1 **(a)** The ideal gas equation may be written as

$$pV = nRT.$$

State the meaning of the terms n and T.

n .....

T ..... **[2]**

(b) Fig. 6.1 shows a cylinder that contains a fixed amount of an ideal gas. The cylinder is fitted with a piston that moves freely. The gas is at a temperature of 20 °C and the initial volume is $1.2 \times 10^{-4}\,m^3$. Fig. 6.2 shows the cylinder after the gas has been heated to a temperature of 90 °C under constant pressure.

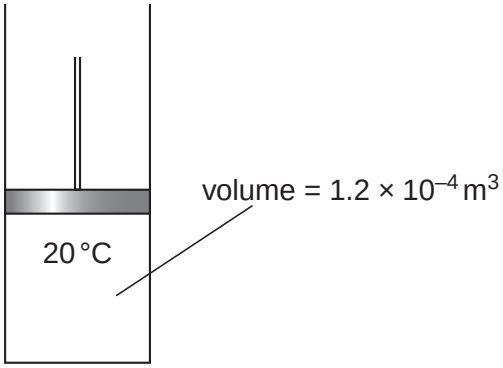

Fig. 6.1

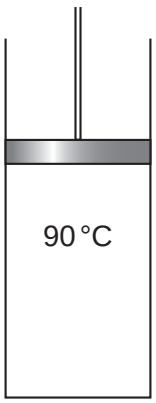

Fig. 6.2

(i) Explain in terms of the motion of the molecules of the gas why the volume of the gas must increase if the pressure is to remain constant as the gas is heated.

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..... **[4]**

(ii) Calculate the volume of the gas at 90 °C.

volume = ... m^3 **[2]**

(c) The mass of each gas molecule is 4.7×10^{-26} kg. Estimate the average speed of the gas molecules at 90 °C.

speed = ... $m\,s^{-1}$ **[3]**

[Total: 11]

2 **(a)** A patient has an X-ray scan taken in hospital. The high-energy X-ray photons interact with the atoms inside the body of the patient.

Explain what is meant by a *photon* and state **one** of its main properties.

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..... **[2]**

(b) An X-ray tube operates using a 150 kV supply. X-ray photons are produced inside the tube when a beam of high-speed electrons accelerated from the cathode collide with the metal anode. About 99% of the total kinetic energy of the electrons at the anode is converted into heat energy which heats the anode. The remaining energy is transformed into the energy of the X-ray photons.

The current in the electron beam between the cathode and the anode is 4.8 mA.

(i) Show that the number of electrons incident at the anode per second is $3.0 \times 10^{16}\,s^{-1}$.

[1]

(ii) The anode is made from metal of specific heat capacity $140\,J\,kg^{-1}\,K^{-1}$. It has a mass of 8.6 g. The X-ray tube is switched on. Calculate the initial rate of increase of temperature of the anode.

rate of temperature increase = ... °C s^{-1} **[3]**

(iii) A single electron is responsible for producing an X-ray photon. Calculate the shortest wavelength of the X-rays produced from the X-ray tube.

wavelength = ... m **[2]**

(c) An X-ray scan of the heart and its blood vessels shows very poor contrast. Describe and explain a technique that can be used to reveal these blood vessels in an X-ray scan.

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..... **[2]**