inkPhysics

ANSWER BOOK

Molecular kinetic theory

Thermal physics · Year 13

AQA 3.6.2.3 · CIE 15.3 · OCR A 5.1.4

10 questions · 30 marks

NAVY EDITION

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SECTION A · Warm-up

A1 Any three of: molecules are in constant random motion; collisions with the walls and each other are perfectly elastic; the volume of the molecules is negligible compared with the container; the time of collisions is negligible; and there are no forces between molecules except during collisions. [2]

A2 Mean KE = $(3/2)kT = 1.5 \times 1.38 \times 10^{-23} \times 300 = 6.21 \times 10^{-21}$ J. [2]

A3 $pV = \frac{1}{3}Nm(c_{rms})^2$, where N is the number of molecules, m the mass of one molecule and c_{rms} the root-mean-square speed. [2]

SECTION B · Standard

B1 Mean KE = $(3/2)kT = 1.5 \times 1.38 \times 10^{-23} \times 400 = 8.28 \times 10^{-21}$ J. [3]

B2 $c_{rms} = \sqrt{(3kT/m)} = \sqrt{((3 \times 1.38 \times 10^{-23} \times 300)/(4.7 \times 10^{-26}))} = 514\ m\ s^{-1}$. [4]

B3 $p = \frac{1}{3}\rho(c_{rms})^2 = (1/3) \times 1.2 \times 500^2 = 1.00 \times 10^5$ Pa. [3]

B4 The light molecule. At a given temperature all molecules have the same average kinetic energy $(3/2)kT$, so $\frac{1}{2}m(c_{rms})^2$ is the same; a smaller mass m therefore requires a larger c_{rms} ($c_{rms} \propto 1/\sqrt{m}$). [3]

SECTION C · Stretch

C1 $c_{rms} = \sqrt{(3kT/m)} = \sqrt{((3 \times 1.38 \times 10^{-23} \times 290)/(5.3 \times 10^{-26}))} = 476\ m\ s^{-1}$. [4]

C2 Since $c_{rms} \propto \sqrt{T}$, doubling c_{rms} needs four times the (absolute) temperature: $T = 4 \times 300 = 1200$ K. [4]

C3 Molecules move randomly and repeatedly collide with the walls. Each collision changes a molecule's momentum, so by Newton's laws the wall exerts a force on it and it exerts an equal force back. The many collisions per second over the wall area produce a steady average pressure. [3]