HIGHER

P3H Particle Model of Matter: Higher Tier Practice

AQA 8463 · Calculator allowed · about 110 minutes

Total Marks

Name: ______________________________ Date: ____ / ____ / ______

Answer ALL questions. Show all your working.

1 A student measures the mass and volume of a small piece of aluminium to calculate its density.

(a) The mass is 13.5 g and the volume is 5.00 cm3. Convert the mass into kilograms. **(1)**

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(b) Calculate the density of the aluminium in kg/m3. (1 cm3 = 1e-6 m3) **(2)**

....

(Total for Question 1 is 3 marks)

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2 A container holds a gas at constant temperature. 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 2 is 3 marks)

3 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)**

....

(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 3 is 4 marks)

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4 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 4 is 3 marks)

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5 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)**

(Total for Question 5 is 4 marks)

6 A cylindrical sealed container of gas has cross-sectional area 0.020 m2 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 x 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)**

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(Total for Question 6 is 5 marks)

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7 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 7 is 4 marks)

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8 An experiment measures the specific heat capacity of a liquid. A mass of 0.750 kg of the liquid is heated from 18.0 degrees C to 38.0 degrees C using an electrical heater supplying 900 W. The heater is switched on for 240 s. Neglect heat losses to the surroundings for the calculation.

(a) Calculate the specific heat capacity c of the liquid using E = m c deltaT, where E is the energy supplied by the heater. **(4)**

....

(Total for Question 8 is 4 marks)

9 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 degrees 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 degrees 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 9 is 5 marks)

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10 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 one particle-level reason why real gases might show small deviations from the ideal Boyle behaviour at high pressures or low volumes. **(3)**

(Total for Question 10 is 6 marks)

11 The density of liquid water is 1000 kg/m3. The density of steam (water vapour) at 100 degrees C and atmospheric pressure is 0.590 kg/m3. A student converts 2.00 x 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 11 is 4 marks)

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12 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 12 is 5 marks)

13 A sealed container shows a pressure reading of 2.50×10^5 Pa. A laboratory assistant records this value and also reports it in kilopascals and in atmospheres. Convert 2.50×10^5 Pa into kilopascals and into atmospheres (1 atm = 1.013×10^5 Pa).

(a) Convert the pressure into kilopascals. **(1)**

(b) Convert the pressure into atmospheres using 1 atm = 1.013×10^5 Pa. Give your answer to 3 significant figures. **(2)**

....

(Total for Question 13 is 3 marks)

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14 A sealed cylinder contains a fixed mass of gas. The gas is compressed slowly at constant temperature from a volume of 5.00×10^{-3} m3 to a volume of 1.00×10^{-3} m3. The initial pressure is 1.00×10^5 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 happens to the internal energy of the gas as a result, assuming no heat is lost. **(4)**

....

(Total for Question 14 is 7 marks)

Mark scheme · P3H Particle Model of Matter: Higher Tier Practice

Question 1

- (a) **B1** conversion: 13.5 g = 0.0135 kg
- **(a) Answer: 0.0135 kg**
- (b) **M1** substitutes mass and volume into density = mass / volume with volume converted to m3
- (b) **A1** density = 2700 kg/m3 cao
- **(b) Answer: 2700 kg/m3**

Question 2

- (a) **M1** states that pressure arises from particles colliding with the container walls and transferring momentum
- (a) **M1** explains that if average speed doubles, momentum transfer per collision increases and collisions deliver greater impulse
- (a) **A1** concludes pressure increases; for ideal gas at same number and volume pressure doubles, cao
- **(a) Answer: Pressure increases; for the same number of particles and same volume, doubling average particle speed doubles the momentum transfer per collision and so doubles the pressure.**

Question 3

- (a) **M1** uses p1V1 = p2V2 and substitutes p1 = 1.20e5 Pa, V1 = 2.50e-3 m3, V2 = 1.00e-3 m3
- (a) **M1** rearranges to p2 = p1V1 / V2
- (a) **A1** p2 = 3.00 x 10^5 Pa cao
- **(a) Answer: 3.00 x 10^5 Pa**
- (b) **B1** the average kinetic energy of the particles stays the same, because it depends only on temperature and the temperature is unchanged, oe
- **(b) Answer: The average kinetic energy of the particles stays the same, because temperature is unchanged.**

Question 4

- (a) **M1** substitutes L = energy / mass
- (a) **A1** L = 1.32 x 10^5 J/kg cao
- **(a) Answer: 1.32 x 10^5 J/kg**
- (b) **B1** one error and one linked improvement, e.g. heat loss to surroundings; improvement use insulation around the block to reduce heat loss
- **(b) Answer: Heat loss to surroundings; improve by insulating the block and container.**

Question 5

- (a) **M1** states that work is done on the gas when the piston compresses it quickly, so energy is transferred to the gas
- (a) **M1** states that the transferred energy increases the kinetic energy of the gas particles
- (a) **M1** relates increased kinetic energy to increased average speed of particles
- (a) **A1** concludes increased average particle speed means a higher temperature (temperature is a measure of average kinetic energy), cao
- **(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 6

- (a) **M1** calculates change in volume: A x distance = 0.020 m2 x 0.020 m = 4.0 x 10^{-4} m3
- (a) **M1** substitutes into W = p x deltaV with p = 1.50 x 10^5 Pa and deltaV = 4.0 x 10^{-4} m3
- (a) **M1** evaluates the product correctly to an intermediate value
- (a) **A1** W = 60 J cao
- (a) **B1** states that work is done on the gas (positive work) cao
- **(a) Answer: 60 J**

Question 7

- (a) **M1** states that average kinetic energy is proportional to absolute temperature
- (a) **M1** sets up ratio KE_final / KE_initial = T_final / T_initial
- (a) **A1** evaluates ratio 500 / 250 = 2.0 cao
- (a) **B1** concludes average kinetic energy doubles
- **(a) Answer: Average kinetic energy doubles; ratio = 2.0**

Question 8

- (a) **M1** calculates energy supplied E = power x time = 900 x 240 = 216000 J
- (a) **M1** substitutes into c = E / (m deltaT) with deltaT = 20.0 degrees C
- (a) **A1** evaluates c = 216000 / (0.750 x 20.0) = 14400 J/kg degrees C cao
- (a) **B1** states units J/kg degrees C cao
- **(a) Answer: 14400 J/kg degrees C**

Question 9

- (a) **M1** calculates energy supplied E = power x time = 600 x 200 = 120000 J
- (a) **M1** substitutes into c = E / (m deltaT) with deltaT = 80.0 degrees C
- (a) **A1** c = 5000 J/(kg degrees C) cao
- **(a) Answer: 5000 J/(kg degrees C)**
- (b) **B1** states the calculated value (5000 J/(kg degrees C)) is higher than the accepted value (4200 J/(kg degrees C)), so does not closely agree
- (b) **B1** 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
- **(b) Answer: The calculated value (5000 J/(kg degrees C)) is higher than the accepted value (4200 J/(kg degrees 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 10

- **Level 1** (0-2): Limited analysis: may show one p x V product or state Boyle's law without calculation; explanation of deviations missing or superficial.
- **Level 2** (3-4): Some correct calculations shown for p x V and a basic explanation of deviations with at least one particle-level idea.
- **Level 3** (5-6): Clear calculations showing p x V approximately constant and a coherent particle-level explanation linking finite size and intermolecular forces to deviations.
- **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 11

- (a) **M1** substitutes into volume = mass / density = 2.00e-3 / 1000
- (a) **A1** 2.00 x 10^{-6} m3 cao
- **(a) Answer: 2.00 x 10^{-6} m3**
- (b) **M1** substitutes into volume = mass / density = 2.00e-3 / 0.590 to get volume of steam
- (b) **A1** factor increase = V_steam / V_liquid = approximately 1690 (accept 1680-1700), cao
- **(b) Answer: Volume of steam = 3.39 x 10^{-3} m3; the volume increases by a factor of about 1690.**

Question 12

- (a) **M1** uses speed = distance / time = 0.250 / 50.0 (converting 25.0 cm to 0.250 m)
- (a) **A1** 5.00 x 10^{-3} m/s cao
- **(a) Answer: 5.00 x 10^{-3} m/s**
- (b) **B1** 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
- (b) **B1** at the same temperature, gas particles with a smaller mass have a higher average speed for a given amount of kinetic energy, oe
- (b) **B1** so ammonia molecules must have a smaller mass than hydrogen chloride molecules, which is why they diffuse further/faster in the same time, oe
- **(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 13

- (a) **B1** 2.50 x 10^{2} kPa (conversion by dividing by 1000)
- **(a) Answer: 250 kPa**
- (b) **M1** substitutes into atm = 2.50e5 / 1.013e5
- (b) **A1** 2.47 atm cao to 3 s.f.
- **(b) Answer: 2.47 atm**

Question 14

- (a) **M1** uses p1V1 = p2V2 and substitutes p1 = 1.00e5 Pa, V1 = 5.00e-3 m3, V2 = 1.00e-3 m3
- (a) **M1** rearranges to p2 = p1V1 / V2
- (a) **A1** p2 = 5.00 x 10^{5} Pa cao
- **(a) Answer: 5.00 x 10^{5} Pa**
- (b) **M1** calculates change in volume: deltaV = V1 - V2 = 5.00e-3 - 1.00e-3 = 4.00e-3 m3
- (b) **M1** calculates average pressure = (1.00e5 + 5.00e5) / 2 = 3.00e5 Pa
- (b) **M1** substitutes into work done = average pressure x deltaV = 3.00e5 x 4.00e-3
- (b) **A1** work done on gas = 1200 J, and states that since no heat is lost, the internal energy of the gas increases by 1200 J and its temperature rises, cao
- **(b) Answer: Work done on gas = 3.00 x 10^{5} x 4.00 x 10^{-3} = 1200 J. As no heat is lost, the internal energy of the gas increases by 1200 J and its temperature rises.**