2.1 Kinetic particle model of matter

Name: _____ Class: _____ Date: _____ **Total: 26 marks**

0 Vocabulary

Word	Example
states of matter 物态 /steɪts ɒv 'mætə/	Solid, liquid and gas are three **states of matter**. 固态、液态和气态是三种**物态**。
solid /'sɒlɪd/ 固体	In a **solid**, the particles are packed tightly and only vibrate. 在**固体**中，粒子排列紧密，只能振动。
liquid /'lɪkwɪd/ 液体	In a **liquid**, the particles are close but can move past each other. 在**液体**中，粒子靠得很近，但可以相互滑过。
gas /gæs/ 气体	In a **gas**, the particles are far apart and move quickly. 在**气体**中，粒子相距较远，运动迅速。
condensation /kɒnden'seɪʃn/ 凝结	**Condensation** forms water droplets as moist air cools. 潮湿空气冷却时，**凝结**会形成小水滴。
kinetic particle model 分子动理论 /kɪ'netɪk 'pɑːtɪkl 'mɒdl/	The **kinetic particle model** says matter is made of tiny moving particles. **分子动理论**认为，物质由不断运动的微小粒子组成。
particle /'pɑːtɪkl/ 粒子	Model the box as a **particle**, so its size does not matter. 将箱子看作**粒子**，这样它的大小就不影响计算。
vibrate /vaɪ'breɪt/ 振动	The particles in a solid **vibrate** in place. 固体中的粒子在原位**振动**。
kinetic energy 动能 /kɪ'netɪk 'enədʒi/	A fast car has a lot of **kinetic energy**. 一辆快速行驶的汽车具有很大的**动能**。
temperature /'temprɪtʃə/ 温度	The thermometer shows the water's **temperature**. 温度计显示水的**温度**。
pressure /'preʃə/ 压强	A sharp knife puts a large **pressure** on the bread. 锋利的刀对面包产生很大的**压强**。

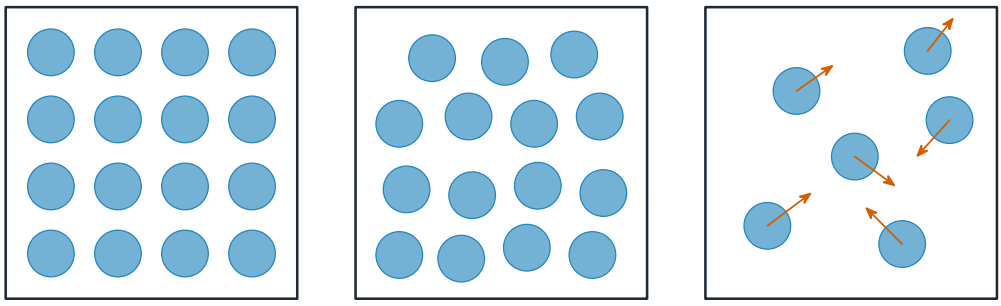
Word	Example
Brownian motion 布朗运动 /ˈbraʊnɪən ˈməʊʃn/	**Brownian motion** is the random jiggling of smoke particles in air. **布朗运动**是烟雾粒子在空气中的无规则抖动。
boiling /ˈbɔɪlɪŋ/ 沸腾	During **boiling**, bubbles form all through the water. **沸腾**时，水中各处都会形成气泡。

1 Key knowledge and worked examples

Study these first. Each one shows the method for a question type used later: follow the steps and you can do the Practice and Exam-style questions yourself.

The three states

	solid	liquid	gas
arrangement	close, regular	close, irregular	far apart, random
motion	vibrate about fixed positions	move around each other	move fast in all directions
forces between particles	strong	weaker	very weak



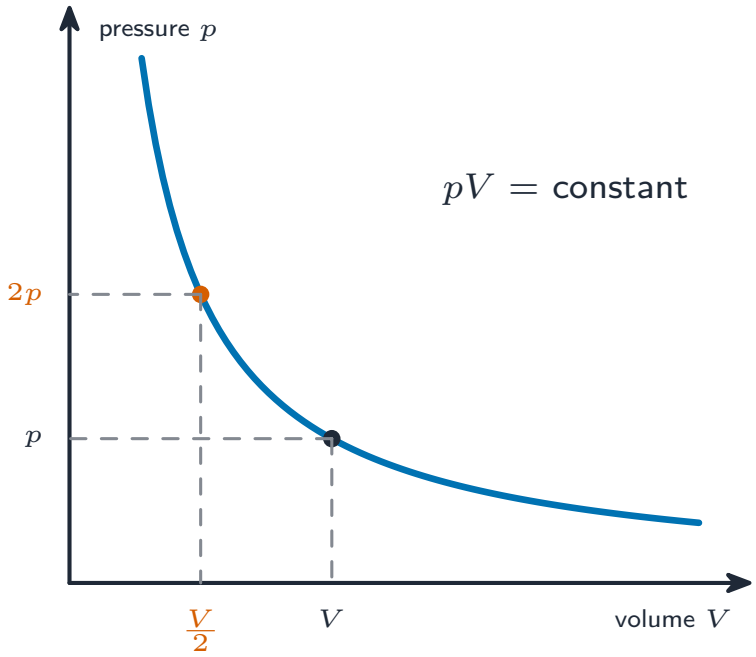
Solid: fixed and ordered; liquid: close but disordered; gas: far apart and fast

- Changes of state: solid **melts** to liquid, liquid **boils** (or evaporates) to gas, gas **condenses** to liquid, liquid **solidifies** (freezes) to solid.
- **Gas pressure:** gas particles collide with the walls; each collision exerts a force, and pressure is the force per unit area.
- **Hotter gas, same volume:** particles move faster, hit the walls more often and harder, so the pressure rises.

- **Smaller volume, same temperature:** particles hit each unit area of wall more often, so the pressure rises.
- **Brownian motion:** smoke specks or pollen grains move in a random, jerky way. They are hit **unevenly on different sides** by many fast, invisible air or water molecules.

■ Worked example 1: compressing a gas

A gas of volume 200 cm^3 at 100 kPa is squeezed to 50 cm^3 at constant temperature. Find the new pressure.



At constant temperature pV is constant: halve V and p doubles

1. Fixed mass of gas at constant temperature, so pV is constant: $p_1V_1 = p_2V_2$, giving $p_2 = \dfrac{p_1V_1}{V_2}$.
2. $$p_2 = \frac{p_1V_1}{V_2} = \frac{(100\ \text{kPa})(200\ \text{cm}^3)}{50\ \text{cm}^3} = \mathbf{400}\ \text{kPa}$$

■ Worked example 2: filling balloons from a cylinder

A cylinder of volume 0.020 m^3 holds gas at 1.2×10^6 Pa. Balloons of volume 0.010 m^3 are filled at atmospheric pressure, 1.0×10^5 Pa, at constant temperature. Find the greatest number of balloons that can be filled.

1. Volume the gas would occupy at atmospheric pressure: $V_2 = \dfrac{p_1 V_1}{p_2}$.

$$V_2 = \frac{p_1 V_1}{p_2} = \frac{(1.2 \times 10^6 \text{ Pa})(0.020 \text{ m}^3)}{1.0 \times 10^5 \text{ Pa}} = 0.24 \text{ m}^3$$

2. Flow stops when the cylinder reaches atmospheric pressure, so 0.020 m^3 stays inside: $0.24 - 0.020 = 0.22 \text{ m}^3$ is available.
3. Number of balloons $= \dfrac{0.22 \text{ m}^3}{0.010 \text{ m}^3} = \mathbf{22}$.

2 Practice

2.1 Describe the arrangement of particles in a solid. [1]

solid

2.2 Describe the arrangement and motion of the particles in a gas. [2]

gas

2.3 Explain why a gas is easily compressed but a solid is not. [2]

gas solid

2.4 A gas of volume 300 cm^3 at 120 kPa is compressed to 100 cm^3 at constant temperature. Find the new pressure. [2]



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3 Exam-style questions

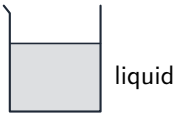
3.1 Gas pressure on the container walls is caused by: [1]



- ☐ **A** particles vibrating in fixed positions
- **B** particles colliding with the walls
- **C** the gas expanding
- **D** the walls heating up

3.2 Which row describes the particles in a liquid? [1]

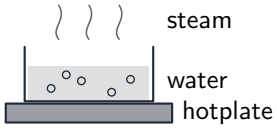
	forces between particles	motion of particles
A	strong	vibrate in fixed positions
B	fairly strong	move around each other
C	weak	vibrate in fixed positions
D	very weak	move randomly at high speed



3.3 Pollen grains in water, seen through a microscope, move in a continuous, rapid and random way. Explain what causes this motion. [2]



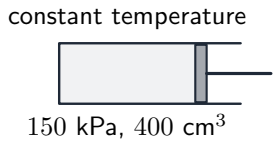
3.4 Water in a pan boils and leaves the liquid as a gas. Explain, in terms of forces and distances between particles, why the gas occupies a much greater volume than the liquid. [2]



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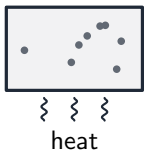
3.5 A fixed mass of gas at constant temperature has $p_1 = 150$ kPa and $V_1 = 400$ cm^3.

(a) Calculate the volume when the pressure is increased to 250 kPa. [3]



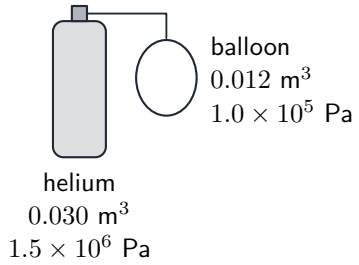
(b) Explain, using the particle model, why the pressure rises as the volume falls. [2]

3.6 A sealed container of gas is heated. Its volume does not change. Explain, in terms of particles, why the pressure of the gas increases. [3]



3.7 A cylinder of volume 0.030 m^3 contains helium at a pressure of 1.5×10^6 Pa. Helium from the cylinder is used to fill balloons. Each balloon holds 0.012 m^3 of helium at atmospheric pressure, 1.0×10^5 Pa. The temperature stays constant.

(a) Calculate the volume the helium would occupy at atmospheric pressure. [2]



(b) Explain why not all of this helium can be put into balloons. [1]

(c) Calculate the greatest number of balloons that can be filled. [2]

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Solutions

Each answer shows the steps, then the **result**.

2.1

- particles are close together in a fixed, regular pattern, vibrating about fixed positions

2.2

- far apart, in no regular arrangement
- moving quickly in random directions

2.3

- in a gas the particles are far apart, with large spaces between them that can be reduced
- in a solid the particles are already touching, closely packed

2.4

- constant temperature, so $p_1V_1 = p_2V_2$ and $p_2 = \dfrac{p_1V_1}{V_2}$

$$p_2 = \frac{p_1V_1}{V_2} = \frac{(120\text{ kPa})(300\text{ cm}^3)}{100\text{ cm}^3} = \mathbf{360}\text{ kPa}$$

3.1 B

- pressure comes from particles colliding with the walls

3.2 B

- liquid particles are close with fairly strong forces, and move around each other; A is a solid, D is a gas

3.3

- the pollen grains are hit by fast-moving water molecules, which are too small to see
- the hits are uneven on different sides, so there is a resultant force in a changing, random direction

3.4

- in the gas the particles are much further apart than in the liquid
- the forces between gas particles are very weak, so they no longer hold the particles close together

3.5

(a)

- constant temperature: $p_1V_1 = p_2V_2$
- rearrange: $V_2 = \dfrac{p_1V_1}{p_2}$

$$V_2 = \frac{p_1V_1}{p_2} = \frac{(150\text{ kPa})(400\text{ cm}^3)}{250\text{ kPa}} = \mathbf{240}\text{ cm}^3$$

(b)

- in a smaller volume the particles hit each unit area of the wall more often
- so the force per unit area, the pressure, increases

3.6

- the particles gain kinetic energy and move faster
- they hit the walls more often
- and with a greater force, so the pressure increases

3.7

(a)

- constant temperature: $p_1V_1 = p_2V_2$, so $V_2 = \dfrac{p_1V_1}{p_2}$

$$V_2 = \frac{p_1V_1}{p_2} = \frac{(1.5 \times 10^6 \text{ Pa})(0.030 \text{ m}^3)}{1.0 \times 10^5 \text{ Pa}} = \mathbf{0.45} \text{ m}^3$$

(b)

- helium stops flowing when the cylinder reaches atmospheric pressure, so 0.030 m^3 of helium stays in the cylinder

(c)

- volume available = 0.45 m^3 − 0.030 m^3 = 0.42 m^3
- number of balloons = $\dfrac{0.42 \text{ m}^3}{0.012 \text{ m}^3} = \mathbf{35}$

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