3.12 Physics: Thermal Physics and Gases: 30-minute Pack

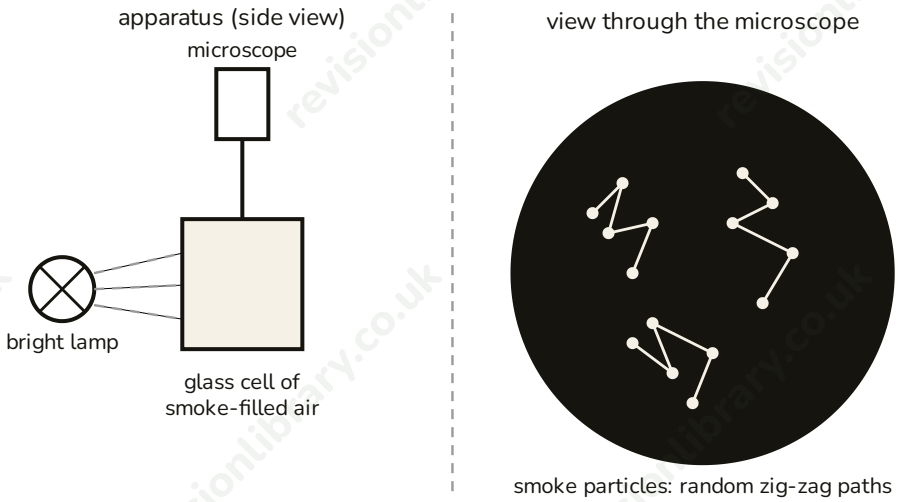
AQA 7408 · Calculator allowed · about 30 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 In a smoke-cell experiment, smoke particles suspended in air are observed under a microscope, illuminated from the side. Small bright specks (the smoke particles) are seen to move continuously in random, zig-zag paths.



(a) Explain how these observations provide evidence for the kinetic theory model of a gas, in which air is made up of molecules in continuous, fast, random motion. **(4)**

(b) State the name given to this random, continuous motion of small particles suspended in a fluid, and give one other example (other than smoke in air) of where it can be observed. **(2)**

(Total for Question 1 is 6 marks)

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2 A sample of neon gas (molar mass 20.2 g/mol) is enclosed in a rigid container of volume 5.00 x 10^{-3} m^3 at a pressure of 2.48 x 10^5 Pa and a temperature of 300 K. The gas may be treated as ideal. Take R = 8.31 J/(mol K) and N_A = 6.02 x 10^{23} /mol. The equation $pV = (1/3)Nm(c^2)$, where the bar denotes a mean, relates the pressure and volume of the gas to the number of molecules N, the mass m of one molecule, and the mean square speed (c^2) of the molecules.

(a) Show that the number of neon molecules in the container is about 3 x 10^{23}. **(3)**

(b) Calculate the mass, in kg, of one neon atom. **(2)**

(c) Using $pV = (1/3)Nm(c^2)$, calculate the mean square speed (c^2) of the neon atoms, and hence calculate their root mean square speed. **(5)**

(Total for Question 2 is 10 marks)

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3 The mean translational kinetic energy of a molecule of an ideal gas is given by (3/2)kT, where k is the Boltzmann constant (k = 1.38 x 10^{-23} J/K) and T is the thermodynamic temperature.

(a) Calculate the mean translational kinetic energy of a gas molecule at a temperature of 25°C. **(3)**

(b) Calculate the temperature, in degrees Celsius, at which the mean translational kinetic energy of a gas molecule would be double the value calculated in part (a). **(3)**

(c) Hence explain why doubling the Celsius temperature of a gas (for example, from 25°C to 50°C) does not double the mean kinetic energy of its molecules. **(2)**

(Total for Question 3 is 8 marks)

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Mark scheme · 3.12 Physics: Thermal Physics and Gases: 30-minute Pack

Question 1

(a) the smoke particles are much larger (and heavier) than individual air molecules, so they are visible as bright specks by reflected/scattered light, whereas the air molecules themselves are far too small to see **B1**

(a) each smoke particle is continuously bombarded (collided with) on all sides by the (invisible) fast-moving air molecules **B1**

(a) at any instant, the number and direction of these collisions is not perfectly balanced (random/unequal from different directions), so the smoke particle experiences a net, randomly-changing (unbalanced) force **B1**

(a) this net random force causes the particle's random, zig-zag motion; since this can only be caused by collisions with individually moving particles, it is indirect evidence that air is made of discrete, fast-moving, randomly-moving molecules, supporting the kinetic theory model (oe) **B1**

(a) Answer: The visible smoke particles are bombarded from all sides by the much smaller, invisible, fast-moving air molecules. Because the number and direction of these collisions is randomly unequal at any instant, the smoke particle receives a net, constantly-changing force, producing its random zig-zag motion. Since this motion can only be caused by collisions with individual moving particles, it is indirect evidence that air is made up of molecules in continuous random motion, as the kinetic theory model proposes.

(b) Brownian motion **B1**

(b) any valid other example, e.g. pollen grains (or dust particles) suspended in water and viewed under a microscope also show random, continuous movement **B1**

(b) Answer: Brownian motion; for example, pollen grains (or dust particles) suspended in water and viewed under a microscope also show this random continuous movement.

Question 2

(a) rearranges pV = nRT to n = pV/(RT) and substitutes correctly, finding n = 0.497 mol **M1**

(a) multiplies by the Avogadro constant: $N = n \times N_A$ **M1**

(a) $N = 2.99 \times 10^{23}$ (approximately 3×10^{23}), with clear supporting working shown **A1**

(a) Answer: N is approximately 3×10^{23} molecules

(b) converts molar mass to kg/mol and divides by the Avogadro constant: $m = M/N_A$ **M1**

(b) $m = 3.36 \times 10^{-26}$ kg, awrt 3 sf **A1**

(b) Answer: $m = 3.36 \times 10^{-26}$ kg

(c) rearranges to make (c^2) the subject: $(c^2) = 3pV/(Nm)$, recognising that N x m equals the total mass of the gas sample **M1**

(c) correct substitution using their N (part a), m (part b), or the equivalent total gas mass **M1**

(c) $(c^2) = 3.70 \times 10^5$ m^2/s^2 (accept 3.6-3.8 x 10^5 m^2/s^2), ft **A1**

(c) takes the square root of their (c^2) to find the root mean square speed **M1**

(c) $c_{rms} = 608$ m/s (accept 600-615 m/s), awrt 3 sf, ft **A1**

(c) Answer: $(c^2) = 3.70 \times 10^5$ m^2/s^2; $c_{rms} = 608$ m/s

Question 3

(a) converts temperature to kelvin: T = 25 + 273 = 298 K **M1**

(a) correct substitution into (3/2)kT **M1**

(a) 6.17×10^{-21} J, awrt 3 sf **A1**

(a) Answer: 6.17×10^{-21} J

(b) recognises that kinetic energy is directly proportional to thermodynamic temperature, so doubling the kinetic energy requires doubling the temperature in kelvin, ft from (a) **M1**

(b) $T_{new} = 2 \times 298 = 596$ K **M1**

(b) 323°C, awrt 3 sf, ft from candidate's T in (a) **A1**

(b) Answer: 323°C

(c) mean kinetic energy is proportional to the thermodynamic (kelvin) temperature, not the Celsius temperature (oe) **M1**

(c) doubling the Celsius value (e.g. 25°C to 50°C) is only a change from 298 K to 323 K, which is nowhere near double the kelvin temperature, so the kinetic energy is far from doubling (oe) **A1**

(c) Answer: Kinetic energy depends on the thermodynamic (kelvin) temperature, not the Celsius value. Doubling 25°C to 50°C only changes T from 298 K to 323 K, a small fractional increase, so the kinetic energy does not come close to doubling.

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