3 **(a)** **(i)** State what is meant by the Avogadro constant.

.....

.....

..... [1]

(ii) State the relationship between the Avogadro constant N_A, the molar gas constant R and the Boltzmann constant k.

[1]

(b) Two samples X and Y of ideal gases are both at thermodynamic temperature T.

Sample X has volume V and consists of N molecules, each of mass m.
Sample Y has volume $2V$ and consists of $2N$ molecules, each of mass $2m$.

(i) Complete Table 3.1 by giving expressions, in terms of some or all of N, m, T, V and the constants in **(a)(ii)**, for the quantities indicated.

Table 3.1

	sample X	sample Y
pressure		
amount of substance		
mean-square speed of molecules		
internal energy		

[4]

(ii) The temperature of sample X is now varied.

On Fig. 3.1, sketch the variation with thermodynamic temperature of the root-mean-square (r.m.s.) speed of the molecules of the gas.

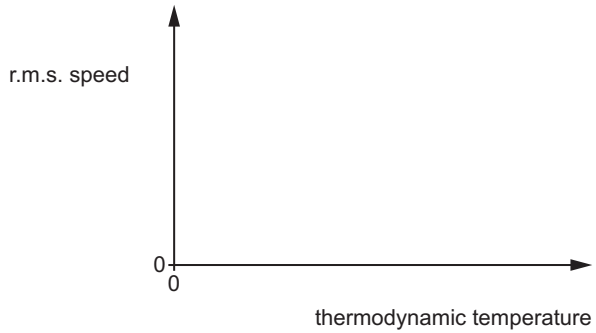

Fig. 3.1

[2]

[Total: 8]

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.

.....

.....

..... [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.

ΔT = ... 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 1.6×10^5 Pa.

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

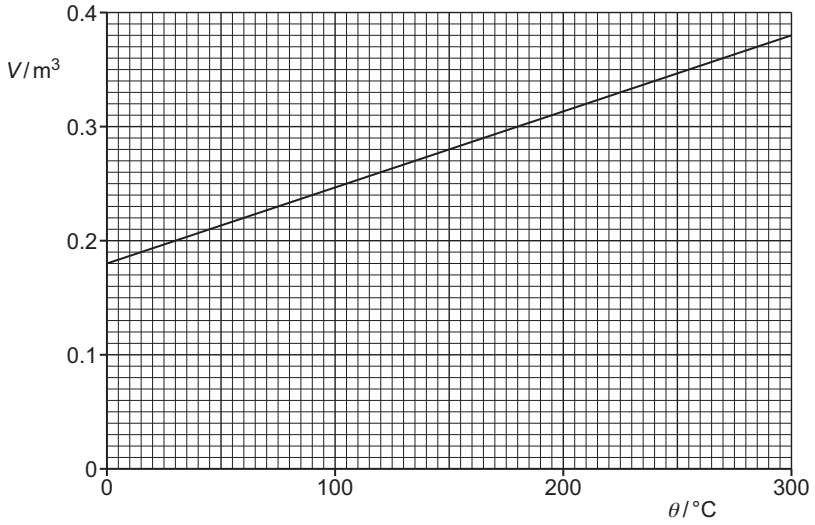

Fig. 3.1

(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 4.7×10^{-26} kg.

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

r.m.s. speed = ... $m\,s^{-1}$ [2]

[Total: 12]

8 Plutonium-238 ($^{238}_{94}Pu$) is unstable and undergoes alpha decay.

(a) Complete the equation to show the decay of plutonium-238.

$$^{238}_{94}Pu \rightarrow \,^{\cdots\cdots}_{\cdots\cdots}U + \,^{\cdots\cdots}_{\cdots\cdots}\alpha$$

[2]

(b) The power source in a space probe contains 0.874 kg of plutonium-238. Each nucleus of plutonium-238 that decays emits 5.59 MeV of energy. The half-life of plutonium-238 is 87.7 years.

(i) Calculate the initial number N_o of nuclei of plutonium-238 in the power source.

N_o = ... [1]

(ii) Determine the initial activity of the source. Give a unit with your answer.

activity = ... unit ..... [2]

(iii) Use your answer in **(b)(ii)** to determine the initial power output from the source due to the decay of plutonium-238.

power output = ... W [2]

(iv) The space probe will continue to function until the power output from the plutonium in the source decreases to 65.3% of its initial value.

Calculate the time, in years, for which the space probe will function.

time = ... years [2]

(c) An alternative power source uses energy generated from the radioactive decay of polonium-210. This isotope has a half-life of 0.378 years. The mass of the isotope needed for the same initial power output as in **(b)** is 3.37 g.

Suggest **one** advantage and **one** disadvantage of using polonium-210 as the source of energy.

advantage .....

.....

disadvantage .....

.....

[2]

[Total: 11]