Internal Energy

heat added to system

Work done against the system/

$$\Delta U = \pm \Delta Q \pm \Delta W$$

heat lost

Work done by the system/against the atmosphere

$\Delta W = P\Delta V$

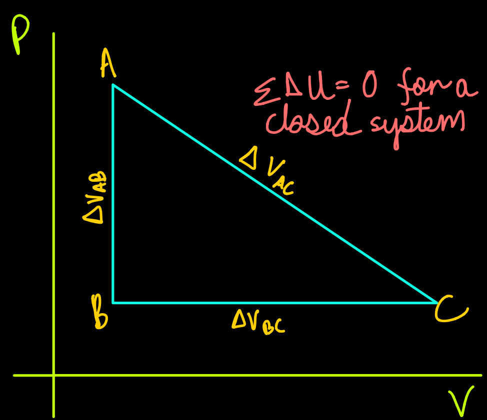
Increase in Internal Energy

=

KE + PE of system

- ΔKE of a system increases if temp increases and vise versa

- ΔPE of a system increases if the gas is real and volume increases, and in ideal gases ΔPE is 0



* A sudden expansion or compression is called adiabatic process, there is no transfer of thermal energy

(a) The first law of thermodynamics may be expressed in the form

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

(i) State, for a system, what is meant by:

1. $+q$

Thermal energy added to the system

2. $+w$.

Work done against the system

[2]

(ii) State what is represented by a negative value of ΔU.

internal energy of the system decreasing

[1]

8

(b) An ideal gas, sealed in a container, undergoes the cycle of changes shown in Fig. 2.1.

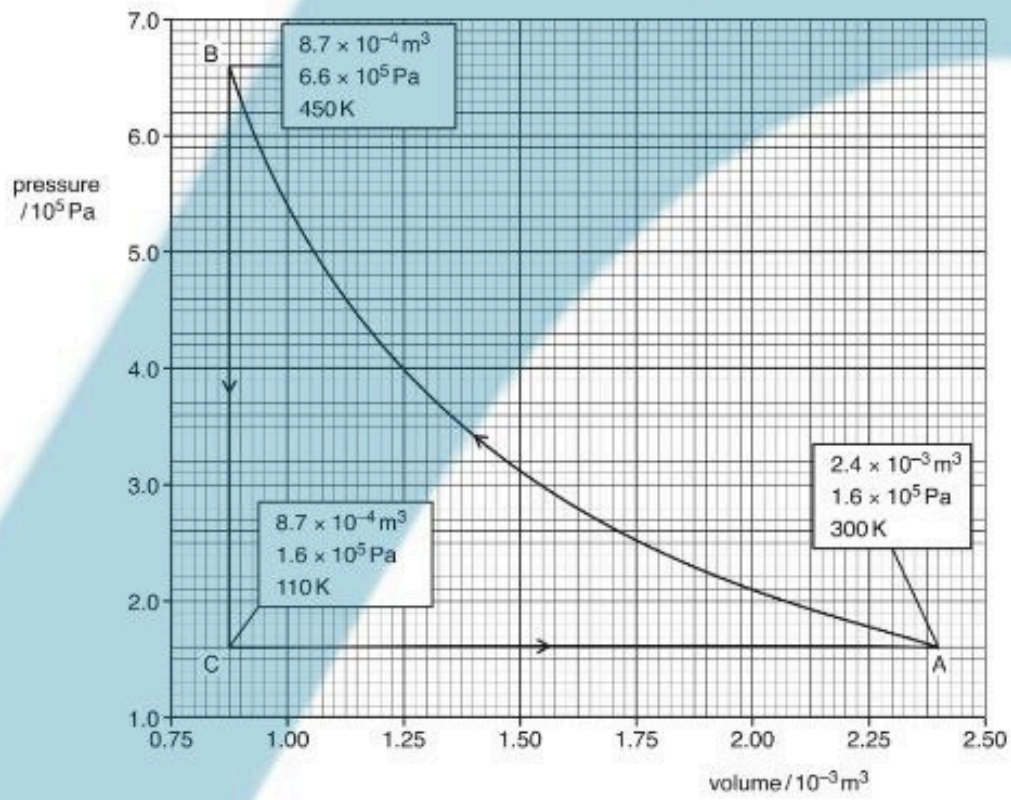


Fig. 2.1

At point A, the gas has volume $2.4 \times 10^{-3}\,m^3$, pressure 1.6×10^5 Pa and temperature 300 K.

The gas is compressed suddenly so that no thermal energy enters or leaves the gas during the compression. The amount of work done is 480 J so that, at point B, the gas has volume $8.7 \times 10^{-4}\,m^3$, pressure 6.6×10^5 Pa and temperature 450 K.

The gas is now cooled at constant volume so that, between points B and C, 1100 J of thermal energy is transferred. At point C, the gas has pressure 1.6×10^5 Pa and temperature 110 K.

Finally, the gas is returned to point A.

(i) State and explain the total change in internal energy of the gas for one complete cycle ABCA.

0 because comes back to same temp, ∴ ke is constant and pe is constant because vol stays the same [2]

(ii) Calculate the external work done on the gas during the expansion from point C to point A.

$W = P\Delta V$

$= 1.6 \times 10^5((2.4 \times 10^{-3}) - (8.7 \times 10^{-4}))$

$= 2.448 \times 10^2$

244.8

work done = −240 J [2]

(iii) Complete Fig. 2.2 for the changes from:

1. point A to point B
2. point B to point C
3. point C to point A.

change	$+q$/J	$+w$/J	ΔU/J
A → B	0	+480	+480
B → C	−1100	0	−1100
C → A	860	−240	620

Fig. 2.2

$480 + (-1100) + x = 0$

$x = 620$

$620 = x - 240$

$x = 860$

[4]

[Total: 11]

(Question 2 of Paper 4, Variant 2, Summer, 2019)

An ideal gas initially has pressure 1.0×10^5 Pa, volume 4.0×10^{-4} m^3 and temperature 300 K, as illustrated in Fig. 2.1.

Fig. 2.1

A change in energy of the gas of 240 J results in an increase of pressure to a final value of 5.0×10^5 Pa at constant volume.
The thermodynamic temperature becomes T.

(a) Calculate

(i) the temperature T,

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \qquad \frac{1 \times 10^5}{300} = \frac{5 \times 10^5}{T}$$

$$T = 1.5 \times 10^3$$

T = 1.5×10^3 K [2]

(ii) the amount of gas.

$$n = \frac{PV}{RT} = \frac{1 \times 10^5 \times 4 \times 10^{-4}}{8.31 \times 300}$$

$$= 0.0160449$$

amount = 0.016 mol [2]

7

(b) The increase in internal energy ΔU of a system may be represented by the expression

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

(i) State what is meant by the symbol

1. $+q$,

increase in thermal energy

2. $+w$.

work done against the system

[2]

(ii) State, for the gas in **(a)**, the value of

1. ΔU,

ΔU = 240 J

2. $+q$,

$+q$ = 240 J

3. $+w$.

$+w$ = 0 J

[3]

[Total: 9]

(a) Write down an equation to represent the first law of thermodynamics in terms of the heating q of a system, the work w done on the system and the increase ΔU in the internal energy.

.... [1]

(b) The pressure of an ideal gas is decreased at constant temperature.
Explain what change, if any, occurs in the internal energy of the gas.

the temp is constant so K.E is constant and there are no i.m.f ∴ Δpe is 0 ∴ ΔU is 0

.... [3]

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

.... [2]

(b) State and explain qualitatively the change, if any, in the internal energy of the following systems:

(i) a lump of ice at 0 °C melts to form liquid water at 0 °C,

Temp is constant ∴ ΔKE is 0, and as the lattice structure is broken, the forces between the molecule is weaker, ∴ P.E increases, thus ΔU increases

.... [3]

(ii) a cylinder containing gas at constant volume is in sunlight so that its temperature rises from 25 °C to 35 °C.

Temp increase ∴ ΔPE increas, and vol is constant ∴ PE is constant ∴ internal energy increases

.... [3]

For Examiner's Use

(a) State an expression, in terms of work done and heating, that is used to calculate the increase in internal energy of a system.

....

....

.... [2]

(b) State and explain, in terms of your expression in **(a)**, the change, if any, in the internal energy

(i) of the water in an ice cube when the ice melts, at atmospheric pressure, to form a liquid without any change of temperature,

heat is being supplied to the system to break the lattice structure of the ice and ΔW is decreasing by a neglegible amount $\therefore \Delta U$ increases

.... [3]

(ii) of the gas in a tyre when the tyre bursts so that the gas suddenly increases in volume. Assume that the gas is ideal.

work is done by the gas because its expanding and there is no time for heat to be supplied or removed from the system $\therefore \Delta U$ decreases

.... [3]