A Level H2 Physics   Tutorial 8: Temperature and Ideal Gases

Syllabus :
(a) show an understanding that regions of equal temperature are in thermal equilibrium .

(b) explain how empirical evidence leads to the gas laws and to the idea of an absolute scale of temperature (i.e. the thermodynamic scale that is independent of the property of any particular substance and has an absolute zero)

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1. The pressure of nitrogen in a tank is measured at temperatures from -10 to 100 ºC.

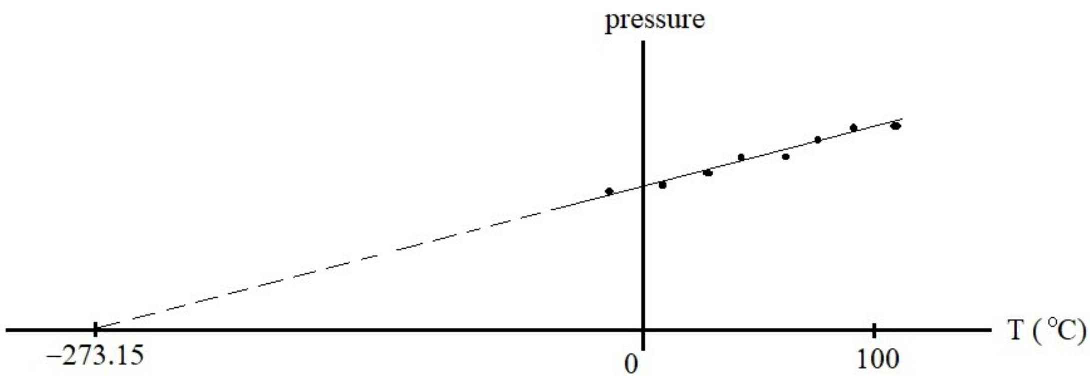

Figure 8-1

Extrapolating backwards gives -273.15 ºC at the intercept with the temperature axis.

(i) What does this suggest about the temperature -273.15 ºC ?

(ii) If we define a new temperature scale with zero at -273.15 ºC, and unit interval same as that of the Celsius scale, what would be the 0 ºC on this new scale?

(This "new" scale is called Kelvin scale, invented by Lord Kelvin in 1848.)

(c) convert temperatures measured in degrees Celsius to kelvin: T /K = T / °C + 273.15

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2. Convert these temperatures to Kelvin unit :

   (i) 0 °C
   (ii) 100 °C
   (iii) -273 °C
   (iv) -273.15 °C

(d) recall and use the equation of state for an ideal gas expressed as pV = nRT, where n is the amount of gas in moles

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(e) state that one mole of any substance contains 6.02×10^{23} particles and use the Avogadro number $N_A = 6.02 \times 10^{23}$ mol^{-1}

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3. (i) How many oxygen molecules are the in 1 mole of oxygen gas?

   (ii) What is the mass of 1 mole of the gas? (mass number of oxygen atom is 16)

   (iii) A cylinder of oxygen gas has a pressure of 1 atm, volume of 100 cm^3, temperature 25 ºC. Find the number of moles of oxygen in the cylinder.

(f) state the basic assumptions of the kinetic theory of gases

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4. State the basic assumptions of the kinetic theory of gases.

(g) explain how molecular movement causes the pressure exerted by a gas and hence derive the relationship $pV = {}^1/_3\, Nm\langle c^2\rangle$, where N is the number of gas molecules (a simple model considering one-dimensional collisions and then extending to three dimensions using ${}^1/_3 \langle c^2\rangle = \langle c_x^2\rangle$ is sufficient)

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5 (a) How does molecular movement give rise to the pressure of a gas?

(b) Derive the relationship $pV = {}^1/_3\, Nm\langle c^2\rangle$, where

- N is the number of gas molecules,
- m the mass of each molecule.

Use a simple model:

- consider 1-D collisions, then
- extend to 3-D using ${}^1/_3\langle c^2\rangle = \langle c_x^2\rangle$

Note : c is velocity of a molecule,
c_x its x component,
$\langle c_x^2\rangle$ the average c_x^2 of all molecules, and
$\langle c^2\rangle$ the average c^2 of all molecules.

(h) recall and apply the relationship that the mean kinetic energy of a molecule of an ideal gas is proportional to the thermodynamic temperature (i.e. ${}^1/_2\, m\langle c^2\rangle = {}^3/_2\, kT$) to new situations or to solve related problems.

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6. (a) Comparing $pV = nRT$
with $pV = {}^1/_3\, N m \langle c^2\rangle$, (see question 5)

show that the average kinetic energy of an ideal gas molecule is

$${}^1/_2\, m\langle c^2\rangle = {}^3/_2\, kT$$

where $k = R/N_A$.

Note: The constants are given in exams. In SI units :

Boltzmann constant	k	=	1.38×10^{-23}
Gas constant	R	=	8.31
Avogadro constant	N_A	=	6.02×10^{23}

(b) Find the total kinetic energy of the molecules in 1 mole of ideal gas – show that it is ${}^3/_2 RT$.

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