

Slowest?

Kinetic Particle Theory – Models

Graph to Show How (Root Mean Square) Velocity of a Molecule in the Gas Phase Varies with Relative Molecular Mass



Fastest

Hydrogen – $H_{2(g)}$
M_r = 1.0 + 1.0 = 2.0

Methane – $CH_{4(g)}$
M_r = 12.0 + (4 × 1.0) = 16.0

Ammonia – $NH_{3(g)}$
M_r = 14.0 + (3 × 1.0) = 17.0

Water Vapour – $H_2O_{(g)}$
M_r = 16.0 + (2 × 1.0) = 18.0

Nitrogen – $N_{2(g)}$
M_r = 2 × 14.0 = 28.0

Oxygen – $O_{2(g)}$
M_r = 2 × 16.0 = 32.0

Carbon Dioxide – $CO_{2(g)}$
M_r = 12.0 + (2 × 16.0) = 44.0

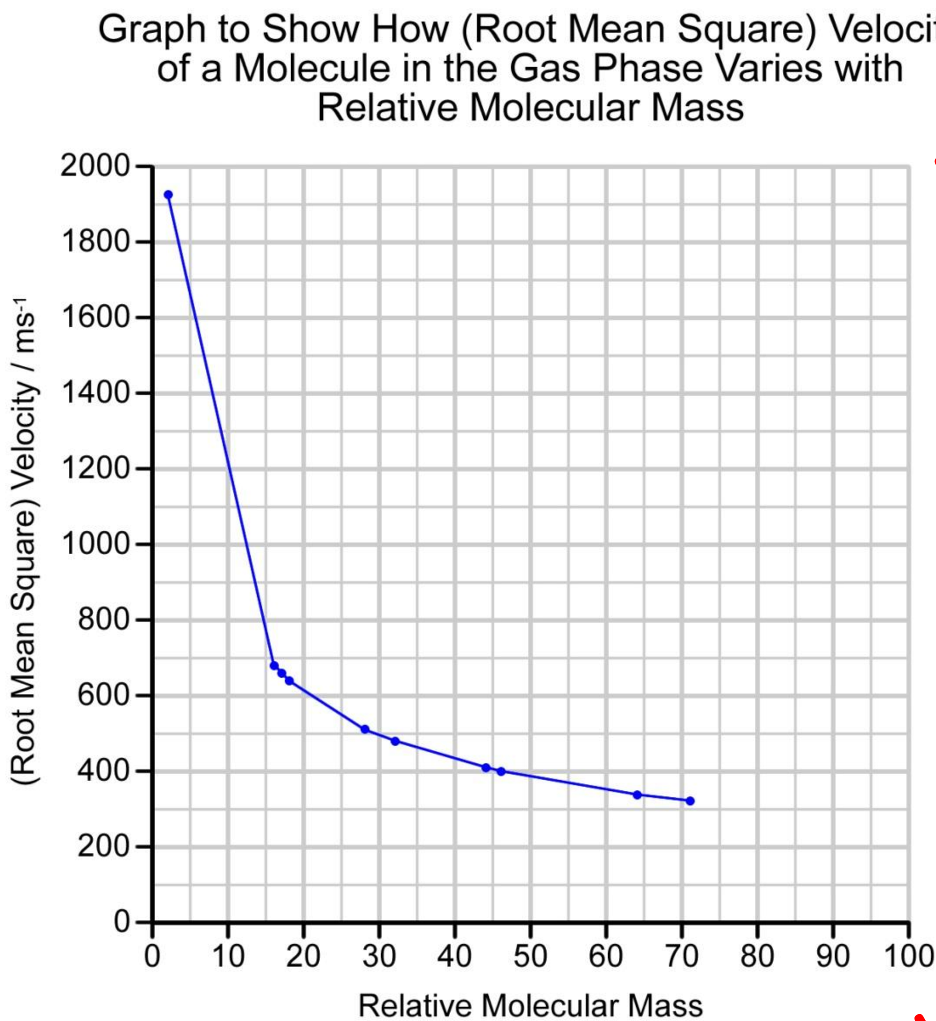
Nitrogen Dioxide – $NO_{2(g)}$
M_r = 14.0 + (2 × 16.0) = 46.0

Sulfur Dioxide – $SO_{2(g)}$
M_r = 32.0 + (2 × 16.0) = 64.0

Chlorine – $Cl_{2(g)}$
M_r = 2 × 35.5 = 71.0

Slowest

Kinetic Particle Theory – Models



Fastest

Hydrogen – $H_{2(g)}$
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M_r = 2 × 35.5 = 71.0

Slowest

Kinetic Particle Theory – Models

What other variable affects the rate at which a gas diffuses?

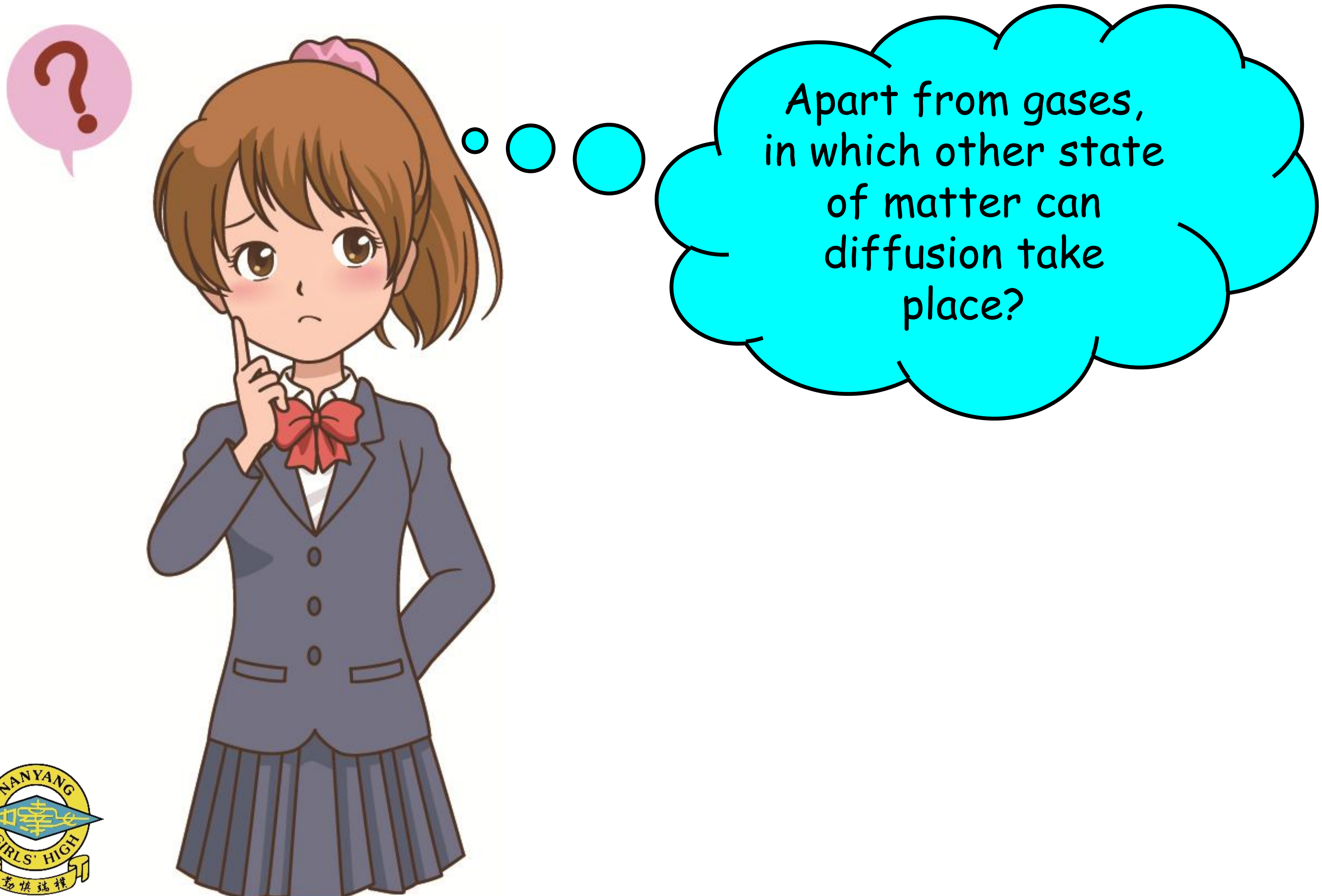
Kinetic Particle Theory – Models

What other variable affects the rate at which a gas diffuses?

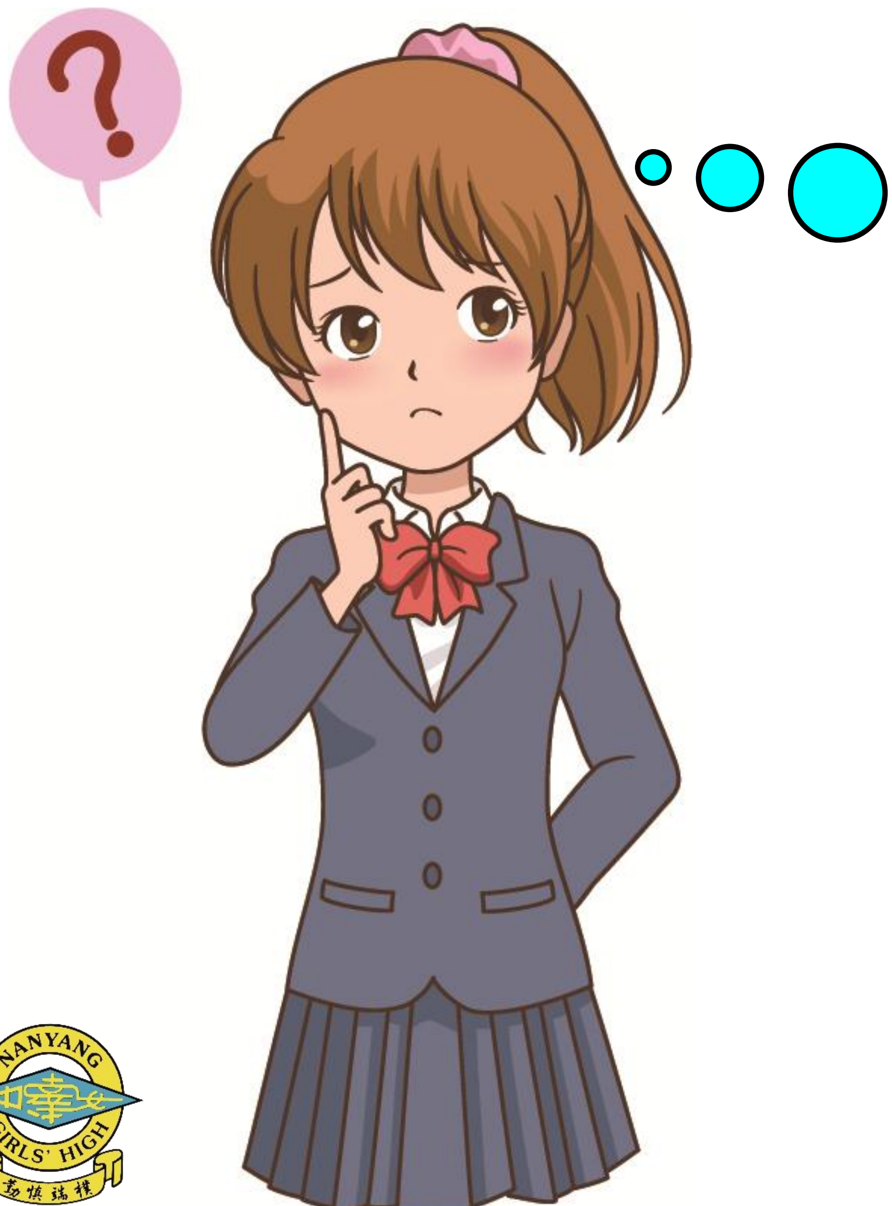
- Temperature.

An increase in temperature will increase the average kinetic energy of the particles. The particles will move faster and therefore diffuse at a greater rate.

Kinetic Particle Theory – Models



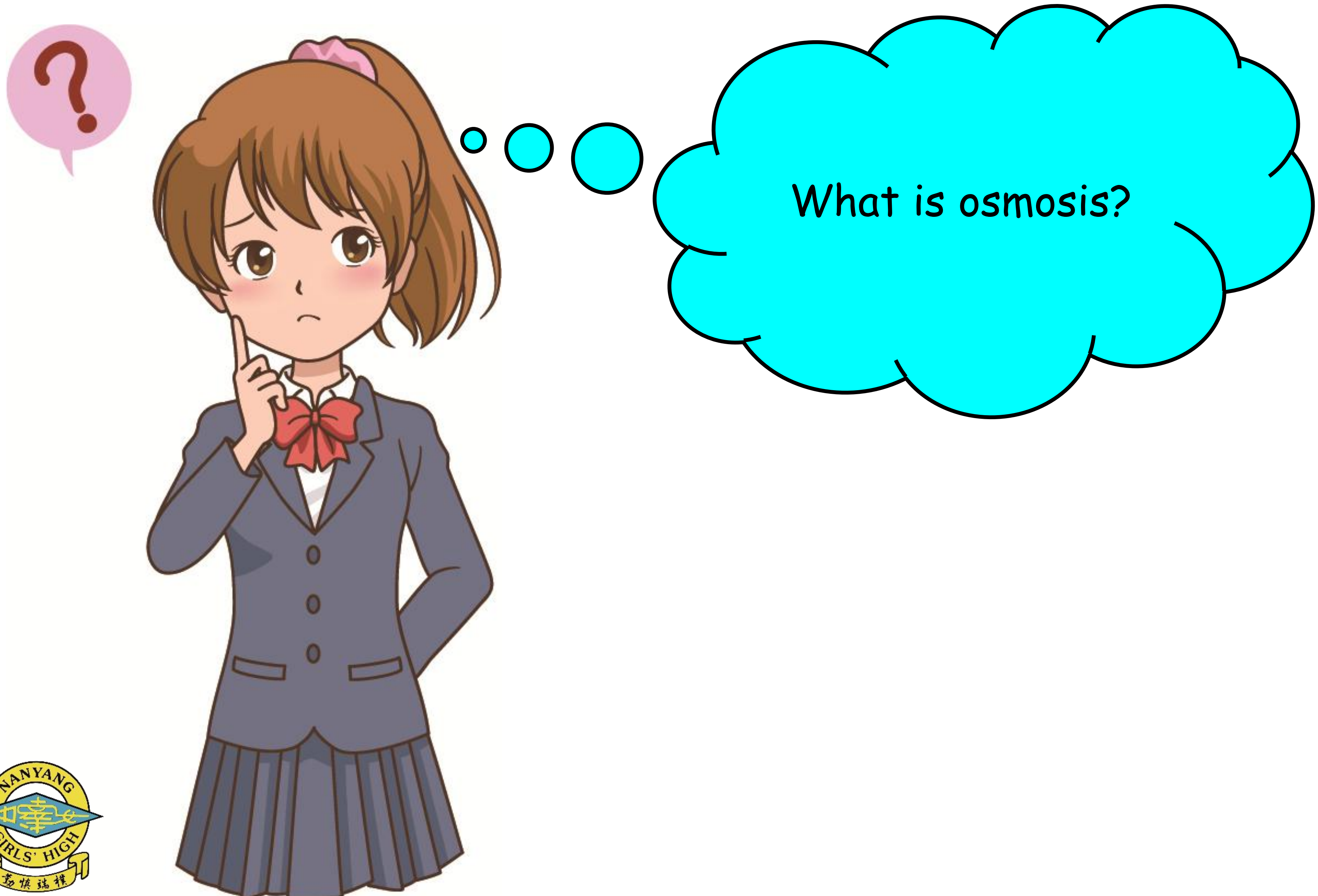
Kinetic Particle Theory – Models



Apart from gases, in which other state of matter can diffusion take place?

- Diffusion can also take place in liquids and solutions because the particles do not have a fixed position – they are able to slide past each other and therefore move from one side of a container to the other.

Kinetic Particle Theory – Models



Kinetic Particle Theory – Models

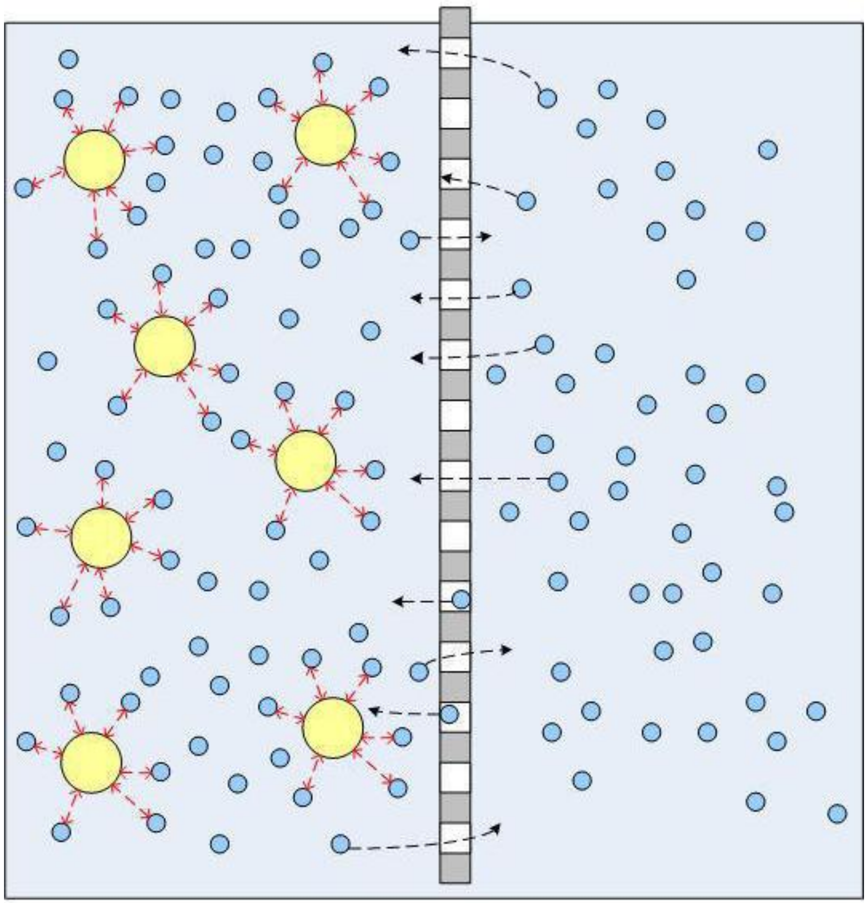
- *Osmosis* is the net movement of water molecules from a region of higher water potential (lower solute concentration) to a region of lower water potential (higher solute concentration) through a partially permeable membrane.
- Water molecules diffuse across the partially permeable membrane in the direction that tends to equalise (balance) the solute concentrations on both sides of the membrane.

Kinetic Particle Theory – Models

- Partially permeable membrane.

↓

- Lower water potential.
- Higher solute concentration.



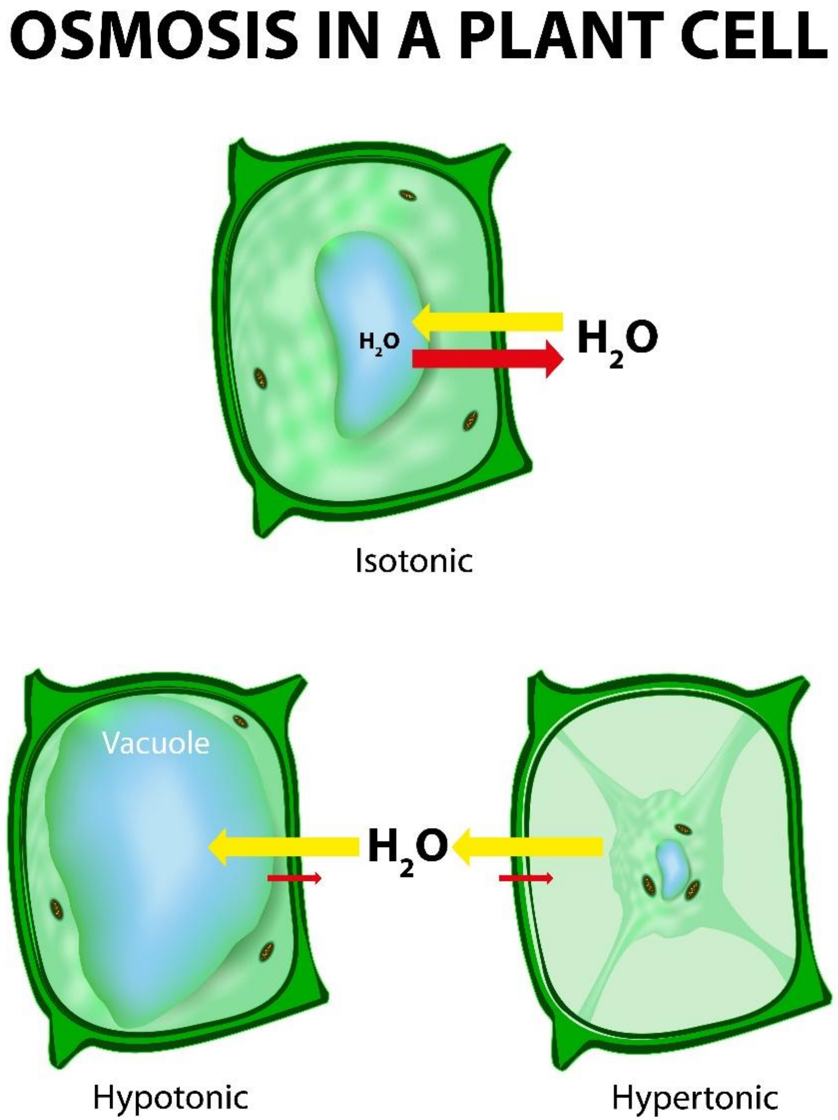
- Higher water potential.
- Lower solute concentration.

← ← Net movement of water molecules. ← ←

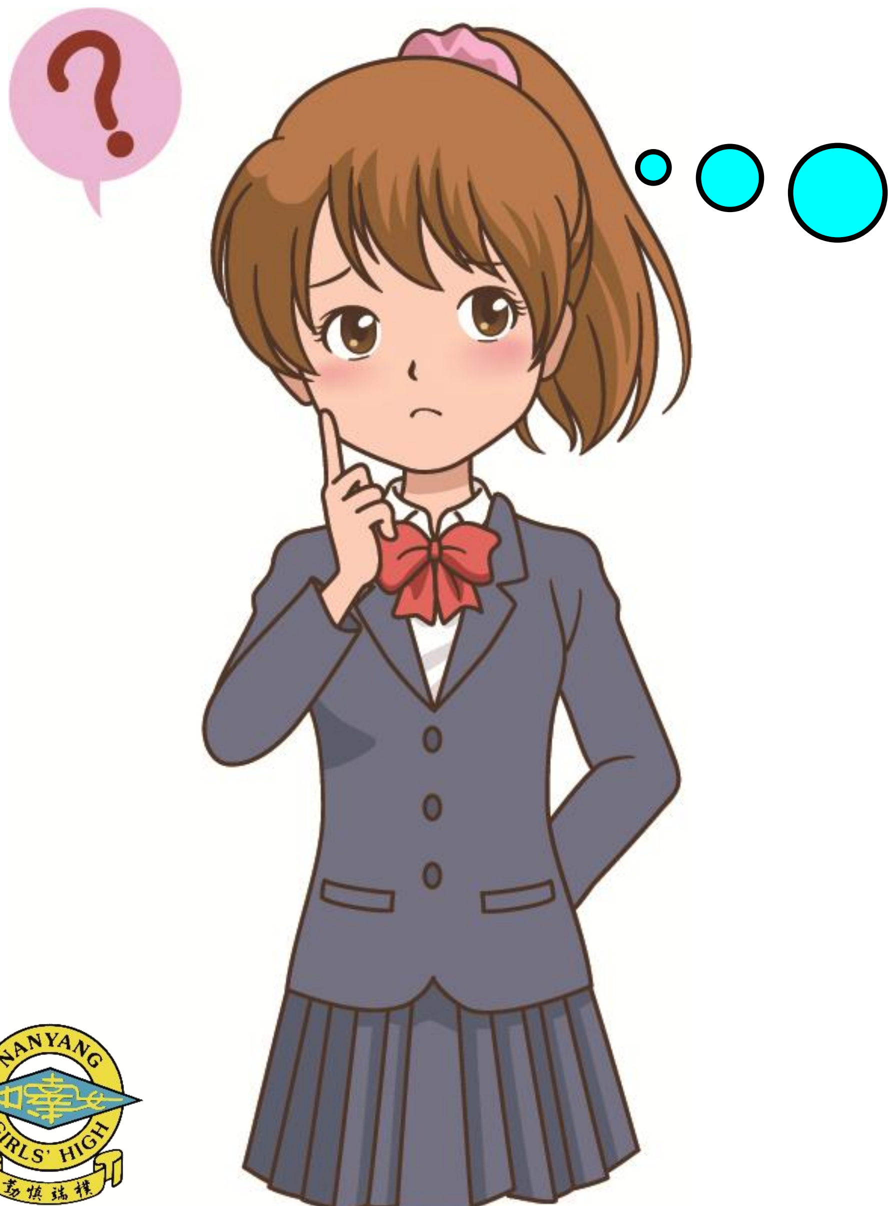
Kinetic Particle Theory – Models

- A *partially permeable membrane* is a type of biological or synthetic membrane that will allow certain molecules or ions to pass through it by diffusion.
- A partially permeable membrane is *selectively permeable* because substances do not cross it indiscriminately. Some molecules, such as oxygen and water can cross the membrane. Many large molecules, such as glucose and other sugars, cannot.

Kinetic Particle Theory – Models



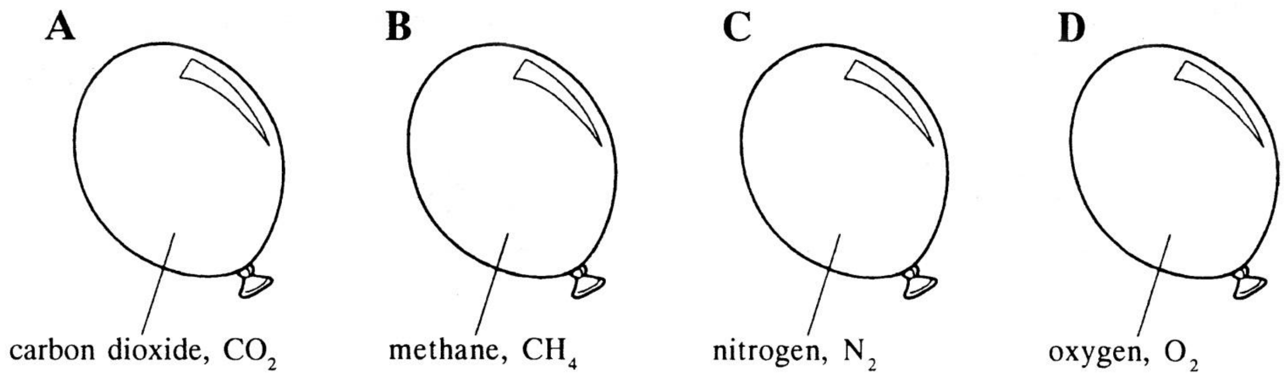
Kinetic Particle Theory – Models



Can I have some questions to check my understanding of kinetic particle theory?

Kinetic Particle Theory – Models

Question: An inflated balloon goes down because gas molecules can diffuse through the rubber. Four balloons are filled with different gases at the same temperature and pressure. Which balloon would go down most quickly?



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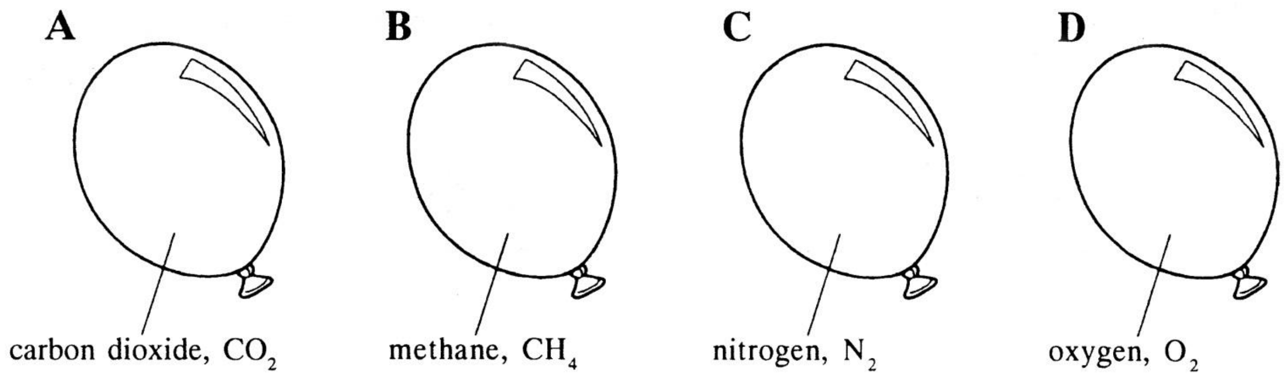
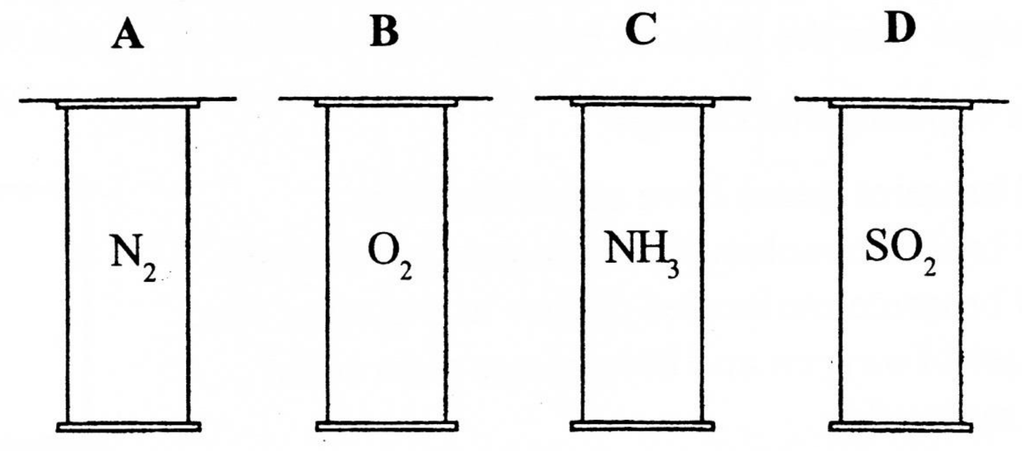


Answer: The correct answer is **B**.

The relative molecular mass (M_r) of carbon dioxide (formula: CO_2) = 12.0 + 16.0 + 16.0 = 44.0
The relative molecular mass (M_r) of methane (formula: CH_4) = 12.0 + 1.0 + 1.0 + 1.0 + 1.0 = 16.0
The relative molecular mass (M_r) of nitrogen (formula: N_2) = 14.0 + 14.0 = 28.0
The relative molecular mass (M_r) of oxygen (formula: O_2) = 16.0 + 16.0 = 32.0
Because it has the lowest relative molecular mass, molecules of *methane* will diffuse out of the balloon faster than molecules of the other three gases. Consequently, the balloon of methane will go down most quickly.

Kinetic Particle Theory – Models

Question: Four identical gas jars are filled with different gases. The lids are removed from the gas jars, and they are left open to the air for a few hours. Which gas jar will then have the most air in it?



Kinetic Particle Theory – Models

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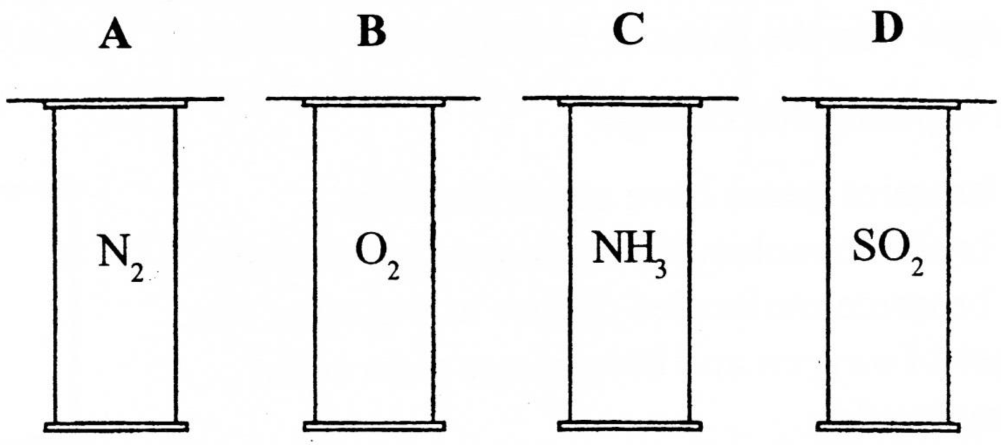


Answer: The correct answer is **C**.

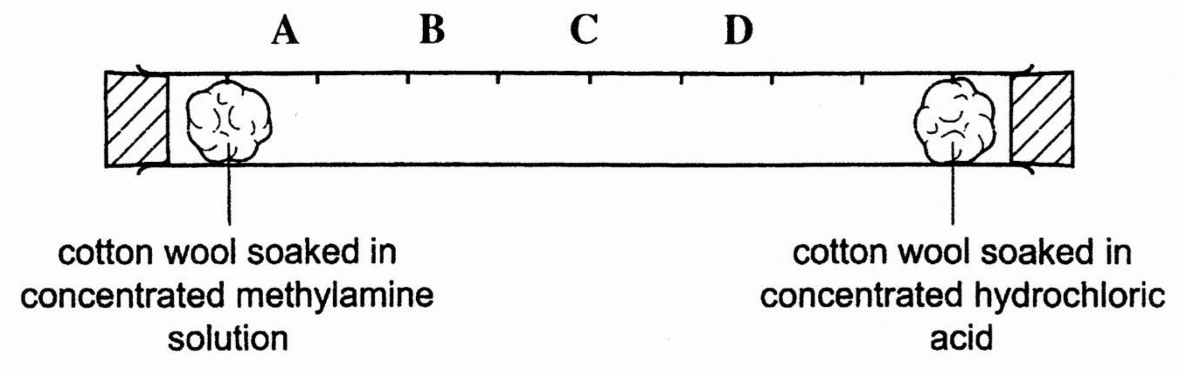
The relative molecular mass (M_r) of nitrogen (formula: N_2) = 14.0 + 14.0 = 28.0
The relative molecular mass (M_r) of oxygen (formula: O_2) = 16.0 + 16.0 = 32.0
The relative molecular mass (M_r) of ammonia (formula: NH_3) = 14.0 + 1.0 + 1.0 + 1.0 = 17.0
The relative molecular mass (M_r) of sulfur dioxide (formula: SO_2) = 32.0 + 16.0 + 16.0 = 64.0

Ammonia has the smallest relative molecular mass and will therefore diffuse out of the gas jar faster than the other three gases. As the ammonia diffuses out of the gas jar, air will take its place.

In addition, nitrogen, oxygen and sulfur dioxide are all *more dense* than ammonia and will therefore tend to remain in their gas jars for a longer period of time.

Kinetic Particle Theory – Models

Question: Methylamine, CH_3NH_2 (M_r = 31.0), and hydrogen chloride, HCl (M_r = 36.5) are both gases which are soluble in water. The gases react together to form a white solid called methylammonium chloride. In an experiment to determine rates of diffusion, the following apparatus is set up. Where will the white solid form?



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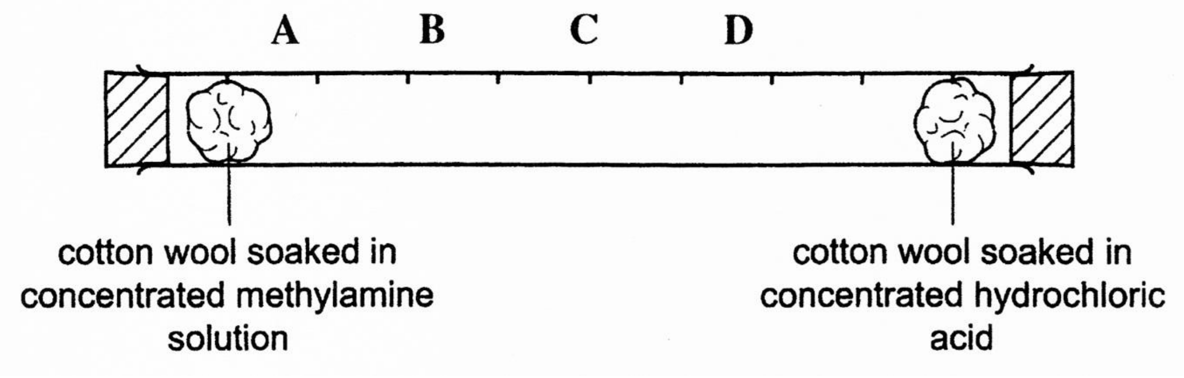
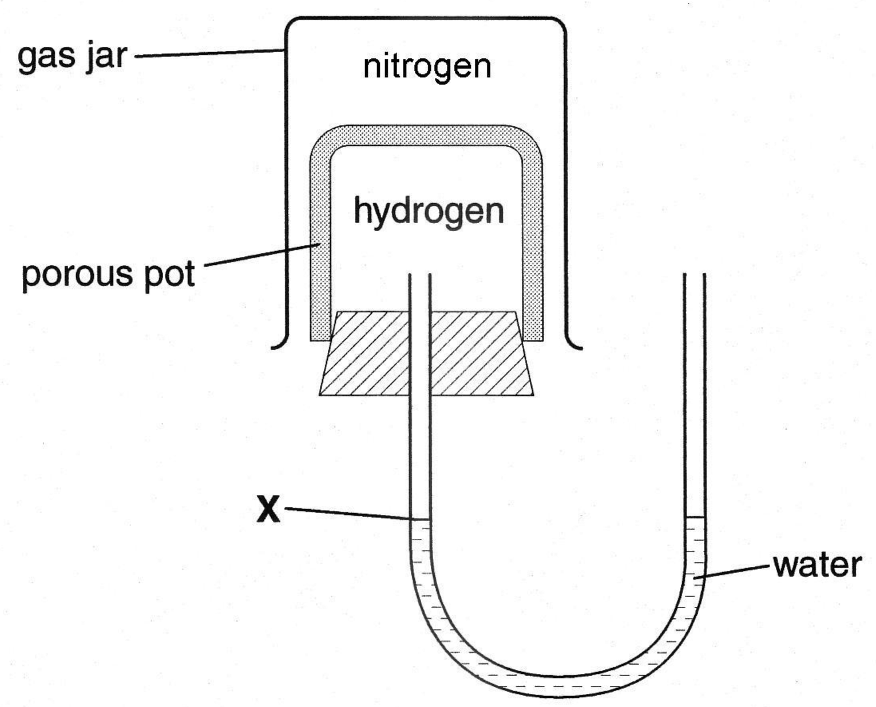


Answer: The correct answer is **D**.

The relative molecular mass (M_r) of methylamine is smaller than that of hydrogen chloride. Because of this, methylamine molecules will diffuse along the glass tube faster than the hydrogen chloride molecules. Molecules of the two gases will collide towards the hydrogen chloride end of the glass tube, forming a white solid.

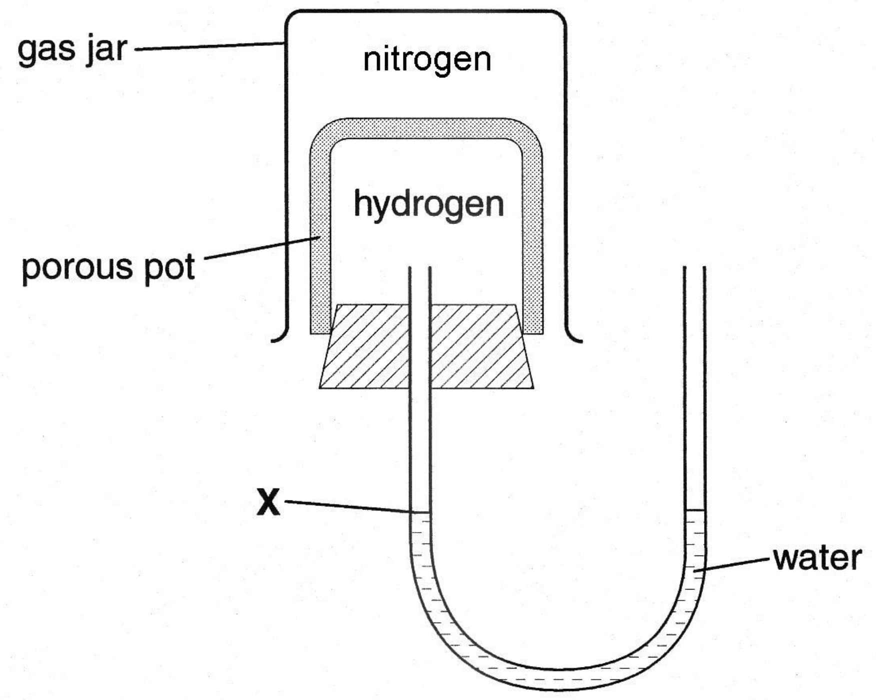
Kinetic Particle Theory – Models

Question: A beaker of nitrogen was inverted over a porous pot containing hydrogen as shown. What will happen to the level of the water at point **X**?



Kinetic Particle Theory – Models

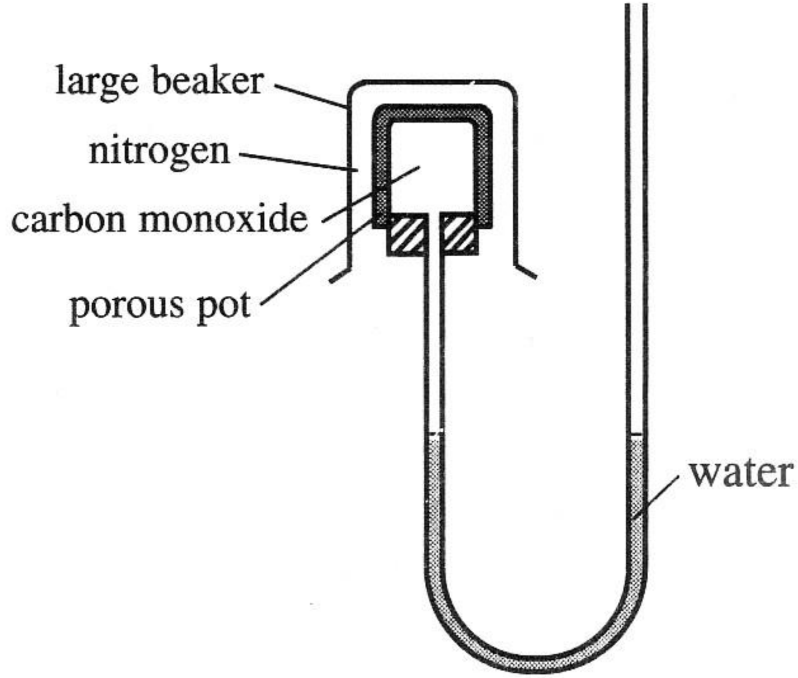
Question: A beaker of nitrogen was inverted over a porous pot containing hydrogen as shown. What will happen to the level of the water at point **X**?



Answer: Both gases can diffuse through the porous pot. Hydrogen (formula: H_2) has a relative molecular mass (M_r) of 1.0 + 1.0 = 2.0 while nitrogen (formula: N_2) has a relative molecular mass (M_r) of 14.0 + 14.0 = 28.0. Because of this, molecules of hydrogen gas will diffuse out of the porous pot faster than molecules of nitrogen gas can diffuse into it. Consequently, there will be fewer gas molecules inside the porous pot. The pressure inside the porous pot will decrease causing the level of the water at **X** to rise. Over a period of time, molecules of nitrogen will slowly diffuse into the porous pot, increasing the pressure inside the porous pot and causing the level of the water at **X** to return to its original level.

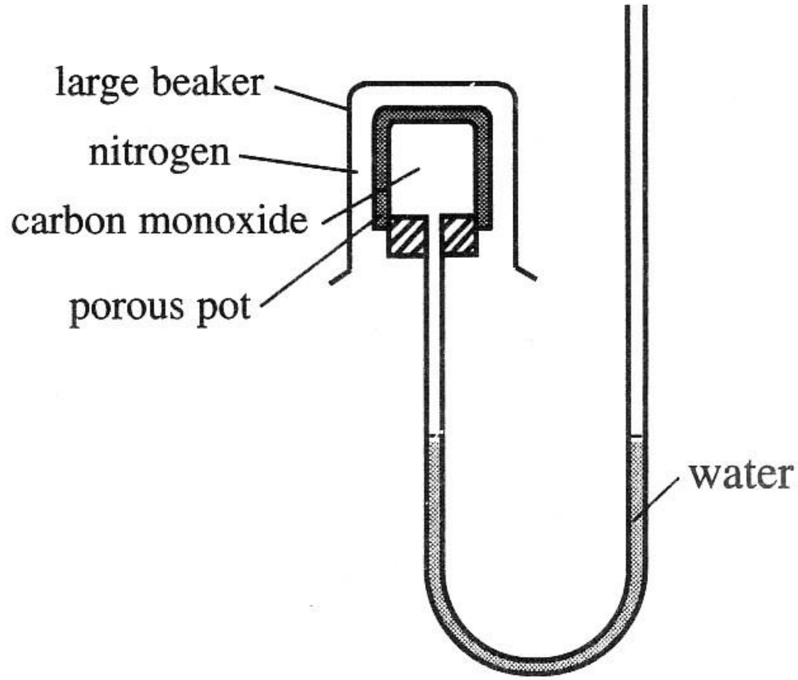
Kinetic Particle Theory – Models

Question: A beaker of nitrogen was inverted over a porous pot containing carbon monoxide as shown. The water level did not change. What is the reason for this?



Kinetic Particle Theory – Models

Question: A beaker of nitrogen was inverted over a porous pot containing carbon monoxide as shown. The water level did not change. What is the reason for this?



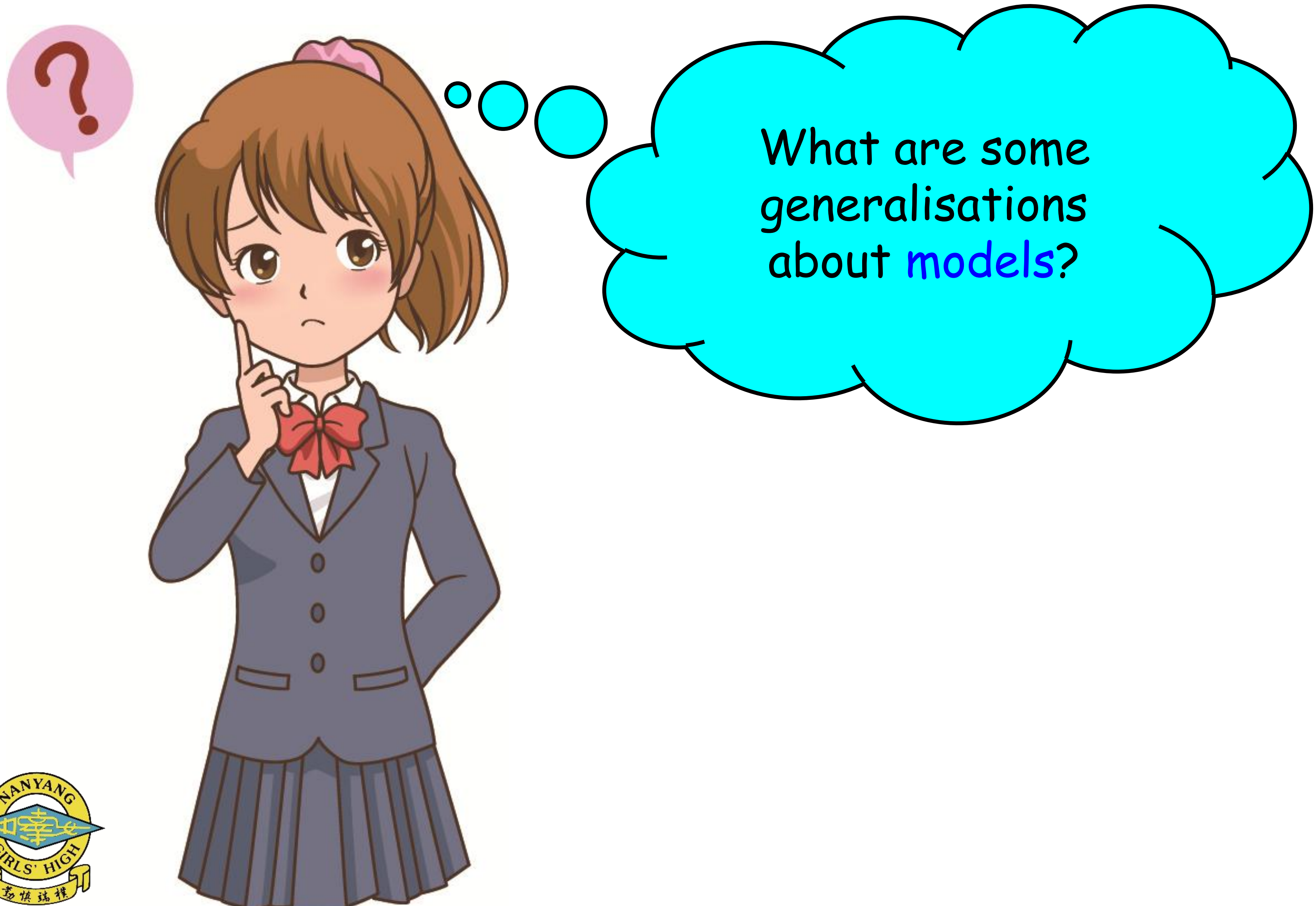
Answer: Both gases can diffuse through the porous pot. Nitrogen (formula: N_2) has a relative molecular mass of 14.0 + 14.0 = 28.0 and carbon monoxide (formula: CO) has a relative molecular mass of 12.0 + 16.0 = 28.0. Because both gases have the same relative molecular mass, they will diffuse through the porous pot at the same rate. Because the total number of gas molecules inside the porous pot does not change, the pressure inside the porous pot will not change and the level of the water will remain constant.

Kinetic Particle Theory – Models

Kinetic particle theory is a conceptual model of how matter behaves.

- Models are often used by scientists in order to explain and investigate scientific concepts and phenomena.

Kinetic Particle Theory – Models



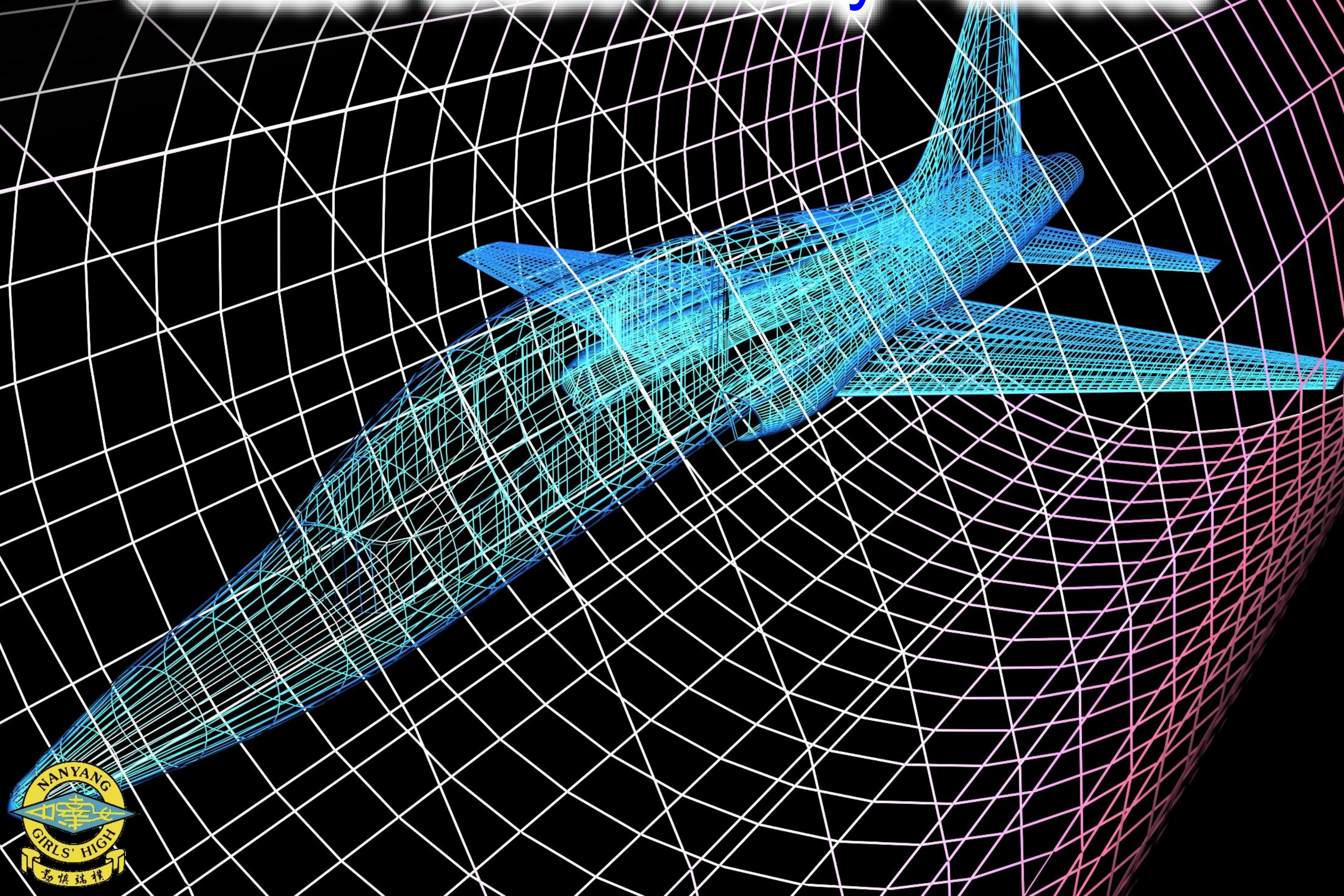
Kinetic Particle Theory – Models

- Models simulate real world processes.
- Models facilitate testing and prediction.
- Models can be physical, conceptual or mathematical.
- Models simplify real world processes or behaviours.
- Models involve variables.
- Models have limitations.

Kinetic Particle Theory – Models

What are some other examples of models?

Kinetic Particle Theory – Models



Kinetic Particle Theory – Models

- Mathematical models allow testing and prediction of an object's behaviour. This often requires a powerful computer and software to simulate how an object will behave under different conditions.
- Mathematical models can be used in conjunction with physical models.
- Mathematical models are useful tools for investigating phenomena that are very dangerous / difficult / expensive to create in a laboratory, *e.g.* modelling the spread of a virus or modelling a nuclear explosion.

Kinetic Particle Theory – Models

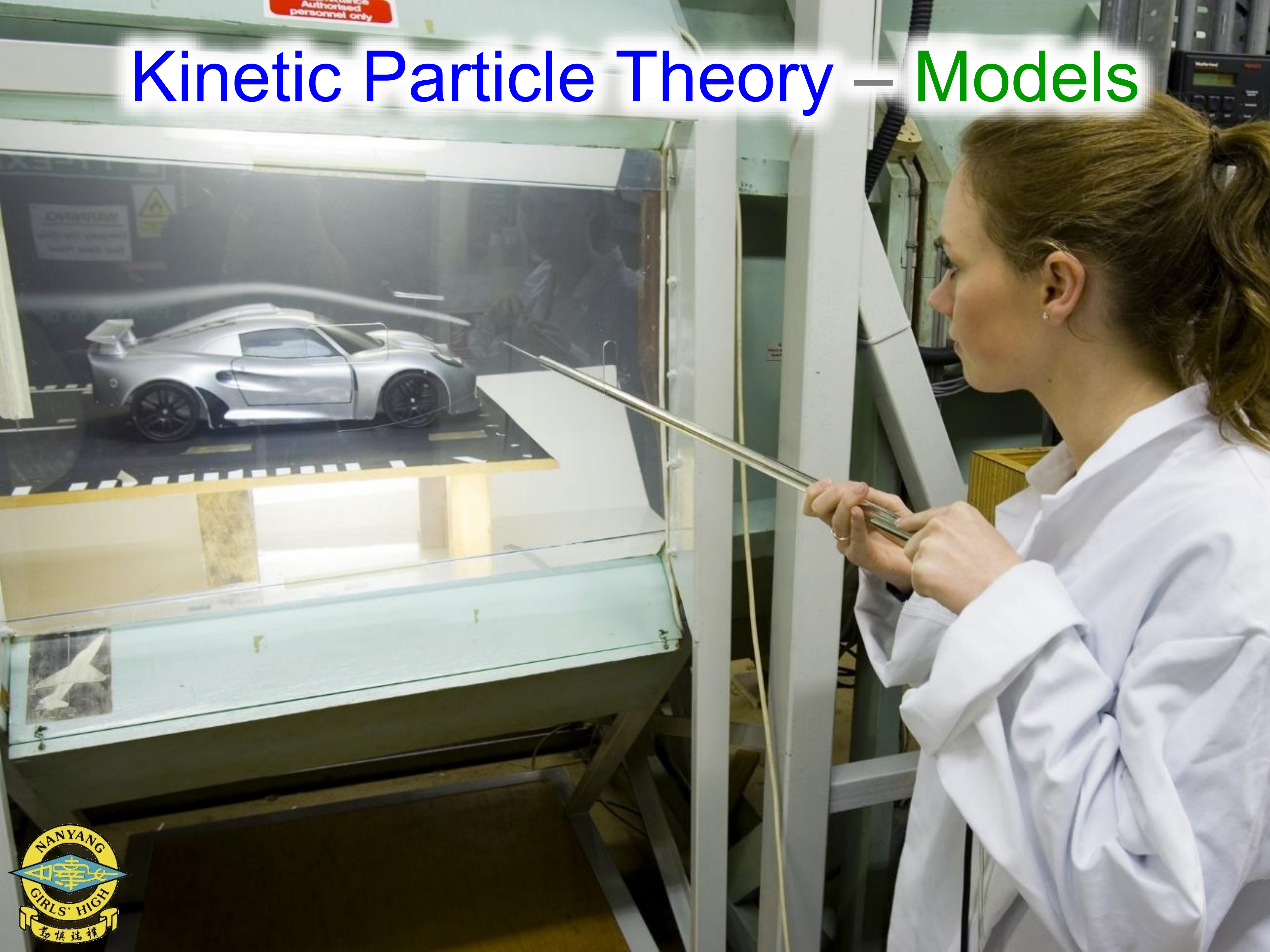
Kinetic Particle Theory – Models

- Physical models used in architecture help designers visualise the building's shape, size and space. Models also help designers see how the building interacts with light and shadow.

- Physical models help architects in the creative process by allowing them to visualise what happens as they experiment with different ideas.

- Physical models allow architects to visualise how a building is suited to its environment.

Kinetic Particle Theory – Models



Kinetic Particle Theory – Models

- This photograph shows a university student testing a scale model of a car in a wind tunnel.

- This type of investigation allows scientists and engineers to examine the aerodynamic stability of the car. Similar experiments can be conducted on scale models of aircraft and ships.

- Based upon observations made when testing the model, the car's design can be modified before the actual car is manufactured, hence saving both time and money.

Kinetic Particle Theory – Models

Are there any abstract models to help me understand kinetic particle theory?

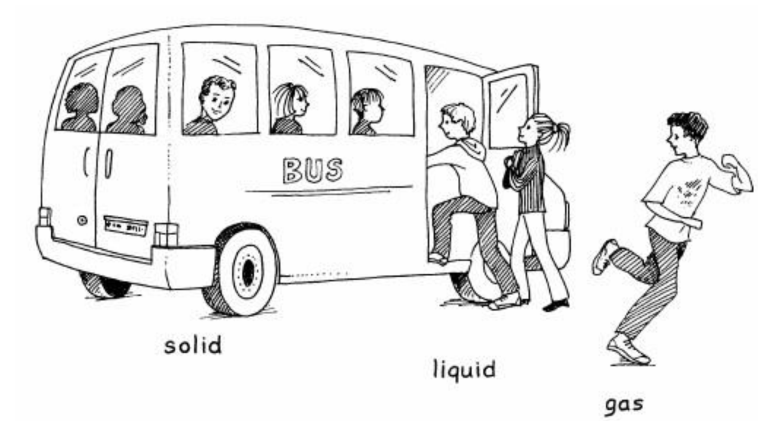
Kinetic Particle Theory – Models

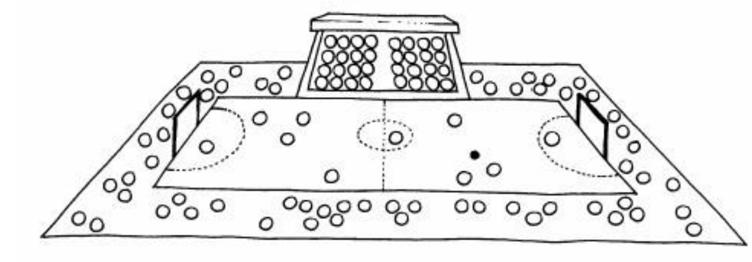
- Models are often used by scientists in order to explain and investigate scientific concepts.

- In what ways do these diagrams model kinetic particle theory?

- What are the strengths and weaknesses of these models?

- What other concepts in science can be understood more clearly by using models?





Kinetic Particle Theory – Models

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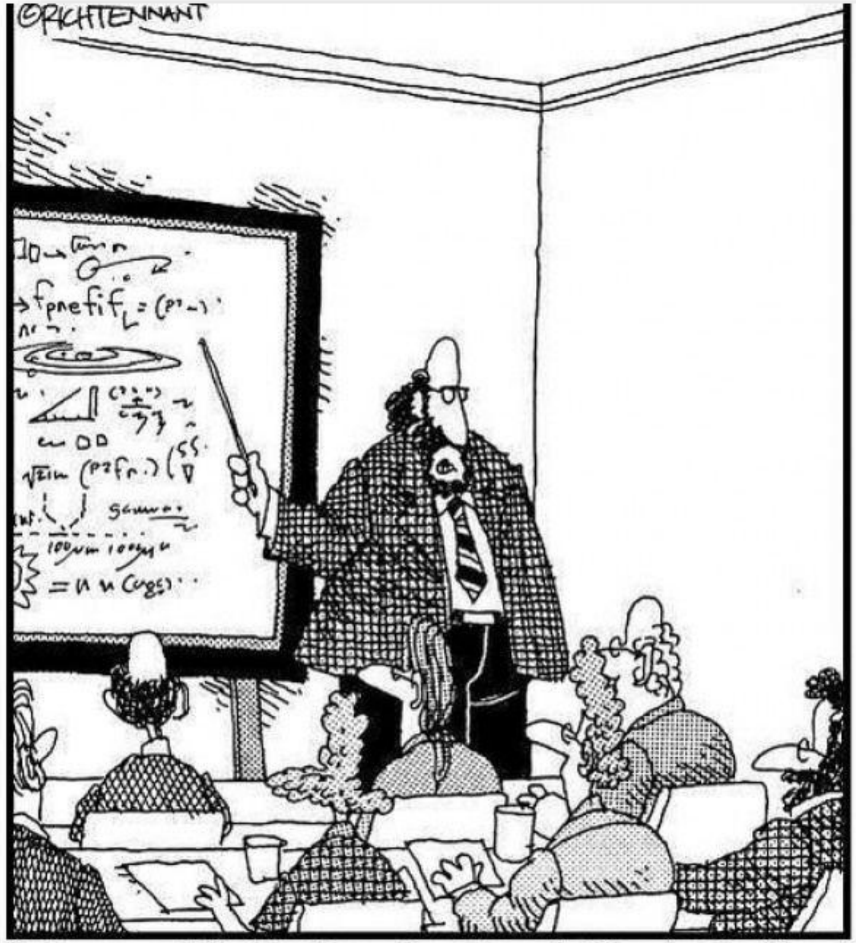
12th September 2015

Kinetic Particle Theory – Models



"Along with 'Antimatter,' and 'Dark Matter,' we've recently discovered the existence of 'Doesn't Matter,' which appears to have no effect on the universe whatsoever."