Chapter

14

Thermodynamics

Thermodynamics is a branch of science which deals with exchange of heat energy between bodies and conversion of the heat energy into mechanical energy and vice-versa.

Some Definitions

(1) **Thermodynamic system**

(i) It is a collection of an extremely large number of atoms or molecules

(ii) It is confined with in certain boundaries.

(iii) Anything outside the thermodynamic system to which energy or matter is exchanged is called its surroundings.

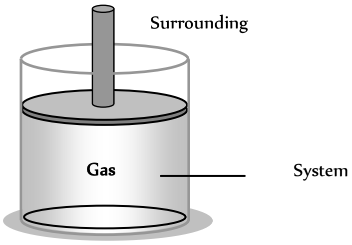


Fig. 14.1

(iv) Thermodynamic system may be of three types

(a) Open system : It exchange both energy and matter with the surrounding.

(b) Closed system : It exchange only energy (not matter) with the surroundings.

(c) Isolated system : It exchange neither energy nor matter with the surrounding.

(2) **Thermodynamic variables and equation of state :** A thermodynamic system can be described by specifying its pressure, volume, temperature, internal energy and the number of moles. These parameters are called thermodynamic variables. The relation between the thermodynamic variables (P, V, T) of the system is called equation of state.

For μ moles of an ideal gas, equation of state is $PV = \mu RT$ and for 1 mole of an it ideal gas is $PV = RT$

(3) **Thermodynamic equilibrium :** In steady state thermodynamic variables are independent of time and the system is said to be in the state of thermodynamic equilibrium. For a system to be in thermodynamic equilibrium, the following conditions must be fulfilled.

(i) Mechanical equilibrium : There is no unbalanced force between the system and its surroundings.

(ii) Thermal equilibrium : There is a uniform temperature in all parts of the system and is same as that of surrounding.

(iii) Chemical equilibrium : There is a uniform chemical composition through out the system and the surrounding.

(4) **Thermodynamic process :** The process of change of state of a system involves change of thermodynamic variables such as pressure P, volume V and temperature T of the system. The process is known as thermodynamic process. Some important processes are

(i) Isothermal process : Temperature remain constant

(ii) Adiabatic process : No transfer of heat

(iii) Isobaric process : Pressure remains constant

(iv) Isochoric (isovolumic process) : Volume remains constant

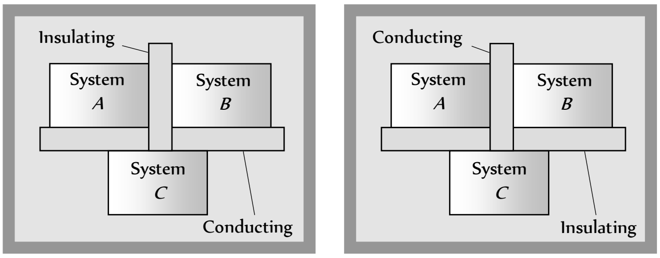
(v) Cyclic and non-cyclic process : Incyclic process Initial and final states are same while in non-cyclic process these states are different.

(vi) Reversible and irreversible process :

(5) **Indicator diagram :** Whenever the state of a gas (*P*, *V*, *T*) is changed, we say the gaseous system is undergone a thermodynamic process. The graphical representation of the change in state of a gas by a thermodynamic process is called indicator diagram. Indicator diagram is plotted generally in pressure and volume of gas.

Zeroth Law of Thermodynamics

If systems *A* and *B* are each in thermal equilibrium with a third system *C*, then *A* and *B* are in thermal equilibrium with each other.



(A) (B)

Fig. 14.3

(1) The zeroth law leads to the concept of temperature. All bodies in thermal equilibrium must have a common property which has the same value for all of them. This property is called the temperature.

(2) The zeroth law came to light long after the first and seconds laws of thermodynamics had been discovered and numbered. It is so named because it logically precedes the first and second laws of thermodynamics.

Heat, Internal Energy and Work in Thermodynamics

(1) **Heat (ΔQ) :** It is the energy that is transferred between a system and its environment because of the temperature difference between them.

(i) Heat is a path dependent quantity *e.g.* Heat required to change the temperature of a given gas at a constant pressure is different from that required to change the temperature of same gas through same amount at constant volume.

(ii) For gases when heat is absorbed and temperature changes $\Rightarrow$ $\Delta Q = \mu C \Delta T$

At constant pressure $(\Delta Q)_P = \mu C_P \Delta T$

At constant volume $(\Delta Q)_V = \mu C_V \Delta T$

(2) **Internal energy (*U*) :** Internal energy of a system is the energy possessed by the system due to molecular motion and molecular configuration.

The energy due to molecular motion is called internal kinetic energy U_K and that due to molecular configuration is called internal potential energy U_P *i.e.* Total internal energy $U = U_K + U_P$

(i) For an ideal gas, as there is no molecular attraction $U_p = 0$

i.e. internal energy of an ideal gas is totally kinetic and is given by $U = U_K = \frac{3}{2}\mu RT$ and change in internal energy $\Delta U = \frac{3}{2}\mu R\,\Delta T$

(ii) In case of gases whatever be the process

$$\Delta U = \mu \frac{f}{2} R\Delta T = \mu C_V \Delta T = \mu \frac{R}{(\gamma - 1)} \Delta T = \frac{\mu\, R(T_f - T_i)}{\gamma - 1}$$

$$= \frac{\mu R T_f - \mu R T_i}{\gamma - 1} = \frac{(P_f V_f - P_i V_i)}{\gamma - 1}$$

(iii) Change in internal energy does not depend on the path of the process. So it is called *a* point function *i.e.* it depends only on the initial and final states of the system, *i.e.* $\Delta U = U_f - U_i$

(3) **Work (ΔW) :** Suppose a gas is confined in a cylinder that has a movable piston at one end. If *P* be the pressure of the gas in the cylinder, then force exerted by the gas on the piston of the cylinder *F* = *PA* (*A* = Area of cross-section of piston)

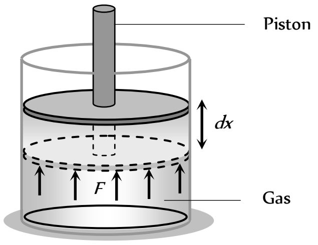


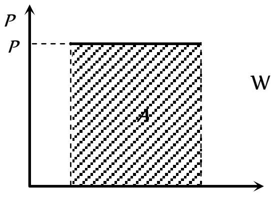
Fig. 14.4

When the piston is pushed outward an infinitesimal distance *dx*, the work done by the gas $dW = F.dx = P(A\,dx) = P\,dV$

For a finite change in volume from V_i to V_f

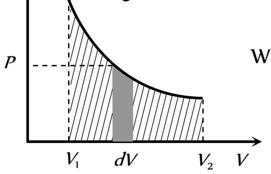
Total amount of work done $W = \int_{Vi}^{V_f} P\,dV = P(V_f - V_i)$

(i) If we draw indicator diagram, the area bounded by *PV*-graph and volume axis represents the work done



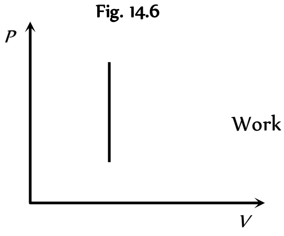
Work = Area = $P(V_2 - V_1)$

Fig. 14.5



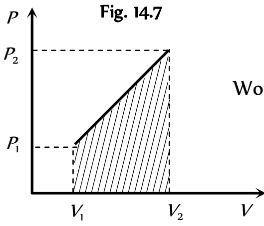
Work $= \int_{V_1}^{V_2} PdV = P(V_2 - V_1)$

Fig. 14.6



Work = 0

Fig. 14.7



Work = Area of the shown trapezium

$$= \frac{1}{2}(P_1 + P_2)(V_2 - V_1)$$

Fig. 14.8

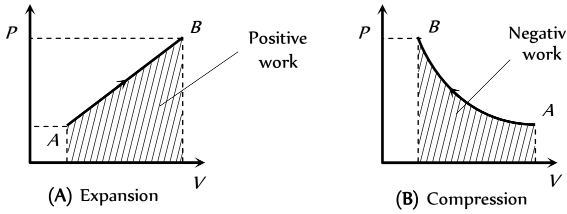
(ii) From $\Delta W = P\Delta V = P(V_f - V_i)$

If system expands against some external force then $V_f > V_i$

$\Rightarrow$ ΔW = positive

If system contracts because of external force then $V_f < V_i$

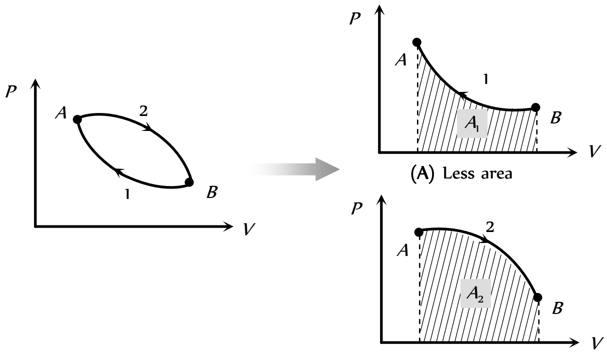
$\Rightarrow$ ΔW = negative



(A) Expansion (B) Compression

Fig. 14.9

(iii) Like heat, work done is also depends upon initial and final state of the system and path adopted for the process



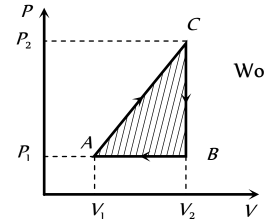
(A) Less area

(B) More area

$\because A_1 < A_2 \Rightarrow W_1 < W_2$

Fig. 14.10

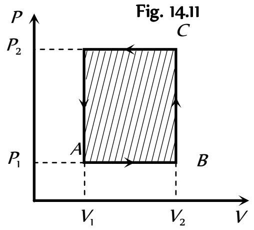
(iv) In cyclic process, work done is equal to the area of closed curve. It is positive if the cycle is clockwise and it is negative if the cycle is anticlockwise.



Work = Area of triangle *ABC*

$$= \frac{1}{2} \times (V_2 - V_1) \times (P_2 - P_1)$$

Fig. 14.11

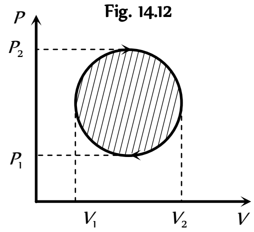


Work = Area of rectangle *ABCD*

= $AB \times AD$

= $(V_2 - V_1)(P_2 - P_1)$

Fig. 14.12



Work = $\frac{\pi}{4}(P_2 - P_1)(V_2 - V_1)$

Fig. 14.13

First Law of Thermodynamics (FLOT)

(1) It is a statement of conservation of energy in thermodynamical process.

(2) According to it heat given to a system (ΔQ) is equal to the sum of increase in its internal energy (ΔU) and the work done (ΔW) by the system against the surroundings.

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

(3) It makes no distinction between work and heat as according to it the internal energy (and hence temperature) of a system may be increased either by adding heat to it or doing work on it or both.

(4) ΔQ and ΔW are the path functions but ΔU is the point function.

(5) In the above equation all three quantities ΔQ, ΔU and ΔW must be expressed either in *Joule* or in *calorie*.

(6) The first law introduces the concept of internal energy.

(7) Limitation : First law of thermodynamics does not indicate the direction of heat transfer. It does not tell anything about the conditions, under which heat can be transformed into work and also it does not indicate as to why the whole of heat energy cannot be converted into mechanical work continuously.

Table 14.1 : Useful sign convention in thermodynamics

Quantity	Sign	Condition
ΔQ	+	When heat is supplied to a system
	–	When heat is drawn from the system
ΔW	+	When work done by the gas (expansion)
	–	When work done on the gas (compression)
ΔU	+	With temperature rise, internal energy increases
	–	With temperature fall, internal energy decreases

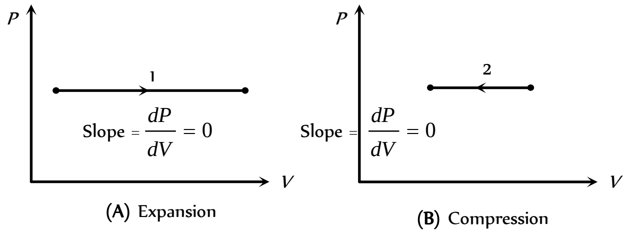
Isobaric Process

When a thermodynamic system undergoes a physical change in such a way that its pressure remains constant, then the change is known as isobaric process.

(1) **Equation of state :** In this process *V* and *T* changes but *P* remains constant. Hence Charle's law is obeyed in this process.

Hence if pressure remains constant $V \propto T \Rightarrow \frac{V_1}{T_1} = \frac{V_2}{T_2}$

(2) **Indicator diagram :** Graph 1 represent isobaric expansion, graph 2 represent isobaric compression.



(A) Expansion (B) Compression

Fig. 14.14

(i) In isobaric expansion (Heating)

Temperature $\longrightarrow$ increases so ΔU is positive

Volume $\longrightarrow$ increases so ΔW is positive

Heat $\longrightarrow$ flows into the system so ΔQ is positive

(ii) In isobaric compression (Cooling)

Temperature $\longrightarrow$ decreases so ΔU is negative

Volume $\xrightarrow{\quad}$ decreases so ΔW is negative

Heat $\xrightarrow{\quad}$ flows out from the system so ΔQ is negative

(3) **Specific heat :** Specific heat of gas during isobaric process $C_P = \left(\frac{f}{2}+1\right)R$

(4) **Bulk modulus of elasticity :** $K = \frac{\Delta P}{\frac{-\Delta V}{V}} = 0$ [As $\Delta P = 0$]

(5) **Work done in isobaric process**

$$\Delta W = \int_{V_i}^{V_f} P\,dV = P\int_{V_i}^{V_f} dV = P[V_f - V_i] \qquad \text{[As } P = \text{constant]}$$

$$\Rightarrow \ \Delta W = P(V_f - V_i) = \mu R[T_f - T_i] = \mu R\,\Delta T$$

(6) **FLOT in isobaric process :** From $\Delta Q = \Delta U + \Delta W$

$$\because \ \Delta U = \mu C_V\,\Delta T = \mu\frac{R}{(\gamma-1)}\Delta T \ \text{ and } \ \Delta W = \mu R\,\Delta T$$

$$\Rightarrow (\Delta Q)_P = \mu\frac{R}{(\gamma-1)}\Delta T + \mu R\,\Delta T = \mu\left(\frac{\gamma}{\gamma-1}\right)R\,\Delta T = \mu C_P\,\Delta T$$

(7) **Examples of isobaric process :** All state changes occurs at constant temperature and pressure.

Boiling of water

(i) Water $\xrightarrow{\quad}$ vapours

(ii) Temperature $\xrightarrow{\quad}$ constant

(iii) Volume $\xrightarrow{\quad}$ increases

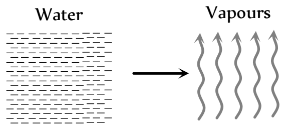


Fig. 14.15

(iv) A part of heat supplied is used to change volume (expansion) against external pressure and remaining part is used to increase it's potential energy (kinetic energy remains constant)

(v) From FLOT $\Delta Q = \Delta U + \Delta W \Rightarrow mL = \Delta U + P(V_f - V_i)$

Freezing of water

(i) Water $\xrightarrow{\quad}$ ice

(ii) Temperature $\xrightarrow{\quad}$ constant

(iii) Volume $\xrightarrow{\quad}$ increases

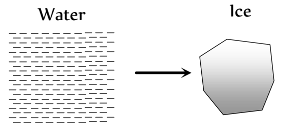


Fig. 14.16

(iv) Heat is given by water it self. It is used to do work against external atmospheric pressure and to decreases the internal potential energy.

(v) From FLOT $\Delta Q = \Delta U + \Delta W \Rightarrow -mL = \Delta U + P(V_f - V_i)$

Isochoric or Isometric Process

When a thermodynamic process undergoes a physical change in such a way that its volume remains constant, then the change is known as isochoric process.

(1) **Equation of state :** In this process P and T changes but V = constant. Hence Gay-Lussac's law is obeyed in this process *i.e.* $P \propto T \Rightarrow \frac{P_1}{T_1} = \frac{P_2}{T_2} = \text{constant}$

(2) **Indicator diagram :** Graph 1 and 2 represent isometric increase in pressure at volume V_1 and isometric decrease in pressure at volume V_2 respectively and slope of indicator diagram $\frac{dP}{dV} = \infty$

(i) Isometric heating

(a) Pressure $\xrightarrow{\quad}$ increases

(b) Temperature $\xrightarrow{\quad}$ increases

(c) $\Delta Q \xrightarrow{\quad}$ positive

(d) $\Delta U \xrightarrow{\quad}$ positive

(ii) Isometric cooling

(a) Pressure $\xrightarrow{\quad}$ decreases

(b) Temperature $\xrightarrow{\quad}$ decreases

(c) $\Delta Q \xrightarrow{\quad}$ negative

(d) $\Delta U \xrightarrow{\quad}$ negative

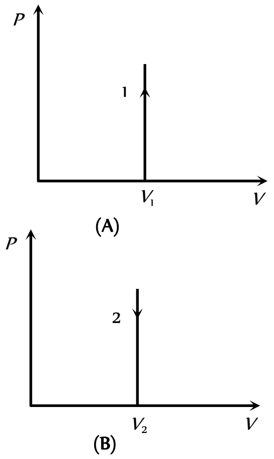


Fig. 14.17

(3) **Specific heat :** Specific heat of gas during isochoric process $C_V = \frac{f}{2}R$

(4) **Bulk modulus of elasticity :** $K = \frac{\Delta P}{\frac{-\Delta V}{V}} = \frac{\Delta P}{0} = \infty$

(5) **Work done in isochoric process**

$$\Delta W = P\Delta V = P[V_f - V_i] = 0 \qquad \text{[As } V = \text{constant]}$$

(6) **FLOT in isochoric process** : From $\Delta Q = \Delta U + \Delta W$

$$\because \Delta W = 0 \Rightarrow (\Delta Q)_V = \Delta U = \mu C_V\,\Delta T = \mu\frac{R}{\gamma-1}\Delta T = \frac{P_f V_f - P_i V_i}{\gamma-1}$$

Isothermal Process

When a thermodynamic system undergoes a physical change in such a way that its temperature remains constant, then the change is known as isothermal changes.

(1) **Essential condition for isothermal process**

(i) The walls of the container must be perfectly conducting to allow free exchange of heat between the gas and its surrounding.

(ii) The process of compression or expansion should be so slow so as to provide time for the exchange of heat.

Since these two conditions are not fully realised in practice, therefore, no process is perfectly isothermal.

(2) **Equation of state :** In this process, P and V change but T = constant *i.e.* change in temperature $\Delta T = 0$.

Boyle's law is obeyed *i.e.* $PV =$ constant $\Rightarrow P_1V_1 = P_2V_2$

(3) **Example of isothermal process :** Melting of ice (at 0°C) and boiling of water (at 100°C) are common example of this process.

(4) **Indicator diagram :** According to PV = constant, graph between P and V is a part of rectangular hyperbola. The graphs at different temperature are parallel to each other are called isotherms.

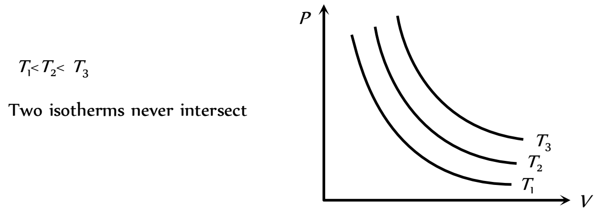


Fig. 14.18

(i) Slope of isothermal curve : By differentiating PV = constant. We get

$$P\,dV + V\,dP = 0$$

$$\Rightarrow PdV = -VdP$$

$$\Rightarrow \text{Slope} = \tan\theta = \frac{dP}{dV} = -\frac{P}{V}$$

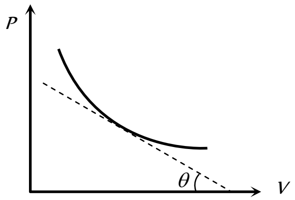


Fig. 14.19

(ii) Area between the isotherm and volume axis represents the work done in isothermal process.

If volume increases ΔW = + (Area under curve) and if volume decreases ΔW = – (Area under curve)

(5) **Specific heat :** Specific heat of gas during isothermal change is infinite. As $C = \frac{Q}{m\Delta T} = \frac{Q}{m\times 0} = \infty$ [As ΔT = 0]

(6) **Isothermal elasticity (E_θ) :** For this process PV = constant.

$$\Rightarrow P\,dV = -V\,dP \Rightarrow P = \frac{dP}{-dV/V} = \frac{\text{Stress}}{\text{Strain}} = E_\theta$$

$\Rightarrow E_\theta = P$ *i.e.* isothermal elasticity is equal to pressure

At N.T.P., E_θ = Atmospheric pressure = $1.01\times 10^5\,N/m^2$

(7) **Work done in isothermal process**

$$W = \int_{V_i}^{V_f} P\,dV = \int_{V_i}^{V_f}\frac{\mu RT}{V}dV \qquad [\text{As } PV = \mu RT]$$

$$W = \mu RT\log_e\left(\frac{V_f}{V_i}\right) = 2.303\,\mu RT\log_{10}\left(\frac{V_f}{V_i}\right)$$

or $$W = \mu RT\log_e\left(\frac{P_i}{P_f}\right) = 2.303\mu RT\log_{10}\left(\frac{P_i}{P_f}\right)$$

(8) **FLOT in isothermal process :** From $\Delta Q = \Delta U + \Delta W$

$\because\ \Delta U = 0$ [As ΔT = 0] $\Rightarrow \Delta Q = \Delta W$

i.e. heat supplied in an isothermal change is used to do work against external surrounding.

or if the work is done on the system than equal amount of heat energy will be liberated by the system.

Adiabatic Process

When a thermodynamic system undergoes a change in such a way that no exchange of heat takes place between System and surroundings, the process is known as adiabatic process.

In this process P, V and T changes but ΔQ = 0.

(1) **Essential conditions for adiabatic process**

(i) There should not be any exchange of heat between the system and its surroundings. All walls of the container and the piston must be perfectly insulating.

(ii) The system should be compressed or allowed to expand suddenly so that there is no time for the exchange of heat between the system and its surroundings.

Since, these two conditions are not fully realised in practice, so no process is perfectly adiabatic.

(2) **Some examples of adiabatic process**

(i) Sudden compression or expansion of a gas in a container with perfectly non-conducting walls.

(ii) Sudden bursting of the tube of bicycle tyre.

(iii) Propagation of sound waves in air and other gases.

(iv) Expansion of steam in the cylinder of steam engine.

(3) **FLOT in adiabatic process :** From $\Delta Q = \Delta U + \Delta W$

For adiabatic process $\Delta Q = 0 \Rightarrow \Delta U = -\Delta W$

If ΔW = positive then ΔU = negative so temperature decreases *i.e.* adiabatic expansion produce cooling.

If ΔW = negative then ΔU = positive so temperature increases *i.e.* adiabatic compression produce heating.

(4) **Equation of state :** In adiabatic change ideal gases do not obeys Boyle's law but obeys Poisson's law. According to it

PV^{γ} = constant; where $\gamma = \frac{C_P}{C_V}$

(i) For temperature and volume

TV^{γ} = constant $\Rightarrow T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$ or $T \propto V^{1-\gamma}$

(ii) For temperature and pressure

$\frac{T^{\gamma}}{P^{\gamma-1}}$ = const. $\Rightarrow T_1^{\gamma}P_1^{1-\gamma} = T_2^{\gamma}P_2^{1-\gamma}$ or $T \propto P^{\frac{\gamma-1}{\gamma}}$ or $P \propto T^{\frac{\gamma}{\gamma-1}}$

Table 14.2 : Special cases of adiabatic process

Type of gas	$P \propto \frac{1}{V^{\gamma}}$	$P \propto T^{\frac{\gamma}{\gamma-1}}$	$T \propto \frac{1}{V^{\gamma-1}}$
Monoatomic γ = 5/3	$P \propto \frac{1}{V^{5/3}}$	$P \propto T^{5/2}$	$T \propto \frac{1}{V^{2/3}}$
Diatomic γ = 7/5	$P \propto \frac{1}{V^{7/5}}$	$P \propto T^{7/2}$	$T \propto \frac{1}{V^{2/5}}$
Polyatomic γ = 4/3	$P \propto \frac{1}{V^{4/3}}$	$P \propto T^{4}$	$T \propto \frac{1}{V^{1/3}}$

(5) **Indicator diagram**

(i) Curve obtained on PV graph are called adiabatic curve.

(ii) Slope of adiabatic curve : From PV^{γ} = constant

By differentiating, we get

$$dP\,V^{\gamma} + P\gamma V^{\gamma-1}\,dV = 0$$

$$\frac{dP}{dV} = -\gamma\frac{PV^{\gamma-1}}{V^{\gamma}} = -\gamma\left(\frac{P}{V}\right)$$

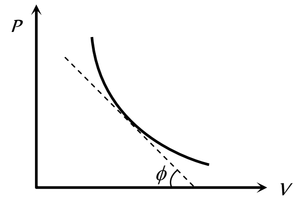


Fig. 14.20

$\therefore$ Slope of adiabatic curve $\tan\phi = -\gamma\left(\frac{P}{V}\right)$

(iii) But we also know that slope of isothermal curve $\tan\theta = \frac{-P}{V}$

Hence $(\text{Slope})_{Adi} = \gamma \times (\text{Slope})_{Iso}$ or $\frac{(\text{Slope})_{Adi}}{(\text{Slope})_{Iso}} > 1$

(6) **Specific heat :** Specific heat of a gas during adiabatic change is zero As $C = \frac{Q}{m\Delta T} = \frac{0}{m\Delta T} = 0$ [As $Q = 0$]

(7) **Adiabatic elasticity (E_ϕ) :** $PV^\gamma = \text{constant}$

Differentiating both sides $d\,PV^\gamma + P\gamma V^{\gamma-1}dV = 0$

$$\gamma P = \frac{dP}{-dV/V} = \frac{\text{Stress}}{\text{Strain}} = E_\phi \Rightarrow E_\phi = \gamma P$$

i.e. adiabatic elasticity is γ times that of pressure

Also isothermal elasticity $E_\theta = P \Rightarrow \frac{E_\phi}{E_\theta} = \gamma = \frac{C_P}{C_V}$

i.e. the ratio of two elasticity of gases is equal to the ratio of two specific heats.

(8) **Work done in adiabatic process**

$$W = \int_{V_i}^{V_f} P\,dV = \int_{V_i}^{V_f} \frac{K}{V^\gamma}dV \Rightarrow W = \frac{[P_iV_i - P_fV_f]}{(\gamma-1)} = \frac{\mu R(T_i - T_f)}{(\gamma-1)}$$

(As $PV^\gamma = K$, $P_fV_f = \mu RT_f$ and $P_iV_i = \mu RT_i$)

(i) $W \propto$ quantity of gas (either M or μ)

(ii) $W \propto$ temperature difference $(T_i - T_f)$

(iii) $W \propto \frac{1}{\gamma-1}$ $\because$ $\gamma_{mono} > \gamma_{di} > \gamma_{tri} \Rightarrow W_{mono} < W_{dia} < W_{tri}$

(9) **Comparison between isothermal and adiabatic indicator diagrams :** Always remember that adiabatic curves are more steeper than isothermal curves

(i) Equal expansion : Graph 1 represent isothermal process and 2 represent adiabatic process

$W_{\text{isothermal}} > W_{\text{adiabatic}}$

$P_{\text{isothermal}} > P_{\text{adiabatic}}$

$T_{\text{isothermal}} > T_{\text{adiabatic}}$

$(\text{Slope})_{\text{Isothermal}} < (\text{Slope})_{\text{Adiabatic}}$

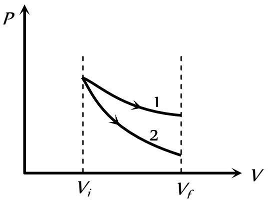


Fig. 14.21

(ii) Compression : Graph 1 represent adiabatic process and 2 represent isothermal process

$W_{\text{Adiabatic}} > W_{\text{Isothermal}}$

$P_{\text{Adiabatic}} > P_{\text{Isothermal}}$

$T_{\text{Adiabatic}} > T_{\text{Isothermal}}$

$(\text{Slope})_{\text{Isothermal}} < (\text{Slope})_{\text{Adiabatic}}$

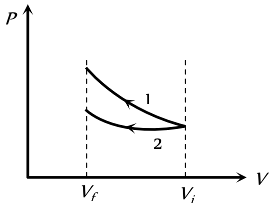


Fig. 14.22

(10) **Free expansion :** Free expansion is adiabatic process in which no work is performed on or by the system. Consider two vessels placed in a system which is enclosed with thermal insulation (asbestos-covered). One vessel contains a gas and the other is evacuated. When suddenly the stopcock is opened, the gas rushes into the evacuated vessel and expands freely.

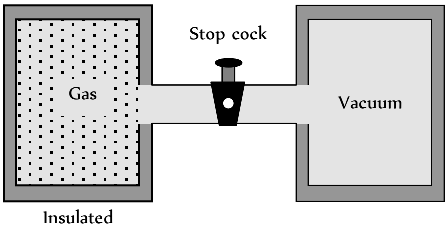


Fig. 14.23

$\Delta W = 0$ (Because walls are rigid)

$\Delta Q = 0$ (Because walls are insulated)

$\Delta U = U_f - U_i = 0$ (Because ΔQ and ΔW are zero. Thus the final and initial energies are equal in free expansion.

Cyclic and Non-cyclic Process

A cyclic process consists of a series of changes which return the system back to its initial state.

In non-cyclic process the series of changes involved do not return the system back to its initial state.

(1) In case of cyclic process as $U_f = U_i \Rightarrow \Delta U = U_f - U_i = 0$

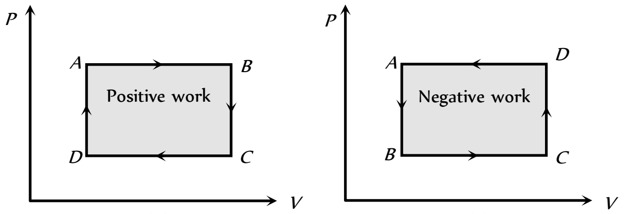
i.e. change in internal energy for cyclic process is zero and also $\Delta U \propto \Delta T \Rightarrow \Delta T = 0$ *i.e.* temperature of system remains constant.

(2) From FLOT $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta Q = \Delta W$

i.e. heat supplied is equal to the work done by the system.

(3) For cyclic process *P-V* graph is a closed curve and area enclosed by the closed path represents the work done.

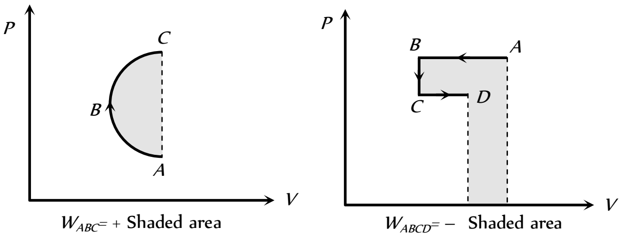
If the cycle is clockwise work done is positive and if the cycle is anticlockwise work done is negative.



(A) (B)

Fig. 14.24

(4) Work done in non cyclic process depends upon the path chosen or the series of changes involved and can be calculated by the area covered between the curve and volume axis on *PV* diagram.



(A) (B)

Fig. 14.25

Quasi Static Process

When we perform a process on a given system, its state is, in general, changed. Suppose the initial state of the system is described by the values P_1, V_1, T_1 and the final state by P_2, V_2, T_2. If the process is performed in such a way that at any instant during the process, the system is very nearly in thermodynamic equilibrium, the process is called quasi-static. This means, we can specify the parameters *P*, *V*, *T* uniquely at any instant during such a process.

Actual processes are not quasi-static. To change the pressure of a gas, we can move a piston inside the enclosure. The gas near the piston is acted upon by piston. The pressure of the gas may not be uniform everywhere while the piston is moving. However, we can move the piston very slowly to make the process as close to quasi-static as we wish. Thus, a quasi-static process is an idealised process in which all changes take place infinitely slowly.

Reversible and Irreversible Process

(1) **Reversible process :** A reversible process is one which can be reversed in such a way that all changes occurring in the direct process are exactly repeated in the opposite order and inverse sense and no change is left in any of the bodies taking part in the process or in the surroundings. For example if heat is absorbed in the direct process, the same amount of heat should be given out in the reverse process, if work is done on the working substance in the direct process then the same amount of work should be done by the working substance in the reverse process. The conditions for reversibility are

(i) There must be complete absence of dissipative forces such as friction, viscosity, electric resistance etc.

(ii) The direct and reverse processes must take place infinitely slowly.

(iii) The temperature of the system must not differ appreciably from its surroundings.

Some examples of reversible process are

(a) All isothermal and adiabatic changes are reversible if they are performed very slowly.

(b) When a certain amount of heat is absorbed by ice, it melts. If the same amount of heat is removed from it, the water formed in the direct process will be converted into ice.

(c) An extremely slow extension or contraction of a spring without setting up oscillations.

(d) When a perfectly elastic ball falls from some height on a perfectly elastic horizontal plane, the ball rises to the initial height.

(e) If the resistance of a thermocouple is negligible there will be no heat produced due to Joule's heating effect. In such a case heating or cooling is reversible. At a junction where a cooling effect is produced due to Peltier effect when current flows in one direction and equal heating effect is produced when the current is reversed.

(f) Very slow evaporation or condensation.

It should be remembered that the conditions mentioned for a reversible process can never be realised in practice. Hence, a reversible process is only an ideal concept. In actual process, there is always loss of heat due to friction, conduction, radiation *etc.*

(2) **Irreversible process :** Any process which is not reversible exactly is an irreversible process. All natural processes such as conduction, radiation, radioactive decay *etc.* are irreversible. All practical processes such as free expansion, Joule-Thomson expansion, electrical heating of a wire are also irreversible. Some examples of irreversible processes are given below

(i) When a steel ball is allowed to fall on an inelastic lead sheet, its kinetic energy changes into heat energy by friction. The heat energy raises the temperature of lead sheet. No reverse transformation of heat energy occurs.

(ii) The sudden and fast stretching of a spring may produce vibrations in it. Now a part of the energy is dissipated. This is the case of irreversible process.

(iii) Sudden expansion or contraction and rapid evaporation or condensation are examples of irreversible processes.

(iv) Produced by the passage of an electric current through a resistance is irreversible.

(v) Heat transfer between bodies at different temperatures is also irreversible.

(vi) Joule-Thomson effect is irreversible because on reversing the flow of gas a similar cooling or heating effect is not observed.

Mixed Graphical Representation

(1) ***PV*-graphs**

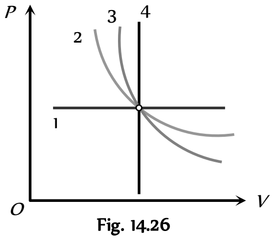


Fig. 14.26

1 ⟶ Isobaric (*P*-constant)

2 ⟶ Isothermal (Because $P \propto \frac{1}{V}$)

3 ⟶ Adiabatic (Because $P \propto \frac{1}{V^{\gamma}}$)

4 ⟶ Isochoric (*V*-constant)

(2) ***PT*-graphs**

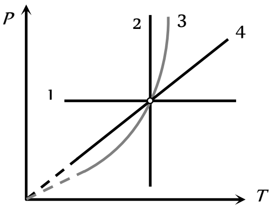


Fig. 14.27

1 ⟶ Isobaric (*P*-constant)

2 ⟶ Isothermal (*T*-constant)

3 ⟶ Adiabatic (Because $P \propto T^{\frac{\gamma}{\gamma-1}}$)

4 ⟶ Isochoric (In isochoric $P \propto T$)

(3) ***VT*-graphs**

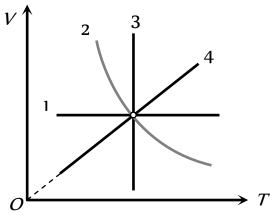


Fig. 14.28

1 ⟶ Isochoric (*V*-constant)

2 ⟶ Adiabatic (Because $V \propto T^{\frac{1}{1-\gamma}}$)

3 ⟶ Isothermal (*T*-constant)

4 ⟶ Isobaric (In isobaric $V \propto T$)

Heat Engine

Heat engine is a device which converts heat into work continuously through a cyclic process.

The essential parts of a heat engine are

(1) **Source :** It is a reservoir of heat at high temperature and infinite thermal capacity. Any amount of heat can be extracted from it.

(2) **Working substance :** Steam, petrol *etc.*

(3) **Sink :** It is a reservoir of heat at low temperature and infinite thermal capacity. Any amount of heat can be given to the sink.

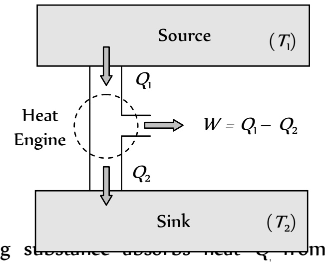


Fig. 14.29

The working substance absorbs heat Q_1 from the source, does an amount of work *W*, returns the remaining amount of heat to the sink and comes back to its original state and there occurs no change in its internal energy.

By repeating the same cycle over and over again, work is continuously obtained.

The performance of heat engine is expressed by means of "efficiency" η which is defined as the ratio of useful work obtained from the engine to the heat supplied to it.

$$\eta = \frac{\text{Work done}}{\text{Heat input}} = \frac{W}{Q_1}$$

For cyclic process $\Delta U = 0$ hence from FLOT $\Delta Q = \Delta W$

So $W = Q_1 - Q_2 \Rightarrow \eta = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$

A perfect heat engine is one which converts all heat into work *i.e.* $W = Q_1$ so that $Q_2 = 0$ and hence $\eta = 1$.

But practically efficiency of an engine is always less than 1.

Refrigerator or Heat Pump

A refrigerator or heat pump is basically a heat engine run in reverse direction.

It essentially consists of three parts

(1) **Source :** At higher temperature T_1.

(2) **Working substance :** It is called refrigerant liquid ammonia and freon works as a working substance.

(3) **Sink :** At lower temperature T_2.

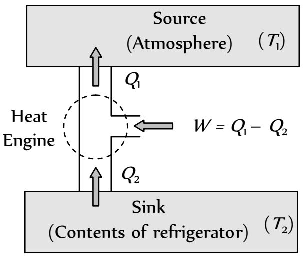


Fig. 14.30

The working substance takes heat Q_2 from a sink (contents of refrigerator) at lower temperature, has a net amount of work done W on it by an external agent (usually compressor of refrigerator) and gives out a larger amount of heat Q_1 to a hot body at temperature T_1 (usually atmosphere). Thus, it transfers heat from a cold to a hot body at the expense of mechanical energy supplied to it by an external agent. The cold body is thus cooled more and more.

The performance of a refrigerator is expressed by means of "coefficient of performance" β which is defined as the ratio of the heat extracted from the cold body to the work needed to transfer it to the hot body.

i.e. $\beta = \frac{\text{Heat extracted}}{\text{Work done}} = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2}$

A perfect refrigerator is one which transfers heat from cold to hot body without doing work

i.e. $W = 0$ so that $Q_1 = Q_2$ and hence $\beta = \infty$

(1) **Carnot refrigerator :** For Carnot refrigerator $\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$

$$\Rightarrow \frac{Q_1 - Q_2}{Q_2} = \frac{T_1 - T_2}{T_2} \text{ or } \frac{Q_2}{Q_1 - Q_2} = \frac{T_2}{T_1 - T_2}$$

So coefficient of performance $\beta = \frac{T_2}{T_1 - T_2}$

where T_1 = temperature of surrounding, T_2 = temperature of cold body. It is clear that $\beta = 0$ when $T_2 = 0$

i.e. the coefficient of performance will be zero if the cold body is at the temperature equal to absolute zero.

(2) **Relation between coefficient of performance and efficiency of refrigerator**

We know $\beta = \frac{Q_2}{Q_1 - Q_2} = \frac{Q_2 / Q_1}{1 - Q_2 / Q_1}$ ..... (i)

But the efficiency $\eta = 1 - \frac{Q_2}{Q_1}$ or $\frac{Q_2}{Q_1} = 1 - \eta$ .....(ii)

From (i) and (ii) we get, $\beta = \frac{1-\eta}{\eta}$

Second Law of Thermodynamics

First law of thermodynamics merely explains the equivalence of work and heat. It does not explain why heat flows from bodies at higher temperatures to those at lower temperatures. It cannot tell us why the converse is possible. It cannot explain why the efficiency of a heat engine is always less than unity. It is also unable to explain why cool water on stirring gets hotter whereas there is no such effect on stirring warm water in a beaker. Second law of thermodynamics provides answers to these questions. Statement of this law is as follows

(1) **Clausius statement :** It is impossible for a self acting machine to transfer heat from a colder body to a hotter one without the aid of an external agency.

From Clausius statement it is clear that heat cannot flow from a body at low temperature to one at higher temperature unless work is done by an external agency. This statement is in fair agreement with our experiences in different branches of physics. For example, electrical current cannot flow from a conductor at lower electrostatic potential to that at higher potential unless an external work is done. Similarly, a body at a lower gravitational potential level cannot move up to higher level without work done by an external agency.

(2) **Kelvin's statement :** It is impossible for a body or system to perform continuous work by cooling it to a temperature lower than the temperature of the coldest one of its surroundings. A Carnot engine cannot work if the source and sink are at the same temperature because work done by the engine will result into cooling the source and heating the surroundings more and more.

(3) **Kelvin-Planck's statement :** It is impossible to design an engine that extracts heat and fully utilises into work without producing any other effect.

From this statement it is clear that any amount of heat can never be converted completely into work. It is essential for an engine to return some amount of heat to the sink. An engine essentially requires a source as well as sink. The efficiency of an engine is always less than unity because heat cannot be fully converted into work.

Carnot Engine

(1) Carnot designed a theoretical engine which is free from all the defects of a practical engine. This engine cannot be realised in actual practice, however, this can be taken as a standard against which the performance of an actual engine can be judged.

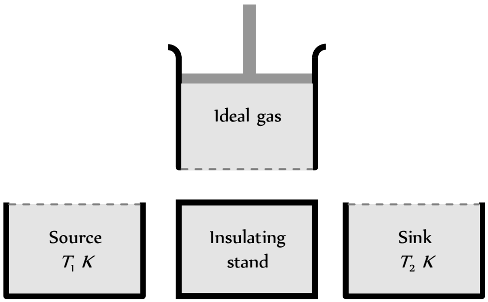


Fig. 14.31

It consists of the following parts

(i) A cylinder with perfectly non-conducting walls and a perfectly conducting base containing a perfect gas as working substance and fitted with a non-conducting frictionless piston

(ii) A source of infinite thermal capacity maintained at constant higher temperature T_1

(iii) A sink of infinite thermal capacity maintained at constant lower temperature T_2.

(iv) A perfectly non-conducting stand for the cylinder.

(2) **Carnot cycle :** As the engine works, the working substance of the engine undergoes a cycle known as Carnot cycle. The Carnot cycle consists of the following four strokes

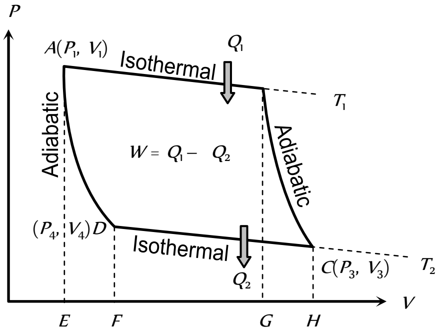


Fig. 14.32

(i) First stroke (Isothermal expansion) (curve *AB*) :

The cylinder containing ideal gas as working substance allowed to expand slowly at this constant temperature T_1.

Work done = Heat absorbed by the system

$$W_1 = Q_1 = \int_{V_1}^{V_2} P\,dV = RT_1 \log_e\left(\frac{V_2}{V_1}\right) = \text{Area } ABGE$$

(ii) Second stroke (Adiabatic expansion) (curve *BC*) :

The cylinder is then placed on the non conducting stand and the gas is allowed to expand adiabatically till the temperature falls from T_1 to T_2.

$$W_2 = \int_{V_2}^{V_3} P\,dV = \frac{R}{(\gamma-1)}[T_1 - T_2] = \text{Area } BCHG$$

(iii) Third stroke (Isothermal compression) (curve *CD*) :

The cylinder is placed on the sink and the gas is compressed at constant temperature T_2.

Work done = Heat released by the system

$$W_3 = Q_2 = -\int_{V_3}^{V_4} P\,dV = -RT_2 \log_e \frac{V_4}{V_3}$$

$$= RT_2 \log_e \frac{V_3}{V_4} = \text{Area } CDFH$$

(iv) Fourth stroke (adiabatic compression) (curve *DA*) : Finally the cylinder is again placed on non-conducting stand and the compression is continued so that gas returns to its initial stage.

$$W_4 = -\int_{V_4}^{V_1} P\,dV = -\frac{R}{\gamma-1}(T_2 - T_1) = \frac{R}{\gamma-1}(T_1 - T_2) = \text{Area } ADFE$$

(3) **Efficiency of Carnot cycle :** The efficiency of engine is defined as the ratio of work done to the heat supplied *i.e.*

$$\eta = \frac{\text{Work done}}{\text{Heat input}} = \frac{W}{Q_1}$$

Net work done during the complete cycle

$$W = W_1 + W_2 + (-W_3) + (-W_4) = W_1 - W_3 = \text{Area } ABCD$$

[As $W_2 = W_4$]

$$\therefore \quad \eta = \frac{W}{Q_1} = \frac{W_1 - W_3}{W_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{W_3}{W_1} = 1 - \frac{Q_2}{Q_1}$$

or $\eta = 1 - \dfrac{RT_2 \log_e(V_3/V_4)}{RT_1 \log_e(V_2/V_1)}$

Since points *B* and *C* lie on same adiabatic curve

$$\therefore \quad T_1 V_2^{\gamma-1} = T_2 V_3^{\gamma-1} \text{ or } \frac{T_1}{T_2} = \left(\frac{V_3}{V_2}\right)^{\gamma-1} \qquad \text{.....(i)}$$

Also point *D* and *A* lie on the same adiabatic curve

$$\therefore \quad T_1 V_1^{\gamma-1} = T_2 V_4^{\gamma-1} \text{ or } \frac{T_1}{T_2} = \left(\frac{V_4}{V_1}\right)^{\gamma-1} \qquad \text{.....(ii)}$$

From (i) and (ii), $\dfrac{V_3}{V_2} = \dfrac{V_4}{V_1}$ or $\dfrac{V_3}{V_4} = \dfrac{V_2}{V_1} \Rightarrow \log_e\left(\dfrac{V_3}{V_4}\right) = \log_e\left(\dfrac{V_2}{V_1}\right)$

So efficiency of Carnot engine $\eta = 1 - \dfrac{T_2}{T_1}$

(i) Efficiency of a heat engine depends only on temperatures of source and sink and is independent of all other factors.

(ii) All reversible heat engines working between same temperatures are equally efficient and no heat engine can be more efficient than Carnot engine (as it is ideal).

(iii) As on Kelvin scale, temperature can never be negative (as 0 *K* is defined as the lowest possible temperature) and T_1 and T_2 are finite, efficiency of a heat engine is always lesser than unity, *i.e.*, whole of heat can never be converted into work which is in accordance with second law.

(4) **Carnot theorem :** The efficiency of Carnot's heat engine depends only on the temperature of source (T_1) and temperature of sink (T_2), *i.e.*, $\eta = 1 - \dfrac{T_2}{T_1}$.

Carnot stated that no heat engine working between two given temperatures of source and sink can be more efficient than a perfectly reversible engine (Carnot engine) working between the same two temperatures. Carnot's reversible engine working between two given temperatures is considered to be the most efficient engine.

Table 14.3 : Difference Between Petrol Engine and Diesel Engine

Petrol engine	Diesel engine
Working substance is a mixture of petrol vapour and air.	Working substance in this engine is a mixture of diesel vapour and air.
Efficiency is smaller (~47%).	Efficiency is larger (~55%).
It works with a spark plug.	It works with an oil plug.
It is associated with the risk of explosion, because petrol vapour and air is compressed. So, low compression ratio is kept.	No risk of explosion, because only air is compressed. Hence compression ratio is kept large.
Petrol vapour and air is created with spark plug.	Spray of diesel is obtained through the jet.

Entropy

Entropy is a measure of disorder of molecular motion of a system. Greater is the disorder, greater is the entropy.

The change in entropy *i.e.*

$$dS = \frac{\text{Heat absorbed by system}}{\text{Absolute temperature}} \text{ or } dS = \frac{dQ}{T}$$

The relation is called the mathematical form of Second Law of Thermodynamics.

(1) **For solids and liquids**

(i) When heat given to a substance changes its state at constant temperature, then change in entropy $dS = \frac{dQ}{T} = \pm\frac{mL}{T}$

where positive sign refers to heat absorption and negative sign to heat evolution.

(ii) When heat given to a substance raises its temperature from T_1 to T_2, then change in entropy

$$dS = \int \frac{dQ}{T} = \int_{T_1}^{T_2} mc\,\frac{dT}{T} = mc\log_e\left(\frac{T_2}{T_1}\right)$$

$$\Rightarrow \quad \Delta S = 2.303\,mc\log_{10}\left(\frac{T_2}{T_1}\right).$$

(2) **For a perfect gas :** Perfect gas equation for n moles is $PV = nRT$

$$\Delta S = \int\frac{dQ}{T} = \int\frac{\mu C_V dT + P\,dV}{T} \qquad [\text{As } dQ = dU + dW]$$

$$\Rightarrow \quad \Delta S = \int\frac{\mu C_V dT + \frac{\mu RT}{V}dV}{T}$$

$$= \mu C_V\int_{T_1}^{T_2}\frac{dT}{T} + \mu R\int_{V_1}^{V_2}\frac{dV}{V} \qquad [\text{As } PV = \mu RT]$$

$$\therefore \quad \Delta S = \mu C_V\log_e\left(\frac{T_2}{T_1}\right) + \mu R\log_e\left(\frac{V_2}{V_1}\right)$$

In terms of T and P, $\Delta S = \mu C_P\log_e\left(\frac{T_2}{T_1}\right) - \mu R\log_e\left(\frac{P_2}{P_1}\right)$

and in terms of P and V $\Delta S = \mu C_V\log_e\left(\frac{P_2}{P_1}\right) + \mu C_P\log_e\left(\frac{V_2}{V_1}\right)$

Tips & Tricks

✍ When a thermos bottle is vigorously shaken :

Heat transferred to the coffee ⇒ $\Delta Q = 0$

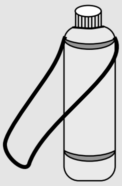
[As thermos flask is insulated from the surrounding]

Work is done on the coffee against viscous force

$\Delta W = (-)$

Internal energy of the coffee increases $\Delta U = (+)$

and temperature of the coffee also increases $\Delta T = (+)$



✍ **Work done without the volume limits**

$$W = \int_{V_i}^{V_f} P\,dV$$

From this equation it seems as if work done can be calculated only when P-V equation is known and limits V_i and V_f are known to us. But it is not so. We can calculate work done if we know the limits of temperature.

For μ moles of an ideal gas if $P = \frac{\alpha}{T}$ with temperature limits T_0 and $2T_0$.

$$\text{From } PV = \mu RT \Rightarrow V = \frac{\mu RT}{P} = \frac{\mu RT^2}{\alpha} \Rightarrow dV = \frac{2\mu RT}{\alpha}dT$$

$$\therefore \quad W = \int_{V_i}^{V_f} P\,dV = \int_{T_0}^{2T_0}\left(\frac{\alpha}{T}\right)\left(\frac{2\mu RT}{\alpha}\right)dT = 2\mu RT_0$$

✍ **Work done with spring :** If mass less piston is attached to a spring of force constant K and a mass m is placed over the piston. If the external pressure is P_0 and due to expansion of gas the piston moves up through a distance x then

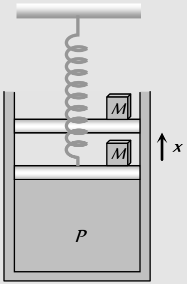
Total work done by the gas

$W = W_1 + W_2 + W_3$

where W_1 = Work done against external pressure (P_0)

W_2 = Work done against spring force (Kx)

W_3 = Work done against gravitational force (mg)



$$\therefore \qquad W = P_0V + \frac{1}{2}Kx^2 + mgx$$

✍ The efficiency of an actual engine is much lesser than that of an ideal engine. Actually the practical efficiency of a steam engine is about (8-15)% while that of a petrol engine is 40%. The efficiency of a diesel engine is maximum and is about (50-55)%.

✍ When P and V bear the relation PV^x = constant, where $x \neq 1$ or γ the process is called a polytropic one. In this process the molar heat capacity is, $C = C_V + \frac{R}{1-x} = \frac{R}{\gamma-1} + \frac{R}{1-x}$

✍ **Enthalpy :** Four quantities called "thermodynamic potentials" are useful in the chemical thermodynamics of reactions and non-cyclic processes. They are internal energy, the enthalpy, the Helmoltz free energy and the Gibbs free energy. Enthalpy is defined by

$$H = U + PV$$

where P and V are the pressure and volume, and U is internal energy, Enthalpy is somewhat parallel to the first law of thermodynamics for a constant pressure system $Q = \Delta U + P\Delta V$ since in this case $Q = \Delta H$.

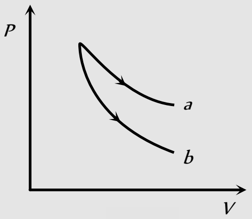
✍ **Confusion about FLOT**

It is typical for chemistry texts to write the first law as

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

It is the same law, of course the thermodynamic expression of the conservation of energy principle. It is just that W is defined as the work done on the system instead of work done by the system. In the context of physics, the common scenario is one of adding heat to a volume of gas and using the expansion of that gas to do work, as in the pushing down of a piston in an internal combustion engine. In the context of chemical reactions and process, it may be more common to deal with situations where work is done on the system rather than by it.

✍ **Possibilities**



If $a \longrightarrow$ Isothermal then $b \longrightarrow$ Must be adiabatic

But If $b \longrightarrow$ adiabatic then it is not compulsory that a must be isothermal, it may be adiabatic also.

OT Ordinary Thinking

Objective Questions

First Law of Thermodynamics ($\Delta Q = \Delta U + \Delta W$)

1. First law of thermnodynamics is given by [CPMT 1977, 91]

(a) $dQ = dU + PdV$ (b) $dQ = dU \times PdV$

(c) $dQ = (dU + dV)P$ (d) $dQ = PdU + dV$

2. The internal energy of an ideal gas depends upon

[RPMT 1997; MP PMT 1999; CPMT 2003]

(a) Specific volume (b) Pressure

(c) Temperature (d) Density

3. In changing the state of thermodynamics from A to B state, the heat required is Q and the work done by the system is W. The change in its internal energy is

[MP PMT 1986; AMU (Med.) 2001]

(a) $Q + W$ (b) $Q - W$

(c) Q (d) $\frac{Q-W}{2}$

4. Heat given to a system is 35 joules and work done by the system is 15 *joules*. The change in the internal energy of the system will be

(a) – 50 J (b) 20 J

(c) 30 J (d) 50 J

5. The temperature of an ideal gas is kept constant as it expands. The gas does external work. During this process, the internal energy of the gas [MP PMT 1990]

(a) Decreases

(b) Increases

(c) Remains constant

(d) Depends on the molecular motion

6. The first law of thermodynamics is concerned with the conservation of [MP PMT 1987; CBSE PMT 1990, 92;

AFMC 1997; CPMT 1999; BHU 1999;

DCE 2000; BCECE 2003]

(a) Momentum (b) Energy

(c) Mass (d) Temperature

7. A thermodynamic system goes from states (i) P_1, V to $2P_1$, V (ii) P, V to P, $2V$. Then work done in the two cases is

[MP PMT 1990]

(a) Zero, Zero (b) Zero, PV_1

(c) PV_1, Zero (d) PV_1, P_1V_1

8. If the amount of heat given to a system be 35 *joules* and the amount of work done by the system be -15 *joules*, then the change in the internal energy of the system is

[MP PMT 1989]

(a) -50 *joules* (b) 20 *joules*

(c) 30 *joules* (d) 50 *joules*

9. A system is given 300 calories of heat and it does 600 *joules* of work. How much does the internal energy of the system change in this process

(J = 4.18 *joules/cal*) [MP PET 1991]

(a) 654 *Joule* (b) 156.5 *Joule*

(c) – 300 *Joule* (d) – 528.2 *Joule*

10. Work done on or by a gas, in general depends upon the

(a) Initial state only

(b) Final state only

(c) Both initial and final states only

(d) Initial state, final state and the path

11. If R = universal gas constant, the amount of heat needed to raise the temperature of 2 mole of an ideal monoatomic gas from 273K to 373K when no work is done [MP PET 1990]

(a) 100 R (b) 150 R

(c) 300 R (d) 500 R

12. Find the change in internal energy of the system when a system absorbs 2 *kilocalorie* of heat and at the same time does 500 *joule* of work [EAMCET 1984]

(a) 7900 J (b) 8200 J

(c) 5600 J (d) 6400 J

[MP PET/PMT 1988]

13. A system performs work ΔW when an amount of heat is ΔQ added to the system, the corresponding change in the internal energy is ΔU. A unique function of the initial and final states (irrespective of the mode of change) is

[CPMT 1981; J & KCET 2004]

(a) ΔQ (b) ΔW

(c) ΔU and ΔQ (d) ΔU

14. A container of volume $1 m^3$ is divided into two equal compartments by a partition. One of these compartments contains an ideal gas at 300 *K*. The other compartment is vacuum. The whole system is thermally isolated from its surroundings. The partition is removed and the gas expands to occupy the whole volume of the container. Its temperature now would be **[Manipal MEE 1995]**

(a) 300 *K* (b) 239 *K*

(c) 200 *K* (d) 100 *K*

15. 110 *J* of heat is added to a gaseous system, whose internal energy change is 40 *J*, then the amount of external work done is **[CBSE PMT 1993; DPMT 1996, 03; AFMC 1999; JIPMER 2000; MH CET 2000; Pb. PMT 2003]**

(a) 150 *J* (b) 70 *J*

(c) 110 *J* (d) 40 *J*

16. Which of the following is not thermodynamical function

[CBSE PMT 1993; CPMT 2001; DCE 1996; 2001]

(a) Enthalpy (b) Work done

(c) Gibb's energy (d) Internal energy

17. When the amount of work done is 333 *cal* and change in internal energy is 167 *cal*, then the heat supplied is

[AFMC 1998]

(a) 166 *cal* (b) 333 *cal*

(c) 500 *cal* (d) 400 *cal*

18. First law thermodynamics states that **[KCET 1999]**

(a) System can do work

(b) System has temperature

(c) System has pressure

(d) Heat is a form of energy

19. A thermo-dynamical system is changed from state (P_1, V_1) to (P_2, V_2) by two different process. The quantity which will remain same will be **[RPET 1999]**

(a) ΔQ (b) ΔW

(c) $\Delta Q + \Delta W$ (d) $\Delta Q - \Delta W$

20. In thermodynamic process, 200 *Joules* of heat is given to a gas and 100 *Joules* of work is also done on it. The change in internal energy of the gas is **[AMU (Engg.) 1999]**

(a) 100 *J* (b) 300 *J*

(c) 419 *J* (d) 24 *J*

21. A perfect gas contained in a cylinder is kept in vacuum. If the cylinder suddenly bursts, then the temperature of the gas

[MH CET 1999]

(a) Remains constant (b) Becomes zero

(c) Increases (d) Decreases

22. If 150 *J* of heat is added to a system and the work done by the system is 110 *J*, then change in internal energy will be

[AMU (Engg.) 1999; BHU 2000]

(a) 260 *J* (b) 150 *J*

(c) 110 *J* (d) 40 *J*

23. If ΔQ and ΔW represent the heat supplied to the system and the work done on the system respectively, then the first law of thermodynamics can be written as **[Roorkee 2000]**

(a) $\Delta Q = \Delta U + \Delta W$ (b) $\Delta Q = \Delta U - \Delta W$

(c) $\Delta Q = \Delta W - \Delta U$ (d) $\Delta Q = -\Delta W - \Delta U$

where ΔU is the internal energy

24. For free expansion of the gas which of the following is true

[AMU (Med.) 2000]

(a) $Q = W = 0$ and $\Delta E_{int} = 0$

(b) $Q = 0, W > 0$ and $\Delta E_{int} = -W$

(c) $W = 0, Q > 0,$ and $\Delta E_{int} = Q$

(d) $W > 0, Q < 0$ and $\Delta E_{int} = 0$

25. Which of the following can not determine the state of a thermodynamic system **[AFMC 2001]**

(a) Pressure and volume

(b) Volume and temperature

(c) Temperature and pressure

(d) Any one of pressure, volume or temperature

26. Which of the following is not a thermodynamics co-ordinate

[AIIMS 2001]

(a) *P* (b) *T*

(c) *V* (d) *R*

27. In a given process for an ideal gas, $dW = 0$ and $dQ < 0$. Then for the gas **[IIT-JEE (Screening) 2001]**

(a) The temperature will decrease

(b) The volume will increase

(c) The pressure will remain constant

(d) The temperature will increase

28. The specific heat of hydrogen gas at constant pressure is $C_P = 3.4 \times 10^3 cal/kg\,^oC$ and at constant volume is $C_V = 2.4 \times 10^3 cal/kg\,^oC$. If one kilogram hydrogen gas is heated from 10^oC to 20^oC at constant pressure, the external work done on the gas to maintain it at constant pressure is

(a) 10^5 *cal* (b) 10^4 *cal*

(c) 10^3 *cal* (d) 5×10^3 *cal*

29. Which of the following parameters does not characterize the thermodynamic state of matter **[CPMT 2001; AIEEE 2003]**

(a) Volume (b) Temperature

(c) Pressure (d) Work

30. In a thermodynamic system working substance is ideal gas, its internal energy is in the form of **[MP PMT 2003]**

(a) Kinetic energy only

(b) Kinetic and potential energy

(c) Potential energy

(d) None of these

31. Which of the following statements is correct for any thermodynamic system **[AIEEE 2004]**

(a) The internal energy changes in all processes

(b) Internal energy and entropy are state functions

(c) The change in entropy can never be zero

(d) The work done in an adiabatic process is always zero

32. A system is provided with 200 cal of heat and the work done by the system on the surrounding is 40 *J*. Then its internal energy

(a) Increases by 600 *J* (b) Decreases by 800 *J*

(c) Increases by 800 *J* (d) Decreases by 50 *J*

33. In a thermodynamic process, pressure of a fixed mass of a gas is changed in such a manner that the gas molecules gives out 20 *J* of heat and 10 *J* of work is done on the gas. If the initial internal energy of the gas was 40 *J*, then the final internal energy will be

(a) 30 *J* (b) 20 *J*

(c) 60 *J* (d) 40 *J*

34. Heat is not being exchanged in a body. If its internal energy is increased, then **[RPMT 2002]**

(a) Its temperature will increase

(b) Its temperature will decrease

(c) Its temperature will remain constant

(d) None of these

35. Out of the following which quantity does not depend on path

(a) Temperature (b) Energy

(c) Work (d) None of these

36. First law of thermodynamics is a special case of

[CPMT 1985; RPET 2000; DCE 2000; CBSE PMT 2000; AIEEE 2002; AFMC 2002]

(a) Newton's law

(b) Law of conservation of energy

(c) Charle's law

(d) Law of heat exchange

37. One mole of an ideal monoatomic gas is heated at a constant pressure of one atmosphere from 0^oC to 100^oC. Then the change in the internal energy is **[Pb. PMT 2001]**

(a) 6.56 *joules* (b) 8.32×10^2 *joules*

(c) 12.48×10^2 *joules* (d) 20.80 *joules*

38. If the ratio of specific heat of a gas at constant pressure to that at constant volume is γ , the change in internal energy of a mass of gas, when the volume changes from *V* to 2V constant pressure *p*, is

(a) $R/(\gamma-1)$ (b) pV

(c) $pV/(\gamma-1)$ (d) $\gamma pV/(\gamma-1)$

39. If $C_V = 4.96 cal/mole$ *K*, then increase in internal energy when temperature of 2 moles of this gas is increased from 340 *K* to 342 *K* **[RPET 1997]**

(a) 27.80 *cal* (b) 19.84 *cal*

(c) 13.90 *cal* (d) 9.92 *cal*

40. Temperature is a measurement of coldness or hotness of an object. This definition is based on **[RPET 2003]**

(a) Zeroth law of thermodynamics

(b) First law of thermodynamics

(c) Second law of thermodynamics

(d) Newton's law of cooling

41. When heat energy of 1500 *Joules*, is supplied to a gas at constant pressure $2.1\times10^5 N/m^2$, there was an increase in its volume equal to $2.5\times10^{-3}m^3$. The increase in internal energy of the gas in Joules is **[EAMCET (Engg.) 1999]**

(a) 450 **[Orissa PMT 2004]** (b) 525

(c) 975 (d) 2025

42. If heat given to a system is 6 *kcal* and work done is 6 k*J*. Then change in internal energy is **[BHU Med. 2000]**

(a) 19.1 *kJ* (b) 12.5 *kJ*

(c) 25 *kJ* **[DPMT 2004]** (d) Zero

43. In a thermodynamics process, pressure of a fixed mass of a gas is changed in such a manner that the gas releases 20 *J* of heat and 8*J* of work is done on the gas. If the initial internal energy of the gas was 30*J*. The final internal energy will be

(a) 18*J* (b) 9*J*

(c) 4.5*J* (d) 36*J*

44. A monoatomic gas of *n*-moles is heated from temperature T_1 to T_2 under two different conditions (i) at constant volume and (ii) at constant pressure. The change in internal energy of the gas is

(a) More for (i) **[RPET 2002]**

(b) More for (ii)

(c) Same in both cases

(d) Independent of number of moles

45. The state of a thermodynamic system is represented by

[MH CET 2004]

(a) Pressure only

(b) Volume only

(c) Pressure, volume and temperature

(d) Number of moles

46. A perfect gas goes from state *A* to another state *B* by absorbing $8\times10^5 J$ of heat and doing $6.5\times10^5 J$ of external work. It is now transferred between the same two states in another process in which it absorbs $10^5 J$ of heat. Then in the second process

(a) Work done on the gas is $0.5\times10^5 J$

(b) Work done by gas is $0.5\times10^5 J$

[CBSE PMT 1998]

(c) Work done on gas is $10^5 J$

(d) Work done by gas is $10^5 J$

47. If a system undergoes contraction of volume then the work done by the system will be **[BHU 1999]**

(a) Zero (b) Negligible

(c) Negative
(d) Positive

48. Which of the following is *incorrect* regarding the first law of thermodynamics [AIEEE 2005]

(a) It introduces the concept of the internal energy
(b) It introduces the concept of the entropy
(c) It is not applicable to any cyclic process
(d) None of the above

Isothermal Process

1. For an ideal gas, in an isothermal process [BHU 1998]

(a) Heat content remains constant
(b) Heat content and temperature remain constant
(c) Temperature remains constant
(d) None of the above

2. Can two isothermal curves cut each other

(a) Never
(b) Yes
(c) They will cut when temperature is $0°C$
(d) Yes, when the pressure is critical pressure

3. In an isothermal expansion [KCET 2000; AFMC 2001]

(a) Internal energy of the gas increases
(b) Internal energy of the gas decreases
(c) Internal energy remains unchanged
(d) Average kinetic energy of gas molecule decreases

4. In an isothermal reversible expansion, if the volume of 96 *gm* of oxygen at $27°C$ is increased from 70 *litres* to 140 *litres*, then the work done by the gas will be

(a) $300\,R\log_{10}2$
(b) $81\,R\log_e 2$
(c) $900\,R\log_{10}2$
(d) $2.3\times 900\,R\log_{10}2$

5. A vessel containing 5 *litres* of a gas at 0.8 *m* pressure is connected to an evacuated vessel of volume 3 *litres*. The resultant pressure inside will be (assuming whole system to be isolated)

(a) 4/3 *m*
(b) 0.5 *m*
(c) 2.0 *m*
(d) 3/4 *m*

6. For an isothermal expansion of a perfect gas, the value of $\frac{\Delta P}{P}$ is equal [CPMT 1980]

(a) $-\gamma^{1/2}\frac{\Delta V}{V}$
(b) $-\frac{\Delta V}{V}$
(c) $-\gamma\frac{\Delta V}{V}$
(d) $-\gamma^2\frac{\Delta V}{V}$

7. The gas law $\frac{PV}{T}=$ constant is true for

[MNR 1974; MP PMT 1984; BHU 1995, 98, 2000]

(a) Isothermal changes only
(b) Adiabatic changes only
(c) Both isothermal and adiabatic changes
(d) Neither isothermal nor adiabatic changes

8. One mole of O_2 gas having a volume equal to 22.4 *litres* at 0^oC and 1 atmospheric pressure in compressed isothermally so that its volume reduces to 11.2 *litres*. The work done in this process is

(a) $1672.5\ J$
(b) 1728 J
(c) $-1728J$
(d) $-1572.5\ J$

9. If a gas is heated at constant pressure, its isothermal compressibility

(a) Remains constant
(b) Increases linearly with temperature
(c) Decreases linearly with temperature
(d) Decreases inversely with temperature

10. Work done per mol in an isothermal change is

[RPMT 2004; BCECE 2005]

(a) $RT\log_{10}\frac{V_2}{V_1}$
(b) $RT\log_{10}\frac{V_1}{V_2}$
(c) $RT\log_e\frac{V_2}{V_1}$
(d) $RT\log_e\frac{V_1}{V_2}$

11. The isothermal Bulk modulus of an ideal gas at pressure P is

[CPMT 1974, 81; UPSEAT 1998; IIT 1998]

(a) P
(b) γP
(c) $P/2$
(d) P/γ

12. In isothermal expansion, the pressure is determined by

[AFMC 1995]

(a) Temperature only
(b) Compressibility only
(c) Both temperature and compressibility
(d) None of these

13. The isothermal bulk modulus of a perfect gas at normal pressure is

(a) $1.013\times10^5 N/m^2$
(b) $1.013\times10^6 N/m^2$
(c) $1.,013\times10^{-11} N/m^2$
(d) $1.013\times10^{11} N/m^2$

14. In an isothermal change, an ideal gas obeys

[MP PMT 1993] [EAMCET 1994; CPMT 1999]

(a) Boyle's law
(b) Charle's law
(c) Gaylussac law
(d) None of the above

15. In isothermic process, which statement is wrong

[RPMT 1997]

(a) Temperature is constant
(b) Internal energy is constant
(c) No exchange of energy
(d) (a) and (b) are correct

16. An ideal gas A and a real gas B have their volumes increased from V to 2 V under isothermal conditions. The increase in internal energy

[CBSE PMT 1993; JIPMER 2001, 02]

(a) Will be same in both A and B
(b) Will be zero in both the gases
(c) Of B will be more than that of A
(d) Of A will be more than that of B

17. The specific heat of a gas in an isothermal process is

[AFMC 1998]

(a) Infinite
(b) Zero
(c) Negative
(d) Remains constant

18. A thermally insulated container is divided into two parts by a screen. In one part the pressure and temperature are P and T for an ideal gas filled. In the second part it is vacuum. If now a small hole is created in the screen, then the temperature of the gas will

(a) Decrease (b) Increase
(c) Remain same (d) None of the above

19. A container that suits the occurrence of an isothermal process should be made of [Pb. PMT 2000]

(a) Copper (b) Glass
(c) Wood (d) Cloth

20. In an isothermal process the volume of an ideal gas is halved. One can say that [MP PMT 2004]

(a) Internal energy of the system decreases
(b) Work done by the gas is positive
(c) Work done by the gas is negative
(d) Internal energy of the system increases

21. A thermodynamic process in which temperature T of the system remains constant though other variable P and V may change, is called [Pb. PMT 2004]

(a) Isochoric process (b) Isothermal process
(c) Isobaric process (d) None of these

22. If an ideal gas is compressed isothermally then [RPMT 2003]

(a) No work is done against gas
(b) Heat is relased by the gas
(c) The internal energy of gas will increase
(d) Pressure does not change

23. When an ideal gas in a cylinder was compressed isothermally by a piston, the work done on the gas was found to be 1.5×10^4 *joules*. During this process about

[MP PMT 1987]

(a) 3.6×10^3 *cal* of heat flowed out from the gas
(b) 3.6×10^3 *cal* of heat flowed into the gas
(c) 1.5×10^4 *cal* of heat flowed into the gas
(d) 1.5×10^4 *cal* of heat flowed out from the gas

24. When heat is given to a gas in an isothermal change, the result will be [MP PET 1995; RPMT 1997]

(a) External work done
(b) Rise in temperature
(c) Increase in internal energy
(d) External work done and also rise in temp.

25. When 1 *gm* of water at 0^oC and $1\times10^5\ N/m^2$ pressure is converted into ice of volume $1.091\,cm^2$, the external work done will be

(a) 0.0091 *joule* (b) 0.0182 *joule*
(c) – 0.0091 *joule* (d) – 0.0182 *joule*

26. The latent heat of vaporisation of water is 2240 *J/gm.* If the work done in the process of expansion of 1 *g* is 168 *J*, then increase in internal energy is [Pb. PET 1998; CPMT 2000]

(a) 2408 *J* (b) 2240 *J*
(c) 2072 *J* (d) 1904 *J*

27. 540 *calories* of heat convert 1 cubic centimeter of water at 100^oC into 1671 cubic centimeter of steam at 100^oC at a pressure of one atmosphere. Then the work done against the atmospheric pressure is nearly [RPET 1999]

(a) 540 *cal* (b) 40 *cal*
(c) Zero *cal* (d) 500 *cal*

28. One mole of an ideal gas expands at a constant temperature of 300 *K* from an initial volume of 10 *litres* to a final volume of 20 *litres*. The work done in expanding the gas is

(R = 8.31 *J/mole-K*) [MP PMT 1995; UPSEAT 2000]

(a) 750 *joules* (b) 1728 *joules*
(c) 1500 *joules* (d) 3456 *joules*

29. A cylinder fitted with a piston contains 0.2 *moles* of air at temperature 27°*C*. The piston is pushed so slowly that the air within the cylinder remains in thermal equilibrium with the surroundings. Find the approximate work done by the system if the final volume is twice the initial volume

[BHU (Med.) 2000]

(a) 543 *J* (b) 345 *J*
(c) 453 *J* (d) 600 *J*

30. The volume of an ideal gas is 1 litre and its pressure is equal to 72*cm* of mercury column. The volume of gas is made 900 *cm* by compressing it isothermally. The stress of the gas will be

(a) 8 *cm* (mercury) (b) 7 *cm* (mercury)
(c) 6 *cm* (mercury) (d) 4 *cm* (mercury)

31. During an isothermal expansion of an ideal gas

[UPSEAT 2005]

(a) Its internal energy decreases
(b) Its internal energy does not change
(c) The work done by the gas is equal to the quantity of heat absorbed by it
(d) Both (b) and (c) are correct

Adiabatic Process

1. If a cylinder containing a gas at high pressure explodes, the gas undergoes [MP PET/PMT 1988]

(a) Reversible adiabatic change and fall of temperature
(b) Reversible adiabatic change and rise of temperature
(c) Irreversible adiabatic change and fall of temperature
(d) Irreversible adiabatic change and rise of temperature

2. The work done in an adiabatic change in a gas depends only on [CPMT 1971; MP

(a) Change is pressure (b) Change is volume
(c) Change in temperature (d) None of the above

3. In adiabatic expansion [DPMT 1999]

(a) $\Delta U=0$ (b) $\Delta U=$ negative
(c) $\Delta U=$ positive (d) $\Delta W=$ zero

4. The pressure in the tyre of a car is four times the atmospheric pressure at 300 *K*. If this tyre suddenly bursts, its new temperature will be $(\gamma=1.4)$

[RPMT 1996; MP PMT 1990]

(a) $300\,(4)^{1.4/0.4}$ (b) $300\left(\frac{1}{4}\right)^{-0.4/1.4}$
(c) $300\,(2)^{-0.4/1.4}$ (d) $300\,(4)^{-0.4/1.4}$

5. A gas at NTP is suddenly compressed to one-fourth of its original volume. If γ is supposed to be $\frac{3}{2}$, then the final pressure is

(a) 4 atmosphere (b) $\frac{3}{2}$ atmosphere

(c) 8 atmosphere (d) $\frac{1}{4}$ atmosphere

6. A monoatomic gas $(\gamma = 5/3)$ is suddenly compressed to $\frac{1}{8}$ of its original volume adiabatically, then the pressure of the gas will change to **[CPMT 1976, 83; MP PMT 1994; DPMT 1996; Roorkee 2000; KCET 2000; Pb. PMT 1999, 2001]**

(a) $\frac{24}{5}$

(b) 8

(c) $\frac{40}{3}$

(d) 32 times its initial pressure

7. The pressure and density of a diatomic gas $(\gamma = 7/5)$ change adiabatically from (P, d) to (P', d'). If $\frac{d'}{d} = 32$, then $\frac{P'}{P}$ should be**[CPMT 1982; EAMCET 2001]**

(a) 1/128 (b) 32

(c) 128 (d) None of the above

8. An ideal gas at 27^oC is compressed adiabatically to $\frac{8}{27}$ of its original volume. If $\gamma = \frac{5}{3}$, then the rise in temperature is**[CPMT 1984; CBSE PMT 1999; DPMT 2000; BHU 2001; Pb. PET 2001; UPSEAT 2002, 03; KCET 2003;]**

(a) 450 *K* (b) 375 *K*

(c) 225 *K* (d) 405 *K*

9. Two identical samples of a gas are allowed to expand (i) isothermally (ii) adiabatically. Work done is **[MNR 1998]**

(a) More in the isothermal process

(b) More in the adiabatic process

(c) Neither of them

(d) Equal in both processes

10. Which is the correct statement **[MP PMT 1993]**

(a) For an isothermal change PV = constant

(b) In an isothermal process the change in internal energy must be equal to the work done

(c) For an adiabatic change $\frac{P_2}{P_1} = \left(\frac{V_2}{V_1}\right)^{\gamma}$, where γ is the ratio of specific heats

(d) In an adiabatic process work done must be equal to the heat entering the system

11. The slopes of isothermal and adiabatic curves are related as **[CPMT 1971; BHU 1996; MH CET 1999; UPSEAT 2000; RPET 2003]**

(a) Isothermal curve slope = adiabatic curve slope

(b) Isothermal curve slope = $\gamma \times$ adiabatic curve slope

(c) Adiabatic curve slope = $\gamma \times$ isothermal curve slope

(d) Adiabatic curve slope = $\frac{1}{2} \times$ isothermal curve slope **[BHU 1995]**

12. Pressure-temperature relationship for an ideal gas undergoing adiabatic change is $(\gamma = C_p / C_v)$ **[CPMT 1992; MP PMT 1986, 87, 94, 97; Pb. PET 1998; DCE 2001; MP PET 2001; UPSEAT 1999, 2001; AFMC 2002]**

(a) PT^{γ} = constant (b) $PT^{-1+\gamma}$ = constant

(c) $P^{\gamma-1}T^{\gamma}$ = constant (d) $P^{1-\gamma}T^{\gamma}$ = constant

13. The amount of work done in an adiabatic expansion from temperature T to T_1 is **[MP PMT 1989]**

(a) $R(T-T_1)$ (b) $\frac{R}{\gamma-1}(T-T_1)$

(c) RT (d) $R(T-T_1)(\gamma-1)$

14. During the adiabatic expansion of 2 moles of a gas, the internal energy of the gas is found to decrease by 2 *joules*, the work done during the process on the gas will be equal to **[CPMT 1988]**

(a) 1 *J* (b) -1 *J*

(c) 2 *J* (d) -2 *J*

15. The adiabatic elasticity of hydrogen gas $(\gamma = 1.4)$ at NTP is **[MP PMT 1990]**

(a) $1 \times 10^5\ N/m^2$ (b) $1 \times 10^{-8}\ N/m2$

(c) $1.4\ N/m^2$ (d) $1.4 \times 10^5 N/m^2$

16. If γ denotes the ratio of two specific heats of a gas, the ratio of slopes of adiabatic and isothermal PV curves at their point of intersection is **[NCERT 1990; MH CET 1999; MP PMT 2000]**

(a) $1/\gamma$ (b) γ

(c) $\gamma - 1$ (d) $\gamma + 1$

17. Air in a cylinder is suddenly compressed by a piston, which is then maintained at the same position. With the passage of time **[NCERT 1971; DPMT 1 KCET 2000; AIIMS 2000; MH CET 2001]**

(a) The pressure decreases

(b) The pressure increases

(c) The pressure remains the same

(d) The pressure may increase or decrease depending upon the nature of the gas

18. When a gas expands adiabatically **[CPMT 1990]**

(a) No energy is required for expansion

(b) Energy is required and it comes from the wall of the container of the gas

(c) Internal energy of the gas is used in doing work

(d) Law of conservation of energy does not hold

19. One *gm* mol of a diatomic gas $(\gamma = 1.4)$ is compressed adiabatically so that its temperature rises from 27^oC to 127^oC. The work done will be

(a) 2077.5 *joules* (b) 207.5 *joules*

(c) 207.5 *ergs* (d) None of the above

20. Compressed air in the tube of a wheel of a cycle at normal temperature suddenly starts coming out from a puncture. The air inside [NCERT 1970]

(a) Starts becoming hotter

(b) Remains at the same temperature

(c) Starts becoming cooler

(d) May become hotter or cooler depending upon the amount of water vapour present

21. The adiabatic Bulk modulus of a perfect gas at pressure is given by[CPMT 1982; MH CET 2001]

(a) P (b) $2P$

(c) $P/2$ (d) γP

22. An adiabatic process occurs at constant [MNR 1985; AFMC 1996; AIIMS 1999; UPSEAT 1999, 2000; Pb. PET 2004]

(a) Temperature

(b) Pressure

(c) Heat

(d) Temperature and pressure

23. A polyatomic gas $\left(\gamma = \frac{4}{3}\right)$ is compressed to $\frac{1}{8}$ of its volume adiabatically. If its initial pressure is P_o, its new pressure will be[MP PET 1994; BHU 1995]

(a) $8P_o$ (b) $16P_0$

(c) $6P_o$ (d) $2P_o$

24. For adiabatic processes $\left(\gamma = \frac{C_p}{C_v}\right)$ [KCET 1999; MP PET 1995; CPMT 2003]

(a) $P^{\gamma}V$ = constant (b) $T^{\gamma}V$ = constant

(c) $TV^{\gamma-1}$ =constant (d) TV^{γ} = constant

25. An ideal gas is expanded adiabatically at an initial temperature of 300 K so that its volume is doubled. The final temperature of the hydrogen gas is $(\gamma = 1.40)$ [MP PMT 1995; DPMT 1999]

(a) 227.36 K (b) 500.30 K

(c) 454.76 K (d) -47^oC

26. A given system undergoes a change in which the work done by the system equals the decrease in its internal energy. The system must have undergone an [Haryana CEE 1996; UPSEAT 2003]

(a) Isothermal change (b) Adiabatic change

(c) Isobaric change (d) Isochoric change

27. During the adiabatic expansion of 2 moles of a gas, the internal energy was found to have decreased by 100 J. The work done by the gas in this process is [MP PET 1996, 97]

(a) Zero (b) –100 J

(c) 200 J (d) 100 J

28. In an adiabatic expansion of a gas initial and final temperatures are T_1 and T_2 respectively, then the change in internal energy of the gas is [MP PET 1997]

(a) $\frac{R}{\gamma-1}(T_2 - T_1)$ (b) $\frac{R}{\gamma-1}(T_1 - T_2)$

(c) $R(T_1 - T_2)$ (d) Zero

29. Helium at 27^oC has a volume of 8 *litres*. It is suddenly compressed to a volume of 1 *litre*. The temperature of the gas will be $[\gamma = 5/3]$ [CBSE PMT 1993; MP PMT 1999; Pb. PMT 2002]

(a) 108^oC (b) 9327^oC

(c) 1200^oC (d) 927^oC

30. A cycle tyre bursts suddenly. This represents an [SCRA 1994]

(a) Isothermal process (b) Isobaric process

(c) Isochoric process (d) Adiabatic process

31. One mole of helium is adiabatically expanded from its initial state (P_i, V_i, T_i) to its final state (P_f, V_f, T_f). The decrease in the internal energy associated with this expansion is equal to [SCRA 1994; BHU 2002]

(a) $C_V(T_i - T_f)$ (b) $C_P(T_i - T_f)$

(c) $\frac{1}{2}(C_P + C_V)(Ti - T_f)$ (d) $(C_P - C_V)(T_i - T_f)$

32. At N.T.P. one mole of diatomic gas is compressed adiabatically to half of its volume $\gamma = 1.41$. The work done on gas will be

(a) 1280 J (b) 1610 J

(c) 1815 J (d) 2025 J

33. For adiabatic process, wrong statement is [RPMT 1997]

(a) $dQ = 0$ (b) $dU = -dW$

(c) Q = constant (d) Entropy is not constant

34. A diatomic gas initially at 18°C is compressed adiabatically to one-eighth of its original volume. The temperature after compression will be [Pb. PET 1995; CBSE PMT 1996; CPMT 1999]

(a) 10^oC (b) 887^oC

(c) $668K$ (d) 144^oC

35. A gas is being compressed adiabatically. The specific heat of the gas during compression is [SCRA 1996]

(a) Zero (b) Infinite

(c) Finite but non-zero (d) Undefined

36. The process in which no heat enters or leaves the system is termed as [Pb. PET 1996; BHU 1998; BCECE 2003]

(a) Isochoric (b) Isobaric

(c) Isothermal (d) Adiabatic

37. Two moles of an ideal monoatomic gas at 27^oC occupies a volume of V. If the gas is expanded adiabatically to the volume $2V$, then the work done by the gas will be $[\gamma = 5/3, R = 8.31 J/mol K]$ [RPET 1999]

(a) $-2767.23J$ (b) $2767.23J$

(c) $2500J$ (d) $-2500J$

38. At $27^o C$ a gas is suddenly compressed such that its pressure becomes $\frac{1}{8}th$ of original pressure. Temperature of the gas will be $(\gamma = 5/3)$ **[BHU 2000]**

(a) $420K$
(b) $327^o C$
(c) $300K$
(d) $-142^o C$

39. $\Delta U + \Delta W = 0$ is valid for **[RPMT 2000]**

(a) Adiabatic process
(b) Isothermal process
(c) Isobaric process
(d) Isochoric process

40. An ideal gas at a pressures of 1 atmosphere and temperature of $27^o C$ is compressed adiabatically until its pressure becomes 8 times the initial pressure, then the final temperature is (γ = 3/2) **[EAMCET (Engg.)2000]**

(a) $627^o C$
(b) $527^o C$
(c) $427^o C$
(d) $327^o C$

41. Air is filled in a motor tube at $27^o C$ and at a pressure of 8 atmospheres. The tube suddenly bursts, then temperature of air is $[\text{Given } \gamma \text{ of air} = 1.5]$ **[MP PMT 2002]**

(a) $27.5^o C$
(b) $75^o K$
(c) $150\,K$
(d) $150^o C$

42. If $\gamma = 2.5$ and volume is equal to $\frac{1}{8}$ times to the initial volume then pressure P' is equal to (Initial pressure = P) **[RPET 2003]**

(a) $P' = P$
(b) $P' = 2P$
(c) $P' = P \times (2)^{15/2}$
(d) $P' = 7P$

43. In an adiabatic process, the state of a gas is changed from $P_1, V_1, T_1,$ to P_2, V_2, T_2. Which of the following relation is correct **[Orissa JEE 2003]**

(a) $T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$
(b) $P_1 V_1^{\gamma-1} = P_2 V_2^{\gamma-1}$
(c) $T_1 P_1^{\gamma} = T_2 P_2^{\gamma}$
(d) $T_1 V_1^{\gamma} = T_2 V_2^{\gamma}$

44. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its absolute temperature. The ratio C_p / C_v for the gas is **[AIEEE 2003]**

(a) $\frac{3}{2}$
(b) $\frac{4}{3}$
(c) 2
(d) $\frac{5}{3}$

45. In adiabatic expansion of a gas **[BCECE 2001; MP PET 2003]**

(a) Its pressure increases
(b) Its temperature falls
(c) Its density increases
(d) Its thermal energy increases

46. One mole of an ideal gas at an initial temperature of $T\,K$ does 6 R joules of work adiabatically. If the ratio of specific heats of this gas at constant pressure and at constant volume is 5/3, the final temperature of gas will be **[CBSE PMT 2004]**

(a) $(T + 2.4)K$
(b) $(T - 2.4)K$
(c) $(T + 4)K$
(d) $(T - 4)K$

47. A gas is suddenly compressed to 1/4 th of its original volume at normal temperature. The increase in its temperature is $(\gamma = 1.5)$

(a) 273 K
(b) 573 K
(c) 373 K
(d) 473 K

48. A gas $(\gamma = 1.3)$ is enclosed in an insulated vessel fitted with insulating piston at a pressure of $10^5\, N/m^2$. On suddenly pressing the piston the volume is reduced to half the initial volume. The final pressure of the gas is **[RPET 2002]**

(a) $2^{0.7} \times 10^5$
(b) $2^{1.3} \times 10^5$
(c) $2^{1.4} \times 10^5$
(d) None of these

49. The internal energy of the gas increases In **[MP PMT 1989; RPMT 2001]**

(a) Adiabatic expansion
(b) Adiabatic compression
(c) Isothermal expansion
(d) Isothermal compression

50. We consider a thermodynamic system. If ΔU represents the increase in its internal energy and W the work done by the system, which of the following statements is true **[CBSE PMT 1998]**

(a) $\Delta U = -W$ in an adiabatic process
(b) $\Delta U = W$ in an isothermal process
(c) $\Delta U = -W$ in an isothermal process
(d) $\Delta U = W$ in an adiabatic process

51. A gas is suddenly compressed to one fourth of its original volume. What will be its final pressure, if its initial pressure is P **[Pb. PET 2002]**

(a) Lesss than P
(b) More than P
(c) P
(d) Either (a) or (c)

52. A gas for which $\gamma = 1.5$ is suddenly compressed to $\frac{1}{4}th$ of the initial volume. Then the ratio of the final to the initial pressure is **[EAMCET 200**

(a) 1 : 16
(b) 1 : 8
(c) 1 : 4
(d) 8 : 1

53. One mole of an ideal gas with $\gamma = 1.4$, is adiabatically compressed so that its temperature rises from 27°C to 35°C. The change in the internal energy of the gas is $(R = 8.3\, J/mol.K)$ **[EAMCET 2001]**

(a) –166 J
(b) 166 J
(c) –168 J
(d) 168 J

54. The volume of a gas is reduced adiabatically to $\frac{1}{4}$ of its volume at 27°C, if the value of $\gamma = 1.4$, then the new temperature will be

(a) $350 \times 4^{0.4} K$
(b) $300 \times 4^{0.4}\, K$
(c) $150 \times 4^{0.4}\, K$
(d) None of these

55. During an adiabatic expansion of 2 moles of a gas, the change in internal energy was found –50J. The work done during the process is **[Pb. PET 1996]**

(a) Zero
(b) 100J
(c) – 50J
(d) 50J

56. Adiabatic modulus of elasticity of a gas is $2.1 \times 10^5\, N/m^2$. What will be its isothermal modulus of elasticity $\left(\frac{C_p}{C_v} = 1.4\right)$

[UPSEAT 1999]

(a) $1.8\times10^5\,N/m^2$
(b) $1.5\times10^5\,N/m^2$
(c) $1.4\times10^5\,N/m^2$
(d) $1.2\times10^5\,N/m^2$

57. For an adiabatic expansion of a perfect gas, the value of $\frac{\Delta P}{P}$ is equal to [CPMT 1983; MP PMT 1990]

(a) $-\sqrt{\gamma}\,\frac{\Delta V}{V}$
(b) $-\frac{\Delta V}{V}$
(c) $-\gamma\,\frac{\Delta V}{V}$
(d) $-\gamma^2\,\frac{\Delta V}{V}$

Isobaric and Isochoric Processes

1. A gas expands under constant pressure P from volume V_1 to V_2. The work done by the gas is

[CBSE PMT 1990; RPMT 2003]

(a) $P(V_2-V_1)$
(b) $P(V_1-V_2)$
(c) $P(V_1^\gamma-V_2^\gamma)$
(d) $P\frac{V_1V_2}{V_2-V_1}$

2. When heat in given to a gas in an isobaric process, then

[DPMT 2001]

(a) The work is done by the gas
(b) Internal energy of the gas increases
(c) Both (a) and (b)
(d) None from (a) and (b)

3. One mole of a perfect gas in a cylinder fitted with a piston has a pressure *P*, volume *V* and temperature *T*. If the temperature is increased by 1 *K* keeping pressure constant, the increase in volume is

(a) $\frac{2V}{273}$
(b) $\frac{V}{91}$
(c) $\frac{V}{273}$
(d) V

4. A gas is compressed at a constant pressure of $50N/m^2$ from a volume of $10m^3$ to a volume of $4m^3$. Energy of 100 *J* then added to the gas by heating. Its internal energy is

[MNR 1994]

(a) Increased by 400 *J*
(b) Increased by 200 *J*
(c) Increased by 100 *J*
(d) Decreased by 200 *J*

5. Work done by air when it expands from 50 *litres* to 150 *litres* at a constant pressure of 2 atmosphere is

(a) 2×10^4 *joules*
(b) 2×100 *joules*
(c) $2\times10^5\times100$ *joules*
(d) $2\times10^{-5}\times100$ joules

6. Work done by 0.1 mole of a gas at 27^oC to double its volume at constant pressure is $(R = 2\ cal\ mol^{-1}\,{}^oC^{-1})$

[EAMCET 1994]

(a) 54 *cal*
(b) 600 *cal*
(c) 60 *cal*
(d) 546 *cal*

7. Unit mass of a liquid with volume V_1 is completely changed into a gas of volume V_2 at a constant external pressure *P* and temperature *T*. If the latent heat of evaporation for the given mass is *L*, then the increase in the internal energy of the system is

(a) Zero
(b) $P(V_2-V_1)$
(c) $L-P(V_2-V_1)$
(d) *L*

8. A gas expands $0.25m^3$ at constant pressure $10^3N/m^2$, the work done is

[CPMT 1997; UPSEAT 1999; JIPMER 2001, 02]

(a) 2.5 *ergs*
(b) 250 *J*
(c) 250 *W*
(d) 250 *N*

9. Two kg of water is converted into steam by boiling at atmospheric pressure. The volume changes from $2\times10^{-3}\,m^3$ to $3.34m^3$. The work done by the system is about

(a) – 340 *kJ*
(b) – 170 *kJ*
(c) 170 *kJ*
(d) 340 *kJ*

10. An ideal gas has volume V_0 at 27^oC. It is heated at constant pressure so that its volume becomes $2V_0$. The final temperature is

[BCECE 2003]

(a) 54^oC
(b) 32.6^oC
(c) $327\,°C$
(d) 150 *K*

11. If 300 *ml* of a gas at 27^oC is cooled to 7^oC at constant pressure, then its final volume will be

[Pb. PET 1999; BHU 2003; CPMT 2004]

(a) 540 *ml*
(b) 350 *ml*
(c) 280 *ml*
(d) 135 *ml*

12. Which of the following is correct in terms of increasing work done for the same initial and final state [RPMT 1996]

(a) Adiabatic < Isothermal < Isobaric
(b) Isobaric < Adiabatic < Isothermal
(c) Adiabatic < Isobaric < Isothermal
(d) None of these

13. A sample of gas expands from volume V_1 to V_2. The amount of work done by the gas is greatest when the expansion is

[CBSE PMT 1997; AIIMS 1998; JIPMER 2000]

(a) Isothermal
(b) Isobaric
(c) Adiabatic
(d) Equal in all cases

14. Which of the following is a slow process [J & K CET 2000]

(a) Isothermal
(b) Adiabatic
(c) Isobaric
(d) None of these

15. How much work to be done in decreasing the volume of and ideal gas by an amount of $2.4\times10^{-4}m^3$ at normal temperature and constant normal pressure of $1\times10^5\,N/m^2$

[UPSEAT 1999]

(a) 28 *joule*
(b) 27 *joule*
(c) 25 *joule*
(d) 24 *joule*

16. A Container having 1 mole of a gas at a temperature 27°*C* has a movable piston which maintains at constant pressure in container of 1 *atm*. The gas is compressed until temperature becomes 127°*C*. The work done is (C_p for gas is 7.03 *cal*/*mol*-*K*)

(a) 703 *J*
(b) 814 *J*
(c) 121 *J*
(d) 2035 *J*

17. In a reversible isochoric change [NCERT 1990]

[Roorkee 1999]

(a) $\Delta W = 0$ (b) $\Delta Q = 0$

(c) $\Delta T = 0$ (d) $\Delta U = 0$

18. Entropy of a thermodynamic system does not change when this system is used for **[AIIMS 1995]**

(a) Conduction of heat from a hot reservoir to a cold reservoir

(b) Conversion of heat into work isobarically

(c) Conversion of heat into internal energy isochorically

(d) Conversion of work into heat isochorically

19. The work done in which of the following processes is zero **[UPSEAT 2003]**

(a) Isothermal process (b) Adiabatic process

(c) Isochoric process (d) None of these

20. In which thermodynamic process, volume remains same **[Orissa PMT 2004]**

(a) Isobaric (b) Isothermal

(c) Adiabatic (d) Isochoric

21. In an isochoric process if $T_1 = 27^o C$ and $T_2 = 127^o C$, then P_1 / P_2 will be equal to **[RPMT 2003]**

(a) 9 / 59 (b) 2 / 3

(c) 3 / 4 (d) None of these

22. Which is incorrect **[DCE 2001]**

(a) In an isobaric process, $\Delta p = 0$

(b) In an isochoric process, $\Delta W = 0$

(c) In an isothermal process, $\Delta T = 0$

(d) In an isothermal process, $\Delta Q = 0$

23. Which relation is correct for isometric process **[RPMT 2001; BCECE 2003]**

(a) $\Delta Q = \Delta U$ (b) $\Delta W = \Delta U$

(c) $\Delta Q = \Delta W$ (d) None of these

Heat Engine, Refrigerator and Second Law of Thermodynamics

1. A Carnot engine working between $300\ K$ and $600 K$ has work output of 800 *J* per cycle. What is amount of heat energy supplied to the engine from source per cycle **[DPMT 1999; Pb. PMT 2002, 05; Kerala PMT 2004]**

(a) 1800 *J/cycle* (b) 1000 *J/cycle*

(c) 2000 *J/cycle* (d) 1600 *J/cycle*

2. The coefficient of performance of a Carnot refrigerator working between $30^o C$ and $0^o C$ is **[UPSEAT 2002]**

(a) 10 (b) 1

(c) 9 (d) 0

3. If the door of a refrigerator is kept open, then which of the following is true **[DPMT 2001; BHU 2001; JIPMER 2002; AIEEE 2002; CPMT 2003]**

(a) Room is cooled

(b) Room is heated

(c) Room is either cooled or heated

(d) Room is neither cooled nor heated

4. In a cyclic process, the internal energy of the gas

(a) Increases (b) Decreases

(c) Remains constant (d) Becomes zero

5. Irreversible process is

(a) Adiabatic process

(b) Joule-Thomson expansion

(c) Ideal isothermal process

(d) None of the above

6. For a reversible process, necessary condition is

(a) In the whole cycle of the system, the loss of any type of heat energy should be zero

(b) That the process should be too fast

(c) That the process should be slow so that the working substance should remain in thermal and mechanical equilibrium with the surroundings

(d) The loss of energy should be zero and it should be *quasistatic*

7. In a cyclic process, work done by the system is **[BHU 2002]**

(a) Zero

(b) Equal to heat given to the system

(c) More than the heat given to system

(d) Independent of heat given to the system

8. An ideal gas heat engine operates in a Carnot's cycle between $227^o C$ and $127^o C$. It absorbs 6×10^4 *J* at high temperature. The amount of heat converted into work is .... **[KCET 2004]**

(a) $4.8 \times 10^4\ J$ (b) $3.5 \times 10^4\ J$

(c) $1.6 \times 10^4\ J$ (d) $1.2 \times 10^4\ J$

9. An ideal heat engine exhausting heat at $77^o C$ is to have a 30% efficiency. It must take heat at **[BCECE 2004]**

(a) $127^o C$ (b) $227^o C$

(c) $327^o C$ (d) $673^o C$

10. Efficiency of Carnot engine is 100% if **[Pb. PET 2000]**

(a) $T_2 = 273\ K$ (b) $T_2 = 0\ K$

(c) $T_1 = 273\ K$ (d) $T_1 = 0\ K$

11. A Carnot's engine used first an ideal monoatomic gas then an ideal diatomic gas. If the source and sink temperature are $411^o C$ and $69^o C$ respectively and the engine extracts 1000 *J* of heat in each cycle, then area enclosed by the *PV* diagram is

(a) 100 *J* (b) 300 *J*

(c) 500 *J* (d) 700 *J*

12. A Carnot engine absorbs an amount *Q* of heat from a reservoir at an abosolute temperature *T* and rejects heat to a sink at a temperature of *T*/3. The amount of heat rejected is **[UPSEAT 2004]**

(a) $Q / 4$ (b) $Q / 3$

(c) $Q / 2$ (d) $2Q / 3$

13. The temperature of sink of Carnot engine is $27^o C$. Efficiency of engine is 25%. Then temperature of source is

[DCE 2002; CPMT 2002]

(a) $227^o C$ (b) $327^o C$

(c) $127^o C$ (d) $27^o C$

14. The temperature of reservoir of Carnot's engine operating with an efficiency of 70% is 1000*K*. The temperature of its sink is

(a) 300 *K* (b) 400 *K*

(c) 500 *K* (d) 700 *K*

15. In a Carnot engine, when $T_2 = 0^o C$ and $T_1 = 200^o C,$ its efficiency is η_1 and when $T_1 = 0\ ^oC$ and $T_2 = -200\ ^oC$, Its efficiency is η_2, then what is η_1 / η_2 [DCE 2004]

(a) 0.577 (b) 0.733

(c) 0.638 (d) Can not be calculated

16. The efficiency of Carnot's engine operating between reservoirs, maintained at temperatures $27^o C$ and $-123^o C,$ is

(a) 50% (b) 24%

(c) 0.75% (d) 0.4%

17. A Carnot engine operates between $227^o C$ and $27^o C.$ Efficiency of the engine will be [DCE 1999; BHU 2004]

(a) $\frac{1}{3}$ (b) $\frac{2}{5}$

(c) $\frac{3}{4}$ (d) $\frac{3}{5}$

18. A measure of the degree of disorder of a system is known as

[Pb. PET 1997; MH CET 1999]

(a) Isobaric (b) Isotropy

(c) Enthalpy (d) Entropy

19. A carnot engine has the same efficiency between 800 *K* to 500 *K* and *x K* to 600 *K*. The value of *x* is

[Pb. PMT 1996; CPMT 1996]

(a) 1000 *K* (b) 960 *K*

(c) 846 *K* (d) 754 *K*

20. A scientist says that the efficiency of his heat engine which operates at source temperature 127°*C* and sink temperature 27°*C* is 26%, then [CBSE PMT 2001]

(a) It is impossible

(b) It is possible but less probable

(c) It is quite probable

(d) Data are incomplete

21. A Carnot's engine is made to work between 200°*C* and 0°*C* first and then between 0°*C* and –200°*C*. The ratio of efficiencies of the engine in the two cases is [KCET 2002]

(a) 1.73 : 1 (b) 1 : 1.73

(c) 1 : 1 (d) 1 : 2

22. Efficiency of a Carnot engine is 50% when temperature of outlet is 500 *K*. In order to increase efficiency up to 60% keeping temperature of intake the same what is temperature of outlet [CBSE PMT 2002]

(a) 200 *K* (b) 400 *K*

(c) 600 *K* (d) 800 *K*

23. Even Carnot engine cannot give 100% efficiency because we cannot[AIEEE 2002]

(a) Prevent radiation

(b) Find ideal sources

(c) Reach absolute zero temperature

(d) Eliminate friction

24. "Heat cannot by itself flow from a body at lower temperature to a body at higher temperature" is a statement or consequence of [AIEEE 2003, EAM

[DCE 2003]

(a) Second law of thermodynamics

(b) Conservation of momentum

(c) Conservation of mass

(d) First law of thermodynamics

25. A Carnot engine takes $3 \times 10^6\, cal.$ of heat from a reservoir at 627°*C*, and gives it to a sink at 27°*C*. The work done by the engine is [AIEEE 2003]

(a) $4.2 \times 10^6\, J$ (b) $8.4 \times 10^6\, J$

(c) $16.8 \times 10^6\, J$ (d) Zero

26. The first operation involved in a Carnot cycle is

[AFMC 1998]

[DPMT 2002, 03; BVP 2004]

(a) Isothermal expansion (b) Adiabatic expansion

(c) Isothermal compression (d) Adiabatic compression

27. For which combination of working temperatures the efficiency of Carnot's engine is highest [KCET 2000]

(a) 80 *K*, 60 *K* (b) 100 *K*, 80 *K*

(c) 60 *K*, 40 *K* (d) 40 *K*, 20 *K*

28. The efficiency of Carnot engine when source temperature is T_1 and sink temperature is T_2 will be [DCE 2000]

(a) $\frac{T_1 - T_2}{T_1}$ (b) $\frac{T_2 - T_1}{T_2}$

(c) $\frac{T_1 - T_2}{T_2}$ (d) $\frac{T_1}{T_2}$

29. An ideal heat engine working between temperature T_1 and T_2 has an efficiency η, the new efficiency if both the source and sink temperature are doubled, will be [DPMT 2000]

(a) $\frac{\eta}{2}$ (b) η

(c) 2η (d) 3η

30. An ideal refrigerator has a freezer at a temperature of $-13°C.$ The coefficient of performance of the engine is 5. The temperature of the air (to which heat is rejected) will be

[BHU 2000; CPMT 2002]

(a) 325°*C* (b) 325*K*

(c) 39°*C* (d) 320°*C*

31. In a mechanical refrigerator, the low temperature coils are at a temperature of – 23°*C* and the compressed gas in the condenser has a temperature of 27°*C*. The theoretical coefficient of performance is [UPSEAT 2001]

(a) 5 (b) 8

(c) 6 (d) 6.5

32. An engine is supposed to operate between two reservoirs at temperature 727°*C* and 227°*C*. The maximum possible efficiency of such an engine is [UPSEAT 2005]

(a) 1/2 (b) 1/4

(c) 3/4 (d) 1

33. An ideal gas heat engine operates in Carnot cycle between 227°*C* and 127°*C*. It absorbs 6×10^4 *cals* of heat at higher temperature. Amount of heat converted to work is

[CBSE PMT 2005]

(a) 2.4×10^4 *cal* (b) 6×10^4 *cal*

(c) 1.2×10^4 *cal* (d) 4.8×10^4 *cal*

34. Which of the following processes is reversible

[CBSE PMT 2005]

(a) Transfer of heat by radiation
(b) Electrical heating of a nichrome wire
(c) Transfer of heat by conduction
(d) Isothermal compression

CT Critical Thinking

Objective Questions

1. When an ideal diatomic gas is heated at constant pressure, the fraction of the heat energy supplied which increases the internal energy of the gas, is

[IIT 1990; UPSEAT 1998; RPET 2000]

(a) $\frac{2}{5}$ (b) $\frac{3}{5}$

(c) $\frac{3}{7}$ (d) $\frac{5}{7}$

2. $1 cm^3$ of water at its boiling point absorbs 540 calories of heat to become steam with a volume of $1671 cm^3$.If the atmospheric pressure = $1.013 x 10^5 N/m^2$ and the mechanical equivalent of heat = $4.19 J/calorie$, the energy spent in this process in overcoming intermolecular forces is

[MP PET 1999, 2001; Orissa JEE 2002]

(a) 540 *cal* (b) 40 *cal*
(c) 500 *cal* (d) Zero

3. During the melting of a slab of ice at 273 *K* at atmospheric pressure

(a) Positive work is done by ice-water system on the atmosphere
(b) Positive work is done on the ice-water system by the atmosphere
(c) The internal energy of the ice-water system increases
(d) The internal energy of the ice-water system decreases

4. Two identical containers *A* and *B* with frictionless pistons contain the same ideal gas at the same temperature and the same volume *V*. The mass of the gas in *A* is m_A and that in *B* is m_B. The gas in each cylinder is now allowed to expand isothermally to the same final volume 2*V*. The changes in the pressure in *A* and *B* are found to be ΔP and 1.5 ΔP respectively. Then

(a) $4m_A = 9m_B$ (b) $2m_A = 3m_B$

(c) $3m_A = 2m_B$ (d) $9m_A = 3m_B$

5. A monoatomic ideal gas, initially at temperature T_1, is enclosed in a cylinder fitted with a frictionless piston. The gas is allowed to expand adiabatically to a temperature. T_2 by releasing the piston suddenly. If L_1 and L_2 are the lengths of the gas column before and after expansion respectively, then T_1 / T_2 is given by

[IIT-JEE (Screening) 2000]

(a) $\left(\frac{L_1}{L_2}\right)^{2/3}$ (b) $\frac{L_1}{L_2}$

(c) $\frac{L_2}{L_1}$ (d) $\left(\frac{L_2}{L_1}\right)^{2/3}$

6. A closed hollow insulated cylinder is filled with gas at $0^o C$ and also contains an insulated piston of negligible weight and negligible thickness at the middle point. The gas on one side of the piston is heated to $100^o C$. If the piston moves $5 cm$, the length of the hollow cylinder is **[EAMCET 2001]**

(a) 13.65 *cm* (b) 27.3 *cm*
(c) 38.6 *cm* (d) 64.6 *cm*

7. A mono atomic gas is supplied the heat *Q* very slowly keeping the pressure constant. The work done by the gas will be

(a) $\frac{2}{3}Q$ (b) $\frac{3}{5}Q$

(c) $\frac{2}{5}Q$ (d) $\frac{1}{5}Q$

8. A gas mixture consists of 2 moles of oxygen and 4 moles argon at temperature *T*. Neglecting all vibrational modes, the total internal energy of the system is

[IIT 1999; UPSEAT 2003]

(a) 4 *RT* (b) 15 *RT*
(c) 9 *RT* (d) 11 *RT*

9. An ideal gas expands isothermally from a volume V_1 to V_2 and then compressed to original volume V_1 adiabatically. Initial pressure is P_1 and final pressure is P_3. The total work done is *W*. Then

(a) $P_3 > P_1, W > 0$ (b) $P_3 < P_1, W < 0$

(c) $P_3 > P_1, W < 0$ **[IIT 1998]** (d) $P_3 = P_1, W = 0$

10. Work done by a system under isothermal change from a volume V_1 to V_2 for a gas which obeys Vander Waal's equation $(V - \beta n)\left(P + \frac{\alpha n^2}{V}\right) = nRT$

(a) $nRT \log_e\left(\frac{V_2 - n\beta}{V_1 - n\beta}\right) + \alpha n^2 \left(\frac{V_1 - V_2}{V_1 V_2}\right)$

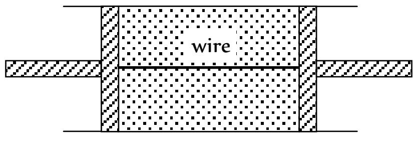
[IIT 1998]

(b) $nRT \log_{10}\left(\frac{V_2 - \alpha\beta}{V_1 - \alpha\beta}\right) + \alpha n^2 \left(\frac{V_1 - V_2}{V_1 V_2}\right)$

(c) $nRT \log_e\left(\frac{V_2 - n\alpha}{V_1 - n\alpha}\right) + \beta n^2 \left(\frac{V_1 - V_2}{V_1 V_2}\right)$

(d) $nRT \log_e\left(\frac{V_1 - n\beta}{V_2 - n\beta}\right) + \alpha n^2 \left(\frac{V_1 V_2}{V_1 - V_2}\right)$

11. A cylindrical tube of uniform cross-sectional area *A* is fitted with two air tight frictionless pistons. The pistons are connected to each other by a metallic wire. Initially the pressure of the gas is P_o and temperature is T_o, atmospheric pressure is also P_o. Now the temperature of the gas is increased to $2T_o$, the tension in the wire will be



(a) $2P_0A$ (b) P_0A

(c) $\frac{P_0A}{2}$ (d) $4P_0A$

12. The molar heat capacity in a process of a diatomic gas if it does a work of $\frac{Q}{4}$ when a heat of *Q* is supplied to it is

(a) $\frac{2}{5}R$ (b) $\frac{5}{2}R$

(c) $\frac{10}{3}R$ (d) $\frac{6}{7}R$

13. An insulator container contains 4 moles of an ideal diatomic gas at temperature *T*. Heat *Q* is supplied to this gas, due to which 2 moles of the gas are dissociated into atoms but temperature of the gas remains constant. Then

(a) $Q = 2RT$ (b) $Q = RT$

(c) $Q = 3RT$ (d) $Q = 4RT$

14. The volume of air increases by 5% in its adiabatic expansion. The percentage decrease in its pressure will be

(a) 5% (b) 6%

(c) 7% (d) 8%

15. The temperature of a hypothetical gas increases to $\sqrt{2}$ times when compressed adiabatically to half the volume. Its equation can be written as

(a) $PV^{3/2}$ = constant (b) $PV^{5/2}$ = constant

(c) $PV^{7/3}$ = constant (d) $PV^{4/3}$ = constant

16. Two Carnot engines *A* and *B* are operated in succession. The first one, *A* receives heat from a source at $T_1 = 800K$ and rejects to sink at T_2K. The second engine *B* receives heat rejected by the first engine and rejects to another sink at $T_3 = 300K$. If the work outputs of two engines are equal, then the value of T_2 is

(a) 100*K* (b) 300*K*

(c) 550*K* (d) 700*K*

17. When an ideal monoatomic gas is heated at constant pressure, fraction of heat energy supplied which increases the internal energy of gas, is **[AIIMS 1995]**

(a) $\frac{2}{5}$ (b) $\frac{3}{5}$

(c) $\frac{3}{7}$ (d) $\frac{3}{4}$

18. When an ideal gas ($\gamma = 5/3$) is heated under constant pressure, then what percentage of given heat energy will be utilised in doing external work **[RPET 1999]**

(a) 40 % (b) 30 %

(c) 60 % (d) 20 %

19. Which one of the following gases possesses the largest internal energy **[SCRA 1998]**

(a) 2 moles of helium occupying $1m^3$ at 300 *K*

(b) 56 *kg* of nitrogen at $107Nm^{-2}$ and 300 *K*

(c) 8 grams of oxygen at 8 atm and 300 *K*

(d) 6×10^{26} molecules of argon occupying $40m^3$ at 900 *K*

20. Two samples *A* and *B* of a gas initially at the same pressure and temperature are compressed from volume *V* to *V/2* (A isothermally and adiabatically). The final pressure of *A* is

[MP PET 1996, 99; MP PMT 1997, 99]

(a) Greater than the final pressure of *B*

(b) Equal to the final pressure of *B*

(c) Less than the final pressure of *B*

(d) Twice the final pressure of *B*

21. Initial pressure and volume of a gas are *P* and *V* respectively. First it is expanded isothermally to volume $4V$ and then compressed adiabatically to volume *V*. The final pressure of gas will be **[CBSE PMT 1999]**

(a) 1*P* (b) 2*P*

(c) 4*P* (d) 8*P*

22. A thermally insulated rigid container contains an ideal gas heated by a filament of resistance 100 Ω through a current of 1*A* for 5 min then change in internal energy is

[IIT-JEE (Screening) 2005]

(a) 0 *kJ* (b) 10 *kJ*

(c) 20 *kJ* (d) 30 *kJ*

23. A reversible engine converts one-sixth of the heat input into work. When the temperature of the sink is reduced by 62°*C*, the efficiency of the engine is doubled. The temperatures of the source and sink are **[CBSE PMT 2000]**

(a) 80°*C*, 37°*C* (b) 95°*C*, 28°*C*

(c) 90°*C*, 37°*C* (d) 99°*C*, 37°*C*

24. An engineer claims to have made an engine delivering 10 *kW* power with fuel consumption of 1 *g/sec*. The calorific value of the fuel is 2 *kcal/g*. Is the claim of the engineer

[J & K CET 2000]

(a) Valid

(b) Invalid

(c) Depends on engine design

(d) Depends of the load

25. Find the change in the entropy in the following process 100 *gm* of ice at 0°*C* melts when dropped in a bucket of water at 50°*C* (Assume temperature of water does not change) **[BHU (Med.) 2000]**

(a) – 4.5 *cal/K* (b) + 4.5 *cal/K*

(c) +5.4 *cal/K* (d) – 5.4 *cal/K*

26. An ideal gas expands in such a manner that its pressure and volume can be related by equation PV^2 = constant. During this process, the gas is **[UPSEAT 2002]**

(a) Heated

(b) Cooled

(c) Neither heated nor cooled

(d) First heated and then cooled

27. A Carnot engine whose low temperature reservoir is at 7°C has an efficiency of 50%. It is desired to increase the efficiency to 70%. By how many degrees should the temperature of the high temperature reservoir be increased

[UPSEAT 2005]

(a) 840 K (b) 280 K

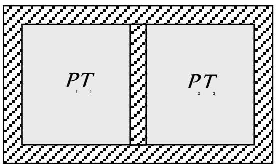
(c) 560 K (d) 380 K

28. P-V diagram of a diatomic gas is a straight line passing through origin. The molar heat capacity of the gas in the process will be

(a) 4 R (b) 2.5 R

(c) 3 R (d) $\frac{4R}{3}$

29. Following figure shows on adiabatic cylindrical container of volume V_0 divided by an adiabatic smooth piston (area of cross-section = A) in two equal parts. An ideal gas $(C_P / C_V = \gamma)$ is at pressure P_1 and temperature T_1 in left part and gas at pressure P_2 and temperature T_2 in right part. The piston is slowly displaced and released at a position where it can stay in equilibrium. The final pressure of the two parts will be (Suppose x = displacement of the piston)



(a) P_2 (b) P_1

(c) $\frac{P_1\left(\frac{V_0}{2}\right)^\gamma}{\left(\frac{V_0}{2}+Ax\right)^\gamma}$ (d) $\frac{P_2\left(\frac{V_0}{2}\right)^\gamma}{\left(\frac{V_0}{2}+Ax\right)^\gamma}$

30. Two cylinders A and B fitted with pistons contain equal amounts of an ideal diatomic gas at 300 K. The piston of A is free to move while that of B is held fixed. The same amount of heat is given to the gas in each cylinder. If the rise in temperature of the gas in A is 30 K, then the rise in temperature of the gas in B is

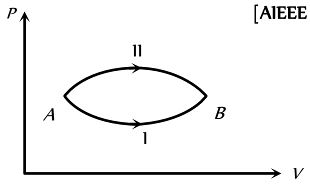
(a) 30 K (b) 18 K

(c) 50 K (d) 42 K

GQ Graphical Questions

1. A system goes from A to B via two processes I and II as shown in figure. If ΔU_1 and ΔU_2 are the changes in internal energies in the processes I and II respectively, then

[AIEEE 2005]



(a) $\Delta U_{II} > \Delta U_I$

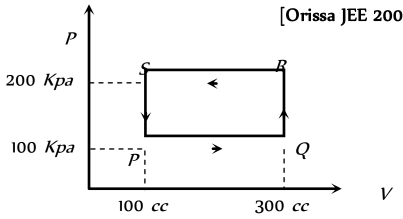
(b) $\Delta U_{II} < \Delta U_I$

(c) $\Delta U_I = \Delta U_{II}$

(d) Relation between ΔU_I and ΔU_{II} can not be determined

2. A thermodynamic system is taken through the cycle $PQRSP$ process. The net work done by the system is

[Orissa JEE 2002]



(a) 20 J

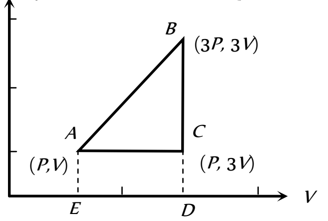
(b) – 20 J

(c) 400 J

(d) – 374 J

[IIT 1998]

3. An ideal gas is taken around *ABCA* as shown in the above *P-V* diagram. The work done during a cycle is [KCET 2001]



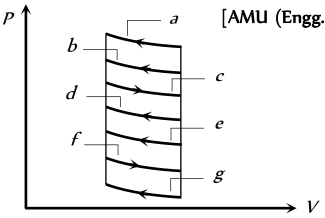
(a) $2PV$

(b) PV

(c) $1/2PV$

(d) Zero

4. The *P-V* diagram shows seven curved paths (connected by vertical paths) that can be followed by a gas. Which two of them should be parts of a closed cycle if the net work done by the gas is to be at its maximum value [AMU (Engg.) 2000]



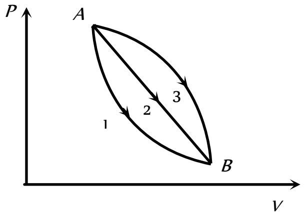
(a) *ac*

(b) *cg*

(c) *af*

(d) *cd*

5. An ideal gas of mass *m* in a state *A* goes to another state *B* via three different processes as shown in figure. If Q_1, Q_2 and Q_3 denote the heat absorbed by the gas along the three paths, then



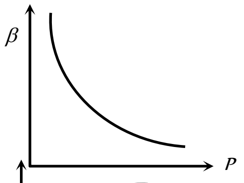
(a) $Q_1 < Q_2 < Q_3$

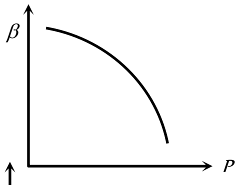
(b) $Q_1 < Q_2 = Q_3$

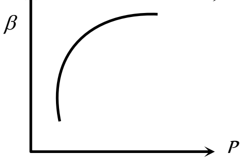
(c) $Q_1 = Q_2 > Q_3$

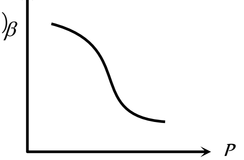
(d) $Q_1 > Q_2 > Q_3$

6. Which of the following graphs correctly represents the variation of $\beta = -(dV/dP)/V$ with *P* for an ideal gas at constant temperature [IIT-JEE (Screening) 2002]

(a)


(b)


(c)


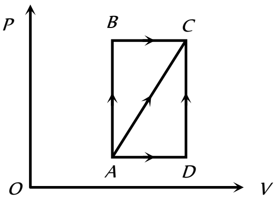
(d)


7. A thermodynamic process is shown in the figure. The pressures and volumes corresponding to some points in the figure are :

$P_A = 3\times10^4\,Pa, P_B = 8\times10^4\,Pa$ and

$V_A = 2\times10^{-3}m^3, V_D = 5\times10^{-3}m^3$

In process *AB*, 600 *J* of heat is added to the system and in process *BC*, 200 *J* of heat is added to the system. The change in internal energy of the system in process *AC* would be



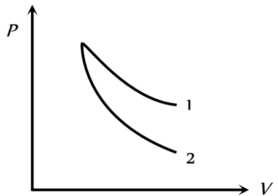
(a) 560 *J*

(b) 800 *J*

(c) 600 *J*

(d) 640 *J*

8. *P-V* plots for two gases during adiabatic process are shown in the figure. Plots 1 and 2 should correspond respectively to [IIT-JEE (Screening) 2001]



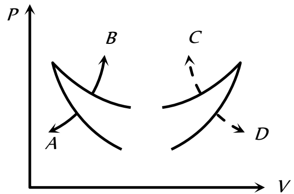
(a) *He* and O_2

(b) O_2 and *He*

(c) *He* and *Ar*

(d) O_2 and N_2

9. Four curves *A*, *B*, *C* and *D* are drawn in the adjoining figure for a given amount of gas. The curves which represent adiabatic and isothermal changes are [CPMT 1986; UPSEAT 1999]



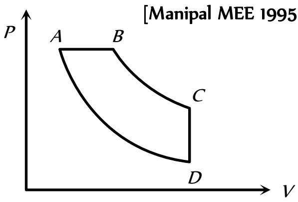
(a) *C* and *D* respectively

(b) *D* and *C* respectively

(c) *A* and *B* respectively

(d) *B* and *A* respectively

10. In pressure-volume diagram given below, the isochoric, isothermal, and isobaric parts respectively, are [Manipal MEE 1995]



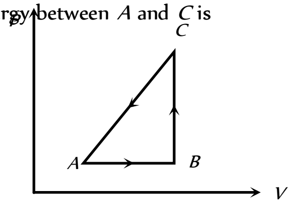
(a) *BA*, *AD*, *DC* [MP PET 1992]

(b) *DC*, *CB*, *BA*

(c) *AB*, *BC*, *CD*

(d) *CD*, *DA*, *AB*

11. The *P-V* diagram of a system undergoing thermodynamic transformation is shown in figure. The work done on the system in going from $A \rightarrow B \rightarrow C$ is 50 *J* and 20 *cal* heat is given to the system. The change in internal energy between *A* and *C* is



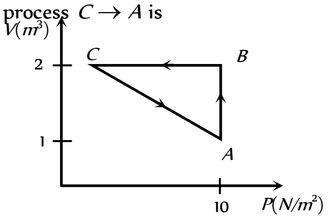
(a) 34 *J*

(b) 70 *J*

(c) 84 *J*

(d) 134 *J*

12. An ideal gas is taken through the cycle $A \rightarrow B \rightarrow C \rightarrow A$, as shown in the figure. If the net heat supplied to the gas in the cycle is 5 *J*, the work done by the gas in the process $C \rightarrow A$ is



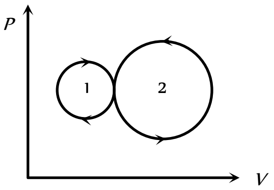
(a) – 5 *J*

(b) – 10 *J*

(c) – 15 *J*

(d) – 20 *J*

13. In the following indicator diagram, the net amount of work done will be [CBSE PMT 1992]



(a) Positive

(b) Negative

(c) Zero

(d) Infinity

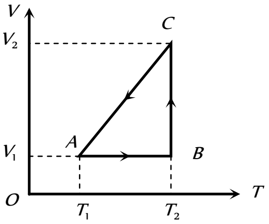
14. A cyclic process for 1 mole of an ideal gas is shown in figure in the *V-T*, diagram. The work done in *AB*, *BC* and *CA* respectively

(a) $0, RT_2 \ln\left(\frac{V_1}{V_2}\right), R(T_1 - T_2)$

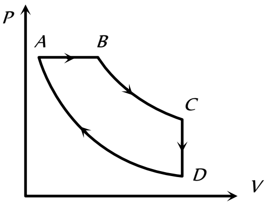
(b) $R(T_1 - T_2), 0, RT_1 \ln\frac{V_1}{V_2}$

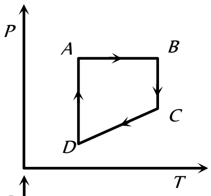
(c) $0, RT_2 \ln\left(\frac{V_2}{V_1}\right), R(T_1 - T_2)$

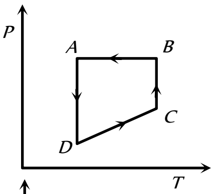
(d) $0, RT_2 \ln\left(\frac{V_2}{V_1}\right), R(T_2 - T_1)$

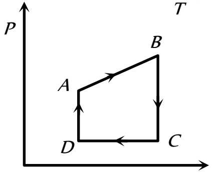


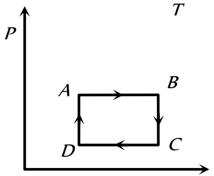
15. A cyclic process *ABCD* is shown in the figure *P-V* diagram. Which of the following curves represent the same process



(a)


(b)


(c)


(d)


16. Carnot cycle (reversible) of a gas represented by a Pressure-Volume curve is shown in the diagram

Consider the following statements

I. Area *ABCD* = Work done on the gas

II. Area *ABCD* = Net heat absorbed

III. Change in the internal energy in cycle = 0

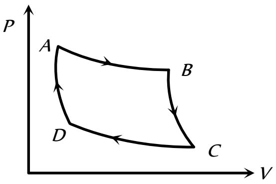
Which of these are correct [AMU (Med.) 2001]

(a) I only

(b) II only

(c) II and III

(d) I, II and III



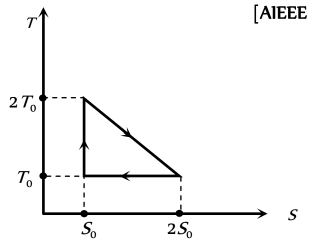
17. The temperature-entropy diagram of a reversible engine cycle is given in the figure. Its efficiency is [AIEEE 2005]

(a) 1/3

(b) 2/3

(c) 1/2

(d) 1/4



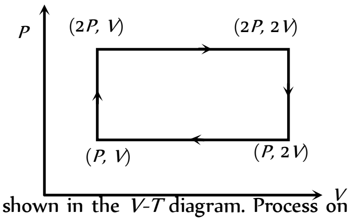
18. Work done in the given *P-V* diagram in the cyclic process is [UPSEAT 1998; RPET 2000; Kerala PMT 2002]

(a) *PV*

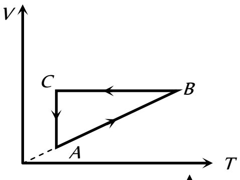
(b) 2*PV*

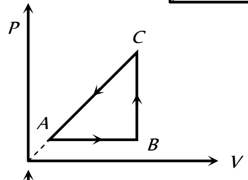
(c) *PV*/2

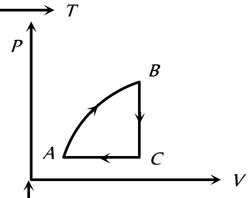
(d) 3*PV*

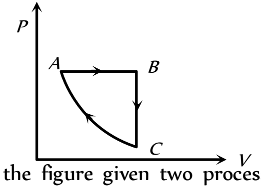


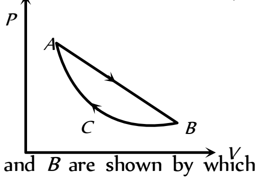
19. A cyclic process *ABCA* is shown in the *V-T* diagram. Process on the *P-V* diagram is



(a)


(b)


(c)


(d)


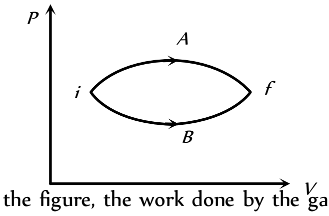
20. In the figure given two processes *A* and *B* are shown by which a thermo-dynamical system goes from initial to final state *F*. If ΔQ_A and ΔQ_B are respectively the heats supplied to the systems then

(a) $\Delta Q_A = \Delta Q_B$

(b) $\Delta Q_A \geq \Delta Q_B$

(c) $\Delta Q_A < \Delta Q_B$

(d) $\Delta Q_A > \Delta Q_B$



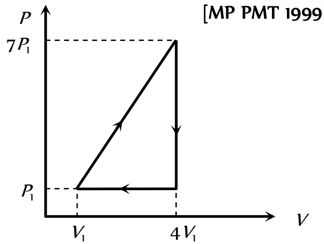
21. In the cyclic process shown in the figure, the work done by the gas in one cycle is [MP PMT 1999]

(a) $28\,P_1V_1$

(b) $14\,P_1V_1$

(c) $18\,P_1V_1$

(d) $9\,P_1V_1$



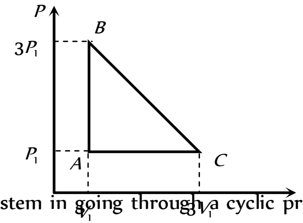
22. An ideal gas is taken around the cycle *ABCA* as shown in the *P-V* diagram. The net work done by the gas during the cycle is equal to

(a) $12\,P_1V_1$

(b) $6\,P_1V_1$

(c) $3\,P_1V_1$

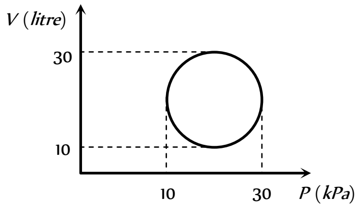
(d) $2P_1V_1$



23. Heat energy absorbed by a system in going through a cyclic process shown in figure is [AIIMS 1995; BHU 2002]

(a) $10^7\ \pi J$

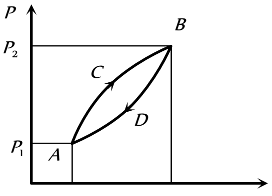
(b) $10^4\ \pi J$



(c) 10 π J

(d) $10^{-3}\ \pi J$

24. A thermodynamic system is taken from state *A* to *B* along *ACB* and is brought back to *A* along *BDA* as shown in the *PV* diagram. The net work done during the complete cycle is given by the area



(a) $P_1ACBP_2P_1$

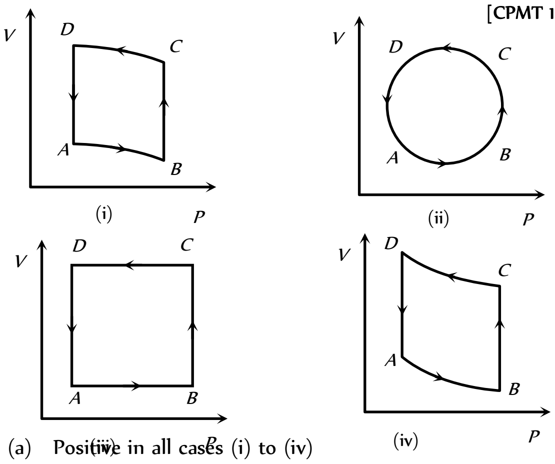
(b) *ACBB′A′A*

(c) *ACBDA*

(d) *ADBB′A′A*

25. In the diagrams (i) to (iv) of variation of volume with changing pressure is shown. A gas is taken along the path *ABCD*. The change in internal energy of the gas will be

[CPMT 1986, 88]



(i) (ii) (iii) (iv)

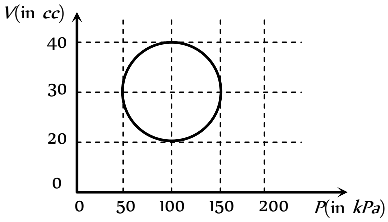
(a) Positive in all cases (i) to (iv)

(b) Positive in cases (i), (ii) and (iii) but zero in (iv) case

(c) Negative in cases (i), (ii) and (iii) but zero in (iv) case

(d) Zero in all four cases

26. A system is taken through a cyclic process represented by a circle as shown. The heat absorbed by the system is



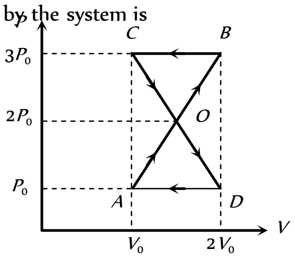
(a) $\pi\times10^{3}\,J$

(b) $\dfrac{\pi}{2}\,J$

(c) $4\pi\times10^{2}\,J$

(d) $\pi\ J$

27. A thermodynamic system undergoes cyclic process *ABCDA* as shown in figure. The work done by the system is



(a) P_0V_0

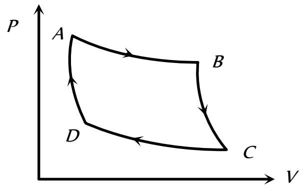
(b) $2P_0V_0$

(c) $\dfrac{P_0V_0}{2}$

(d) Zero

28. The *P-V* graph of an ideal gas cycle is shown here as below. The adiabatic process is described by

[CPMT 1985; UPSEAT 2003]



(a) *AB* and *BC*

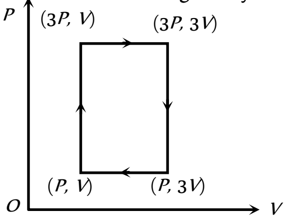
(b) *AB* and *CD*

(c) *BC* and *DA*

(d) *BC* and *CD*

[CBSE PMT 1992]

29. An ideal monoatomic gas is taken round the cycle ABCDA as shown in following *P-V* diagram. The work done during the cycle is [IIT 1983; CPMT 19



(a) *PV*

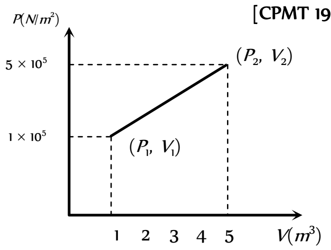
(b) 2 *PV*

(c) 4 *PV*

(d) Zero

30. A system changes from the state (P_1, V_1) to (P_2V_2) as shown in the figure. What is the work done by the system

[CPMT 1981]



(a) 7.5×10^{5} *joule*

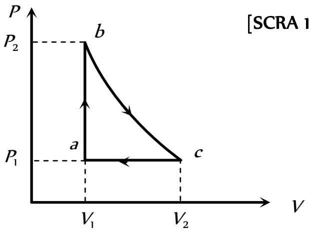
(b) 7.5×10^{5} *erg*

(c) 12×10^{5} *joule*

(d) 6×10^{5} *joule*

31. Carbon monoxide is carried around a closed cycle *abc* in which *bc* is an isothermal process as shown in the figure. The gas absorbs 7000 *J* of heat as its temperature increases from 300 *K to* 1000 *K* in going from *a* to *b*. The quantity of heat rejected by the gas during the process *ca* is

[SCRA 1994]



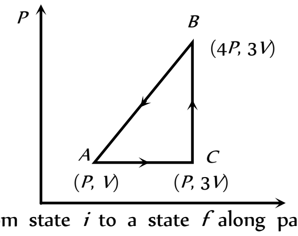
(a) 4200 *J*

(b) 5000 *J*

(c) 9000 *J*

(d) 9800 *J*

32. A sample of ideal monoatomic gas is taken round the cycle *ABCA* as shown in the figure. The work done during the cycle is



(a) Zero

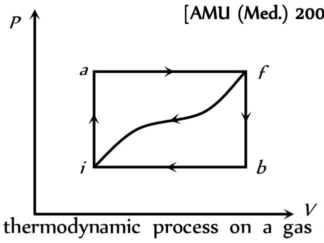
(b) 3 *PV*

(c) 6 *PV*

(d) 9*PV*

33. When a system is taken from state *i* to a state *f* along path *iaf*, $Q=50\ J$ and $W=20J$. Along path *ibf*, $Q=35J$. If $W=-13J$ for the curved return path *f i*, *Q* for this path is

[AMU (Med.) 2000]



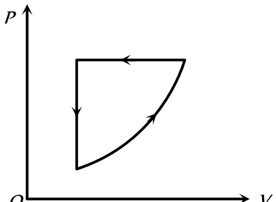
(a) 33 *J*

(b) 23 *J*

(c) − 7 *J*

(d) − 43 *J*

34. For one complete cycle of a thermodynamic process on a gas as shown in the *P-V* diagram, Which of following is correct



(a) $\Delta E_{\text{int}} = 0, Q < O$

(b) $\Delta E_{\text{int}} = 0, Q > 0$

(c) $\Delta E_{\text{int}} > 0, Q < 0$

(d) $\Delta E_{\text{int}} < 0, Q > 0$

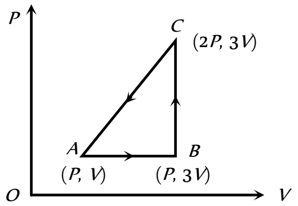
35. An ideal gas is taken around $ABCA$ as shown in the above P-V diagram. The work done during a cycle is **[UPSEAT 2001]**

(a) Zero

(b) $\frac{1}{2}PV$

(c) 2 PV

(d) PV



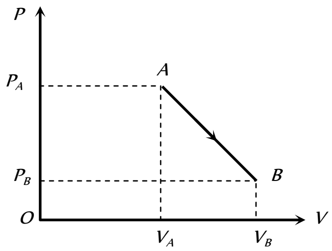
36. An ideal gas is taken from point A to the point B, as shown in the P-V diagram, keeping the temperature constant. The work done in the process is **[UPSEAT 2005]**

(a) $(P_A - P_B)(V_B - V_A)$

(b) $\frac{1}{2}(P_B - P_A)(V_B + V_A)$

(c) $\frac{1}{2}(P_B - P_A)(V_B - V_A)$

(d) $\frac{1}{2}(P_B + P_A)(V_B - V_A)$



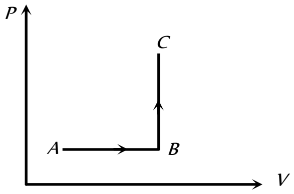
37. The P-V diagram of a system undergoing thermodynamic transformation is shown in figure. The work done by the system in going from $A \to B \to C$ is 30J and 40J heat is given to the system. The change in internal energy between A and C is

(a) 10 J

(b) 70 J

(c) 84 J

(d) 134 J



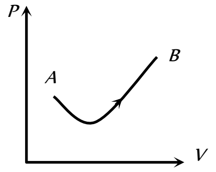
38. Consider a process shown in the figure. During this process the work done by the system

(a) Continuously increases

(b) Continuously decreases

(c) First increases, then decreases

(d) First decreases, then increases



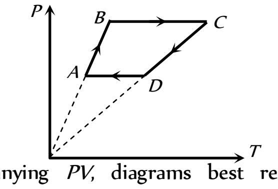
39. Six moles of an ideal gas perfomrs a cycle shown in figure. If the temperature are T_A = 600 K, T_B = 800 K, T_C = 2200 K and T_D = 1200 K, the work done per cycle is **[BCECE 2005]**

(a) 20 kJ

(b) 30 kJ

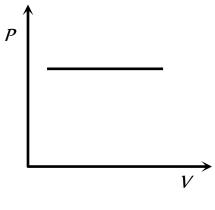
(c) 40 kJ

(d) 60 kJ

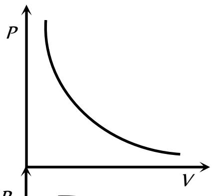


40. Which of the accompanying PV, diagrams best represents an isothermal process **[MP PET 2005]**

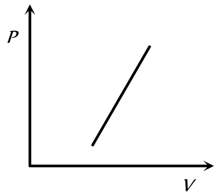
(a)



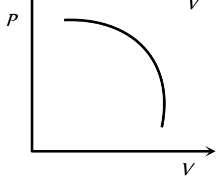
(b)



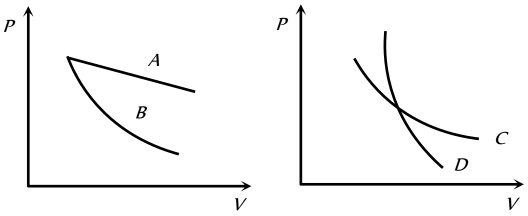
(c)



(d)



41. In the following figure, four curves A, B, C and D are shown. The curves are **[DCE 2003]**



(a) Isothermal for A and D while adiabatic for B and C

(b) Adiabatic for A and C while isothermal for B and D

(c) Isothermal for A and B while adiabatic for C and D

(d) Isothermal for A and C while adiabatic for B and D

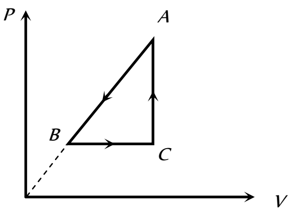
42. P-V diagram of a cyclic process $ABCA$ is as shown in figure. Choose the correct statement **[BCECE 2005]**

(a) $\Delta Q_{A\to B}$ = negative

(b) $\Delta U_{B\to C}$ = positive

(c) ΔW_{CAB} = negative

(d) All of these



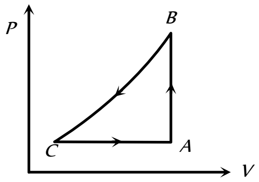
43. A sample of an ideal gas is taken through a cycle a shown in figure. It absorbs 50J of energy during the process AB, no heat during BC, rejects 70J during CA. 40J of work is done on the gas during BC. Internal energy of gas at A is 1500J, the internal energy at C would be

(a) 1590 J

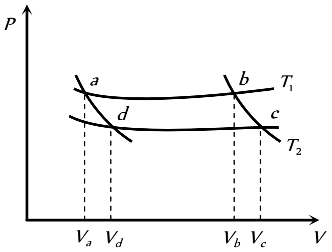
(b) 1620 J

(c) 1540 J

(d) 1570 J



44. In the following P-V diagram two adiabatics cut two isothermals at temperatures T_1 and T_2 (fig.). The value of $\frac{V_a}{V_d}$ will be



(a) $\frac{V_b}{V_c}$ (b) $\frac{V_c}{V_b}$

(c) $\frac{V_d}{V_a}$ (d) $V_b V_c$

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : Reversible systems are difficult to find in real world.
Reason : Most processes are dissipative in nature [AIIMS 2005]

2. Assertion : Air quickly leaking out of a balloon becomes coolers
Reason : The leaking air undergoes adiabatic expansion.[AIIMS 2005]

3. Assertion : Thermodynamic process in nature are irreversible.
Reason : Dissipative effects can not be eliminated. [AIIMS 2004]

4. Assertion : When a bottle of cold carbonated drink is opened, a slight fog forms around the opening.
Reason : Adiabatic expansion of the gas causes lowering of temperature and condensation of water vapours.[AIIMS 2003]

5. Assertion : The isothermal curves intersect each other at a certain point.
Reason : The isothermal change takes place slowly, so the isothermal curves have very little slope. [AIIMS 2001]

6. Assertion : In adiabatic compression, the internal energy and temperature of the system get decreased.
Reason : The adiabatic compression is a slow process [AIIMS 2001]

7. Assertion : In isothermal process whole of the heat energy supplied to the body is converted into internal energy.
Reason : According to the first law of thermodynamics $\Delta Q = \Delta U + p\Delta V$. [AIIMS 1997]

8. Assertion : We can not change the temperature of a body without giving (or taking) heat to (or from) it.
Reason : According to principle of conservation of energy, total energy of a system should remains conserved.

9. Assertion : The specific heat of a gas is an adiabatic process is zero and in an isothermal process is infinite.
Reason : Specific heat of a gas in directly proportional to change of heat in system and inversely proportional to change in temperature.

10. Assertion : Work and heat are two equivalent form of energy.
Reason : Work is the transfer of mechanical energy irrespective of temperature difference, whereas heat is the transfer of thermal energy because of temperature difference only.

11. Assertion : The heat supplied to a system is always equal to the increase in its internal energy.
Reason : When a system changes from one thermal equilibrium to another, some heat is absorbed by it.

12. Assertion : A room can be cooled by opening the door of a refrigerator in a closed room.
Reason : Heat flows from lower temperature (refrigerator) to higher temperature (room).

13. Assertion : It is not possible for a system, unaided by an external agency to transfer heat from a body at lower temperature to another body at higher temperature.
Reason : According to Clausius statement, " No process is possible whose sole result is the transfer of heat from a cooled object to a hotter object.

14. Assertion : If an electric fan be switched on in a closed room, the air of the room will be cooled.
Reason : Fan air decrease the temperature of the room.

15. Assertion : The internal energy of an isothermal process does not change.
Reason : The internal energy of a system depends only on pressure of the system.

16. Assertion : In an adiabatic process, change in internal energy of a gas is equal to work done on or by the gas in the process.
Reason : Temperature of gas remains constant in a adiabatic process.

17. Assertion : An adiabatic process is an isoentropic process.
Reason : Change in entropy is zero in case of adiabatic process.

18. Assertion : Work done by a gas in isothermal expansion is more than the work done by the gas in the same expansion, adiabatically.
Reason : Temperature remains constant in isothermal expansion and not in adiabatic expansion.

19. Assertion : First law of thermodynamics is a restatement of the principle of conservation
Reason : Energy is fundamental quantity.

20. Assertion : Zeroth law of thermodynamic explain the concept of energy.
Reason : Energy is dependent on temperature.

21. Assertion : Efficiency of a Carnot engine increase on reducing the temperature of sink.
Reason : The efficiency of a Carnot engine is defined as ratio of net mechanical work done per cycle by the gas to the amount of heat energy absorbed per cycle from the source.

22. Assertion : The entropy of the solids is the highest
Reason : Atoms of the solids are arranged in orderly manner.

Answers

First Law of Thermodynamics ($\Delta Q = \Delta U + \Delta W$)

1	a	2	c	3	b	4	b	5	c

6	b	7	b	8	d	9	a	10	d
11	c	12	a	13	d	14	a	15	b
16	b	17	c	18	d	19	d	20	b
21	a	22	d	23	b	24	a	25	d
26	d	27	a	28	b	29	d	30	a
31	b	32	c	33	c	34	a	35	a
36	b	37	c	38	c	39	b	40	a
41	c	42	a	43	a	44	c	45	c
46	a	47	c	48	b				

Isothermal Process

1	c	2	a	3	c	4	d	5	b
6	b	7	c	8	d	9	a	10	c
11	a	12	b	13	a	14	a	15	c
16	c	17	a	18	c	19	a	20	c
21	b	22	b	23	a	24	a	25	a
26	c	27	b	28	b	29	b	30	a
31	d								

Adiabatic Process

1	c	2	c	3	b	4	d	5	c
6	d	7	c	8	b	9	a	10	a
11	c	12	d	13	b	14	d	15	d
16	b	17	a	18	c	19	a	20	c
21	d	22	c	23	b	24	c	25	a
26	b	27	d	28	a	29	d	30	d
31	a	32	c	33	d	34	c	35	a
36	d	37	b	38	d	39	a	40	d
41	c	42	c	43	a	44	a	45	b
46	d	47	a	48	b	49	b	50	a
51	b	52	d	53	b	54	b	55	d
56	b	57	c						

Isobaric and Isochoric Processes

1	a	2	c	3	c	4	a	5	a
6	c	7	c	8	b	9	d	10	c
11	c	12	a	13	b	14	a	15	d
16	b	17	a	18	d	19	c	20	d
21	d	22	d	23	a				

Heat Engine, Refrigerator and Second Law of Thermodynamics

1	d	2	c	3	b	4	c	5	b
6	d	7	b	8	d	9	b	10	b
11	c	12	b	13	c	14	a	15	a
16	a	17	b	18	d	19	b	20	a
21	b	22	b	23	c	24	a	25	b
26	a	27	d	28	a	29	b	30	c
31	a	32	a	33	c	34	d		

Critical Thinking Questions

1	d	2	c	3	bc	4	c	5	d
6	d	7	c	8	d	9	c	10	a
11	b	12	c	13	b	14	c	15	a
16	c	17	b	18	a	19	b	20	c
21	b	22	d	23	d	24	b	25	b
26	b	27	d	28	c	29	c	30	d

Graphical Questions

1	c	2	b	3	a	4	c	5	a
6	a	7	a	8	b	9	c	10	d
11	d	12	a	13	b	14	c	15	a
16	c	17	a	18	a	19	c	20	d
21	d	22	d	23	c	24	c	25	d
26	b	27	d	28	c	29	c	30	c
31	d	32	b	33	d	34	a	35	d
36	d	37	a	38	a	39	c	40	b
41	d	42	d	43	a	44	a		

Assertion & Reason

1	a	2	a	3	a	4	a	5	e
6	d	7	e	8	d	9	a	10	a
11	d	12	d	13	a	14	d	15	c
16	c	17	a	18	b	19	c	20	e
21	b	22	a						

Answers and Solutions

First Law of Thermodynamics ($\Delta Q = \Delta U + \Delta W$)

1. (a) $\Delta Q = \Delta U + \Delta W$ and $\Delta W = P\Delta V$

2. (c)

3. (b) $\Delta Q = \Delta U + \Delta W$

$\Rightarrow \Delta U = \Delta Q - \Delta W = Q - W$ (using proper sign)

4. (b) $\Delta U = \Delta Q - W = 35 - 15 = 20\ J$

5. (c) Internal energy depends only on the temperature of the gas.

6. (b)

7. (b) (i) Case $\rightarrow$ Volume = constant $\Rightarrow \int PdV = 0$

(ii) Case $\rightarrow$ P = constant $\Rightarrow \int_{V_1}^{2V_1} PdV = P\int_{V_1}^{2V_1} dV = PV_1$

8. (d) $\Delta Q = \Delta W + \Delta U \Rightarrow 35 = -15 + \Delta U \Rightarrow \Delta U = 50J$

9. (a) $J\Delta Q = \Delta U + \Delta W,\ \Delta U = J\Delta Q - \Delta W$

$\Delta U = 4.18 \times 300 - 600 = 654\ Joule$

10. (d) Work done $= \int_1^2 PdV$, which is state dependent as well as path dependent.

11. (c) $\Delta Q = \Delta U + \Delta W \because \Delta W = 0 \Rightarrow \Delta Q = \Delta U = \frac{f}{2}\mu R\Delta T$

$= \frac{3}{2} \times 2R(373 - 273) = 300R$.

12. (a) $\Delta Q = 2k\,cal = 2 \times 10^3 \times 4.2J = 8400J$ and $\Delta W = 500J$.

Hence from $\Delta Q = \Delta U + \Delta W,\ \Delta W = \Delta Q - \Delta U = 8400 - 500 = 7900\ J$

13. (d) Change in internal energy (ΔU) depends upon initial an find state of the function while ΔQ and ΔW are path dependent also.

14. (a) This is the case of free expansion and in this case $\Delta W = 0$, $\Delta U = 0$ so temperature remains same *i.e.* 300 *K*.

15. (b) $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta W = \Delta Q - \Delta U = 100 - 40 = 70J$

16. (b) Work done is not a thermodynamical function.

17. (c) $\Delta Q = \Delta U + \Delta W = 167 + 333 = 500\ cal$

18. (d) Heat always refers to energy in transit from one body to another because of temperature difference.

19. (d) Change in internal energy does not depend upon path so $\Delta U = \Delta Q - \Delta W$ remain constant.

20. (b) $\Delta Q = \Delta U + \Delta W$; $\Delta Q = 200J$ and $\Delta W = -100J$

$\Rightarrow \Delta U = \Delta Q - \Delta W = 200 - (-100) = 300J$

21. (a) During free expansion of a perfect gas no, work is done and also no heat is supplied from outside. Therefore, no change in internal energy. Hence, temperature remain constant.

22. (d) $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = \Delta Q - \Delta W = 150 - 110 = 40\ J$

23. (b) From FLOT $\Delta Q = \Delta U + \Delta W$

$\because$ Heat supplied to the system so $\Delta Q \rightarrow$ Positive

and work is done on the system so $\Delta W \rightarrow$ Negative

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

24. (a)

25. (d) State of a thermodynamic state cannot determine by a single variable (P or V or T)

26. (d) R is the universal gas constant.

27. (a) From FLOT

$\Rightarrow dU = dQ - dW \Rightarrow dU = dQ (< 0) \quad (\because dW = 0)$

$\Rightarrow dU < 0$ So temperature will decrease.

28. (b) From FLOT $\Delta Q = \Delta U + \Delta W$

Work done at constant pressure $(\Delta W)_P = (\Delta Q)_P - \Delta U$

$(\Delta Q)_P - (\Delta Q)_V$ (As we know $(\Delta Q)_V = \Delta U$)

Also $(\Delta Q)_P = mc_P \Delta T$ and $(\Delta Q)_V = mc_V \Delta T$

$\Rightarrow (\Delta W)_P = m(c_P - c_V)\Delta T$

$\Rightarrow (\Delta W)_P = 1 \times (3.4 \times 10^3 - 2.4 \times 10^3) \times 10 = 10^4 cal$

29. (d)

30. (a) Ideal gas possess only kinetic energy.

31. (b) The internal energy and entropy depend only on the initial and final states of the system and not on the path followed to attain that state.

32. (c) $\Delta Q = \Delta U + \Delta W$

$\because \Delta Q = 200 cal = 200 \times 4.2 = 840J$ and $\Delta W = 40J$

$\Rightarrow \Delta U = \Delta Q - \Delta W = 840 - 40 = 800J$

33. (c) $\Delta Q = \Delta U + \Delta W = (U_f - U_i) + \Delta W$

$\Rightarrow 30 = (U_f - 40) + 10 \Rightarrow U_f = 60J$

34. (a) With rise in temperature, internal energy also increases.

35. (a)

36. (b) Heat supplied to a gas raise its internal energy and does some work against expansion, so it is a special case of law of conservation of energy.

37. (c) Change in internal energy is always equal to the heat supplied at constant volume.

i.e. $\Delta U = (\Delta Q)_V = \mu C_V \Delta T$.

For monoatomic gas $C_V = \dfrac{3}{2}R$

$\Rightarrow \Delta U = \mu\left(\dfrac{3}{2}R\right)\Delta T = 1 \times \dfrac{3}{2} \times 8.31 \times (100 - 0)$

$= 12.48 \times 10^2 J$

38. (c) $\Delta U = \mu C_V \Delta T = n\left(\dfrac{R}{\gamma - 1}\right)\Delta T$

$\Rightarrow \Delta U = \dfrac{P\Delta V}{(\gamma - 1)} = \dfrac{P(2V - V)}{\gamma - 1} = \dfrac{PV}{(\gamma - 1)}$

39. (b) $\Delta U = \mu C_V \Delta T = 2 \times 4.96 \times (342 - 340) = 19.84\ cal$

40. (a)

41. (c) According to FLOT

$\Delta Q = \Delta U + P(\Delta V) \Rightarrow \Delta U = \Delta Q - P(\Delta V)$

$= 1500 - (2.1 \times 10^5)(2.5 \times 10^{-3}) = 975$ *Joule*

42. (a) $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = \Delta Q - \Delta W$

$= 6 \times 4.18 - 6 = 19.08 kJ \approx 19.1 kJ$

43. (a) Given $\Delta Q = -20J$, $\Delta W = -8J$ and $U_i = 30J$

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

$\Rightarrow (U_f - U_i) = (U_f - 30) = -20 - (-8) \Rightarrow U_f = 18J$

44. (c) Change in internal energy $\Delta U = \mu C_V \Delta T$

it doesn't depend upon type of process. Actually it is a state function

45. (c)

46. (a) In first process using $\Delta Q = \Delta U + \Delta W$

$\Rightarrow 8 \times 10^5 = \Delta U + 6.5 \times 10^5 \Rightarrow \Delta U = 1.5 \times 10 J$

Since final and initial states are same in both process

So ΔU will be same in both process

For second process using $\Delta Q = \Delta U + \Delta W$

$\Rightarrow 10^5 = 1.5 \times 10^5 + \Delta W \Rightarrow \Delta W = -0.5 \times 10^5\ J$

47. (c) $\Delta W = P\Delta V$; here ΔV is negative so ΔW will be negative

48. (b) Entropy is related to second law of thermodynamics.

Isothermal Process

1. (c) In isothermal process temperature remains constant.

2. (a) If isothermal curves cut each other then at equilibrium two temperature will be there which is impossible.

3. (c) In isothermal expansion temperature remains constant, hence no change in internal energy.

4. (d) $W = \mu RT \log_e \dfrac{V_2}{V_1}$

$= \left(\dfrac{m}{M}\right) RT \log_e \dfrac{V_2}{V_1} = 2.3 \times \dfrac{m}{M} RT \log_{10} \dfrac{V_2}{V_1}$

$= 2.3 \times \dfrac{96}{32} R\ (273 + 27) \log_{10} \dfrac{140}{70} = 2.3 \times 900 R \log_{10} 2$

5. (b) $0.8 \times 5 = P \times (3 + 5) \Rightarrow P = 0.5\ m$

6. (b) Differentiate $PV =$ constant *w.r.t* V

$\Rightarrow P\Delta V + V\Delta P = 0 \Rightarrow \dfrac{\Delta P}{P} = -\dfrac{\Delta V}{V}$

7. (c)

8. (d) $W = -\mu RT \log_e \frac{V_2}{V_1} = -1 \times 8.31 \times (273+0) \log_e \left(\frac{22.4}{11.2}\right)$

$= -8.31 \times 273 \times \log_e 2 = -1572.5 J$ $[\because \log_e 2 = 0.693]$

9. (a) $E_\theta = P$, if $P =$ constant, $E_\theta =$ constant

10. (c) For isothermal process $PV = RT \Rightarrow P = \frac{RT}{V}$

$\therefore W = PdV = \int_{V_1}^{V_2} \frac{RT}{V} dV = RT \log_e \frac{V_2}{V_1}$

11. (a) $E_\theta = P$

12. (b) For such a case, pressure $= \frac{1}{\text{Compressibility}}$

13. (a) $E_\theta = P = 1.013 \times 10^5 N/m^2$

14. (a) In isothermal process, compressibility $E_\theta = \rho$.

15. (c) In isothermal process, exchange of energy takes place between system and surrounding to maintain the system temperature constant.

16. (c) No change in the internal energy of ideal gas but for real gas internal energy increases because work is done against intermolecular forces.

17. (a) In isothermal process temperature remains constant. *i.e.*, $\Delta T = 0$. Hence according to $C = \frac{Q}{m\Delta T} \Rightarrow C_{iso} = \infty$

18. (c) This is the case of free expansion of gas. In free expansion $\Delta U = 0 \Rightarrow$ Temp. remains same.

19. (a) An isothermal process takes place at constant temperature, must be carried out in a vessel with conducting wall so that heat generated should go out at once.

20. (c) For isothermal process

$dU = 0$ and work done $= dW = P(V_2 - V_1)$

$\because V_2 = \frac{V_1}{2} = \frac{V}{2} \therefore dW = -\frac{PV}{2}$

21. (b) In isothermal process, temperature remains constant.

22. (b) In isothermal process, heat is released by the gas to maintain the constant temperature.

23. (a) In isothermal compression, there is always an increase of heat. which must flow out the gas.

$\Delta Q = \Delta U + \Delta W \Rightarrow \Delta Q = \Delta W$ $(\because \Delta U = 0)$

$\Rightarrow \Delta Q = -1.5 \times 10^4 J = \frac{1.5 \times 10^4}{4.18} cal = -3.6 \times 10^3 cal$

24. (a) In isothermal change, temperature remains constant, Hence $\Delta U = 0$.

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

25. (a) It is an isothermal process. Hence work done $= P(V_2 - V_1)$

$= 1 \times 10^5 \times (1.091 - 1) \times 10^{-6} = 0.0091 J$

26. (c) $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = \Delta Q - \Delta W = 2240 - 168 = 2072 J$.

27. (b) Amount of heat given $= 540$ *calories*

Change in volume $\Delta V = 1670$ *c.c*

Atmospheric pressure $P = 1.01 \times 10^6$ *dyne / cm*^{2}

Work done against atmospheric pressure

$W = P\Delta V = \frac{1.01 \times 10^6 \times 1670}{4.2 \times 10^7} \approx 40$ *cal*

28. (b) $W_{iso} = \mu RT \log_e \frac{V_2}{V_1} = 1 \times 8.31 \times 300 \log_e \frac{20}{10} = 1728 J$

29. (b) $W = \mu RT \log_e \left(\frac{V_2}{V_1}\right) = 0.2 \times 8.3 \times \log_e 2 \times (27 + 273)$

$= 0.2 \times 8.3 \times 300 \times 0.693 = 345 J$

30. (a) For isothermal process $P_1 V_1 = P_2 V_2$

$\Rightarrow P_2 = \frac{P_1 V_1}{V_2} = \frac{72 \times 1000}{900} = 80$ *cm*

Stress $\Delta P = P_2 - P_1 = 80 - 72 = 8 cm$

31. (d) During isothermal change $T =$ constant $\Rightarrow \Delta U = 0$

also from FLOT, $\Delta Q = \Delta W$.

Adiabatic Process

1. (c) Gas cylinder suddenly explodes is an irreversible adiabatic change and work done against expansion reduces the temperature.

2. (c) Work done in adiabatic change $= \frac{\mu R(T_1 - T_2)}{\gamma - 1}$

3. (b) In case of adiabatic expansion $\Delta W =$ positive and $\Delta Q = 0$

from FLOT $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = -\Delta W$ *i.e.*, ΔU will be negative.

4. (d) For adiabatic process $\frac{T^\gamma}{P^{\gamma - 1}} =$ constant

$$\Rightarrow \frac{T_2}{T_1} = \left(\frac{P_1}{P_2}\right)^{\frac{1-\gamma}{\gamma}} \Rightarrow \frac{T_2}{300} = \left(\frac{4}{1}\right)^{\frac{(1-1.4)}{1.4}} \Rightarrow T_2 = 300(4)^{-\frac{0.4}{1.4}}$$

5. (c) $PV^\gamma = \text{constant} \Rightarrow \frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^\gamma \Rightarrow \frac{P_2}{1} = \left(\frac{V_1}{V_1/4}\right)^{3/2} = 8$

$\Rightarrow P_2 = 8\ atm.$

6. (d) PV^γ =constant $\Rightarrow \frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^\gamma \Rightarrow P_2 = (8)^{5/3} P_1 = 32\ P_1$

7. (c) Volume of the gas $V = \frac{m}{d}$ and using $PV^\gamma =$ constant

We get $\frac{P'}{P} = \left(\frac{V}{V'}\right)^\gamma = \left(\frac{d'}{d}\right)^\gamma = (32)^{7/5} = 128$

8. (b) $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma - 1} \Rightarrow T_2 = 300\left(\frac{27}{8}\right)^{\frac{5}{3} - 1} = 300\left(\frac{27}{8}\right)^{\frac{2}{3}}$

$$= 300\left\{\left(\frac{27}{8}\right)^{1/3}\right\}^2 = 800\left(\frac{3}{2}\right)^2 = 675K$$

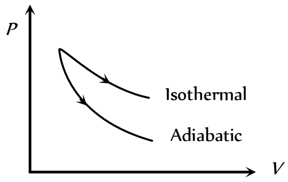
$\Rightarrow \Delta T = 675 - 300 = 375\ K$

9. (a) In thermodynamic processes.

Work done = Area covered by *PV* diagram with *V*-axis

From graph it is clear that $(\text{Area})_{iso} > (\text{Area})_{adi}$

$\Rightarrow W_{iso} > W_{adi}$



10. (a) Since $PV = RT$ and $T = \text{constant}$; $\therefore PV = \text{constant}$.

11. (c) For Isothermal process $PV = \text{constant}$

$$\Rightarrow \left(\frac{dP}{dV}\right) = \frac{-P}{V} = \text{ Slope of Isothermal curve}$$

For adiabatic $PV^{\gamma} = \text{constant}$

$$\Rightarrow \frac{dP}{dV} = \frac{-\gamma P}{V} = \text{ Slop of adiabatic curve slope}$$

Clearly, $\left(\frac{dP}{dV}\right)_{\text{adiabatic}} = \gamma\left(\frac{dP}{dV}\right)_{\text{Isothermal}}$

12. (d) $PV^{\gamma} = \text{constant} \Rightarrow P\left(\frac{RT}{P}\right)^{\gamma} = \text{constant}$

$\Rightarrow P^{1-\gamma}T^{\gamma} = \text{constant.}$

13. (b) $W_{adi} = \frac{R}{\gamma-1}(T_i - T_f) = \frac{R}{\gamma-1}(T - T_1)$

14. (d) $dQ = 0 = -2 + dW \Rightarrow dW = 2\ J$

$\Rightarrow$ Work done by the gas $= 2\ J$

$\Rightarrow$ Work done on the gas $= -2\ J$

15. (d) $E_{\phi} = \gamma P = 1.4 \times (1 \times 10^5) = 1.4 \times 10^5\ N/m^2$

16. (b) Slope of adiabatic curve = $\gamma \times$ (Slope of isothermal curve)

17. (a) Due to compression the temperature of the system increases to a very high value. This causes the flow of heat from system to the surroundings, thus decreasing the temperature. This decrease in temperature results in decrease in pressure.

18. (c) $\Delta Q = \Delta U + \Delta W = 0 \Rightarrow \Delta W = -\Delta U$

if ΔW is positive *i.e.,* gas does work then ΔU should be negative meaning internal energy is used in doing work.

19. (a) $W = \frac{R}{\gamma-1}(T_1 - T_2)$

$$= \frac{8.31 \times \{(273+27)-(273+127)\}}{1.4-1} = -2077.5\ joules$$

20. (c) Pressure is reduced, so the temperature falls.

21. (d) Adiabatic Bulk modulus $E_{\phi} = \gamma P$

22. (c) In adiabatic process, no heat transfers between system and surrounding.

23. (b) $\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} \Rightarrow P_2 = P_1\left(\frac{V_1}{V_2}\right)^{\gamma} = P_0(8)^{4/3} = 16P_0.$

24. (c) In adiabatic process $PV^{\gamma} = \text{constant}$

$$\Rightarrow \left(\frac{RT}{V}\right).V^{\gamma} = \text{constant} \Rightarrow TV^{\gamma-1} = \text{constant}$$

25. (a) $TV^{\gamma-1} = \text{constant} \Rightarrow \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} \Rightarrow T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma}$

$$\Rightarrow T_2 = 300\left(\frac{1}{2}\right)^{0.4} = 227.36\ K$$

26. (b) In adiabatic change $Q = \text{constant} \Rightarrow \Delta Q = 0$

So $\Delta W = -\Delta U$ ($\because \Delta Q = \Delta U + \Delta W$)

27. (d) For adiabatic process from FLOT

$\Delta W = -\Delta U \qquad (\because \Delta Q = 0)$

$\Rightarrow \Delta W = -(-100) = +100 J$

28. (a) $\Delta U = -\Delta W = -\frac{R(T_1 - T_2)}{(\gamma-1)} = \frac{R(T_2 - T_1)}{\gamma-1}$

29. (d) $TV^{\gamma-1} = \text{constant} \Rightarrow T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = 927^{o}C$

30. (d) The process is very fast, so the gas fails to gain or lose heat. Hence this process in adiabatic

31. (a) $\Delta U = \mu C_V \Delta T = 1 \times C_V(T_f - T_i) = -C_V(T_i - T_f)$

$\Rightarrow |\Delta U| = C_v(T_i - T_f)$

32. (c) $T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = 273(2)^{0.41} = 273 \times 1.328 = 363K$

$$W = \frac{R(T_1 - T_2)}{\gamma-1} = \frac{8.31(273-363)}{1.41-1} = -1824$$

$\Rightarrow |W| \approx 1815\ J$

33. (d)

34. (c) $TV^{\gamma-1} = \text{constant}$

$$\Rightarrow T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = (273+18)\left(\frac{V}{V/8}\right)^{0.4} = 668K$$

35. (a) $\Delta Q = mc\Delta\theta$. Here $\Delta Q = 0$, hence $c = 0$

36. (d) In adiabatic process, no transfer of heat takes place between system and surrounding.

37. (b) $W = \frac{\mu R(T_1 - T_2)}{(\gamma-1)} = \frac{\mu RT_1}{(\gamma-1)}\left[1 - \frac{T_2}{T_1}\right]$

$$= \frac{\mu RT_1}{(\gamma-1)}\left[1 - \left(\frac{V_1}{V_2}\right)^{\gamma-1}\right]$$

$$= \frac{2 \times 8.31 \times 300}{\left(\frac{5}{3}-1\right)}\left[1 - \left(\frac{1}{2}\right)^{\frac{5}{3}-1}\right] = +2767.23\ J$$

38. (d) $T^{\gamma}P^{1-\gamma} = \text{constant} \Rightarrow T \propto P^{\frac{\gamma-1}{\gamma}}$

$$\Rightarrow \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{1}{8}\right)^{\frac{5/3-1}{5/3}}$$

$$T_2 = 300 \times \left(\frac{1}{8}\right)^{0.4} = 131K = -142°C$$

39. (a) In adiabatic process $\Delta Q = 0 \Rightarrow \Delta U + \Delta W = 0$

$(\because \Delta Q = \Delta U + \Delta W)$

40. (d) Using relation $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = (8)^{\frac{3/2-1}{3/2}} = 2$.

$\Rightarrow T_2 = 2T_1 \Rightarrow T_2 = 2(273+27) = 600K = 327°C$

41. (c) $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \Rightarrow \frac{T_2}{T_1} = \left(\frac{1}{8}\right)^{\frac{1.5-1}{1.5}} = \left(\frac{1}{8}\right)^{\frac{1}{3}} = \frac{1}{2}$

$\Rightarrow T_2 = \frac{T_1}{2} = \frac{300}{2} = 150K$.

42. (c) $\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} \Rightarrow \frac{P'}{P} = (8)^{5/2} \Rightarrow P' = P \times (2)^{15/2}$

43. (a)

44. (a) Given $P \propto T^3$, but we know for an adiabatic process, the pressure $P \propto T^{\gamma/\gamma-1}$

So $\frac{\gamma}{\gamma-1} = 3 \Rightarrow \gamma = \frac{3}{2} \Rightarrow \frac{C_P}{C_V} = \frac{3}{2}$

45. (b)

46. (d) $W = \frac{R(T_i - T_f)}{\gamma - 1} \Rightarrow 6R = \frac{R(T - T_f)}{\left(\frac{5}{3} - 1\right)} \Rightarrow T_f = (T-4)K.$

47. (a) $\because TV^{\gamma-1} = \text{constant} \Rightarrow T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$\Rightarrow T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = T_1(4)^{1.5-1} = 2T_1$

$\therefore$ change in temperature

$= T_2 - T_1 = 2T_1 - T_1 = T_1 = 273\,K$

48. (b) $\because PV^{\gamma} = k$ (constant) $\Rightarrow P_1V_1^{\gamma} = P_2V_2^{\gamma}$

$\Rightarrow P_2 = P_1\left(\frac{V_1}{V_2}\right)^{\gamma} = 10^5 \times (2)^{1.3}$ $\quad (\because V_2 = \frac{V_1}{2})$

49. (b) In adiabatic process $\Delta U = -\Delta W$. In compression ΔW is negative, so ΔU is positive *i.e.* internal energy increases.

50. (a) According to the first law of thermodynamics

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

In adiabatic process $\Delta Q = 0$, hence $\Delta U = -\Delta W$

51. (b) $PV^{\gamma} = \text{constant} \Rightarrow \frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} = \left(\frac{V_1}{V_1/4}\right)^{\gamma} = 4^{\gamma}$

$\Rightarrow P_2 = 4^{\gamma}P$

As γ is always greater than one so $4^{\gamma} > 4 \Rightarrow P_2 > 4P$

52. (d) $P_1V_1^{\gamma} = P_2V_2^{\gamma} \Rightarrow \frac{P_2}{P_1} = \left[\frac{V_1}{V_2}\right]^{\gamma} = \left[\frac{4}{1}\right]^{3/2} = \frac{8}{1}$

53. (b) Change in internal energy of the gas

$$\Delta U = -\Delta W \frac{R}{\gamma-1}[T_2 - T_1] = \frac{8.3}{(1.4-1)}[308-300] = 166J$$

54. (b) For adiabatic change $TV^{\gamma-1}$ = constant

$\Rightarrow \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \Rightarrow T_2 = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \times T_1$

$\Rightarrow T_2 = \left(\frac{V}{V/4}\right)^{1.4-1} \times 300 = 300 \times (4)^{0.4}K$

55. (d) For adiabatic forces $\Delta W = -\Delta U$ $\quad (\because \Delta Q = 0)$

$\Rightarrow \Delta W = -(-50) = +50J$

56. (b) $\frac{\text{Adiabaticelasticicty}\,(E_{\phi})}{\text{Isothermal elasticicty}\,(E_{\theta})} = \gamma \Rightarrow E_{\theta} = \frac{E_{\phi}}{\gamma}$

$\Rightarrow E_{\theta} = \frac{2.1 \times 10^5}{1.4} = 1.5 \times 10^5\,N/m^2$

57. (c) PV^{γ} = constant : Differentiating both sides

$P\gamma V^{\gamma-1}dV + V^{\gamma}dP = 0 \Rightarrow \frac{dP}{P} = -\gamma\frac{dV}{V}$

Isobaric and Isochoric Processes

1. (a) Work done $= P\Delta V = P(V_2 - V_1)$

2. (c) When heat is supplied at constant pressure, a part of it goes in the expansion of gas and remaining part is used to increase the temperature of the gas which in turn increases the internal energy.

3. (c) For isobaric process $\frac{V_2}{V_1} = \frac{T_2}{T_1} \Rightarrow V_2 = V \times \frac{274}{273}$

Increase $= \frac{274\,V}{273} - V = \frac{V}{273}$

4. (a) From FLOT $\Delta Q = \Delta U + \Delta W = \Delta U + P\Delta V$

$\Rightarrow 100 = \Delta U + 50 \times (4-10) \Rightarrow \Delta U = 400\,J$

5. (a) $W = P \times \Delta V = 2 \times 10^5(150-50) \times 10^{-3} = 2 \times 10^4\,J$

6. (c) $W = P\Delta V = nR\Delta T = 0.1 \times 2 \times 300 = 60\,cal$

7. (c) $\Delta Q = \Delta V + P\Delta V \Rightarrow mL = \Delta U + P(V_2 - V_1)$

$\Rightarrow \Delta U = L - P(V_2 - V_1)$ $\quad (\because m = 1)$

8. (b) $\Delta W = P\Delta V = 10^3 \times 0.25 = 250\,J$

9. (d) $W = P\Delta V = 1.01 \times 10^5(3.34 - 2 \times 10^{-3})$

$= 337 \times 10^3\,J \approx 340\,KJ$

10. (c) $\frac{T_2}{T_1} = \frac{V_2}{V_1} = 2 \Rightarrow T_2 = 2 \times T_1 = 2 \times 300 = 600\,K = 327^o\,C$

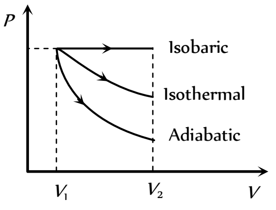
11. (c) $V \propto T$ at constant pressure

$\Rightarrow \frac{V_1}{V_2} = \frac{T_1}{T_2} \Rightarrow V_2 = \frac{V_1T_2}{T_1} = \frac{300 \times 280}{300} = 280\,ml.$

12. (a) In thermodynamic process, work done is equal to the area covered by the PV curve with volume axis.

Hence, according to graph shown

$W_{adiabatic} < W_{isothermal} < W_{isobaric}$



13. (b) (Similar to previous question)

14. (a)

15. (d) $W = P\Delta V = 2.4 \times 10^{-4} \times 1 \times 10^{5} = 24 J$

16. (b) At constant pressure

$$W = P\Delta V = \mu R \Delta T = 1 \times 8.31 \times 100 = 831 \approx 814 J$$

17. (a) $\Delta V = 0 \Rightarrow P\Delta V = 0 \Rightarrow \Delta W = 0$

18. (d) Entropy of a reversible process does not change.

19. (c) $W = P\Delta V = 0$ (As $\Delta V = 0$)

20. (d)

21. (d) At constant volume $P \propto T \Rightarrow \frac{P_1}{P_2} = \frac{T_1}{T_2} \Rightarrow \frac{P_1}{P_2} = \frac{300}{400} = \frac{3}{4}$

22. (d) In isothermal process $\Delta Q \neq 0$.

23. (a) For isochoric process $\Delta V = 0 \Rightarrow \Delta W = 0$

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

Heat Engine, Refrigerator and Second Law of Thermodynamics

1. (d) $\eta = \frac{T_1 - T_2}{T_1} - \frac{W}{Q} \Rightarrow Q = \left(\frac{T_1}{T_1 - T_2}\right) W$

$$= \frac{600}{(600 - 300)} \times 800 = 1600 J$$

2. (c) Coefficient of performance

$$K = \frac{T_2}{T_1 - T_2} = \frac{273}{303 - 273} = \frac{273}{30} = 9$$

3. (b) In a refrigerator, the heat dissipated in the atmosphere is more than that taken from the cooling chamber, therefore the room is heated if the door of a refrigerator is kept open.

4. (c) Internal energy is a state function.

5. (b)

6. (d) For a reversible process $\int \frac{dQ}{T} = 0$

7. (b) For cyclic forces $\Delta U = 0$ So, $\Delta Q = \Delta W$

8. (d) $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{400}{500} = \frac{1}{5} \because \eta = \frac{W}{Q} \Rightarrow \frac{1}{5} = \frac{W}{Q}$

$$\Rightarrow W = \frac{Q}{5} = \frac{6}{5} \times 10^4 = 1.2 \times 10^4 \ J$$

9. (b) $\eta = 1 - \frac{T_2}{T_1} \Rightarrow \frac{30}{100} = 1 - \frac{350}{T_1}$

$$\Rightarrow \frac{350}{T_1} = 1 - \frac{50}{100} = \frac{70}{100} = \frac{7}{10} \Rightarrow T_1 = 500\,K = 227°C$$

10. (b) $\eta = 1 - \frac{T_2}{T_1}$ for 100% efficiency $\eta = 1$ which gives $T = 0$ K.

11. (c) $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{(273 + 69)}{(273 + 411)} = 0.5$

$\Rightarrow$ Work done $= \eta \times Q = 0.5 \times 1000 = 500 \ J$

12. (b) $\because \eta = 1 - \frac{T_2}{T_1} = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$

where $Q_1 =$ heat absorbed, $Q_2 =$ heat rejected

$$\Rightarrow 1 - \frac{T/3}{T} = \frac{W}{Q_1} \Rightarrow \frac{2}{3} = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$$

$$\Rightarrow \frac{2}{3} = 1 - \frac{Q_2}{Q_1} \Rightarrow \frac{Q_2}{Q_1} = \frac{1}{3} \Rightarrow Q_2 = \frac{Q_1}{3} = \frac{Q}{3}$$

13. (c) $\eta = 1 - \frac{T_2}{T_1} \Rightarrow \frac{25}{100} = 1 - \frac{300}{T_1} \Rightarrow \frac{1}{4} = 1 - \frac{300}{T_1}$

$T_1 = 400\,K = 127°C$

14. (a) $\eta = 1 - \frac{T_2}{T_1} \Rightarrow \frac{70}{100} = 1 - \frac{T_2}{1000} \Rightarrow T_2 = 300\,K$

15. (a) $\eta = 1 - \frac{T_2}{T_1} = \frac{T_1 - T_2}{T_1} \Rightarrow \eta_1 = \frac{(473 - 273)}{473} = \frac{200}{473}$

and $\eta_2 = \frac{273 - 73}{273} = \frac{200}{273}$

So required ratio $\frac{\eta_1}{\eta_2} = \frac{273}{473} = 0.577$

16. (a) $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{(273 + 123)}{(273 + 27)} = 1 - \frac{150}{300} = \frac{1}{2} = 50\%$

17. (b) $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{300}{500} = \frac{2}{5}$

18. (d)

19. (b) In first case, $(\eta_1) = 1 - \frac{500}{800} = \frac{3}{8}$

and in second case, $(\eta_2) = 1 - \frac{600}{x}$

Since $\eta_1 = \eta_2$, therefore $\frac{3}{8} = 1 - \frac{600}{x}$

or $\frac{600}{x} = 1 - \frac{3}{8} = \frac{5}{8}$ or $x = \frac{600 \times 8}{5} = 960 K$

20. (a) $\eta_{\max} = 1 - \frac{T_2}{T_1} = 1 - \frac{300}{400} = \frac{1}{4} = 25\%$

So 26% efficiency is impossible

21. (b) In first case $\eta_1 = 1 - \frac{T_2}{T_1} = 1 - \frac{(273 + 0)}{(273 + 200)} = \frac{200}{473}$

In second case $\eta_2 = 1 - \frac{(273 - 200)}{(273 + 0)} = \frac{200}{273}$

$$\Rightarrow \frac{\eta_1}{\eta_2} = \frac{1}{\left(\frac{473}{273}\right)} = 1 : 1.73$$

22. (b) $\eta = 1 - \frac{T_2}{T_1} \Rightarrow \frac{1}{2} = 1 - \frac{500}{T_1} \Rightarrow \frac{500}{T_1} = \frac{1}{2}$ .....(i)

$\frac{60}{100} = 1 - \frac{T_2'}{T_1} \Rightarrow \frac{T_2'}{T_1} = \frac{2}{5}$ .....(ii)

Dividing equation (i) by (ii), $\frac{500}{T_2'} = \frac{5}{4} \Rightarrow T_2' = 400K$

23. (c)

24. (a)

25. (b) $\eta = 1 - \frac{T_2}{T_1} = \frac{W}{Q} \Rightarrow W = \left(1 - \frac{T_1}{T_2}\right) Q = \left\{1 - \frac{(273+27)}{(273+627)}\right\}$

$$\Rightarrow W = \left(1 - \frac{300}{900}\right) \times 3 \times 10^6 = 2 \times 10^6 \times 4.2\ J = 8.4 \times 10^6\ J$$

26. (a)

27. (d) $\eta = 1 - \frac{T_2}{T_1}$; for η to be max. ratio $\frac{T_2}{T_1}$ should be min.

28. (a)

29. (b) In first case $\eta_1 = \frac{T_1 - T_2}{T_1}$

In second case $\eta_2 = \frac{2T_1 - 2T_2}{2T_1} = \frac{T_1 - T_2}{T_1} = \eta$

30. (c) Coefficient of performance

$$K = \frac{T_2}{T_1 - T_2} \Rightarrow 5 = \frac{(273-13)}{T_1 - (273-13)} = \frac{260}{T_1 - 260}$$

$$\Rightarrow 5T_1 - 1300 = 260 \Rightarrow 5T_1 = 1560$$

$$\Rightarrow T_1 = 312K \rightarrow 39°C$$

31. (a) Coefficient of performance $K = \frac{T_2}{T_1 - T_2}$

$$= \frac{(273-23)}{(273+27)-(273-23)} = \frac{250}{300-250} = \frac{250}{20} = 5$$

32. (a) $\eta = \frac{T_1 - T_2}{T_1} = \frac{(273+727)-(273+227)}{273+727} = \frac{1000-500}{1000} = \frac{1}{2}$

33. (c) $\eta = \frac{T_1 - T_2}{T_1} = \frac{W}{Q} \Rightarrow W = \frac{Q(T_1 - T_2)}{T_1}$

$$= \frac{6 \times 10^4 \left[(227+273)-(273+127)\right]}{(227+273)}$$

$$= \frac{6 \times 10^4 \times 100}{500} = 1.2 \times 10^4\ cal$$

34. (d) Slow isothermal expansion or compression of an ideal gas is reversible process, while the other given process are irreversible in nature.

Critical Thinking Questions

1. (d) Fraction of supplied energy which in creases the internal energy is given by

$$f = \frac{\Delta U}{(\Delta Q)_P} = \frac{(\Delta Q)_V}{(\Delta Q)_P} = \frac{\mu C_V \Delta T}{\mu C_P \Delta T} = \frac{1}{\gamma}$$

For diatomic gas $\gamma = \frac{7}{5} \Rightarrow f = \frac{5}{7}$

2. (c) $\Delta Q = \Delta U + \Delta W$

$$\therefore\ \Delta U = \Delta Q - \Delta W = 540 - \frac{P(V_2 / V_1)}{J}$$

$$= 540 - \frac{1.013 \times 10^5 \times [(1671-1) \times 10^{-6}]}{4.2}$$

$$= 540 - 39.7 = 500\ calories$$

3. (b,c) There is a decrease in volume during melting on an ice slab at 273*K*. Therefore, negative work is done by ice-water system on the atmosphere or positive work is done on the ice-water system by the atmosphere. Hence option (b) is correct. Secondly heat is absorbed during melting (*i.e.* ΔQ is positive) and as we have seen, work done by ice-water system is negative (ΔW is negative). Therefore, from first law of thermodynamics $\Delta U = \Delta Q - \Delta W$.

Change in internal energy of ice-water system, ΔU will be positive or internal energy will increase.

4. (c) Process is isothermal. There fore, *T* = constant, $\left(P \propto \frac{1}{V}\right)$ volume is increasing, therefore pressure will decreases.

In chamber *A* :

$$\Delta P = P_i - P_f = \frac{\mu_A RT}{V} - \frac{\mu_A RT}{2V} = \frac{\mu_A RT}{2V} \quad .....(i)$$

In chamber *B* :

$$1.5\Delta P = P_i - P_f = \frac{\mu_B RT}{V} - \frac{\mu_B RT}{2V} = \frac{\mu_B RT}{2V} \quad .....(ii)$$

from equations (i) and (ii) $\frac{\mu_A}{\mu_B} = \frac{1}{1.5} = \frac{2}{3}$

$$\Rightarrow \frac{m_A / M}{m_B / M} = \frac{2}{3} \Rightarrow 3m_A = 2m_B.$$

5. (d) $T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1} \Rightarrow \frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} = \left(\frac{L_2 A}{L_1 A}\right)^{\frac{5}{3}-1} = \left(\frac{L_2}{L_1}\right)^{\frac{2}{3}}$

6. (d) Using Boyle's law, we have $\frac{V}{T}$ = constant

$$\Rightarrow \frac{\frac{l}{2}+5}{373} = \frac{\frac{l}{2}-5}{273}$$

As the piston moves 5 *cm*, the length of one side will be $\left(\frac{l}{2}+5\right)$ and other side $\left(\frac{l}{2}-5\right)$. On solving this equation, we get *l* = 64.6 *cm*.

7. (c) $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta W = (\Delta Q)_P - \Delta U = (\Delta Q)_P\left[1 - \frac{(\Delta Q)_V}{(\Delta Q)_P}\right]$

$= (\Delta Q)_P\left[1 - \frac{C_V}{C_P}\right] = Q = \left[1 - \frac{3}{5}\right] = \frac{2}{5}Q$

$\because (\Delta Q)_P = Q$ and $\gamma = \frac{5}{3}$ for monatomic gas

8. (d) Oxygen is diatomic gas, hence its energy of two moles $= 2 \times \frac{5}{2}RT = 5RT$

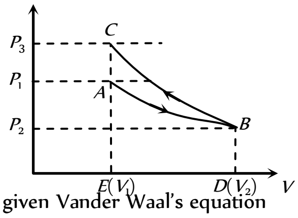
Argon is a monoatomic gas, hence its internal energy of 4 moles $= 4 \times \frac{3}{2}RT = 6RT$

Total Internal energy $= (6+5)RT = 11RT$

9. (c) From graph it is clear that $P_3 > P_1$.

Since area under adiabatic process (*BCED*) is greater than that of isothermal process (*ABDE*). Therefore net work done

$W = W_i + (-W_A) \ \because W_A > W_i \ \Rightarrow \ W < 0$



10. (a) According to given Vander Waal's equation

$$P = \frac{nRT}{V - n\beta} - \frac{\alpha n^2}{V^2}$$

Work done, $W = \int_{V_1}^{V_2} P dV = nRT\int_{V_1}^{V_2}\frac{dV}{V - n\beta} - \alpha n^2\int_{V_1}^{V_2}\frac{dV}{V^2}$

$$= nRT\left[\log_e(V - n\beta)\right]_{V_1}^{V_2} + \alpha n^2\left[\frac{1}{V}\right]_{V_1}^{V_2}$$

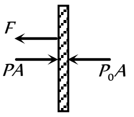
$$= nRT\log_e\frac{V_2 - n\beta}{V_1 - n\beta} + \alpha n^2\left(\frac{V_1 - V_2}{V_1V_2}\right)$$

11. (b) Volume of the gas is constant $V =$ constant $\therefore \ P \propto T$

i.e., pressure will be doubled if temperature is doubled

$\therefore \ P = 2P_0$

Now let F be the tension in the wire. Then equilibrium of any one piston gives



$F = (P - P_0)A = (2P_0 - P_0)A = P_0A$

12. (c) $dU = C_VdT = \left(\frac{5}{2}R\right)dT$ or $dT = \frac{2(dU)}{5R}$

From first law of thermodynamics

$dU = dQ - dW = Q - \frac{Q}{4} = \frac{3Q}{4}$. Now molar heat capacity

$C = \frac{dQ}{dT} = \frac{Q}{\frac{2(dU)}{5R}} = \frac{5RQ}{2\left(\frac{3Q}{4}\right)} = \frac{10}{3}R$.

13. (b) $Q = \Delta U = U_f - U_i$ = [internal energy of 4 moles of a monoatomic gas + internal energy of 2 moles of a diatomic gas] – [internal energy of 4 moles of a diatomic gas]

$= \left(4 \times \frac{3}{2}RT + 2 \times \frac{5}{2}RT\right) - \left(4 \times \frac{5}{2}RT\right) = RT$

Note : (a) 2 moles of diatomic gas becomes 4 moles of a monoatomic gas when gas dissociated into atoms.

(b) Internal energy of μ moles of an ideal gas of degrees of freedom F is given by $U = \frac{f}{2}\mu RT$

$F =$ 3 for a monoatomic gas and 5 for diatomic gas.

14. (c) $PV^{\gamma} = K$ or $P\gamma\, V^{\gamma-1}dV + dP.\, V^{\gamma} = 0$

or $\frac{dP}{P} = -\gamma\frac{dV}{V}$ or $\frac{dP}{P} \times 100 = -\gamma\left(\frac{dV}{V} \times 100\right)$

$= -1.4 \times 5 = 7\%$

15. (a) $TV^{\gamma-1}$ = constant

$\therefore \ \frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1}$ or $\left(\frac{1}{2}\right)^{\gamma-1} = \sqrt{\frac{1}{2}}$

$\therefore \ \gamma - 1 = \frac{1}{2}$ or $\gamma = \frac{3}{2}$ $\qquad \therefore \ PV^{3/2}$ = constant

16. (c) $\eta_A = \frac{T_1 - T_2}{T_1} = \frac{W_A}{Q_1} \Rightarrow \eta_B = \frac{T_2 - T_3}{T_2} = \frac{W_B}{Q_2}$

$\therefore \ \frac{Q_1}{Q_2} = \frac{T_1}{T_2} \times \frac{T_2 - T_3}{T_1 - T_2} = \frac{T_1}{T_2}$ $\qquad \therefore \ W_A = W_B$

$\therefore \ T_2 = \frac{T_1 + T_3}{2} = \frac{800 + 300}{2} = 550K$

17. (b) For monoatomic gas

$\gamma = \frac{C_P}{C_V} = \frac{5}{3}$ we know $\Delta Q = nC_P\Delta T$

and $\Delta U = nC_V\Delta T \Rightarrow \frac{\Delta U}{\Delta Q} = \frac{C_V}{C_P} = \frac{3}{5}$

i.e. fraction of heat energy to increase the internal energy be 3/5.

18. (a) $\Delta Q = \Delta U + \Delta W \Rightarrow \frac{\Delta W}{\Delta Q} = 1 - \frac{\Delta U}{\Delta Q} = 1 - \frac{nC_VdT}{nC_PdT}$

$\Rightarrow \frac{\Delta W}{\Delta Q} = 1 - \frac{C_V}{C_P} = 1 - \frac{3}{5} = \frac{2}{5} = 0.4$

19. (b) $\Delta U = \mu C_V\Delta T = \frac{m}{M}C_V\Delta T = \frac{N}{N_A}C_V\Delta T$

$\Rightarrow (\Delta U)_N = \frac{56 \times 10^3}{14} \times \frac{5}{2}R \times 300$

and $(\Delta U)_A = \frac{6 \times 10^{26}}{6 \times 10^{23}} \times \frac{3}{2}R \times 900 \Rightarrow (\Delta U)_N > (\Delta U)_A$

20. (c) A is compressed isothermally, hence

$P_1 V = P_2\frac{V}{2} \Rightarrow P_2 = 2P_1$

and B is compressed adiabatically, hence

$P_1V^{\gamma} = P_2\left(\frac{V}{2}\right)^{\gamma} \Rightarrow P_2 = (2)^{\gamma}P_1$

Since $\gamma > 1$, hence $P_2' > P_2$ or $P_2 < P_2'$

21. (b) In isothermal process $P_1V_1 = P_2V_2$

or $PV = P_2 \times 4V$ $\qquad \therefore \ P_2 = \frac{P}{4}$

In adiabatic process

$$P_2V_2^{\gamma}=P_3V_3^{\gamma}\Rightarrow \frac{P}{4}\times(4V)^{1.5}=P_2V^{1.5}\Rightarrow P_3=2P$$

22. (d) Volume of the ideal gas is constant so $W=P\Delta V=0$ using FLOT $\Delta Q=\Delta U\Rightarrow \Delta U=i^2Rt=1^2\times100\times5\times60$

$=30\times10^3=30KJ$

23. (d) Initially $\eta=\left(1-\frac{T_2}{T_1}\right)=\frac{W}{Q}=\frac{1}{6}$ ...(i)

Finally $\eta'=\left(1-\frac{T_2'}{T_1}\right)=\left(1-\frac{(T_2-62)}{T_1}\right)=1-\frac{T_2}{T_1}+\frac{62}{T_1}$

$=\eta+\frac{62}{T_1}$ ....(ii)

It is given that $\eta'=2\eta$. Hence solving equation (i) and (ii)

$\Rightarrow T_1=372\,K=99°C$ and $T_2=310K=37°C$

24. (b) Input energy $=\frac{1g}{\sec}\times\frac{2kcal}{g}=2kcal/\sec$.

Output energy $=10\ KW=10\ K\ J/S=\frac{10}{4.2}kcal/\sec$.

$\Rightarrow \eta=\frac{\text{output energy}}{\text{input energy}}=\frac{10}{4.2\times2}>1$, it is impossible.

25. (b) Gain of entropy of ice

$$S_1=\frac{\Delta Q}{T}=\frac{mL}{T}=\frac{80\times100}{(0+273)}=\frac{8\times10^3}{273}cal/K$$

Loss of entropy of water $=S_2=-\frac{\Delta Q}{T}=-\frac{mL}{T}$

$$=\frac{80\times100}{(273+50)}=\frac{8\times10^3}{323}cal/K$$

Total change of entropy

$$S_1+S_2=\frac{8\times10^3}{273}-\frac{8\times10^3}{323}=+4.5\ cal/K$$

26. (b) $PV^2=$ constant represents adiabatic equation. So during the expansion of ideal gas internal energy of gas decreases and temperature falls.

27. (d) Initially $\eta=\frac{T_1-T_2}{T_1}\Rightarrow 0.5=\frac{T_1-(273+7)}{T_1}$

$$\Rightarrow \frac{1}{2}=\frac{T_1-280}{T_1}\Rightarrow T_1=560K$$

Finally $\eta_1'=\frac{T_1'-T_2}{T_1'}\Rightarrow 0.7=\frac{T_1'-(273+7)}{T_1'}\Rightarrow T_1'=933K$

$\therefore$ increase in temperature $=933-560=373K\approx380K$

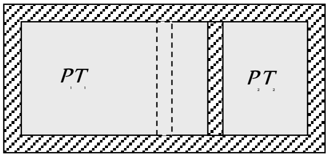
28. (c) *P-V* diagram of the gas is a straight line passing through origin. Hence $P\propto V$ or $PV^{-1}=$ constant

Molar heat capacity in the process $PV^x=\text{constant is}$

$C=\frac{R}{\gamma-1}+\frac{R}{1-x}$; Here $\gamma=1.4$ (For diatomic gas)

$$\Rightarrow C=\frac{R}{1.4-1}+\frac{R}{1+1}\Rightarrow C=3R$$

29. (c) As finally the piston is in equilibrium, both the gases must be at same pressure P_f. It is given that displacement of piston be in final state x and if A is the area of cross-section of the piston. Hence the final volumes of the left and right part finally can be given by figure as



$$V_L=\frac{V_0}{2}+Ax \text{ and } V_R=\frac{V_0}{2}-Ax$$

As it is given that the container walls and the piston are adiabatic in left side and the gas undergoes adiabatic expansion and on the right side the gas undergoes adiabatic compressive. Thus we have for initial and final state of gas on left side

$P_1\left(\frac{V_0}{2}\right)^{\gamma}=P_f\left(\frac{V_0}{2}+Ax\right)^{\gamma}$ .....(i)

Similarly for gas in right side, we have

$P_2\left(\frac{V_0}{2}\right)^{\gamma}=P_f\left(\frac{V_0}{2}-Ax\right)^{\gamma}$ .....(ii)

From eq. (i) and (ii)

$$\frac{P_1}{P_2}=\frac{\left(\frac{V_0}{2}+Ax\right)^{\gamma}}{\left(\frac{V_0}{2}-Ax\right)^{\gamma}}\Rightarrow Ax=\frac{V_0}{2}\left[\frac{P_1^{1/\gamma}-P_2^{1/\gamma}}{P_1^{1/\gamma}+P_2^{1/\gamma}}\right]$$

Now from equation (i) $P_f=\dfrac{P_1\left(\frac{V_0}{2}\right)^{\gamma}}{\left[\frac{V_0}{2}+Ax\right]^{\gamma}}$

30. (d) In both cylinders *A* and *B* the gases are diatomic (γ = 1.4). Piston *A* is free to move *i.e.* it is isobaric process. Piston *B* is fixed *i.e.* it is isochoric process. If same amount of heat ΔQ is given to both then

$$(\Delta Q)_{\text{isobaric}}=(\Delta Q)_{\text{isochoric}}\Rightarrow \mu C_p(\Delta T)_A=\mu C_v(\Delta T)_B$$

$$\Rightarrow(\Delta T)_B=\frac{C_p}{C_v}(\Delta T)_A=\gamma(\Delta T)_A=1.4\times30=42\,K.$$

Graphical Questions

1. (c) As internal energy is a point function therefore change in internal energy does not depends upon the path followed i.e. $\Delta U_{\text{I}}=\Delta U_{\text{II}}$

2. (b) Work done by the system = Area of shaded portion on *P-V* diagram

$$=(300-100)10^{-6}\times(200-10)\times10^3=20\ J$$

3. (a) Work done = Area enclosed by triangle

$$ABC=\frac{1}{2}AC\times BC=\frac{1}{2}\times(3V-V)\times(3P-P)=2\,PV$$

4. (c) Area enclosed between *a* and *f* is maximum. So work done in closed cycles follows *a* and *f* is maximum.

5. (a) Initial and final states are same in all the process.

Hence $\Delta\ U=0$; in each case.

By FLOT; $\Delta Q=\Delta W=$ Area enclosed by curve with volume axis.

$\because$ $(\text{Area})_1<(\text{Area})_2<(\text{Area})_1\Rightarrow Q_1<Q_2<Q_3$.

6. (a) For an isothermal process $PV=$ constant

$$\Rightarrow PdV+VdP=0\Rightarrow -\frac{1}{V}\left(\frac{dV}{dP}\right)=\frac{1}{P}$$

So, $\beta=\frac{1}{P}$ $\therefore$ graph will be rectangular hyperbola.

7. (a) By adjoining graph $W_{AB}=0$ and

$$W_{BC} = 8 \times 10^4 [5-2] \times 10^{-3} = 240\, J$$

$$\therefore\; W_{AC} = W_{AB} + W_{BC} = 0 + 240 = 240\, J$$

Now, $\Delta Q_{AC} = \Delta Q_{AB} + \Delta Q_{BC} = 600 + 200 = 800\, J$

From FLOT $\Delta Q_{AC} = \Delta U_{AC} + \Delta W_{AC}$

$\Rightarrow 800 = \Delta U_{AC} + 240 \Rightarrow \Delta U_{AC} = 560\, J.$

8. (b) In adiabatic process, slope of *PV*-graph.

$$\frac{dP}{dV} = -\gamma \frac{P}{V} \Rightarrow |\text{Slope}| \propto \gamma$$

From the given graph $(\text{Slope})_2 > (\text{Slope})_1 \Rightarrow \gamma_2 > \gamma_1$

therefore 1 should correspond to O_2 ($\gamma = 1.4$) and 2 should correspond to *He* ($\gamma = 1.66$)

9. (c) As we know that slope of isothermal and adiabatic curves are always negative and slope of adiabatic curve is always greater than that of isothermal curve

Hence in the given graph curve *A* and *B* represents adiabatic and isothermal changes respectively.

10. (d) Process *CD* is isochoric as volume is constant, Process *DA* is isothermal as temperature constant and Process *AB* is isobaric as pressure is constant.

11. (d) Heat given $\Delta Q = 20\, cal = 20 \times 4.2 = 84\, J$.

Work done $\Delta W = -50\, J$ [As process is anticlockwise]

By first law of thermodynamics

$\Rightarrow \Delta U = \Delta Q - \Delta W = 84 - (-50) = 134\, J$

12. (a) For cyclic process. Total work done $= W_{AB} + W_{BC} + W_{CA}$

$\Delta W_{AB} = P\Delta V = 10(2-1) = 10 J$ and $\Delta W_{BC} = 0$

(as V = constant)

From FLOT, $\Delta Q = \Delta U + \Delta W$

$\Delta U = 0$ (Process *ABCA* is cyclic)

$\Rightarrow \Delta Q = \Delta W_{AB} + \Delta W_{BC} + \Delta W_{CA}$

$\Rightarrow 5 = 10 + 0 + \Delta W_{CA} \Rightarrow \Delta W_{CA} = -5\, J$

13. (b) The cyclic process 1 is clockwise where as process 2 is anticlockwise. Clockwise area represents positive work and anticlockwise area represents negative work. Since negative area (2) > positive area (1), hence net work done is negative.

14. (c) Process *AB* is isochoric, $\therefore\; W_{AB} = P\,\Delta V = 0$

Process *BC* is isothermal $\therefore\; W_{BC} = RT_2 . \ln\left(\frac{V_2}{V_1}\right)$

Process *CA* is isobaric

$\therefore\; W_{CA} = -P\Delta V = -R\Delta T = -R(T_1 - T_2) = R(T_2 - T_1)$

(Negative sign is taken because of compression)

15. (a) *AB* is isobaric process, *BC* is isothermal process, *CD* is isometric process and *DA* is isothermal process

These process are correctly represented by graph (a).

16. (c) Work done by the gas (as cyclic process is clockwise) $\therefore \Delta W$ = Area *ABCD*

So from the first law of thermodynamics ΔQ (net heat absorbed) = ΔW = Area *ABCD*

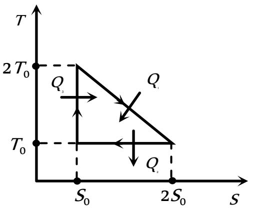
As change in internal energy in cycle $\Delta U = 0$.

17. (a) $Q_1 = T_0 S_0 + \frac{1}{2} T_0 S_0 = \frac{3}{2} T_0 S_0$

$Q_2 = T_0 S_0$ and $Q_3 = 0$

$$\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$$

$$= 1 - \frac{Q_2}{Q_1} = 1 - \frac{2}{3} = \frac{1}{3}$$



18. (a) Work done = Area of closed *PV* diagram

$= (2V - V) \times (2P - P) = PV$

19. (c) From the given *VT* diagram,

In process *AB*, $V \propto T \Rightarrow$ Pressure is constant (As quantity of the gas remains same)

In process *BC*, V = Constant and in process *CA*, T = constant

$\therefore$ These processes are correctly represented on *PV* diagram by graph (c).

20. (d) $\Delta Q = \Delta U + \Delta W$; ΔU does not depend upon path.

$\because\; \Delta W_A > \Delta W_B \Rightarrow \Delta Q_A > \Delta Q_B$

21. (d) Work done = Area under curve $= \frac{6P_1 \times 3V_1}{2} = 9\, P_1V_1$

22. (d) Work done $= \frac{1}{2} \times 2P_1 \times 2V_1 = 2P_1V_1$

23. (c) In a cyclic, $\Delta U = 0$

From FLOT, $\Delta Q = \Delta U + \Delta W = 0 + \Delta W$ = Area of closed curve

$\Rightarrow \Delta Q = \pi r\;\; \pi\left(\frac{20}{2}\right)^2 kP_a \times litre$

$$= 100\,\pi \times 10^3 \times 10^{-3} J = 100\,\pi J$$

24. (c) The work done in cyclic process is equal to the area enclosed by the *PV* diagram

25. (d) In all given cases, process is cyclic and in cyclic process $\Delta U = 0$.

26. (b) In cyclic process ΔQ = Work done = Area inside the closed curve.

Treat the circle as an ellipse of area $= \frac{\pi}{4}(P_2 - P_1)(V_2 - V_1)$

$$\Rightarrow \Delta Q = \frac{\pi}{4}\{(150-50) \times 10^3\} = \frac{\pi}{2} J$$

27. (d) $W_{BCOB} = -$ Area of triangle $BCO = -\frac{P_0V_0}{2}$

$W_{AODA} = +$ Area of triangle $AOD = +\frac{P_0V_0}{2}$

28. (c) *AD* and *BC* represent adiabatic process (more slope)

AB and *DC* represent isothermal process (less slope)

29. (c) Work done = Area of curve enclosed

$= 2V \times 2P = 4PV$

30. (c) Work done = Area of *PV* graph (here trapezium)

$$= \frac{1}{2}(1 \times 10^5 + 5 \times 10^5) \times (5-1) = 12 \times 10^5 J$$

31. (d) For path ab : $(\Delta U)_{ab} = 7000\, J$

By using $\Delta U = \mu C_V \Delta T$

$$7000 = \mu \times \frac{5}{2} R \times 700 \Rightarrow \mu = 0.48$$

For path ca :

$(\Delta Q)_{ca} = (\Delta U)_{ca} + (\Delta W)_{ca}$ ....(i)

$\because (\Delta U)_{ab} + (\Delta U)_{bc} + (\Delta U)_{ca} = 0$

$\therefore 7000 + 0 + (\Delta U)_{ca} = 0 \Rightarrow (\Delta U)_{ca} = -7000\ J$ ....(ii)

Also $(\Delta W)_{ca} = P_1(V_1 - V_2) = \mu R(T_1 - T_2)$

$= 0.48 \times 8.31 \times (300 - 1000) = -2792.16\ J$ ....(iii)

on solving equations (i), (ii) and (iii)

$(\Delta Q)_{ca} = -7000 - 2792.16 = -9792.16\ J = -9800\ J$

32. (b) Work done = Area enclosed by indicator diagram

$$= \frac{1}{2} \times (3V - V)(4P - P) = 3PV$$

33. (d) ΔU, remains same for both path

For path *iaf*: $\Delta U = \Delta Q - \Delta W = 50 - 20 = 30J$.

For path fi : $\Delta U = -30\ J$ and $\Delta W = -13J$

$\Rightarrow \Delta Q = -30 - 13 = -43\ J$.

34. (a) $\Delta E_{\text{int}} = 0$, for a complete cycle and for given cycle work done is negative, so from first law of thermodynamics Q will be negative *i.e.* $Q < 0$.

35. (d) Work done = Area enclosed by the curve

$$= \frac{1}{2}(3V - V)(2P - P) = PV$$

36. (d) W = Area bonded by the indicator diagram with V-axis)

$$= \frac{1}{2}(P_A + P_B)(V_B - V_A)$$

37. (a) Heat given ΔQ = 40 *J* and Work done ΔW = 30 *J*

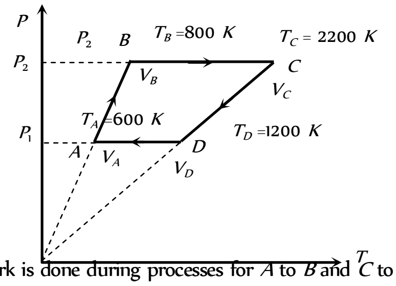
$\Rightarrow \Delta U = \Delta Q - \Delta W = 40 - 30 = 10\ J$.

38. (a) As the volume is continuously increasing and the work of expansion is always positive, so the work done by the system continuously increases.

39. (c) Processes *A* to *B* and *C* to *D* are parts of straight line graphs of the form $y = mx$

Also $P = \frac{\mu R}{V} T$ (μ = 6)

$\Rightarrow P \propto T$. So volume remains constant for the graphs *AB* and *CD*



So no work is done during processes for *A* to *B* and *C* to *D* *i.e.*, $W_{AB} = W_{CD} = 0$ and $W_{BC} = P_2(V_C - V_B) = \mu R(T_C - T_B)$

$= 6R\ (2200 - 800) = 6R \times 1400\ J$

Also $W_{DA} = P_1(V_A - V_D) = \mu R(T_A - T_B)$

$= 6R\ (600 - 1200) = -6R \times 600\ J$

Hence work done in complete cycle

$W = W_{AB} + W_{BC} + W_{CD} + W_{DA}$

$= 0 + 6R \times 1400 + 0 - 6R \times 600$

$= 6R \times 900 = 6 \times 8.3 \times 800 \approx 40\ kJ$

40. (b) In isothermal process $P \propto \frac{1}{V}$.

Hence graph between *P* and *V* is a hyperbola.

41. (d) Adiabatic curves are more stepper than isothermal curves.

42. (d) During process *A* to *B*, pressure and volume both are decreasing. Therefore, temperature and hence, internal energy of the gas will decrease ($T \propto PV$) or $\Delta U_{A \to B}$ = negative. Further $\Delta W_{A \to B}$ is also negative as the volume of the gas is decreasing. Thus $\Delta Q_{A \to B}$ is negative.

In process *B* to *C* pressure of the gas is constant while volume is increasing. Hence temperature should increase or $\Delta U_{B \to C}$ = positive. During *C* to *A* volume is constant while pressure is increasing. Therefore, temperature and hence, internal energy of the gas should increase or $\Delta U_{C \to A}$ = positive. During process *CAB* volume of the gas is decreasing. Hence, work done by the gas is negative.

43. (a) $\Delta W_{AB} = 0$ as V = constant

$\therefore \Delta Q_{AB} = \Delta U_{AB} = 50J$ (Given)

$U_A = 1500J \ \therefore \ U_B = (1500 + 50)J = 1550J$

$\Delta W_{BC} = -\Delta U_{BC} = -40J$ (Given)

$\therefore \Delta U_{BC} = 40J \ \therefore \ U_C = (1550 + 40)J = 1590J$

44. (a) For adiabatic process $T_1 V_b^{\gamma - 1}$ = Constant

For *bc* curve $T_1 V_b^{\gamma-1} = T_2 V_c^{\gamma-1}$ or $\frac{T_2}{T_1} = \left(\frac{V_b}{V_c}\right)^{\gamma-1}$ .....(i)

For *ad* curve $T_1 V_a^{\gamma-1} = T_2 V_d^{\gamma-1}$ or $\frac{T_2}{T_1} = \left(\frac{V_a}{V_d}\right)^{\gamma-1}$ .....(ii)

From equation (i) and (ii) $\frac{V_b}{V_c} = \frac{V_a}{V_d}$

Assertion and Reason

1. (a) In a perfectly reversible system, there is no loss of energy. Losses can be minimised, friction can be reduced, the resistance in L-C oscillating system can also be negligible. But one cannot completely eliminate energy losses. This makes a perfectly reversible system, an ideal.

2. (a) Adiabatic expansion produces cooling.

3. (a) In reversible process, there always occurs some loss of energy. This is because energy spent in working against the dissipative force is not recovered back. Some irreversible process occur in nature such as friction where extra work to cancel the effect of friction. Salt dissolves in water but a salt does not separate by itself into pure salt and pure water.

4. (a) When a bottle of cold carbonated drink is opened. A slight fog forms around the opening. This is because of adiabatic expansion of gas causes lowering of temperature and condensation of water vapours.

5. (e) As isothermal processes are very slow and so the different isothermal curves have different slopes so they cannot intersect each other.

6. (d) Adiabatic compression is a rapid action and both the internal energy and the temperature increases.

7. (e) As there is no change in internal energy of the system during an isothermal change. Hence, the energy taken by the gas is utilised by doing work against external pressure. According to FLOT $\Delta Q = \Delta U + P\Delta V$

Hence $\Delta Q = \Delta U = P\Delta V$

Therefore, reason is true and assertion is false.

8. (d) We can change the temperature of a body without giving (or taking) heat to (or from) it. For example in an adiabatic compression temperature rises and in an adiabatic expansion temperature false, although no heat is given or taken from the system in the respective changes.

9. (a) $c = \dfrac{Q}{m.\Delta\theta}$; a gas may be heated by putting pressure, so it can have values for 0 to ∞.

C_P and C_V are it's two principle specific heats, out of infinite possible values.

In adiabatic process $C = 0$ and in isothermal process $C = \infty$.

10. (a) Heat is similar to work in that both represent ways of transferring energy. Neither heat nor work is an intrinsic property of a system, that is, we cannot say that a system contains a certain amount of heat or work.

11. (d) According to first law of thermodynamics, $\Delta Q = \Delta U + \Delta W = \Delta U + P\Delta V$. If heat is supplies in such a manner that volume does not change $\Delta V = 0$ *i.e.*, isochoric process, then whole of the heat energy supplied to the system will increase internal energy only. But, in any other process it is not possible.

Also heat may absorbed or evolved when state of thermal equilibrium changes.

12. (d) When the door of refrigerator is kept open, heat rejected by the refrigerator to the room will be more than the heat taken by the refrigerator from the room (by an amount equal to work done by the compressor). Therefore, temperature of room will increase and so it will be warmed gradually. As according to 2nd law of thermodynamics, heat cannot be transferred on its own, from a body at lower temperature to another at higher temperature.

13. (a) Second law of thermodynamics can be explained with the help of example of refrigerator, as we know that refrigerator, the working substance extracts heat from colder body and rejects a large amount of heat to a hotter body with the help of an external agency i.e., the electric supply of the refrigerator. No refrigerator can ever work without external supply of electric energy to it.

14. (d) If an electric fan is switched on in a closed room, the air will be heated because due to motion of the fan, the speed of air molecules will increase. In fact, we feel cold due to evaporation of our sweat.

15. (c) The internal energy of system depends only on its temperature. In isothermal process temperature does not change, therefore, internal energy of the system remains the same.

16. (c) In an adiabatic process, no exchange of heat is permissible i.e., $\Delta Q = 0$.

As, $\Delta Q = \Delta U + \Delta W = 0 \Rightarrow \Delta U = -\Delta W$.

Also in adiabatic process, temperature of gas changes.

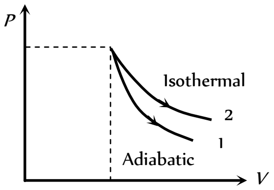
17. (a) Change in entropy, $\Delta S = \dfrac{\Delta Q}{T}$. In an adiabatic change, heat transfer $\Delta Q = 0$. $\therefore$ $\Delta S = 0$, or $S =$ constant i.e., entropy remains constant in an adiabatic process, or an adiabatic process is an isoentropic process.

18. (b) As we know, in thermodynamic processes work done = Area covered by *P-V* diagram with volume axis.

Hence, according to following graph.

$$(\text{Area})_1 < (\text{Area})_2 \Rightarrow W_{adi} < W_{iso}$$

Also in isothermal changes temperature remains same but in adiabatic changes temperature also changes.



19. (c) First law of thermodynamics is restatement of the principal of conservation of energy as applied to heat energy.

20. (e) Zeroth law of thermodynamics explain the concept of temperature. According to which there exist a scalar quantity called temperature which is property of all thermodynamic system.

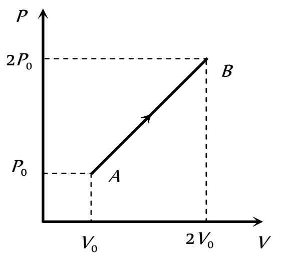
21. (b) Efficiency of cannot cycle $\eta = \dfrac{W}{Q_1} = 1 - \dfrac{T_2}{T_1}$, for Carnot engine when T_2 decrease η increases.

22. (a) Entropy is a measure of the disorder or randomness of the system. Greater the randomness, greater the entropy.

Thermodynamics

SET Self Evaluation Test -14

1. The *P-V* diagram of 2 *gm* of helium gas for a certain process $A \to B$ is shown in the figure. what is the heat given to the gas during the process $A \to B$



(a) $4P_oV_o$

(b) $6P_oV_o$

(c) $4.5P_oV_o$

(d) $2P_oV_o$

2. A certain mass of gas at 273 *K* is expanded to 81 times its volume under adiabatic condition. If $\gamma = 1.25$ for the gas, then its final temperature is [Pb. PET 1997]

(a) – 235°*C* (b) – 182°*C*

(c) – 91°*C* (d) 0°*C*

3. In an adiabatic process 90*J* of work is done on the gas. The change in internal energy of the gas is [CPMT 1996]

(a) – 90 *J*

(b) +90 *J*

(c) 0 *J*

(d) Depends on initial temperature

4. If a Carnot's engine functions at source temperature 127°*C* and at sink temperature 87°*C*, what is its efficiency

[DCE 1997]

(a) 10% (b) 25%

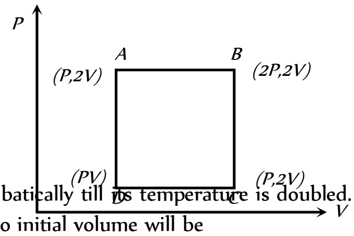
(c) 40% (d) 50%

5. In the case of diatomic gas, the heat given at constant pressure is that part of energy which is used for the expansion of gas, is

(a) $\frac{2}{5}$ (b) $\frac{3}{7}$

(c) $\frac{2}{7}$ (d) $\frac{5}{7}$

6. An ideal monoatomic gas is taken round the cycle *ABCDA* shown in the *PV* diagram in the given fig. The work done during the cycle is



(a) $\frac{1}{2}PV$

(b) $2\,PV$

(c) *PV*

(d) Zero

7. A gas is compressed adiabatically till its temperature is doubled. The ratio of its final volume to initial volume will be

(a) 1 / 2 (b) More than 1 / 2

(c) Less than 1 / 2 (d) Between 1 and 2

8. A tyre filled with air ($27^o C$, and 2 *atm*) bursts, then what is temperature of air ($\gamma = 1.5$) [RPMT 2002]

(a) $-33^o C$ (b) $0^o C$

(c) $27^o C$ (d) $240^o C$

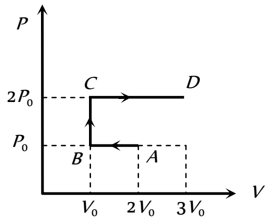
9. A gas expands adiabatically at constant pressure such that its temperature $T \propto \frac{1}{\sqrt{V}}$, the value of C_P / C_V of gas is

[RPMT 2002; MHCET 2004]

(a) 1.30 (b) 1.50

(c) 1.67 (d) 2.00

10. *P-V* diagram of an ideal gas is as shown in figure. Work done by the gas in process *ABCD* is



(a) $4\ P_0V_0$

(b) $2\ P_0V_0$

(c) $3\ P_0V_0$

(d) P_0V_0

11. An engineer claims to have made an engine delivering 10 *kW* power with fuel consumption of $1\,g\,s^{-1}$. The calorific value of fuel is 2*k cal*/*g*. His claim [J & K CET 2000]

(a) Is non-valid (b) Is valid

(c) Depends on engine (d) Depends on load

12. An ideal gas heat engine operates in a Carnot cycle between 27°*C* and 127°*C*. It absorbs 6 *kcal* at the higher temperature. The amount of heat (in *kcal*) converted into work is equal to

(a) 3.5 (b) 1.6

(c) 1.2 (d) 4.8

13. A gas expands with temperature according to the relation $V = kT^{2/3}$. What is the work done when the temperature changes by $30^o C$

[UPSEAT 1998]

(a) 10 *R* (b) 20 *R*

(c) 30 *R* (d) 40 *R*

14. An ideal gas ($\gamma = 1.5$) is expanded adiabatically. How many times has the gas to be expanded to reduce the root mean square velocity of molecules 2.0 times

(a) 4 times (b) 16 times

(c) 8 times (d) 2 times

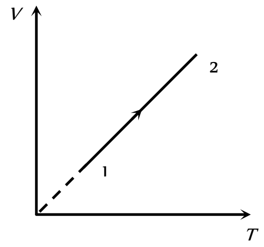
15. Three samples of the same gas *A*, *B* and $C(\gamma = 3/2)$ have initially equal volume. Now the volume of each sample is doubled. The process is adiabatic for *A* isobaric for *B* and isothermal for *C*. If the final pressures are equal for all three samples, the ratio of their initial pressures are

[BHU 1997]

(a) $2\sqrt{2}:2:1$ (b) $2\sqrt{2}:1:2$

(c) $\sqrt{2}:1:2$ (d) $2:1:\sqrt{2}$

16. Volume versus temperature graph of two moles of helium gas is as shown in figure. The ratio of heat absorbed and the work done by the gas in process 1-2 is



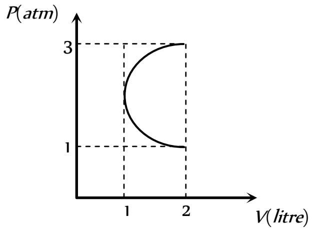
(a) 3

(b) $\frac{5}{2}$

(c) $\frac{5}{3}$

(d) $\frac{7}{2}$

17. In the *P-V* diagram shown in figure *ABC* is a semicircle. The work done in the process *ABC* is



(a) Zero

(b) $\frac{\pi}{2} atm - lt$

(c) $-\frac{\pi}{2} atm - lt$

(d) 4 *atm-lt*

18. Heat is supplied to a diatomic gas at constant pressure. The ratio of $\Delta Q : \Delta U : \Delta W$ is

(a) 5 : 3 : 2 (b) 5 : 2 : 3

(c) 7 : 5 : 2 (d) 7 : 2 : 5

19. A gas undergoes a change of state during which 100 *J* of heat is supplied to it and it does 20 *J* of work. The system is brought back to its original state through a process during which 20 *J* of heat is released by the gas. The work done by the gas in the second process is

(a) 60 *J* (b) 40 *J*

(c) 80 *J* (d) 20 *J*

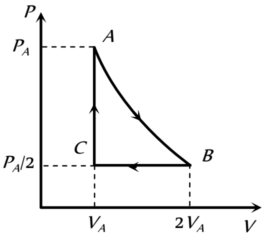
20. *N* moles of an ideal diatomic gas are in a cylinder at temperature *T*. suppose on supplying heat to the gas, its temperature remain constant but *n* moles get dissociated into atoms. Heat supplied to the gas is

(a) Zero (b) $\frac{1}{2}nRT$

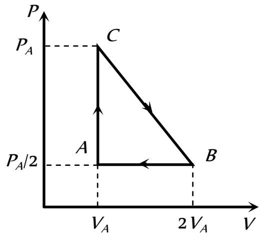
(c) $\frac{3}{2}nRT$ (d) $\frac{3}{2}(N-n)RT$

21. Three moles of an ideal gas $\left(C_P = \frac{7}{2}R\right)$ at pressure P_A and temperature T_A is isothermally expanded to twice its initial volume. It is then compressed at constant pressure to its original volume. Finally the gas is compressed at constant volume to its original pressure P_A. The correct *P-V* and *P-T* diagrams indicating the process are

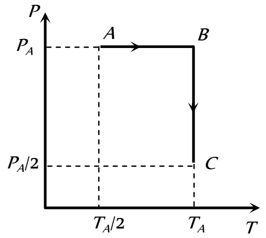
(a)



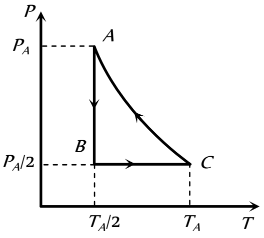
(b)



(c)



(d)



22. A cylinder of mass 1*kg* is given heat of 20000 *J* at atmospheric pressure. If initially temperature of cylinder is 20°*C*, then work done by the cylinder will be (Given that Specific heat of cylinder = 400 $J\,kg^{-1}$, Coefficient of volume expansion = $9 \times 10^{-5}\,°C^{-1}$, Atmospheric pressure = 10^5 N/m^2 and density of cylinder 9000 kg/m^3)

(a) 0.02 *J* (b) 0.05 *J*

(c) 0.08 *J* (d) 0.1 *J*

23. In a thermodynamic process pressure of a fixed mass of a gas is changed in such a manner that the gas releases 30 *joules* of heat and 10 joules of work was done on the gas. If the initial internal energy of the gas was 30 *joules*, then the final internal energy will be [**CPMT 1986**]

(a) 2 *J* (b) – 18 *J*

(c) 10 *J* (d) 58 *J*

24. In an adiabatic change, the pressure *P* and temperature *T* of a monoatomic gas are related by the relation $P \propto T^C$, where *c* equals [**CBSE PMT 1994; BHU 1997; AIIMS 2001; MH CET 2000**]

(a) 5 / 3 (b) 2 / 5

(c) 3 / 5 (d) 5 / 2

25. The internal energy of an ideal gas increases during an isothermal process when the gas is [**SCRA 1998**]

(a) Expanded by adding more molecules to it

(b) Expanded by adding more heat to it

(c) Expanded against zero pressure

(d) Compressed by doing work on it

AS Answers and Solutions

(SET -14)

1. (b) Change in internal energy from $A \to B$ is

$$\Delta U = \frac{f}{2}\mu R\Delta T = \frac{f}{2}(P_f V_f - P_i V_i)$$

$$=\frac{3}{2}(2P_0\times 2V_0-P_0\times V_0)=\frac{9}{2}P_0V_0$$

Work done in process $A\to B$ is equal to the Area covered by the graph with volume axis i.e.,

$$W_{A\to B}=\frac{1}{2}(P_0+2P_0)\times(2V_0-V_0)=\frac{3}{2}P_0V_0$$

Hence, $\Delta Q=\Delta U+\Delta W=\frac{9}{2}P_0V_0+\frac{3}{2}P_0V_0=6P_0V_0$

2. (b) For adiabatic process $TV^{\gamma-1}$ = constant

$$\Rightarrow \frac{T_2}{T_1}=\left(\frac{V_1}{V_2}\right)^{\gamma-1}\Rightarrow T_2=\left(\frac{V_1}{V_2}\right)^{\gamma-1}\times T_1$$

$$\Rightarrow T_2=\left(\frac{1}{81}\right)^{1.25-1}\times 273=\left(\frac{1}{81}\right)^{0.25}\times 273$$

$$=\frac{273}{3}=91K\to -182°C$$

3. (b) For adiabatic process $\Delta Q=0$

From $\Delta Q=\Delta U+\Delta W\Rightarrow 0=\Delta U-90\Rightarrow \Delta U=+90J$

4. (d) $\eta=\frac{T_1-T_2}{T_1}=\frac{(127+273)-(87+273)}{(127+273)}$

$$=\frac{400-360}{400}=0.1\to 10\%$$

5. (c) $\Delta W=$ energy used for expansion $=PdV=RdT$

$\Delta Q=$ heat supplied to diatomic gas at constant P

$$=C_pdT=\frac{7}{2}RdT\ \left(\because C_p=\frac{7}{2}R\right)\ \therefore \frac{\Delta W}{\Delta Q}=\frac{RdT}{\frac{7}{2}RdT}=\frac{2}{7}$$

6. (c)

7. (c) $\frac{T_2}{T_1}=\left(\frac{V_1}{V_2}\right)^{\gamma-1}=2\Rightarrow\left(\frac{V_2}{V_1}\right)^{\gamma-1}=\frac{1}{2}\Rightarrow\frac{V_2}{V_1}=\left(\frac{1}{2}\right)^{\frac{1}{\gamma-1}}<\frac{1}{2}$

$$\Rightarrow V_2<\frac{V_1}{2}$$

8. (a) $\frac{T_2}{T_1}=\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\Rightarrow\frac{T_2}{(273+27)}=\left(\frac{1}{2}\right)^{\frac{1.5-1}{1.5}}=\left(\frac{1}{2}\right)^{\frac{1}{3}}=\frac{1}{2.5}$

$$\Rightarrow T_2=\frac{T_1}{1.25}=\frac{(273+27)}{1.25}=238\,K=-34.8°C$$

9. (b) $TV^{\gamma-1}=$ constant $\Rightarrow T\propto V^{1-\gamma}$

According to question $T\propto V^{-\frac{1}{2}}$

Hence $1-\gamma=-\frac{1}{2}\Rightarrow\gamma\frac{3}{2}=1.5$

10. (c) $W_{AB}=-P_0V_0$, $W_{BC}=0$ and $W_{CD}=4P_0V_0$

$$\Rightarrow W_{ABCD}=-P_0V_0+0+4P_0V_0=3P_0V_0$$

11. (a) Power $=10\,KW=10000\,J/s=\frac{10000}{4.2}=2.38\,k\,cal/gm$

But the calorific value of fuel is only 2 *k cal/gm*. Hence claim is invalid.

12. (c) Efficiency of a carnot engine is given by $\eta=1-\frac{T_2}{T_1}$

or $\frac{W}{Q}=1-\frac{T_2}{T_1}\Rightarrow\frac{W}{6}=1-\frac{(273+127)}{(273+227)}\Rightarrow W=1.2\,k\,cal$

13. (b) $W=\int PdV=\int\frac{RT}{V}dV$

Since $V=kT^{2/3}\Rightarrow dV=\frac{2}{3}KT^{-1/3}dT$

Eliminating K, we find $\frac{dV}{V}=\frac{2}{3}\frac{dT}{T}$

Hence $W=\int_{T_1}^{T_2}\frac{2}{3}\frac{RT}{T}dT=\frac{2}{3}R(T_2-T_1)=\frac{2}{3}R(30)=20\,R$

14. (b) $v_{rms}=\sqrt{\frac{3RT}{M}}\Rightarrow v_{rms}\propto\sqrt{T}$

v_{rms} is to reduce two times *i.e.* temperature of the gas will have to reduce four times or $\frac{T'}{T}=\frac{1}{4}$

During adiabatic process $TV^{\gamma-1}=T'V'^{\gamma-1}$

$$\Rightarrow\frac{V'}{V}=\left(\frac{T}{T'}\right)^{\frac{1}{\gamma-1}}=(4)^{\frac{1}{1.5-1}}=(4)^2=16\Rightarrow V'=16V$$

15. (b) Let the initial pressure of the three samples be P_A, P_B and P_C, then $P_A(V)^{3/2}=(2V)^{3/2}P$, $P_B=P$ and $P_C(V)=P(2V)$

$$\Rightarrow P_A:P_B:P_C=(2)^{3/2}:1:2=2\sqrt{2}:1:2$$

16. (b) *V-T* graph is a straight line passing through origin. Hence, $V\propto T$ or $P=\text{constant}$

$\therefore\quad \Delta Q=nC_P\Delta T$ and $\Delta U=nC_V\Delta T$

Also $\Delta W=\Delta Q-\Delta U=\mu(C_P-C_V)\Delta T$

$$\therefore\quad \frac{\Delta Q}{\Delta W}=\frac{nC_P\Delta T}{n(C_P-C_V)\Delta T}=\frac{C_P}{C_P-C_V}=\frac{1}{1-\frac{C_V}{C_P}}$$

$\frac{C_V}{C_P}=\frac{3}{5}$ for helium gas. Hence $\frac{\Delta Q}{\Delta W}=\frac{1}{1-3/5}=\frac{5}{2}$

17. (b) W_{AB} is negative (volume is decreasing) and

W_{BC} is positive (volume is increasing) and

since, $|W_{BC}|>|W_{AB}|$

∴ net work done is positive and area between semicircle which is equal to $\frac{\pi}{2}atm-lt$.

18. (c) $\Delta Q=\mu C_P\Delta T=\frac{7}{2}\mu R\Delta T\quad\left(C_P=\frac{7}{2}R\right)$

$\Delta U=\mu C_V\Delta T=\frac{5}{2}\mu R\Delta T\quad\left(C_V=\frac{5}{2}R\right)$

and $\Delta W=\Delta Q-\Delta U=\mu R\Delta T$

$\Rightarrow \Delta Q : \Delta U : \Delta W = 7 : 5 : 2$

19. (a) In a cyclic process $\Delta U = 0 \Rightarrow \Delta Q = \Delta W$

$\Rightarrow (100 - 20) = 20 + W_2 \Rightarrow W_2 = 60\ J$

20. (b) Since the gas is enclosed in a vessel, therefore, during heating process, volume of the gas remains constant. Hence, no work is done by the gas. It means heat supplied to the gas is used to increase its internal energy only.

Initial internal energy of the gas is $U_1 = N\left(\frac{5}{2}R\right)T$

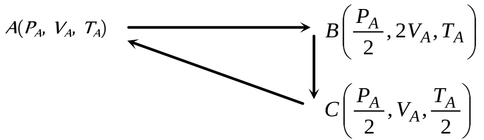
Since n moles get dissociated into atoms, therefore, after heating, vessel contains $(N - n)$ moles of diatomic gas and $2n$ moles of a mono-atomic gas. Hence the internal energy for the gas, after heating, will be equal to

$$U_2 = (N - n)\left(\frac{5}{2}R\right)T + 2n\left(\frac{3}{2}R\right)T = \frac{5}{2}NRT + \frac{1}{2}nRT$$

Hence, the heat supplied = increase in internal energy

$$=(U_2 - U_1) = \frac{1}{2}nRT$$

21. (a) Let the process start from initial pressure P_A, volume V_A and temperature T_A.



(i) Isothermal expansion $(PV = \text{constant})$ at temperature T_A to twice the initial volume V_A

(ii) Compression at constant pressure $\frac{P_A}{2}$ to original volume V_A $(i.e. V \propto T)$

(iii) Isochoric process (at volume V_A) to initial condition $(i.e. P \propto T)$

22. (b) $\Delta Q = mc\Delta T \Rightarrow \Delta T = \frac{20000J}{1kg \times (400J/kg°C)} = 50°C$

$\Rightarrow T_{Final} = 70°C$

Hence $W = P_{atm}\Delta V = P_{atm}V_0\gamma\,\Delta T$

$$= (10^5\,N/m^2)\left(\frac{1}{9\times10^3}m^3\right)(9\times10^{-5}/°C)(50°C) = 0.05J$$

23. (c) $\Delta Q = \Delta U + \Delta W = (U_f - U_i) + \Delta W$

$\Rightarrow -30 = (U_f - 30) - 10 \Rightarrow U_f = 10\ J$

24. (d) $T^{\gamma}P^{1-\gamma}$ = constant $\Rightarrow P \propto T^{\frac{\gamma}{\gamma-1}}$

Comparing above equation with given equation

$$P \propto T^C \Rightarrow C = \frac{\gamma}{\gamma - 1} = \frac{5/3}{5/3 - 1} = \frac{5}{2}$$

25. (a) Internal energy of an ideal gas is given by

$$U = \frac{f}{2}\mu RT = \frac{f}{2}\left(\frac{N}{N_A}\right)RT \Rightarrow U \propto NT.$$

In isothermal process T = constant $\Rightarrow U \propto N$.

i.e. internal energy increases by increasing number of molecules (N).

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