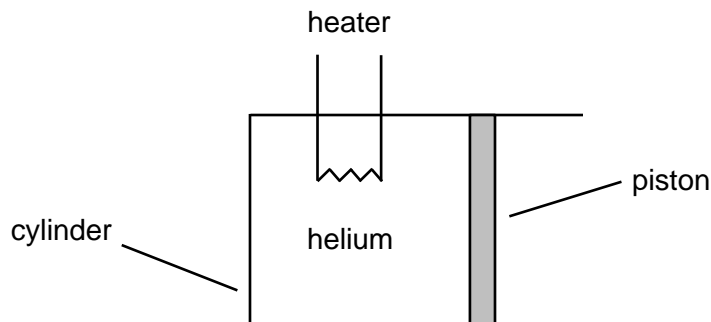**3** Fig. 3.1 shows a frictionless piston-cylinder with a built-in heater.

heater

Fig. 3.1

Before the heater is switched on, the cylinder contains 0.60 m³ of helium gas at pressure 101 kPa and temperature of 28 °C. When the heater is switched on for 15 minutes, the gas expands at constant pressure and its temperature rises to 57 °C. A heat loss of 7000 J to the surrounding occurs during the process.

Assume the gas behaves like an ideal gas and the heater is rated at 24 W and 120 V.

(a) **(i)** Using the kinetic theory of gases, explain why the volume of the gas expands when it is heated at constant pressure.

....

....

....

....

....   [2]

(ii) On Fig. 3.2, sketch the pressure-volume graph for the process. Label the graph with appropriate values of pressure and volume.
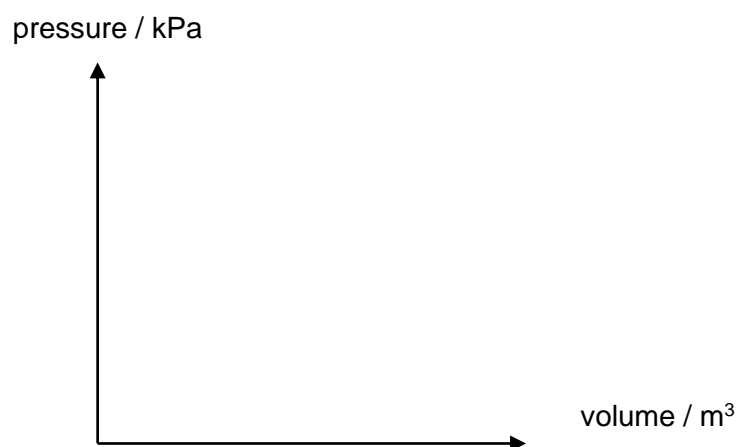
pressure / kPa

volume / m³

Fig. 3.2

[2]

(iii) Using *first law of thermodynamics*, determine the change in internal energy of the helium gas.

change in internal energy = ... J   [3]

(b) The thermodynamic temperature of a gas T is a measure of the average translational kinetic energy of a molecule in the gas. The pressure p of an ideal gas is related to its microscopic quantities by the relationship $pV = \frac{1}{3}Nm\langle c^2 \rangle$ where

V : volume occupied by the gas
N : total number of gas molecues
m : mass of each gas molecule
$\langle c^2 \rangle$: mean square speed of the gas molecules.

(i) By comparing the above relationship with $pV = Nkt$, where k is the Boltzmann constant, show that the average kinetic energy of the molecules is $E = \frac{3}{2}kT$.

[1]

(ii) Hence, calculate the root-mean-square speed of a helium molecule at 57.0 °C. The mass of one mole of helium molecules is 4.00 g.

root-mean-square speed = ... m s^{-1} [2]