3.3 Particle Model of Matter: 2-hour Pack

AQA 8463 · Calculator allowed · about 120 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

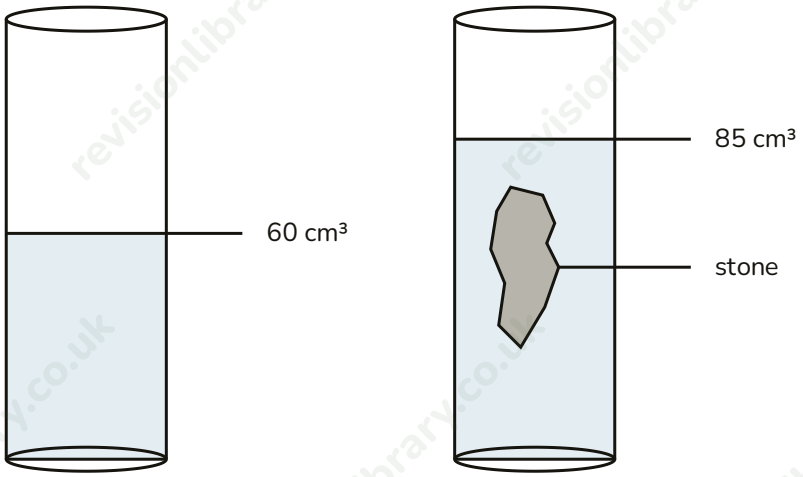
Answer ALL questions. Show all your working.

1 Required practical: a student wants to determine the density of an irregular-shaped stone using a displacement method.

(a) Describe a method the student could use to measure the volume of the stone, using a measuring cylinder containing water. **(3)**

(b) The student records: initial volume = 60 cm^3, final volume = 85 cm^3, mass of stone = 67.5 g. Calculate the density of the stone. **(3)**

Diagram NOT accurately drawn



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(c) State one precaution the student could take to improve the accuracy of the volume measurement. **(1)**

(Total for Question 1 is 7 marks)

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2 A gas is trapped inside a sealed, rigid container.

(a) Explain, in terms of particles, why the gas exerts a pressure on the walls of the container. **(2)**

(b) The container is heated, so the temperature of the gas increases, while its volume stays the same. Explain, in terms of particles, why the pressure of the gas increases. **(2)**

(Total for Question 2 is 4 marks)

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3 An aerosol can carries a warning label that says: 'Do not puncture or place near a heat source, even after use.'

(a) Use ideas about the particle model to suggest why heating a sealed aerosol can could be dangerous. **(2)**

(Total for Question 3 is 2 marks)

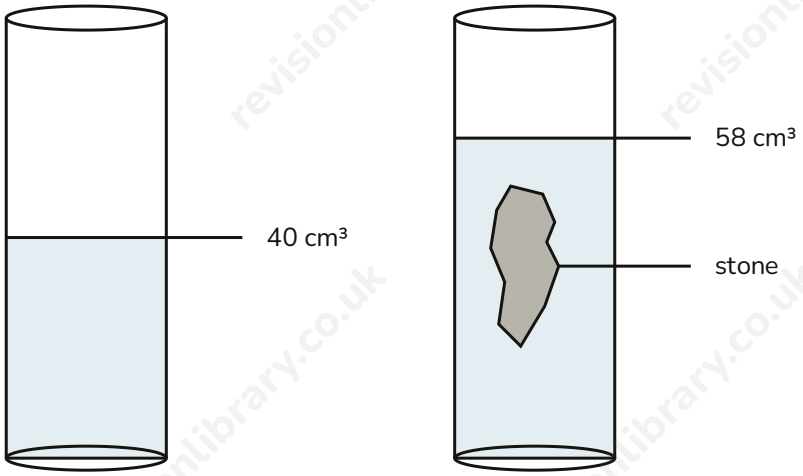
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4 A student wants to measure the density of a small irregularly shaped stone, using the equipment: a balance, a measuring cylinder, water and a piece of string.

(a) Describe how the student could measure the volume of the stone. **(3)**

(b) The initial volume of water was 40 cm^3. After the stone was added, the volume reading was 58 cm^3. The mass of the stone was 45 g. Calculate the density of the stone. **(3)**

Diagram NOT accurately drawn



(Total for Question 4 is 6 marks)

5 Internal energy is the energy stored inside a system by the particles that make it up.

(a) State what internal energy is the sum of. **(1)**

(b) A beaker of water is heated but does not change state. Explain what happens to the internal energy of the water, and why its temperature rises. **(2)**

(Total for Question 5 is 3 marks)

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6 A pure solid is heated at a constant rate from room temperature until it has completely melted and the resulting liquid is warming up. A graph of its temperature against time shows the temperature rising steadily, then staying constant for a period of time, then rising steadily again.

(a) State what is happening to the substance during the part of the graph where the temperature stays constant. **(1)**

(b) Explain why the temperature does not rise during this part of the graph, even though the substance is still being heated. **(2)**

(Total for Question 6 is 3 marks)

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7 A container holds a gas. The gas exerts a pressure p on the walls. Describe and explain qualitatively what happens to the pressure if the average speed of the gas particles doubles but the number of particles and volume remain constant.

(a) Explain why the pressure changes and state how it changes. **(3)**

(Total for Question 7 is 3 marks)

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8 A cylindrical sealed container of gas has cross-sectional area 0.020 m^2 and a movable piston. The piston is pushed inwards by 2.0 cm while keeping the process slow enough to be considered quasi-static. The pressure inside is 1.50×10^5 Pa during the movement. Calculate the work done on the gas in joules.

(a) Calculate the work done on the gas while the piston moves 2.0 cm inwards. Use W = p x change in volume. **(5)**

(Total for Question 8 is 5 marks)

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9 A fixed mass of gas is heated at constant volume from 250 K to 500 K. Using particle ideas, state how the average kinetic energy of the molecules changes and calculate the ratio of the final average kinetic energy to the initial average kinetic energy.

(a) State how the average kinetic energy changes and calculate the ratio of final to initial average kinetic energy. **(4)**

(Total for Question 9 is 4 marks)

10 A fixed mass of ice, starting at a temperature of -10°C, is heated steadily until it has become steam at a temperature of 110°C. Using the particle model, explain what happens to the ice/water as it is heated through this whole range of temperatures, including what happens to its temperature and its internal energy at each stage.

(Total for Question 10 is 6 marks)

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11 A sealed cylinder contains a fixed mass of gas at constant temperature. Initially the gas has pressure 1.20×10^5 Pa and volume 2.50×10^{-3} m3. The gas is then compressed at constant temperature to a new volume of 1.00×10^{-3} m3.

(a) Use the relationship pV = constant (at constant temperature) to calculate the new pressure of the gas. **(3)**

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(b) State what happens to the average kinetic energy of the gas particles during this compression, given that the temperature stays constant. **(1)**

(Total for Question 11 is 4 marks)

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12 A student is investigating the specific latent heat of fusion of a metal block. The metal block of mass 0.500 kg is heated and melts. The student measures that the block absorbs 6.6×10^4 J during melting.

(a) Calculate the specific latent heat of fusion of the metal in J/kg. **(2)**

.....

(b) State one practical source of error in this method and a single improvement. **(1)**

(Total for Question 12 is 3 marks)

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13 A sealed piston contains a gas such that when the piston is compressed quickly the temperature rises. Explain, using particle ideas, why the temperature increases during rapid compression.

(a) Explain the increase in temperature in terms of particle collisions and energy transfer. **(4)**

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(Total for Question 13 is 4 marks)

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14 The density of liquid water is 1000 kg/m3. The density of steam (water vapour) at 100°C and atmospheric pressure is 0.590 kg/m3. A student converts 2.00×10^{-3} kg of water completely into steam.

(a) Calculate the volume occupied by the water as a liquid, before it evaporates. **(2)**

(b) Calculate the volume occupied by the steam, and hence calculate the factor by which the volume increases when the water evaporates. **(2)**

(Total for Question 14 is 4 marks)

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15 A student places a few drops of ammonia solution at one end of a 40.0 cm glass tube and drops of hydrochloric acid at the other end, at the same time and the same temperature. A white ring of ammonium chloride forms where the ammonia and hydrogen chloride gases meet by diffusion. The ring forms 25.0 cm from the ammonia end, 50.0 s after the drops were added. Ammonia molecules are known to have a smaller mass than hydrogen chloride molecules.

(a) Calculate the average speed at which the ammonia gas diffused to the point where the ring formed. **(2)**

(b) Explain, using particle ideas, why the ring does not form at the midpoint of the tube (20.0 cm from each end), and state what this shows about the relative masses of ammonia and hydrogen chloride molecules. **(3)**

(Total for Question 15 is 5 marks)

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16 A student carries out an experiment to determine the specific heat capacity of water using an electrical heater. The heater has a power of 600 W and is switched on for 200 s to heat 0.300 kg of water, producing a temperature rise of 80.0°C. Use this data to calculate the specific heat capacity of water implied by the student's results, and compare it with the accepted value of 4200 J/(kg °C).

(a) Calculate the specific heat capacity of water from the student's results, using E = m c deltaT where E is the energy supplied by the heater. **(3)**

(b) State whether this calculated value agrees with the accepted value, and give a reason for any difference. **(2)**

(Total for Question 16 is 5 marks)

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17 A student investigates how pressure of a gas changes with volume at constant temperature. They record the following data for a fixed amount of gas at 300 K: Volume (x 10^{-3} m3): 1.00, 1.25, 1.67, 2.50. Corresponding pressure (kPa): 400, 320, 240, 160. Using these data, analyse whether the gas obeys Boyle's law and explain any small deviations from the ideal behaviour using particle ideas.

(a) Using the data, show that pressure x volume is approximately constant for each measurement and state your conclusion about Boyle's law. **(3)**

(b) Explain two particle-level reasons why real gases might show small deviations from the ideal Boyle behaviour at high pressures or low volumes. **(3)**

(Total for Question 17 is 6 marks)

18 A sealed cylinder contains a fixed mass of gas. The gas is compressed slowly at constant temperature from a volume of 5.00 x 10^{-3} m3 to a volume of 1.00 x 10^{-3} m3. The initial pressure is 1.00 x 10^{5} Pa.

(a) Use pV = constant to calculate the final pressure of the gas. **(3)**

(b) Calculate the change in volume during the compression, then estimate the work done on the gas using an average pressure of (p1 + p2) / 2 for the compression (work done = average pressure x change in volume). State what would happen to the internal energy of the gas if no heat were lost to the surroundings. **(4)**

(Total for Question 18 is 7 marks)

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Mark scheme · 3.3 Particle Model of Matter: 2-hour Pack

Question 1

(a) partially fill the measuring cylinder with water and record the volume, V1 **B1**

(a) tie the stone to a thin piece of string and lower it fully into the water (fully submerged, no air bubbles), then record the new volume, V2 **B1**

(a) volume of stone = V2 - V1 **B1**

(a) Answer: Record initial volume, fully submerge stone, record new volume; volume of stone = V2 - V1.

(b) volume of stone = 85 - 60 = 25 cm^3 **M1**

(b) 67.5 / 25 substituted **M1**

(b) 2.7 g/cm^3 cao **A1**

(b) Answer: 2.7 g/cm^3

(c) read the water level at eye level, at the bottom of the meniscus, to avoid a parallax error oe (allow: use the thinnest possible string) **B1**

(c) Answer: Read the meniscus at eye level to avoid parallax error.

Question 2

(a) the particles of the gas are moving quickly, in random directions, oe **B1**

(a) the particles collide with the walls of the container, and these collisions exert a force on the walls, which causes pressure, oe **B1**

(a) Answer: The gas particles are moving quickly in random directions, and they collide with the walls of the container. These collisions exert a force on the walls, which is what causes the gas pressure.

(b) the particles have more kinetic energy and move faster, oe **B1**

(b) this causes more frequent and more forceful collisions with the walls of the container, increasing the pressure, oe **B1**

(b) Answer: The particles have more kinetic energy and move faster, so they collide with the walls of the container more frequently and more forcefully, which increases the pressure.

Question 3

(a) heating the gas inside increases the pressure of the gas (as particles move faster and collide with the walls more often/forcefully), oe **B1**

(a) if the pressure becomes too high, the can could burst/explode, oe **B1**

(a) Answer: Heating the sealed can increases the pressure of the gas inside, because the particles move faster and collide with the walls of the can more often and more forcefully. If the pressure becomes too high, the can could burst or explode.

Question 4

(a) partly fill the measuring cylinder with water and record the volume, oe **B1**

(a) lower the stone into the water (using the string) so it is fully submerged, and record the new volume, oe **B1**

(a) calculate the volume of the stone as the difference between the two readings, oe **B1**

(a) Answer: Partly fill the measuring cylinder with water and record the volume. Lower the stone fully into the water using the string and record the new volume. The volume of the stone is the difference between the two readings.

(b) volume of stone = 58 - 40 = 18 cm^3 **M1**

(b) 45 / 18 **M1**

(b) 2.5 g/cm^3 cao **A1**

(b) Answer: 2.5 g/cm^3

Question 5

(a) the kinetic energy and the potential energy of the particles in the system, oe **B1**

(a) Answer: The kinetic energy and the potential energy of all the particles in the system.

(b) the internal energy of the water increases, oe **B1**

(b) the kinetic energy of the particles increases, so they move faster, which is what causes the temperature to rise, oe **B1**

(b) Answer: The internal energy of the water increases, because the kinetic energy of its particles increases and they move faster; this increase in particle kinetic energy is what causes the temperature to rise.

Question 6

(a) the substance is melting (changing from a solid to a liquid), oe **B1**

(a) Answer: The substance is melting, changing from a solid into a liquid.

(b) the energy supplied is being used to break the bonds/forces holding the particles in fixed positions (to overcome the forces between particles), oe **B1**

(b) instead of increasing the kinetic energy of the particles, so the temperature does not rise while the state is changing, oe **B1**

(b) Answer: The energy supplied is being used to break the bonds holding the particles in fixed positions (to overcome the forces between particles), rather than to increase their kinetic energy, so the temperature does not rise while the substance is changing state.

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Question 7

(a) states that pressure arises from particles colliding with the container walls and transferring momentum **M1**

(a) explains that if average speed doubles, the momentum change per collision doubles and the particles also hit the walls twice as often, so the impulse delivered per second increases fourfold **M1**

(a) concludes pressure increases; for an ideal gas with the same number of particles and volume the pressure increases by a factor of 4 (p is proportional to speed squared), cao **A1**

(a) Answer: Pressure increases; for the same number of particles and the same volume, doubling the average particle speed doubles the momentum change per collision and also doubles how often particles hit the walls, so the pressure increases by a factor of 4.

Question 8

(a) calculates change in volume: A x distance = 0.020 m^2 x 0.020 m = 4.0 x 10^{-4} m3 **M1**

(a) substitutes into W = p x deltaV with p = 1.50 x 10^5 Pa and deltaV = 4.0 x 10^{-4} m3 **M1**

(a) evaluates the product correctly to an intermediate value **M1**

(a) W = 60 J cao **A1**

(a) states that work is done on the gas (positive work) cao **B1**

(a) Answer: 60 J

Question 9

(a) states that average kinetic energy is proportional to absolute temperature **M1**

(a) sets up ratio KE_final / KE_initial = T_final / T_initial **M1**

(a) evaluates ratio 500 / 250 = 2.0 cao **A1**

(a) concludes average kinetic energy doubles **B1**

(a) Answer: Average kinetic energy doubles; ratio = 2.0

Question 10

Level 3 A clear, detailed and correctly ordered explanation covering all stages: heating the ice, melting at a constant temperature, heating the water, boiling at a constant temperature, and heating the steam, with correct reference to particle kinetic energy and to the breaking of bonds/forces between particles during the two changes of state. **5-6**

Level 2 A mostly correct explanation covering several of the stages, with some reference to particle kinetic energy and/or breaking of bonds, but one stage may be missing, muddled or only partly explained. **3-4**

Level 1 A simple, partial description of what happens, for example naming melting and/or boiling, with little or no reference to particle kinetic energy or internal energy. **1-2**

Indicative content:

- As the solid ice is heated from -10°C, its temperature rises steadily, because the particles gain kinetic energy and vibrate/move faster about their fixed positions.
- At 0°C, the ice melts: the temperature stays constant while all the energy supplied is used to break the bonds/forces holding the particles in their fixed positions, increasing the particles' potential energy (and the internal energy of the substance) without increasing their kinetic energy.
- Once melting is complete, the liquid water heats up and its temperature rises steadily again, because the particles' kinetic energy increases further.
- At 100°C, the water boils: the temperature stays constant again while the energy supplied is used to overcome the forces of attraction between the particles completely, so they can separate and move freely as a gas (increasing potential energy/internal energy, not kinetic energy).
- Once boiling is complete, the steam continues to heat up from 100°C to 110°C, and its temperature rises again as the particles' kinetic energy increases.
- Throughout the whole process the internal energy of the substance keeps increasing, both during the temperature rises (kinetic energy increasing) and during the two constant-temperature plateaus (potential energy increasing as bonds break).

Question 11

(a) uses p1V1 = p2V2 and substitutes p1 = 1.20e5 Pa, V1 = 2.50e-3 m^3, V2 = 1.00e-3 m^3 **M1**

(a) rearranges to p2 = p1V1 / V2 **M1**

(a) p2 = 3.00 x 10^5 Pa cao **A1**

(a) Answer: 3.00 x 10^5 Pa

(b) the average kinetic energy of the particles stays the same, because it depends only on temperature and the temperature is unchanged, oe **B1**

(b) Answer: The average kinetic energy of the particles stays the same, because temperature is unchanged.

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Question 12

(a) substitutes L = energy / mass **M1**

(a) L = 1.32 x 10^5 J/kg cao **A1**

(a) Answer: 1.32 x 10^5 J/kg

(b) one error and one linked improvement, e.g. heat loss to surroundings; improvement use insulation around the block to reduce heat loss **B1**

(b) Answer: Heat loss to surroundings; improve by insulating the block and container.

Question 13

(a) states that work is done on the gas when the piston compresses it quickly, so energy is transferred to the gas **M1**

(a) states that the transferred energy increases the kinetic energy of the gas particles **M1**

(a) relates increased kinetic energy to increased average speed of particles **M1**

(a) concludes increased average particle speed means a higher temperature (temperature is a measure of average kinetic energy), cao **A1**

(a) Answer: Work is done on the gas during compression so energy is transferred to the particles, increasing their kinetic energy and average speed; a higher average kinetic energy corresponds to a higher temperature.

Question 14

(a) substitutes into volume = mass / density = 2.00e-3 / 1000 **M1**

(a) 2.00 x 10^{-6} m3 cao **A1**

(a) Answer: 2.00 x 10^{-6} m3

(b) substitutes into volume = mass / density = 2.00e-3 / 0.590 to get volume of steam **M1**

(b) factor increase = V_steam / V_liquid = approximately 1690 (accept 1680-1700), cao **A1**

(b) Answer: Volume of steam = 3.39 x 10^{-3} m3; the volume increases by a factor of about 1690.

Question 15

(a) uses speed = distance / time = 0.250 / 50.0 (converting 25.0 cm to 0.250 m) **M1**

(a) 5.00 x 10^{-3} m/s cao **A1**

(a) Answer: 5.00 x 10^{-3} m/s

(b) the ring forms nearer the hydrochloric acid end (25.0 cm from the ammonia end, only 15.0 cm from the HCl end), showing the ammonia travelled further in the same time, oe **B1**

(b) at the same temperature, gas particles with a smaller mass have a higher average speed for a given amount of kinetic energy, oe **B1**

(b) so ammonia molecules must have a smaller mass than hydrogen chloride molecules, which is why they diffuse further/faster in the same time, oe **B1**

(b) Answer: The ring forms closer to the HCl end, showing ammonia diffused further in the same time. At the same temperature, particles with a smaller mass move faster, so this confirms ammonia molecules have a smaller mass than hydrogen chloride molecules.

Question 16

(a) calculates energy supplied E = power x time = 600 x 200 = 120000 J **M1**

(a) substitutes into c = E / (m deltaT) with deltaT = 80.0°C **M1**

(a) c = 5000 J/(kg °C) cao **A1**

(a) Answer: 5000 J/(kg °C)

(b) states the calculated value (5000 J/(kg °C)) is higher than the accepted value (4200 J/(kg °C)), so does not closely agree **B1**

(b) gives reason: heat is lost to the surroundings and the container during heating, so not all the electrical energy supplied went into heating the water, making the experimental value higher than the true value, oe **B1**

(b) Answer: The calculated value (5000 J/(kg °C)) is higher than the accepted value (4200 J/(kg °C)). This is likely because heat was lost to the surroundings and container, so not all the electrical energy supplied went into heating the water.

Question 17

Level 1 Limited analysis: may show one p x V product or state Boyle's law without calculation; explanation of deviations missing or superficial. **0-2**

Level 2 Some correct calculations shown for p x V and a basic explanation of deviations with at least one particle-level idea. **3-4**

Level 3 Clear calculations showing p x V approximately constant and a coherent particle-level explanation linking finite size and intermolecular forces to deviations. **5-6**

Indicative content:

- Convert units consistently when calculating p x V; show products are approximately equal.
- Explain that at high pressure particles are closer so attractions matter; finite particle volume reduces free volume and affects pressure.

Question 18

(a) uses p1V1 = p2V2 and substitutes p1 = 1.00e5 Pa, V1 = 5.00e-3 m^3, V2 = 1.00e-3 m^3 **M1**

(a) rearranges to p2 = p1V1 / V2 **M1**

(a) p2 = 5.00 x 10^5 Pa cao **A1**

(a) Answer: 5.00 x 10^5 Pa

(b) calculates change in volume: deltaV = V1 - V2 = 5.00e-3 - 1.00e-3 = 4.00e-3 m^3 **M1**

(b) calculates average pressure = (1.00e5 + 5.00e5) / 2 = 3.00e5 Pa **M1**

(b) substitutes into work done = average pressure x deltaV = 3.00e5 x 4.00e-3 **M1**

(b) work done on gas = 1200 J, and states that if no heat were lost, the internal energy of the gas would increase by 1200 J and its temperature would rise, cao **A1**

(b) Answer: Work done on gas = 3.00 x 10^5 x 4.00 x 10^{-3} = 1200 J. If no heat were lost, the internal energy of the gas would increase by 1200 J and its temperature would rise (in a slow compression at constant temperature this energy is instead transferred to the surroundings).

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