PROSPERITY ACADEMY

A2 PHYSCIS 9702
Crash Course

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THERMODYNAMICS

COMPLETE NOTES

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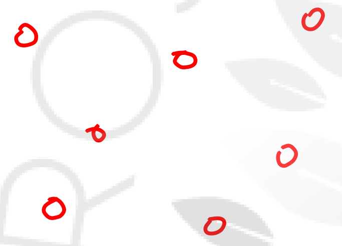
Thermodynamics :-

Based on conservation of energy

1) Internal energy (U) :- Sum of all the microscopic Kinetic and potential energies of particles in a substance.

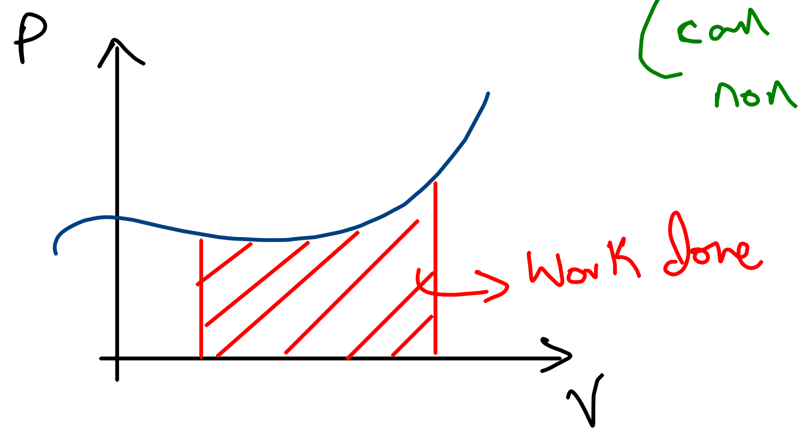


1) Random motion → Kinetic energy (directly linked to temperature of the substance)
2) Potential energy arises because of intermolecular forces
like rubber bands that can store energy as particles move away.

2) Work done (W) :- Characterized by expansion or a compression of a system.

Recall from AS :-

Work done for a gas under constant pressure :- $\boxed{W = P \times \Delta V}$ or



(can be used for non constant pressures)

3) Heat energy (Q)

Specific Heat capacity :- (c)

Amount of energy required to change the temperature of 1.0 Kg of a substance by 1°C or 1 K without a change in the state of the material. It is a scalar quantity measured in $J\ Kg^{-1}\ K^{-1}$

$$c = \frac{Q}{m\Delta\theta} \quad \text{or} \quad Q = mc\Delta\theta$$ *

Heat capacity :- (C)

Amount of energy required to raise the temperature of a substance by 1°C or 1 K without change in the state of the material.

Scalar, measured in $J\ K^{-1}$

$$C = \frac{Q}{\Delta\theta} \quad \text{or} \quad C = mc$$

Specific latent heat of fusion :- (l_f)

Amount of energy required to completely change the state of an object of 1 Kg from solid to liquid (liquid to solid) without changing the temperature.

Scalar, measured in $J\ Kg^{-1}$

$$l_f = \frac{Q}{m}$$

Latent heat of fusion:- (L_f)

Amount of energy required to completely change the state of an object from solid to liquid without changing the temperature.
Scalar, measured in J

$L_f = Q$ or $L_f = m \times l_f$ *

Specific latent heat of vaporisation:- (l_v)

Amount of energy required to completely change the state of an object of 1 Kg from liquid to gas without changing the temperature.
Scalar, measured in $J\ Kg^{-1}$

$$l_v = \frac{Q}{m}$$

Latent heat of vaporisation:- (L_v)

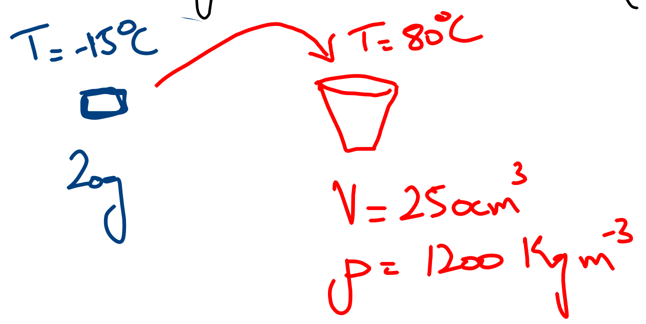
Amount of energy required to completely change the state of an object from liquid to gas without changing the temperature.
Scalar, measured in J

$L_v = Q$ or $L_v = m \times l_v$ *

Question

A 20g of ice cube ($c_i = 4.2\,KJ\,Kg^{-1}\,K^{-1}$) at an initial temperature of $-15°C$ is dropped in a hot cup of coffee of $80°C$ of volume $250\,cm^3$. Given that the density of coffee is $1200\,Kg\,m^{-3}$ and it's specific heat capacity $c_c = 5000\,J\,Kg^{-1}\,K^{-1}$. Determine the final thermal equilibrium temperature of the mixture. ($l_f = 336\,KJ\,Kg^{-1}$, $l_v = 2260\,KJ\,Kg^{-1}$ for H_2O)

specific heat capacity



$\rho = \frac{m}{V}$

$m = \rho \times V$

$m = (1200) \times 250 \times (10^{-2})^3$

$m = 0.3\,Kg$

Heat energy gained by ice cube = Heat energy lost by coffee

$$\underbrace{-15°C \rightarrow 0°C}_{mc\Delta\theta} + \underbrace{\text{Melting at } 0°C}_{L_f} + \underbrace{0°C \rightarrow T}_{mc\Delta\theta} = \underbrace{80°C \rightarrow T}_{mc\Delta\theta}$$

$$(20\times10^{-3})(4.2\times10^3)(15) + (336\times10^3)(20\times10^{-3}) + (20\times10^{-3})(4.2\times10^3)(T-0) = (0.3)(5000)(80-T)$$

$$1260 + 6720 + 84T = 120000 - 1500T$$

$$1584T = 112020$$

$$\boxed{T = 70.7°C}$$

2 (a) On Fig. 2.1, place a tick (✓) against those changes where the internal energy of the body is increasing. [2]

$\uparrow U = Q + W \uparrow$

water freezing at constant temperature	....	decrease
a stone falling under gravity in a vacuum	....	same
water evaporating at constant temperature ($l \rightarrow g \Rightarrow W\uparrow$; no change in K.E)	✓	increase
stretching a wire at constant temperature ($V\uparrow \rightarrow W\uparrow \rightarrow U\uparrow$; $\Delta K.E \uparrow$)	✓	increase

Fig. 2.1

$U : \Sigma K.E + \Sigma P.E$

$\Sigma K.E \rightarrow$ Temperature; $\Sigma P.E \rightarrow$ spacing / Volume

(b) A jeweller wishes to harden a sample of pure gold by mixing it with some silver so that the mixture contains 5.0% silver by weight. The jeweller melts some pure gold and then adds the correct weight of silver. The initial temperature of the silver is 27 °C. Use the data of Fig. 2.2 to calculate the initial temperature of the pure gold so that the final mixture is at the melting point of pure gold.

$K = 27 + 273.15 = 300.15\ K$

	gold	silver
melting point / K	1340	1240
specific heat capacity (solid or liquid) / $J\,kg^{-1}\,K^{-1}$	129	235
specific latent heat of fusion / $kJ\,kg^{-1}$	628	105

Heat energy gained by silver = Heat energy lost by gold

$$\underbrace{mc\Delta\theta}_{300.15 \rightarrow 1240} + \underbrace{L_f}_{1240\text{ (melting)}} + \underbrace{mc\Delta\theta}_{1240 \rightarrow 1340} = \underbrace{mc\Delta\theta}_{T \rightarrow 1340K}$$

$$0.05\cancel{m}(235)(1240 - 300.15) + (105 \times 10^3)(0.05\cancel{m}) + (0.05\cancel{m})(235)(1340 - 1240) = 0.95\cancel{m}(129)(T - 1340)$$

$$11043.2375 + 5250 + 1175 = 122.55T - 164217$$

$$T = 1482\ K \approx \boxed{1480K}$$

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

Amount of energy required to raise the temperature of 1 kg of a substance by 1 K or 1°C without changing the state of the material.

....[2]

(b) A student carries out an experiment to determine the specific heat capacity of a liquid using the apparatus illustrated in Fig. 3.1.

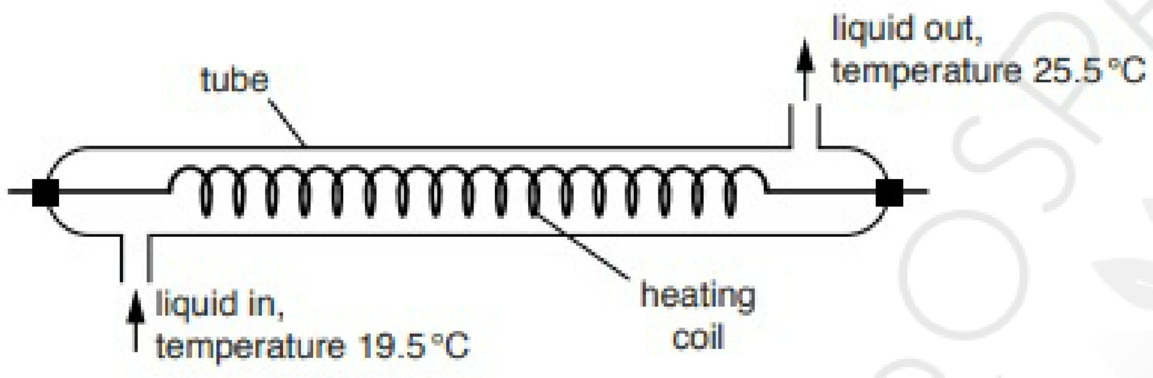


Fig. 3.1

Liquid enters the tube at a constant temperature of 19.5 °C and leaves the tube at a temperature of 25.5 °C. The mass of liquid flowing through the tube per unit time is *m*. Electrical power *P* is dissipated in the heating coil.

The student changes *m* and adjusts *P* until the final temperature of the liquid leaving the tube is 25.5 °C.

The data shown in Fig. 3.2 are obtained.

$m/\text{g s}^{-1}$	P/W
1.11	33.3
1.58	44.9

Fig. 3.2

(i) Suggest why the student obtains data for two values of *m*, rather than for one value.

So that the student can account for heat losses

....[1]

Assumption:- Heat loss is taken to be constant

(ii) Calculate the specific heat capacity of the liquid.

Show your working.

heat loss

$Q = mc\Delta\theta + H$

$P \times \Delta t = mc\Delta\theta + H$

$P = \frac{m}{\Delta t} c \Delta\theta + \frac{H}{\Delta t}$

$33.3 = (1.11\times10^{-3})c(6) + \frac{H}{\Delta t}$

$44.9 = (1.58\times10^{-3})c(6) + \frac{H}{\Delta t}$

$\frac{H}{\Delta t} = (44.9) - (1.58\times10^{-3})c(6)$

$33.3 = (6.66\times10^{-3})c + (44.9) - (9.48\times10^{-3})c$

$-11.6 = -(2.82\times10^{-3})c \Rightarrow c = 4116$

specific heat capacity = ...4116........ $\text{J kg}^{-1}\text{K}^{-1}$ [3]

(c) When the heating coil in **(b)** dissipates 33.3 W of power, the potential difference *V* across the coil is given by the expression

$$V = 27.0 \sin(395t).$$

The potential difference is measured in volts and the time *t* is measured in seconds.

Determine the resistance of the coil.

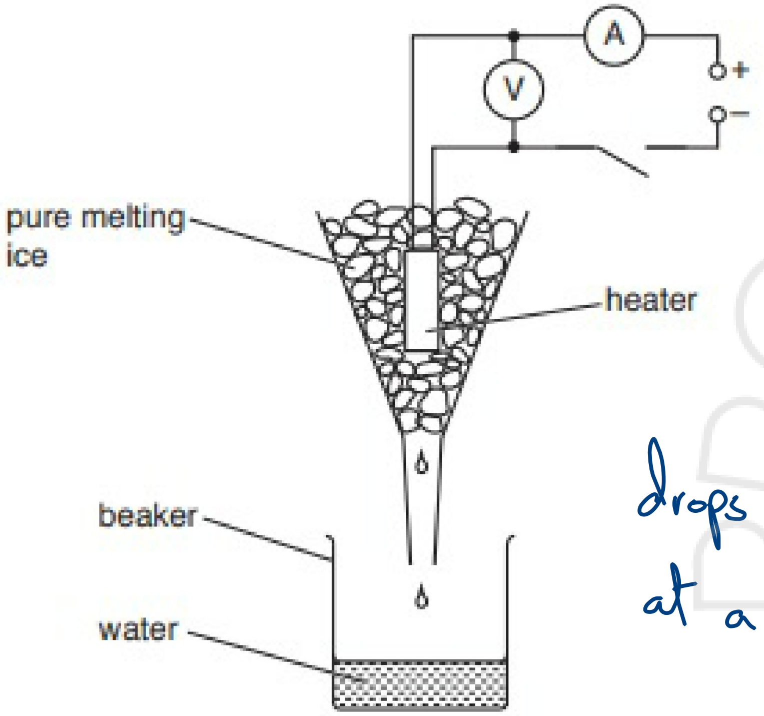
resistance = ... Ω [3]

[Total: 9]

3 (a) Define *specific latent heat of fusion.*

Amount of energy required to completely change the state of an object of 1 kg from solid to liquid without changing the temperature .... [2]

(b) A student sets up the apparatus shown in Fig. 3.1 in order to investigate the melting of ice.



drops are falling at a constant rate

Fig. 3.1

The heater is switched on.
When the pure ice is melting at a constant rate, the data shown in Fig. 3.2 are collected.

voltmeter reading /V	ammeter reading /A	initial mass of beaker plus water/g	final mass of beaker plus water/g	time of collection /minutes
12.8	4.60	121.5	185.0	5.00

Fig. 3.2

The specific latent heat of fusion of ice is 332 J g^{-1}.

(ii) Use the data in Fig. 3.2 to determine the rate at which

1. thermal energy is transferred to the melting ice,

$L_f = l_f \times m$

$= 332 \times (185 - 121.5)$

$= 21082$

$P = \frac{Q}{t}$

$P = \frac{21082}{(5 \times 60)}$

$P = 70.273$

rate = 70.3 W

2. thermal energy is gained from the surroundings.

Q_{Heater} + surrounding = Q_{gained} by ice

IVt + surrounding = 21082

Surrounding = $21082 - (12.8)(4.6)(5 \times 60)$

$= 3418$ J $\rightarrow P = \frac{Q}{t} = \frac{3418}{5 \times 60} = 11.4$

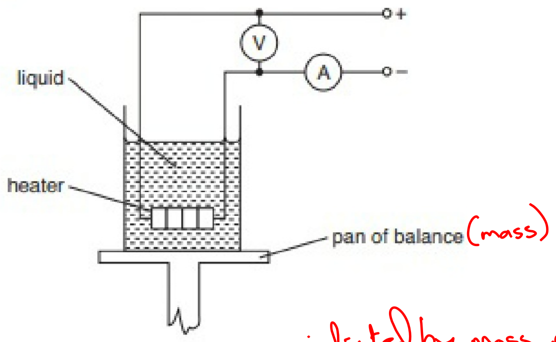
rate = 11.4 W [4]

[Total: 7]

3 **(a)** State what is meant by *specific latent heat.*

Amount of energy required to completely change the state of an object of 1 kg without changing the temperature.
.... [2]

(b) A student determines the specific latent heat of vaporisation of a liquid using the apparatus illustrated in Fig. 3.1.



indicated by mass reading decreasing at a constant rate

Fig. 3.1

The heater is switched on. When the liquid is boiling at a constant rate, the balance reading is noted at 2.0 minute intervals.

After 10 minutes, the current in the heater is reduced and the balance readings are taken for a further 12 minutes.

The readings of the ammeter and of the voltmeter are given in Fig. 3.2.

	ammeter reading /A	voltmeter reading /V
from time 0 to time 10 minutes	1.2	230
after time 10 minutes	1.0	190

Fig. 3.2

The variation with time of the balance reading is shown in Fig. 3.3.

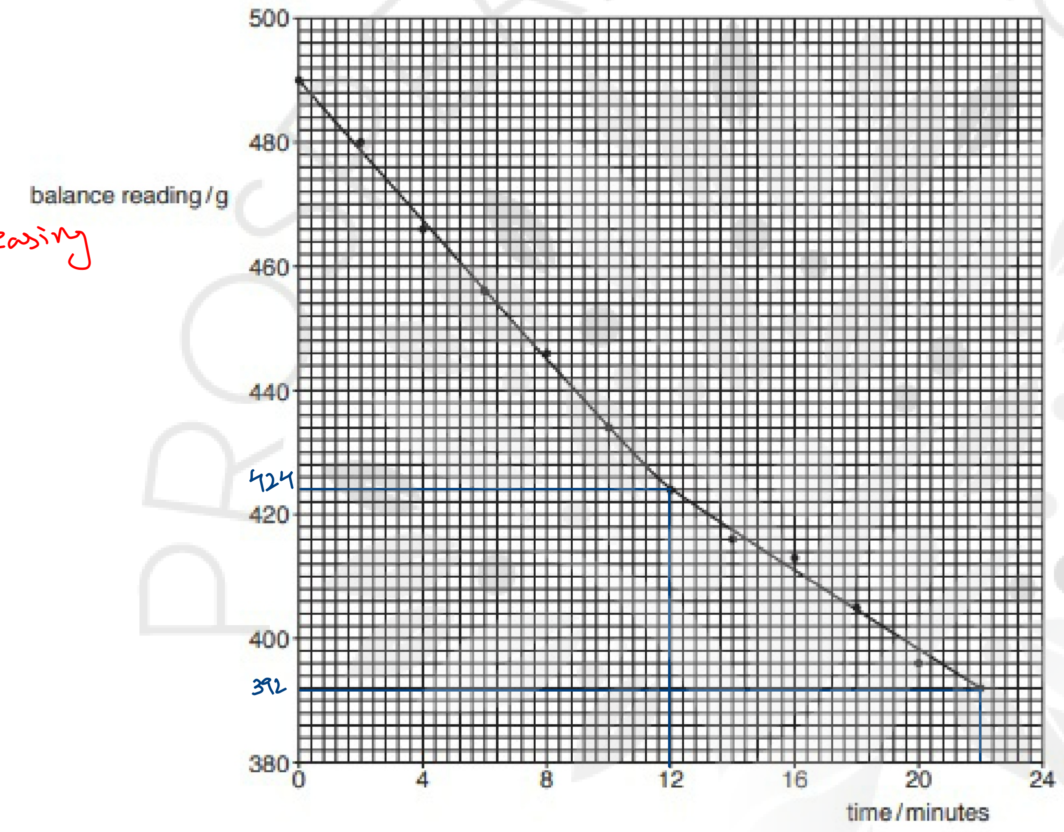


Fig. 3.3

(i) From time 0 to time 10.0 minutes, the mass of liquid evaporated is 56 g.

Use Fig. 3.3 to determine the mass of liquid evaporated from time 12.0 minutes to time 22.0 minutes.

$424 - 392$

mass = ...32........ g [1]

(ii) Explain why, although the power of the heater is changed, the rate of loss of thermal energy to the surroundings may be assumed to be constant.

The temperature difference between the liquid and surrounding is constant
.... [1]

(iii) Determine a value for the specific latent heat of vaporisation L of the liquid.

$Q = (l_v \times m) + H$

$IVt = (l_v \times m) + H$

$(1.2)(230)(10\times60) = (l_v \times 56) + H$

$165600 - 56 l_v = H$

$(1.0)(190)(10\times60) = (l_v \times 32) + H$

$114000 = 32 l_v + 165600 - 56 l_v$

$+51600 = +24 l_v$

$\frac{51600}{24} = l_v$

$l_v = 2150$

L = ...2200........ $J g^{-1}$ [4]

(iv) Calculate the rate at which thermal energy is transferred to the surroundings.

$P = \frac{H}{\Delta t}$

$H = 165600 - 56(2150)$

$H = 45200 J$

$P = \frac{45200}{10\times60}$

$P = 75.33$

rate = ...75........ W [2]

[Total: 10]

First law of thermodynamics :-

It states that the increase in the internal energy (ΔU) of any system, is always equal to the sum of the heat supplied to the system, and the work done on the system.

$$\boxed{\Delta U = Q + W}$$

$+\Delta U$:- increase in internal energy
$-\Delta U$:- decrease in internal energy
$+Q$:- heat supplied to the system
$-Q$:- heat energy lost by system
$+W$:- Work done on the system (Compression)
$-W$:- Work done by the system (Expansion)

Q. 2000 J of work are done by a motor on its surroundings, while releasing 3000 J of heat to the surrounding. Determine the change in the internal energy of the motor.
↳ system

$$\Delta U = Q + W$$
$$\Delta U = -3000 - 2000$$
$$\Delta U = -5000\,J$$

Q. A motor absorbs 3000 J of heat from its surroundings, while doing 2000 J of work on it. Determine the change in internal energy of the surroundings.
↳ system

$$\Delta U = Q + W$$
$$\Delta U = -3000 + 2000$$
$$\Delta U = -1000\,J$$

3 (a) State the first law of thermodynamics in terms of the increase in internal energy ΔU, the heating q of the system and the work w done on the system.

The increase in internal energy of a system is equal to the heat supplied to the system + the work done on the system. [1]

(b) The volume occupied by 1.00 mol of liquid water at 100 °C is $1.87 \times 10^{-5}\,m^3$. When the water is vaporised at an atmospheric pressure of 1.03×10^5 Pa, the water vapour has a volume of $2.96 \times 10^{-2}\,m^3$.

The latent heat required to vaporise 1.00 mol of water at 100 °C and 1.03×10^5 Pa is 4.05×10^4 J.

Determine, for this change of state,

V↑ → expand → Work done by

(i) the work w done on the system,

$W = P \times \Delta V$

$W = (1.03 \times 10^5) \times [(2.96 \times 10^{-2} - 1.87 \times 10^{-5})]$

$= 3046.87$

$w = -3050$ J [2]

(ii) the heating q of the system, $Q = ?$

$q = +4.05 \times 10^4$ J [1]

(iii) the increase in internal energy ΔU of the system.

$\Delta U = Q + W$

$\Delta U = +(4.05 \times 10^4) - (3050)$

$= +37500$

$\Delta U = +37500$ J [1]

(a) First law of thermodynamics may be expressed in the form $\Delta U = q + w$.
Explain symbols in this expression

+ ΔU: increase in internal energy of the system
+ q: heat supplied to the system
+ w: work done on the system

(b)
(i) State what is meant by *specific latent heat*

V↑ expansion
l → g

(ii) Use first law of thermodynamics to explain why specific latent heat of vaporisation is greater than specific latent heat of fusion for a particular substance

s → l

V↑ expansion

$\Delta U = \underset{\text{Latent heat}}{Q} - W \Rightarrow Q = \Delta U + W \Rightarrow Q = \Delta U + (P\Delta V)$

When boiling, the change in volume is greater and therefore the work done is greater and the latent heat↑ $(Q) = \Delta U + W\uparrow$ also becomes greater

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

It is the sum of all microscopic kinetic and potential energies of particles in a system due to their random motion and intermolecular forces [2]

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

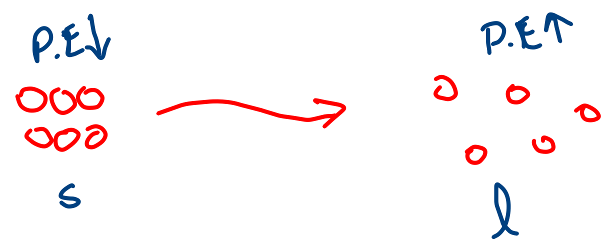
+ ΔU: increase

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

internal energy will increase. The change in temperature is zero, kinetic energy of particles will remain same. The volume has increased and so therefore the work done has increased and so the internal energy increases [3]

V↑

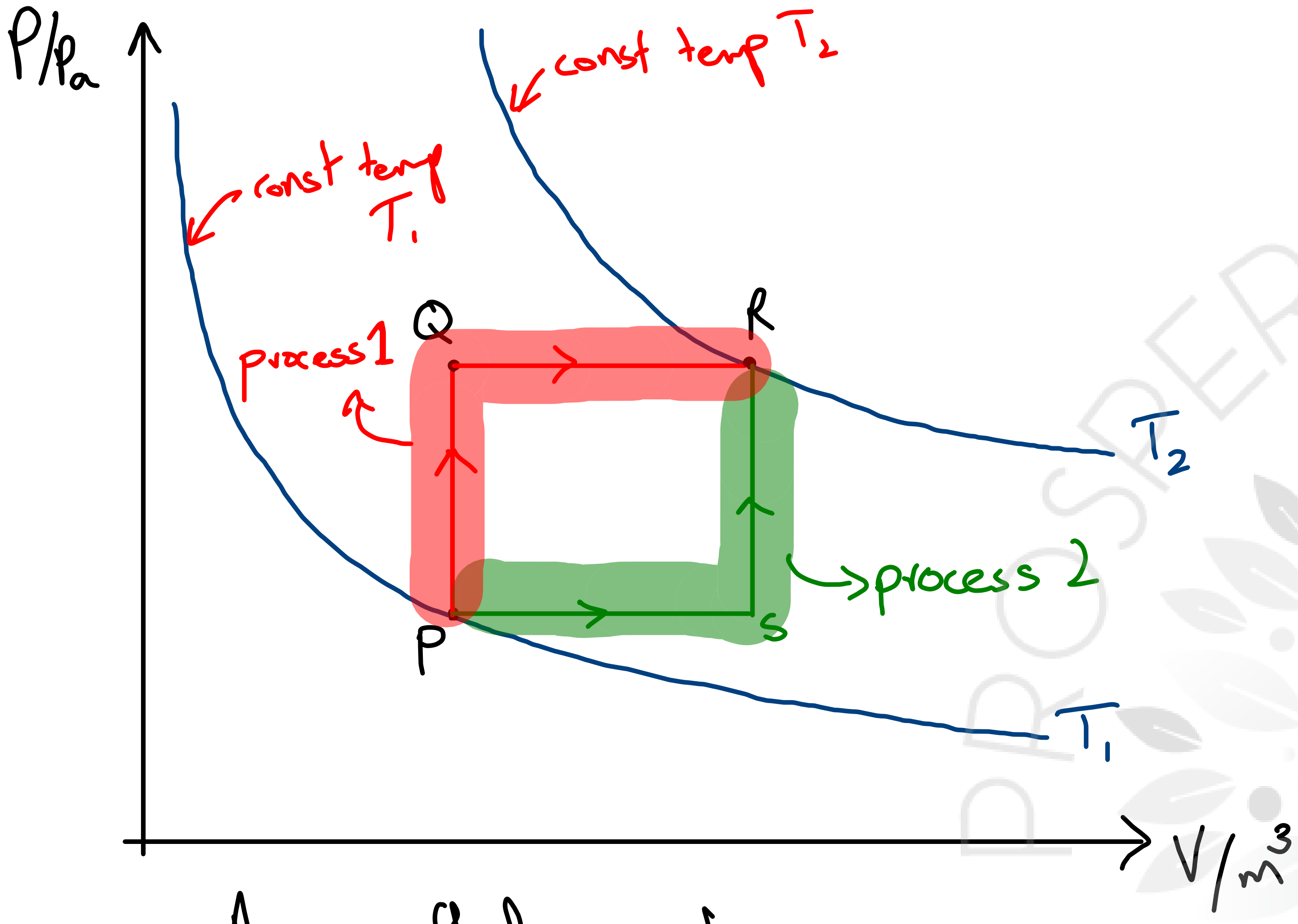
$\uparrow \Delta U = Q + (P\Delta V\uparrow)$ W↑



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

Internal energy increases as the temperature has increased and so the kinetic energy of the particles has increased.

[3]



Assume that we have an ideal gas

Q. In process 1, 8J of heat are absorbed by the ideal gas, while 3J of work are done by it.

In process 2, 1J of work is done by the gas

Determine the amount of heat exchange in process 2

In both processes, ΔT is same, $\Delta U = \frac{3}{2} NK \Delta T$

ΔU will also be same

Process 1 :- $\Delta U = Q + W$

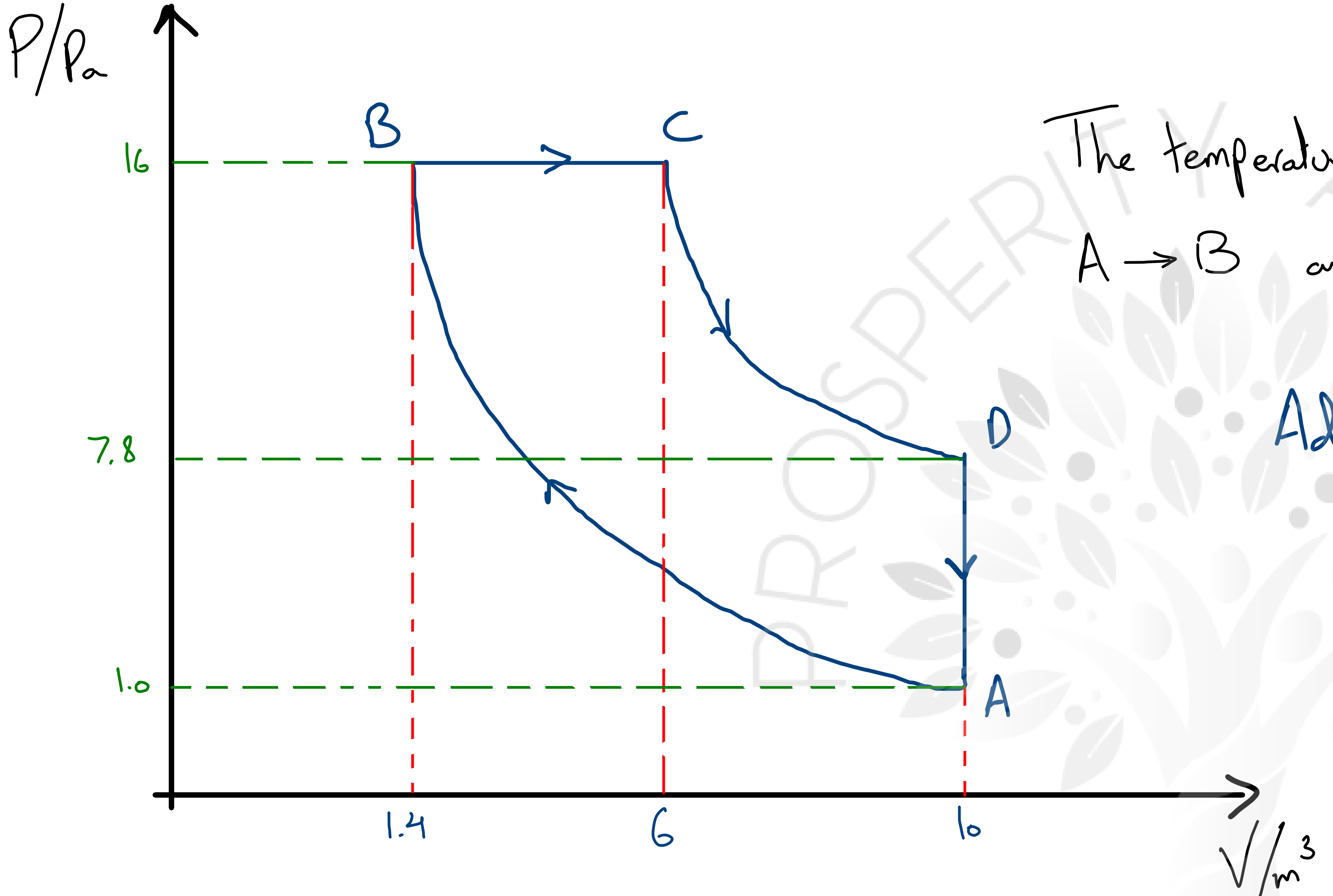
$\Delta U \quad +8 - 3$

$\Delta U = 5$

Process 2 :- $\Delta U = Q + W$

$5 = Q - 1$

$\boxed{Q = 6J}$



The temperature at A & B are 300K and 660K respectively

A → B and C → D are adiabatic processes

Adiabatic :- $Q = 0$

$\Delta U = Q + W \Rightarrow \Delta U = W$

$\Delta U_{B \to C} = Q + W$

$\Delta U = +2580 - 740$

$\Delta U_{D \to A} = Q + W$

$\Delta U = -1700 + 0$

Session of Cycle	Heat Supplied	Work done on gas	Increase in internal energy
A → B	0	+300	+300
B → C	2580	-740	+1840
C → D	0	-440	-440
D → A	-1700	0	-1700

2 (a) (i) State the basic assumption of the kinetic theory of gases that leads to the conclusion that the potential energy between the atoms of an ideal gas is zero.

The intermolecular forces in an ideal gas are negligible .... [1]

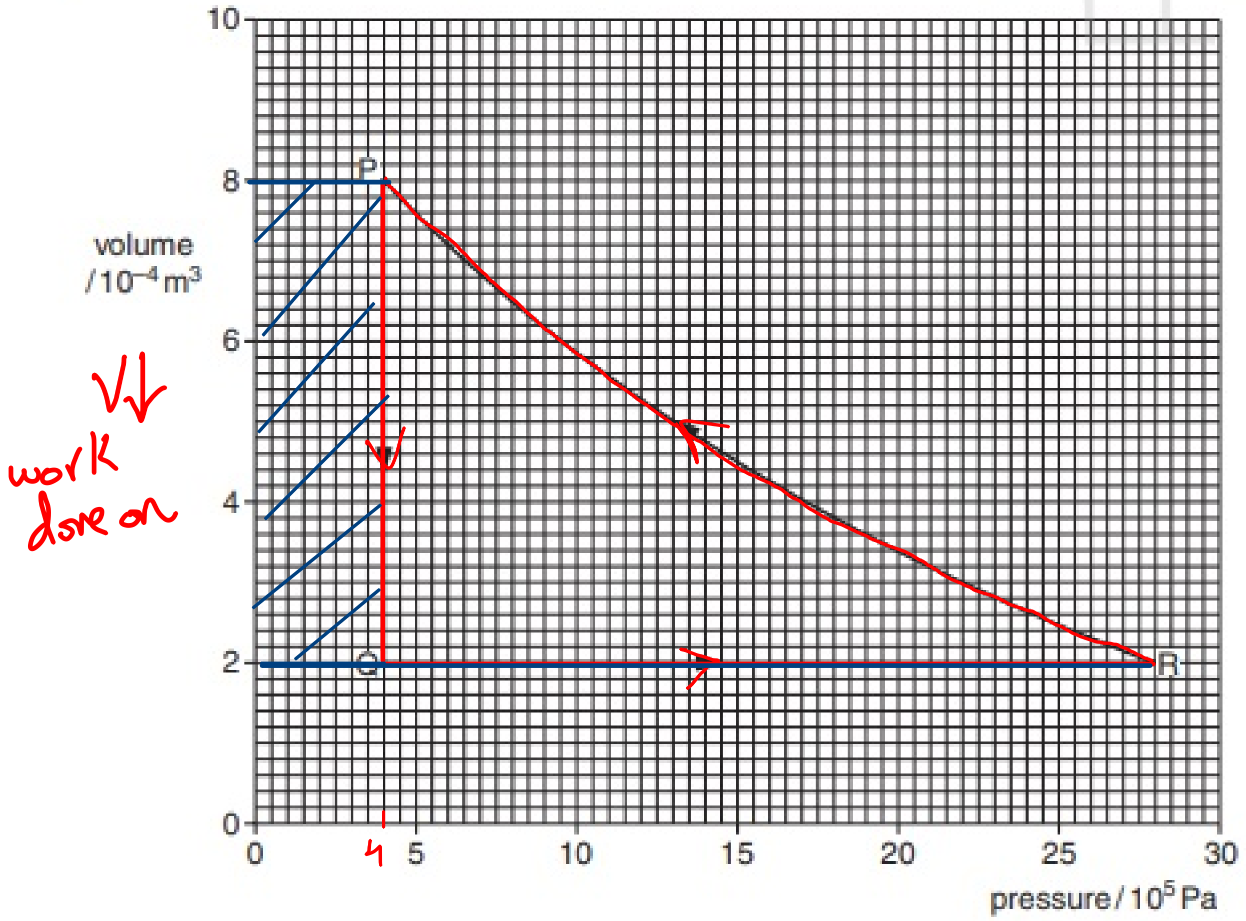
(ii) State what is meant by the *internal energy* of a substance.

It is the sum of all the microscopic kinetic energies and potential energies of all the particles in a system due to their random motion and intermolecular .... [2]

(iii) Explain why an increase in internal energy of an ideal gas is directly related to a rise in temperature of the gas.

As the potential energy of an ideal gas is zero, the internal energy of an ideal gas is only the sum of the microscopic kinetic energies which can be given by $E_K = \frac{3}{2}NKT$ where T is temperature .... [2]

(b) A fixed mass of an ideal gas undergoes a cycle PQRP of changes as shown in Fig. 2.1.



$\Delta U = \frac{3}{2} NK\Delta T$

(i) State the change in internal energy of the gas during one complete cycle PQRP.

change = ... 0 .... J [1]

(ii) Calculate the work done on the gas during the change from P to Q.

$W = P \times \Delta V$

$= (4 \times 10^5) \times [(8-2) \times 10^{-4}]$

$= +240$ J

work done = ... +240 .... J [2]

(iii) Some energy changes during the cycle PQRP are shown in Fig. 2.2.

change	work done on gas / J	heating supplied to gas / J	increase in internal energy / J
P → Q	+240	−600	−360
Q → R	0	+720	+720
R → P	−840	+480	−360

Fig. 2.2

Complete Fig. 2.2 to show all of the energy changes. [3]

$\Delta U = -600 + 240 = -360$

$\Delta U = Q + W \Rightarrow \Delta U = 720$

$\Delta U = Q + W \Rightarrow W = \Delta U - Q$

$= -360 - 480$

$= -840$

$\Delta U_{PQRP} = 0$

$\Delta U_{P \to Q \to R} = \Delta U_{P \to R}$

$\Delta U_{P \to Q \to R} = -\Delta U_{R \to P}$

$-360 + 720 = -\Delta U_{R \to P}$

$\Delta U = -360$

2 A cylinder contains 5.12 mol of an ideal gas at pressure of 5.60×10^5 Pa and volume 3.80×10^4 cm^3.

(a) Determine the temperature of the gas.

$PV = nRT$

$(5.60 \times 10^5)(3.8 \times 10^4 \times 10^{-6}) = 5.12 \times 8.31 \times T$

$T = 500.15$

temperature = ...500...... K [2]

(b) The average kinetic energy E_K of a molecule of the gas is given by the expression

$E_K = \frac{3}{2}kT \Rightarrow E_{K_N} = \frac{3}{2}NkT = U$

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

Charles law

The gas is heated at constant pressure so that its temperature rises by 125 K.

(i) Use your answer in **(a)** to determine the new volume of the gas.

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$\frac{3.8 \times 10^4}{500.15} = \frac{V_2}{625.15}$

$V_2 = 47500$

$PV = nRT$

$(5.6 \times 10^5)V = (5.12)(8.31)(625.15)$

$V = 0.0475\ m^3$

$\times 10^6$

volume = ...47500...... cm^3 [2]

(ii) Calculate the increase in internal energy of the gas. Explain your working.

Ideal gases have no intermolecular forces and so $\Sigma P.E = 0$

$U = \Sigma K.E + \Sigma P.E$

$U = \Sigma K.E$ of all particles

$\Delta U = \frac{3}{2}Nk\Delta T$ (for N particles)

$= \frac{3}{2}(5.12 \times 6.02 \times 10^{23}) \times (1.38 \times 10^{-23}) \times 125$

$= +7980$ J

(c) (i) Use your answer in **(b)(i)** to determine the external work done during the expansion of the gas.

$W = P \times \Delta V$

$V_f - V_i$

$= (5.6 \times 10^5) \times (47500 - 3.8 \times 10^4)$

$= 5320$

work done = ...-5320...... J [2]

(ii) Calculate the total thermal energy required to heat the gas in **(b)**.

$\Delta U = Q + W$

$7980 = Q - 5320$

$Q = +13300$

energy = ...+13300...... J [1]

[Total: 10]

$\Delta U = Q + W$

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

It is the sum of all the microscopic kinetic energies and potential energies of all the particles in a system due to their random motion and intermolecular forces

[2]

(b) An ideal gas undergoes a cycle of changes as shown in Fig. 2.1.

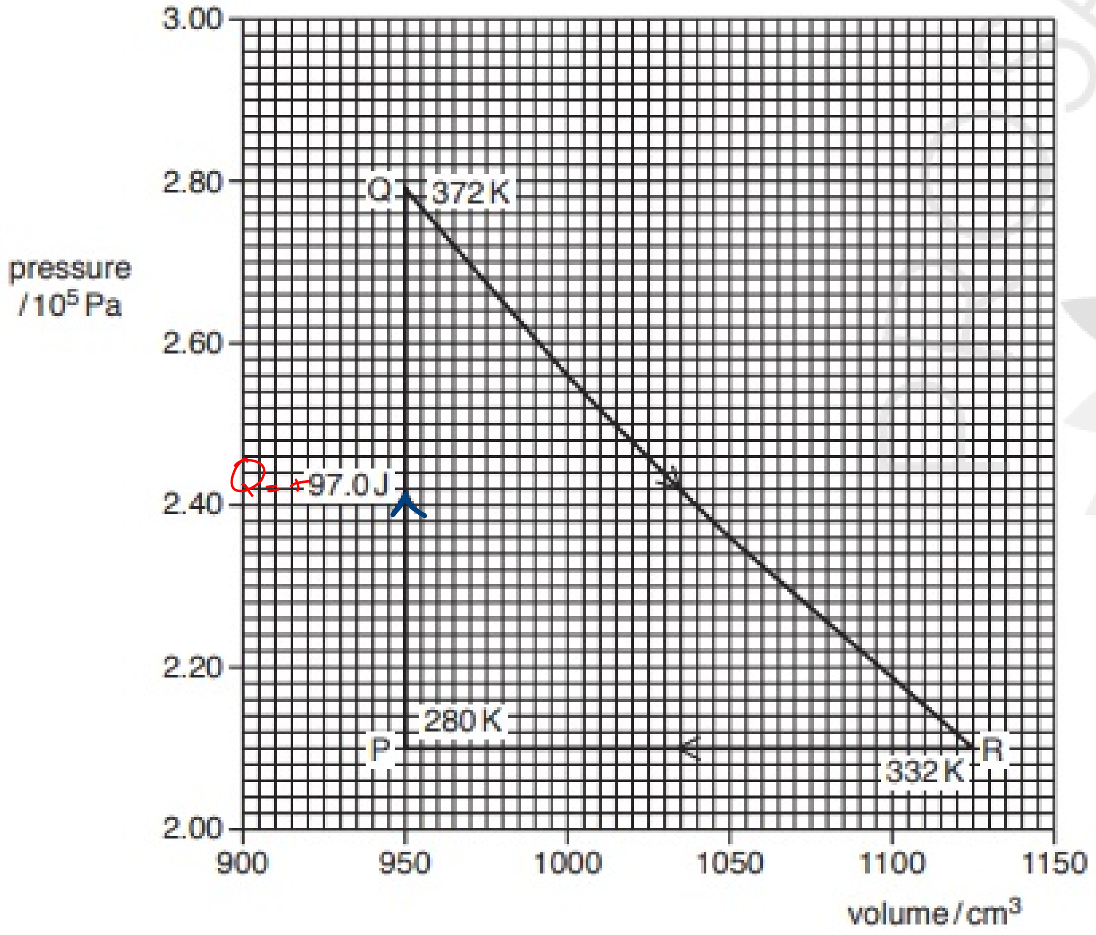


Fig. 2.1

At point P, the gas has volume 950 cm^3, pressure 2.10×10^5 Pa and temperature 280 K.

The gas is heated at constant volume and 97.0 J of thermal energy is transferred to the gas. Its pressure and temperature change so that the gas is at point Q on Fig. 2.1.

The gas then undergoes the change from point Q to point R and then from point R back to point P, as shown on Fig. 2.1.

Some energy changes that take place during the cycle PQRP are shown in Fig. 2.2.

	change P → Q	change Q → R	change R → P
thermal energy transferred to gas / J	+97.0	0	-91.5
work done on gas / J	0	−42.5	+37.0
increase in internal energy of gas / J	+97.0	-42.5	-54.5

Fig. 2.2

$\Delta U = Q + W$

$-54.5 - 37 = W$

$W = -91.5$

(i) State the total change in internal energy of the gas during the complete cycle PQRP. Explain your answer.

zero as the change in temperature is zero from P → Q → R → P

[2]

(ii) On Fig. 2.2, complete the energy changes for the gas during

1. the change P → Q,
2. the change Q → R,
3. the change R → P.

[5]

[Total: 9]

$\Delta U_{P \to Q \to R} = \Delta U_{P \to R}$

$\Delta U_{P \to Q \to R} = -\Delta U_{R \to P}$

$97 - 42.5 = -\Delta U_{R \to P}$

$\Delta U_{R \to P} = -54.5 \text{ J}$

2 A fixed mass of an ideal gas has volume $210\,cm^3$ at pressure 3.0×10^5 Pa and temperature 270 K.

$V\downarrow$ → work done on (+)

The volume of the gas is reduced at constant pressure to $140\,cm^3$, as shown in Fig. 2.1.

Fig. 2.1

The final temperature of the gas is T.

(a) Determine:

(i) the amount of gas

$PV = nRT$

$(3\times10^5)(210\times10^{-6}) = n\,(8.31)(270)$

$n = 0.028$

amount = ... 0.028 ...... mol [3]

(ii) the final temperature T of the gas

$PV = nRT$

$(3\times10^5)(140\times10^{-6}) = 0.028\,(8.31)T$

$T = 180.5\,K$

T = ... 181 ...... K [2]

(iii) the external work done on the gas.

$W = P \times \Delta V$

$= (3\times10^5)\left[(210 - 140)\times10^{-6}\right]$

$= +21\,J$

(b) For this change in volume and temperature of the gas, the thermal energy transferred is 53 J.

Determine ΔU, the change in internal energy of the gas.

$\Delta U = Q + W$

$\Delta U = -53 + 21$

$\Delta U = -32$

ΔU = ... −32 ...... J [3]

[Total: 10]

2 **(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. $+q$

heat energy supplied to the system.

2. $+w$.

Work done on the system.

[2]

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

decrease in the internal energy of a system

[1]

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

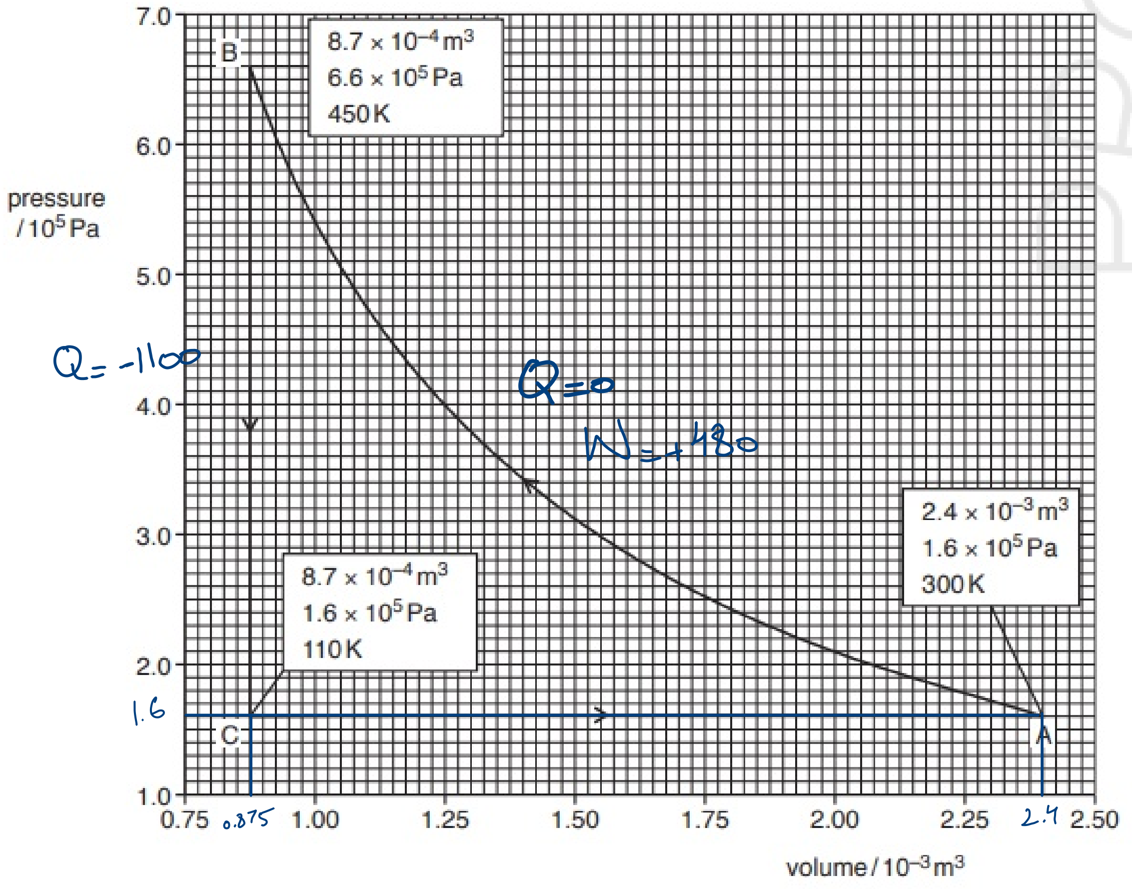


Fig. 2.1

At point A, the gas has volume 2.4×10^{-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 8.7×10^{-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.

zero as the temperature change from A -> B -> C -> A is zero

[2]

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

$W = P \times \Delta V$

$= (1.6 \times 10^5) \times [(2.4 - 0.875) \times 10^{-3}]$

$= 244$

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

[4]

$\Delta U_{ABC} = \Delta U_{AC}$

$\Delta U_{ABC} = -\Delta U_{CA}$

$480 - 1100 = -\Delta U_{CA}$

$+620 = \Delta U_{CA}$

$\Delta U = Q + W$

$620 = Q - 240$

$Q = +860$