AQA, Edexcel, OCR

A Level

A Level Physics

Ideal gases (Answers)

Name:

MME

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Total Marks: /30

1. Real gases have complex behaviours which are difficult to model accurately. One simplified model is the kinetic theory, according to which macroscopic properties temperature and pressure can be calculated from simple assumptions about the microscopic behaviour of atoms and molecules.

Total for Question 1: 9

(a) Calculate the molar mass of N_2O. [1]

Solution: 44 gmol^{-1}

(b) State three assumptions of the kinetic theory of gases. [3]

Solution:
1/ very large number of molecules, random direction and speed
2/ negligible volume compared to volume of the gas
3/ elastic collisions
4/ duration of collisions is negligible compared to time between collisions
5/ negligible electrostatic forces, except during collisions

(c) Explain why a gas exerts a pressure. [2]

Solution: Molecules are continually colliding with each other and with the walls of the container. When a molecule collides with the wall, it exerts a small force on the wall. The pressure exerted by a gas is the sum of all these small collisions.

(d) Explain how you would go about calculating the value of absolute zero using a water bath. [3]

Solution: An air vessel is placed inside a water bath at a known temperature. The air vessel is connected to a pressure sensor.

$p/T = constant$

At 0 K, the internal energy is at a minimum. The particles have zero KE and are not moving; they cannot exert a pressure. By plotting a graph of pressure against temperature and extrapolating back to zero Pa, an approximate value of T can be obtained.

2. A box whose sides all measure 0.4 m contains one molecule of mass 7.6×10^{-26} kg bouncing elastically between opposite walls at 800 ms^{-1}.

Total for Question 2: 12

(a) State Boyle's Law. [1]

Solution: $pV = constant$, where p and V are pressure and volume respectively.

(b) What is the change of momentum when the molecule collides with a wall? [2]

Solution: 1.2×10^{-22} kgms^{-1}

(c) How many collisions occur with a given face in a period of 1.0 s? [1]

Solution: 1000

(d) Calculate the average pressure on a single face. [3]

Solution: 7.5×10^{-19} Pa

(e) When placed on the weighing scales, a different, sealed box measures 100 N. It contains methane (CH_4) at a pressure of 20 kPa and temperature of 25°C. Given that the box alone has a mass of 10 kg, calculate the volume of the box. [5]

Solution: 1.5 m^3

3. This question is about the speed with which particles in an ideal gas move and about how this affects different particles' energies.

Total for Question 3: 9

(a) A box containing fifty helium molecules measures $2.0 \times 0.5 \times 2.0$ m. If the r.m.s. speed of the particles is 1500 ms^{-1}, calculate the pressure inside the box. [3]

> **Solution:** 150 kPa

(b) Using the ideal gas law ($pV = NkT$) and the equation for the r.m.s. speed of a molecule, show that the kinetic energy of a particle is given by $\frac{3}{2}kT$. [3]

> **Solution:** $pV = NkT = \frac{1}{3}Nm\overline{c^2} \rightarrow kT = \frac{1}{3}m\overline{c^2}$
> Divide by 2/3: $\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT$
> This is the mean translational kinetic energy.

(c) What effect will doubling the absolute temperature of an ideal gas have on its internal energy? Justify your answer. [3]

Solution: From the previous part, $E_k \propto T$. Thus, doubling the absolute temperature will double the kinetic energy. The kinetic theory of gases assumes that there are no electrostatic forces between particles, except during collisions. Therefore, there cannot be any potential energies and so internal energy = kinetic energy. So, $internalenergy \propto T$.