2 **(a)** State **two** ways in which the first law of thermodynamics describes that the internal energy of a system may be changed.

1 ....

....

2 ....

....
[2]

(b) **(i)** Use the first law of thermodynamics to explain why a bicycle pump gets hot when it is used to pump up a tyre quickly.

....

....

....

....

.... [3]

(ii) With reference to molecular energies, explain why the temperature of water remains at 100 °C when it vaporises in a kettle, even though it is being heated.

....

....

....

....

.... [3]

[Total: 8]

2 **(a)** Define specific heat capacity.

....

....

.... [2]

(b) An ideal gas of mass 0.35 kg is heated at a constant pressure of 2.0×10^5 Pa so that its internal energy increases by 7600 J. During this process, the volume of the gas increases from $0.038\,\text{m}^3$ to $0.063\,\text{m}^3$ and the temperature increases by 56 °C.

(i) Show that the magnitude of the work done on the gas is 5000 J.

[1]

(ii) Explain whether the work done on the gas is positive or negative.

....

....

.... [2]

(iii) Determine the magnitude of the thermal energy q transferred to the gas.

q = ... J [2]

(iv) Calculate the specific heat capacity of the gas for this process. Give a unit with your answer.

specific heat capacity = ... unit .... [2]

(c) The gas in **(b)** is now heated at constant volume rather than at constant pressure.
The increase in internal energy of the gas is the same as in **(b)**.

Use the first law of thermodynamics to explain whether the specific heat capacity of the gas for this process is less than, the same as, or greater than the answer in **(b)(iv)**.

....

....

....

....

.... [3]

[Total: 12]

2 **(a)** State what is meant by an ideal gas.

....

....

.... [2]

(b) A fixed amount of helium gas is sealed in a container. The helium gas has a pressure of 1.10×10^5 Pa, and a volume of $540\,cm^3$ at a temperature of 27 °C.

The volume of the container is rapidly decreased to $30.0\,cm^3$. The pressure of the helium gas increases to 6.70×10^6 Pa and its temperature increases to 742 °C, as illustrated in Fig. 2.1.

initial state	final state
1.10×10^5 Pa	6.70×10^6 Pa
$540\,cm^3$	$30.0\,cm^3$
27 °C	742 °C

Fig. 2.1

No thermal energy enters or leaves the helium gas during this process.

(i) Show that the helium gas behaves as an ideal gas.

[2]

(ii) The first law of thermodynamics may be expressed as

$$\Delta U = q + W.$$

Use the first law of thermodynamics to explain why the temperature of the helium gas increases.

....

....

....

....

.... [2]

(iii) The average translational kinetic energy E_K of a molecule of an ideal gas is given by

$$E_K = \frac{3}{2}kT$$

where k is the Boltzmann constant and T is the thermodynamic temperature.

Calculate the change in the total kinetic energy of the molecules of the helium gas.

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

(c) The mass of nitrogen gas in another container is 24.0 g at a temperature of 27 °C. The gas is cooled to its boiling point of –196 °C. Assume all the gas condenses to a liquid.

For this change the specific heat capacity of nitrogen gas is 1.04 $kJ\,kg^{-1}\,K^{-1}$.

The specific latent heat of vaporisation of nitrogen is 199 $kJ\,kg^{-1}$.

Determine the thermal energy, in kJ, removed from the nitrogen gas.

energy = ... kJ [3]

[Total: 12]