InkPhysics

ANSWER BOOK

Ideal gases and the gas laws

Thermal physics · Year 13

AQA 3.6.2.2 · CIE 14.2.1, 14.2.2, 14.2.3, 14.2.4, 15.1.2, 15.2.1, 15.2.2, 15.2.3
OCR A 5.1.1(b), 5.1.1(c), 5.1.1(d), 5.1.2(e), 5.1.4(a), 5.1.4(d)(i), 5.1.4(g)

20 questions · 61 marks

NAVY EDITION

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SECTION A · Warm-up

A1 At constant temperature, the pressure of a fixed mass of gas is inversely proportional to its volume (1), so pV = constant (1). [2]

A2 $p = nRT/V = (2.0 \times 8.31 \times 300)/0.050$ (1) [2]
$p = 9.972 \times 10^4$ Pa (1)

A3 For a fixed volume of gas, pressure falls linearly as temperature falls (1). Extending the straight line back to zero pressure gives the temperature at which molecular motion would cease, -273°C, which is absolute zero, 0 K (1). [2]

A4 $T = -63 + 273 = 210$ K (1). [1]

A5 Temperatures in kelvin: 293 K and 350 K; at constant volume p/T is constant (1) [2]
$p_2 = p_1T_2/T_1 = 1.01 \times 10^5 \times 350/293 = 1.21 \times 10^5$ Pa (1)

A6 They are generalisations found from experiment and observation, not derived from a theory or model (1). [1]

SECTION B · Standard

B1 $p_1V_1 = p_2V_2$ (1) [3]
$p_2 = (1.0 \times 10^5 \times 0.020)/0.005$ (1)
$p_2 = 4.0 \times 10^5$ Pa (1)

B2 $V = nRT/p$ (1) [4]
$V = (0.50 \times 8.31 \times 300)/(2.0 \times 10^5)$ (1)
$V = 6.23 \times 10^{-3}$ m^3 (1)
The equation needs absolute temperature: only the kelvin scale starts from the true zero of molecular kinetic energy, so ratios of temperatures mean nothing in °C (1)

B3 $p = NkT/V$ (1) [3]
$p = (3.0 \times 10^{23} \times 1.38 \times 10^{-23} \times 290)/0.010$ (1)
$p = 1.20 \times 10^5$ Pa (1)

B4 At constant pressure V/T is constant (1) [3]
$V_2 = V_1T_2/T_1 = 0.010 \times 400/300$ (1)
$V_2 = 0.0133$ m^3 (1)

B5 For a fixed mass of gas, $p_1V_1/T_1 = p_2V_2/T_2$ (1) [3]
$V_2 = 12.0 \times (101/22.0) \times (218/288)$ (1)
$V_2 = 41.7\ m^3$ (1)

B6 n = mass/molar mass = 0.72/0.032 = 22.5 mol (1) [3]
p = nRT/V = (22.5 × 8.31 × 290)/0.050 (1)
$p = 1.08 \times 10^6$ Pa (1)

B7 Test whether pV is constant (1) [3]
$pV/(kPa\ cm^3)$ = 4000, 4012, 4000, 4020 (1)
The products agree to well within 1%, so the results are consistent with Boyle's law (1)

SECTION C · Stretch

C1 $W = p\Delta V$ (1) [4]
$W = 2.0 \times 10^5 \times (0.015 - 0.010)$ (1)
W = 1000 J (1)
At constant temperature the internal energy is unchanged, so the work done by the gas must be supplied as heating from the surroundings (1)

C2 From pV = NkT: N = pV/(kT) (1) [4]
$N = (1.0 \times 10^5 \times 0.024)/(1.38 \times 10^{-23} \times 300) = 5.80 \times 10^{23}$ molecules (1)
$n = N/N_A = 5.80 \times 10^{23}/(6.02 \times 10^{23})$ (1)
n = 0.96 mol (1)

C3 At low pressure and high temperature, and so at low density, the molecules are far apart (1). Then intermolecular forces are negligible (1) and the molecules' own volume is tiny compared with the container, as the ideal-gas model assumes (1). [3]

C4 Amount per balloon $n = pV/RT = (1.05 \times 10^5 \times 0.012)/(8.31 \times 293) = 0.517$ mol (1) [5]
Amount needed = 250 × 0.517 = 129 mol (1)
Amount in cylinder = $(1.5 \times 10^7 \times 0.040)/(8.31 \times 293) = 246$ mol (1)
Helium left in the cylinder at 1.05×10^5 Pa = 1.7 mol, so the usable amount is 245 mol (1)
245 mol is well above the 129 mol needed, so one cylinder is enough (1)

C5 $n = pV/RT = (1.4 \times 10^5 \times 0.080)/(8.31 \times 300) = 4.49$ mol (1) [4]
Mass of gas = 4.49 × 0.028 = 0.126 kg (1)
$\rho = m/V = 0.126/0.080 = 1.57\ kg\ m^{-3}$ (1)
Mass of one molecule = $0.028/(6.02 \times 10^{23}) = 4.65 \times 10^{-26}$ kg (1)

C6 Sensible room volume, for example 7 m × 7 m × 3 m ≈ 147 m^3 (accept 50 to 500 m^3) (1) [3]
$N = pV/kT = (1.0 \times 10^5 \times 147)/(1.38 \times 10^{-23} \times 300)$ (1)
$N \approx 3.6 \times 10^{27}$ molecules (accept order 10^{27}) (1)

C7 Submerge the flask in the water bath so the trapped air is at the bath temperature, keeping the volume (and mass) of air constant (1). Record the pressure and the temperature; wait at each temperature for the reading to settle so the air reaches the bath temperature (1). Repeat over the widest possible range of temperatures, using ice and the heater to set them (1). Plot pressure against temperature in °C, which gives a straight line (1). Extrapolate the line back to zero pressure (1). The intercept on the temperature axis is absolute zero, expected near -273°C (1). [6]