

4 (a) State the value of absolute zero on:

(i) the Celsius temperature scale

temperature = °C [1]

(ii) the thermodynamic temperature scale. Give a unit with your answer.

temperature = unit [1]

(b) A sample contains a fixed amount of gas. The gas has pressure p , volume V and thermodynamic temperature T .

Fig. 4.1 shows the variation of pV with kT for the sample, where k is the Boltzmann constant.

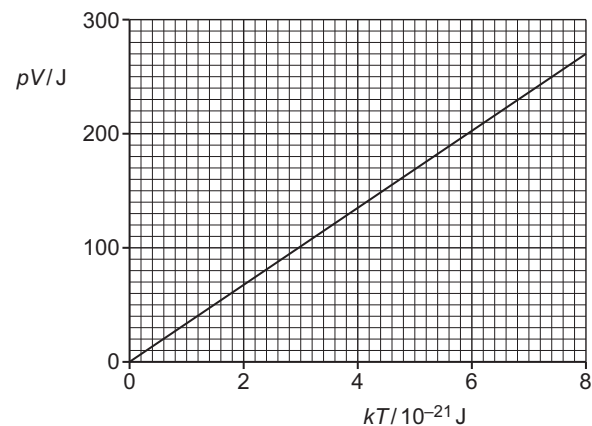


Fig. 4.1

(i) State what is indicated about the nature of the gas from the variation shown in Fig. 4.1.

..... [1]

(ii) Determine the number N of molecules of the gas in the sample.

$N =$ [2]

(iii) Use your answer in (b)(ii) to determine the amount n of gas in the sample.

$n =$ mol [1]

(c) The root-mean-square (r.m.s.) speed of the molecules of the gas is 1900 m s^{-1} when pV is equal to 270 J .

Determine the mass, in u , of one molecule of the gas, where u is the unified atomic mass unit.

mass = u [4]

[Total: 10]

4 (a) (i) State what is meant by the internal energy of a system.

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..... [2]

(ii) Explain why the internal energy of an ideal gas is directly proportional to the thermodynamic temperature of the gas.

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..... [2]

(b) A sample of an ideal gas at thermodynamic temperature T has internal energy U .

The gas is compressed so that its temperature increases to $3T$.
During this compression, work W is done on the gas.

The gas is then cooled at constant volume so that its temperature decreases to $2T$.

Complete Table 4.1 to show, in terms of some or all of W , T and U , the work done on the gas, the thermal energy supplied to the gas and the increase in internal energy of the gas for each of the two processes.

Table 4.1

	work done on gas	thermal energy supplied to gas	increase in internal energy of gas
compression	$+W$		
cooling			

[4]

[Total: 8]

3 (a) Define specific heat capacity.

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..... [2]

(b) A block of aluminium has a volume of $3.612 \times 10^{-3} \text{ m}^3$ at a temperature of 0°C .

Aluminium has a density of $2.700 \times 10^3 \text{ kg m}^{-3}$ at 0°C .
It has a density of $2.620 \times 10^3 \text{ kg m}^{-3}$ at 500°C .

The block is heated so that its temperature increases from 0°C to 500°C at an atmospheric pressure of $1.01 \times 10^5 \text{ Pa}$.
The increase in internal energy of the block is 4.38 MJ .

(i) Calculate the mass of the block.

mass = kg [2]

(ii) Show that the volume of the block at a temperature of 500°C is $3.722 \times 10^{-3} \text{ m}^3$.

[1]

(iii) Use the information in (b)(ii) to determine the magnitude of the work done on the block when its temperature is raised from 0°C to 500°C .

work done = J [2]

(iv) Explain whether the work done on the block is positive or negative.

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..... [2]

(v) Use the first law of thermodynamics to determine, to three significant figures, a value for the specific heat capacity of aluminium. Explain your reasoning. Give a unit with your answer.

specific heat capacity = unit [3]

(c) Without further calculation, suggest with a reason how doubling the pressure in (b) is likely to affect the answer in (b)(v).

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..... [1]

[Total: 13]

3 (a) Two metal cuboids P and Q are in thermal contact with each other.

(i) P and Q are in thermal equilibrium.

State what is meant by the term thermal equilibrium.

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..... [2]

(ii) Data for P and Q are given in Table 3.1.

Table 3.1

	P	Q
specific heat capacity / J kg ⁻¹ K ⁻¹	390	910
mass / kg	0.54	0.37

P and Q are initially both at the same temperature.

P is supplied with 24 kJ of thermal energy. After some time, P and Q are once again both at the same temperature as each other.

P and Q are perfectly insulated from the surroundings.

Determine the change in temperature ΔT of Q.

$\Delta T =$ K [3]

- (b) Nitrogen may be assumed to be an ideal gas. A fixed amount of nitrogen gas is contained at a constant pressure of $1.6 \times 10^5 \text{ Pa}$.

The variation of the volume V of the gas with the temperature θ of the gas is shown in Fig. 3.1.

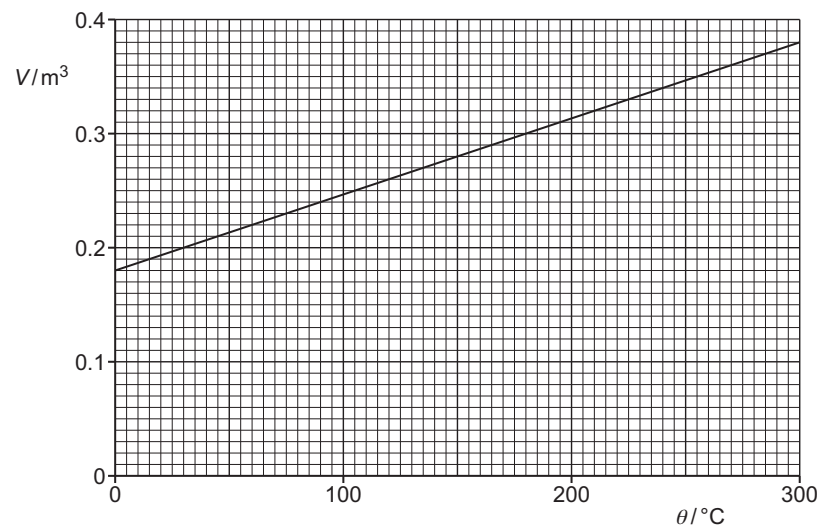


Fig. 3.1

- (i) The temperature of the nitrogen gas is increased from 0°C to 210°C . Determine the work done on the gas.

work done = J [3]

- (ii) Determine the number N of molecules of nitrogen gas.

$N =$ [2]

- (iii) The mass of a nitrogen molecule is $4.7 \times 10^{-26} \text{ kg}$.

Calculate the root-mean-square (r.m.s.) speed of a nitrogen molecule at 210°C .

r.m.s. speed = ms^{-1} [2]

[Total: 12]