InkPhysics

QUESTION WORKBOOK

Molecular kinetic theory

Thermal physics · Year 13

AQA 3.6.2.3 · CIE 15.3.1, 15.3.2, 15.3.3, 15.3.4
OCR A 5.1.2(c), 5.1.4(b), 5.1.4(c), 5.1.4(e), 5.1.4(f), 5.1.4(h), 5.1.4(i)

19 questions · 53 marks

NAVY SCREEN EDITION

SECTION A · Warm-up

A1 State two assumptions of the kinetic theory model of an ideal gas. [2]

A2 Calculate the average kinetic energy of a gas molecule at 300 K, using mean KE = (3/2)kT ($k = 1.38 \times 10^{-23}$ J K^{-1}). [2]

A3 State the kinetic theory equation relating pressure, volume and molecular speed. [2]

A4 Smoke particles suspended in air are viewed through a microscope. Describe what is observed, and state what this observation is evidence for. [2]

A5 State what is meant by the root-mean-square speed of the molecules of a gas. [1]

A6 At one instant, four gas molecules have speeds of 300 m s^{-1}, 400 m s^{-1}, 500 m s^{-1} and 600 m s^{-1}. Calculate their root-mean-square speed. [2]

SECTION B · Standard

B1 Calculate the total kinetic energy of one mole of an ideal gas at 400 K, using R = 8.31 J mol^{-1} K^{-1}. [3]

B2 A nitrogen molecule has a mass of 4.7×10^{-26} kg. Calculate its root-mean-square speed at 300 K, using $\frac{1}{2}m(c_{rms})^2 = (3/2)kT$. [3]

B3 A gas of density 1.2 kg m^{-3} has molecules with an rms speed of 500 m s^{-1}. Calculate its pressure, using $p = \frac{1}{3}\rho(c_{rms})^2$. [3]

B4 At the same temperature, explain which has the greater root-mean-square speed: a light molecule or a heavy one. [3]

B5 A nitrogen molecule of mass 4.65×10^{-26} kg strikes a container wall head-on at 480 m s^{-1} and rebounds along the same line at the same speed. Calculate the change in momentum of the molecule. The molecule returns and strikes the same wall once every 1.2 ms. Go on to calculate the average force it exerts on the wall. [3]

B6 A container holds a mixture of helium (molecular mass 6.6×10^{-27} kg) and argon (molecular mass 6.6×10^{-26} kg) at the same temperature. State the ratio of the mean kinetic energy of a helium molecule to that of an argon molecule, and calculate the ratio c_{rms}(helium)/c_{rms}(argon). [3]

B7 A rigid container of gas is sealed and kept at constant temperature. Explain, with reference to one assumption of the kinetic theory model, why the pressure does not decrease over time. [2]

SECTION C · Stretch

C1 An oxygen molecule in air has a mass of 5.3×10^{-26} kg. Calculate (a) its mean kinetic energy at 290 K and (b) its root-mean-square speed. [4]

C2 A gas is at 300 K. Calculate the temperature to which it must be raised to double the root-mean-square speed of its molecules. [3]

C3 Explain how the kinetic theory model accounts for the pressure a gas exerts on its container. [3]

C4 A cubical box of side L contains N identical molecules, each of mass m, in random motion. Starting from the change in momentum when one molecule collides elastically with a wall, derive the equation $pV = \frac{1}{3}Nm(c_{rms})^2$. [5]

C5 The escape speed from the Earth is 11 km s^{-1}. Calculate the temperature at which hydrogen molecules (mass 3.3×10^{-27} kg) would have a root-mean-square speed equal to the escape speed ($k = 1.38 \times 10^{-23}$ J K^{-1}). The temperature of the upper atmosphere is only a few hundred kelvin, yet it contains almost no hydrogen. Suggest why. [4]

C6 A cylinder holds 0.020 m^3 of helium, an ideal gas, at a pressure of 2.5×10^5 Pa. Explain why the internal energy of the helium is entirely kinetic, and calculate this internal energy. [3]