11 Thermodynamics

Question: For the given cycle, the work done during isobaric process is:

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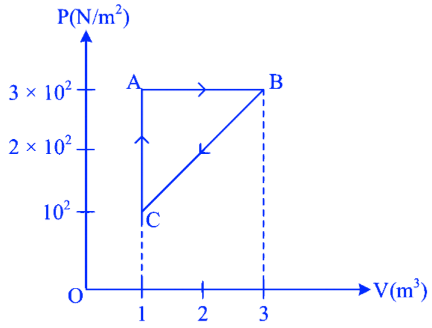
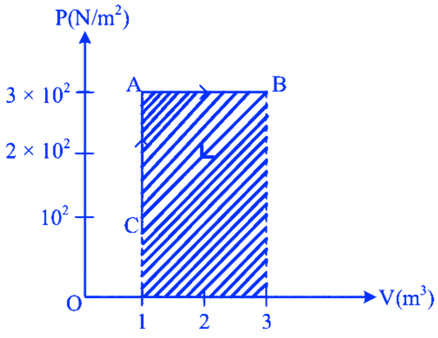


- **A** 200 J
- **B** Zero
- **C** 400 J
- **D** 600 J

Answer: D

Explanation



AB is isobaric process

$$W_{AB} = P(V_2 - V_1)$$

$$W_{AB} = 3 \times 10^2(3 - 1)$$

$$W_{AB} = 3 \times 100 \times 2$$

$$W_{AB} = 600\,J$$

Question: A container of volume 200 cm^3 contains 0.2 mole of hydrogen gas and 0.3 mole of argon gas. The pressure of the system at temperature 200 K ($R=8.3JK^{-1}\ mol^{-1}$) will be :-

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- A $6.15 \times 10^5\,Pa$
- B $6.15 \times 10^4\,Pa$
- C $4.15 \times 10^5\,Pa$
- D $4.15 \times 10^6\,Pa$

Answer: D

Explanation

$$P_{\text{mix}} = \frac{(\mu_1 + \mu_2)RT_{\text{mix}}}{V_{\text{mix}}}$$

$$= \frac{(0.2 + 0.3) \times 8.3 \times 200}{200 \times 10^{-6}}$$

$$= \frac{0.5 \times 8.3 \times 200}{200 \times 10^{-6}}$$

$$P_{\text{mix}} = 4.15 \times 10^6 P_a$$

Question: The temperature of a gas is −50°C. To what temperature the gas should be heated so that the rms speed is increased by 3 times?

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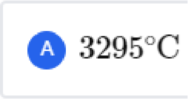
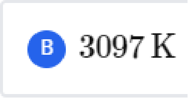
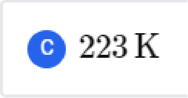

A 3295°C

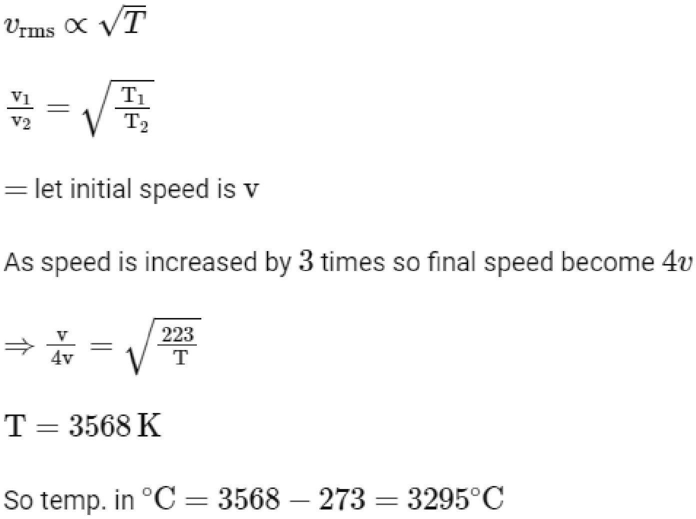

B 3097 K


C 223 K


D 669°C

Answer: A

Explanation


$v_{\mathrm{rms}} \propto \sqrt{T}$

$\frac{\mathrm{v}_1}{\mathrm{v}_2} = \sqrt{\frac{\mathrm{T}_1}{\mathrm{T}_2}}$

$=$ let initial speed is v

As speed is increased by 3 times so final speed become $4v$

$\Rightarrow \frac{\mathrm{v}}{4\mathrm{v}} = \sqrt{\frac{223}{\mathrm{T}}}$

$\mathrm{T} = 3568\,\mathrm{K}$

So temp. in $^\circ\mathrm{C} = 3568 - 273 = 3295^\circ\mathrm{C}$

Question: A Carnot engine has an efficiency of 50% when its source is at a temperature 327°C. The temperature of the sink is :-

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A $15^{\circ}\mathrm{C}$

B $100^{\circ}\mathrm{C}$

C $200^{\circ}\mathrm{C}$

D $27^{\circ}\mathrm{C}$

Answer: D

Explanation

Efficiency of carnot engine

$$
\begin{aligned}
\% \eta &= \left(1-\frac{T_{\text{sink}}}{\mathrm{T}_{\text{source}}}\right) \times 100 \\
T_{\text{source}} &= 327^{\circ}\mathrm{C}=600\,\mathrm{K} \\
50 &= \left(1-\frac{\mathrm{T}_{\text{sink}}}{600}\right) \times 100 \\
\frac{1}{2} &= 1-\frac{\mathrm{T}_{\text{sink}}}{600} \\
\mathrm{T}_{\text{Sink}} &= 300\,\mathrm{K}
\end{aligned}
$$

So temp. of sink is $^{\circ}\mathrm{C}=300-2763=27^{\circ}\mathrm{C}$

2022

MCQ (Single Correct Answer)

Q.1.

An ideal gas follows a process described by the equation $PV^2 = C$ from the initial (P_1, V_1, T_1) to final (P_2, V_2, T_2) thermodynamic states, where C is a constant. Then

A If $P_1 > P_2$ then $V_1 > V_2$

B If $P_1 > P_2$ then $T_1 < T_2$

C If $V_2 > V_1$ then $T_2 > T_1$

D If $V_2 > V_1$ then $T_2 < T_1$

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Ans. (D)

Explanation

We know,

$$PV = nRT$$

Given, $PV^2 =$ constant

$\Rightarrow$ If $P_1 > P_2 \Rightarrow V_1 < V_2$

$P\left(\frac{nRT}{P}\right)^2 =$ constant

$P^{-1}T^2 =$ constant

$\Rightarrow P \propto T^2$

i.e., if $P_1 > P_2 \Rightarrow T_1 > T_2$

Also, $\left(\frac{nRT}{V}\right)V^2 =$ constant

$TV =$ constant

$\Rightarrow$ If $V_2 > V_1$ then $T_2 < T_1$

Q.2 Two rods one made of copper and other made of steel of same length and same cross-sectional area are joined together. The thermal conductivity of copper and steel are 385 J s^{-1} K^{-1} m^{-1} and 50 J s^{-1} K^{-1} m^{-1} respectively. The free ends of copper and steel are held at 100°C and 0°C respectively. The temperature at the junction is, nearly:

- A $88.5^\circ C$
- B $12^\circ C$
- C $50^\circ C$
- D $73^\circ C$

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Ans. (A)

Explanation

We know in conduction, rate of flow of heat $q = \frac{-K.A.\Delta T}{\Delta x}$

As it is a case of steady state heat transfer

$$\Rightarrow \frac{-K_{cu} \times A \times [100 - T_j]}{l} = \frac{-K_{steel} \times A \times [T_j - 0]}{l}$$

Where T_j is temperature of the junction

$$\Rightarrow 385(100 - T_j) = 50(T_j)$$

$$\Rightarrow \frac{100}{T_j} - 1 = \frac{50}{385} \Rightarrow \frac{100}{T_j} = 1 + \frac{50}{385} \Rightarrow \frac{100}{T_j} = 1.1298$$

$$\Rightarrow T_j = 88.5^\circ C$$

Q.3. Three vessels of equal capacity have gases at the same temperature and pressure. The first vessel contains helium (monoatomic), the second contains fluorine (diatomic) and the third contains sulfur hexafluoride (polyatomic). The correct statement, among the following is :

Ⓐ The root mean square speed of sulfur hexafluoride is the largest

Ⓑ All vessels contain unequal number of respective molecules

Ⓒ The root mean square speed of molecules is same in all three cases

Ⓓ The root mean square speed of helium is the largest

NEET 2022 Phase 2

Ans. (D)

Explanation

All three vessels have equal volume and same temperature and pressure.

From ideal gas equation

$$PV = nRT$$

$$nR = \frac{PV}{T}$$

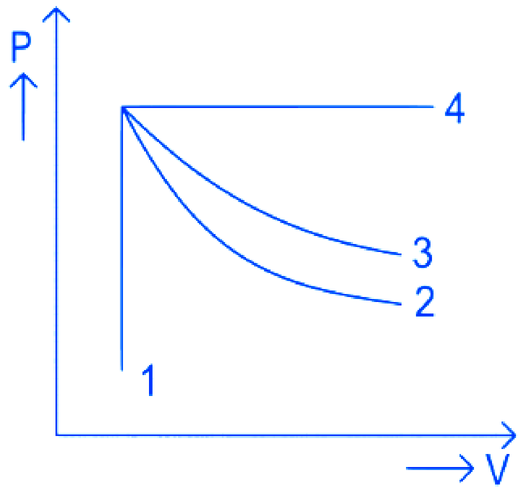
$$n = \frac{PV}{RT} = \text{constant}$$

So, here all three vessels contains equal number of moles and number of gas molecules.

Now, $v_{rms} = \sqrt{\frac{3RT}{M}} \Rightarrow v_{rms} \propto \frac{1}{\sqrt{M}}$

Here, rms speed of helium is the largest.

Q.4. An ideal gas undergoes four different processes from the same initial state as shown in the figure below. Those processes are adiabatic, isothermal, isobaric and isochoric. The curve which represents the adiabatic process among 1, 2, 3 and 4 is



- Ⓐ 1
- Ⓑ 2
- Ⓒ 3
- Ⓓ 4

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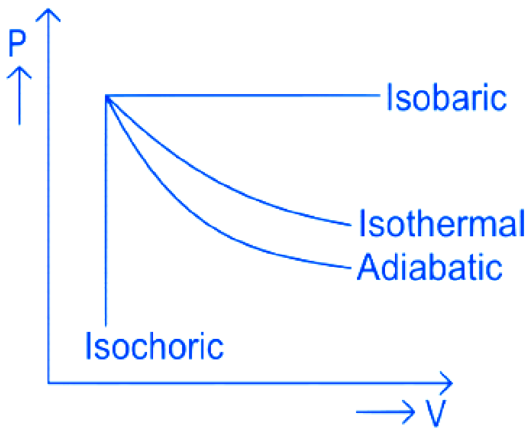
Ans. (B)

Explanation

$$\left(\frac{dP}{dV}\right)_{adiabatic} = -\gamma P$$

$$\left(\frac{dP}{dV}\right)_{isothermal} = -P$$

$$\left(\frac{dP}{dV}\right)_{adiabatic} > \left(\frac{dP}{dV}\right)_{isothermal}$$



Q.5. The volume occupied by the molecules contained in 4.5 kg water at STP, if the intermolecular forces vanish away is

A 5.6×10^6 m^3

B 5.6×10^3 m^3

C 5.6×10^{-3} m^3

D 5.6 m^3

NEET 2022 Phase 1

Ans. (D)

Explanation

From ideal gas equation

$PV = nRT$

$\left[n = \frac{mass\ of\ water}{mol.\ wt.} = \frac{4.5 \times 10^3}{18}\right]$

$V = \frac{nRT}{P}$

At $STP \Rightarrow T = 273\,K$

$P = 10^5$ N/m^2

$V = \frac{4.5 \times 10^3}{18} \times \frac{8.3 \times 273}{10^5} = 5.66$ m^3

TOPIC 1

Zeroth and First Law of Thermodynamics

01 1g of water, of volume 1 cm^3 at 100°C is converted into steam at same temperature under normal atmospheric pressure=$(\simeq 1\times10^5$ Pa). The volume of steam formed equals 1671 cm^3. If the specific latent heat of vaporisation of water is 2256 J/g, the change in internal energy is **[NEET (Odisha) 2019]**

(a) 2423 J (b) 2089 J
(c) 167 J (d) 2256 J

Ans. ***(b)***

Given, mass of water, $m = 1$ g

Volume of 1 g of water $= 1\,cm^3 = 10^{-6}\,m^3$

Volume of 1 g of steam $= 1671\,cm^3$

$= 1671\times10^{-6}\,m^3$

Pressure, $p = 1\times10^5$ Pa

Latent heat of vaporization of water,

$L = 2256$ J/g

Change in volume,

$\Delta V = (1671 - 1)\times10^{-6}\,m^3$

$= 1670\times10^{-6}\,m^3$ ...(i)

Heat supplied,

$\Delta Q = mL = 1\times2256 = 2256$ J ...(ii)

As the steam expands, so the work done in expansion is

$\Delta W = p\Delta V$

$= 1\times10^5\times1670\times10^{-6}$ [from Eq. (i)]

$= 167$ J ...(iii)

According to first law of thermodynamics,

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

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

$= 2256 - 167$ [from Eq. (ii) and (iii)]

$= 2089$ J

02 A sample of 0.1 g of water at 100°C and normal pressure (1.013×10^5 Nm^{-2}) requires 54 cal of heat energy to convert to steam at 100°C. If the volume of the steam produced is 167.1 cc, the change in internal energy of the sample, is **[NEET 2018]**

(a) 42.2 J (b) 208.7 J
(c) 104.3 J (d) 84.5 J

Ans. ***(b)***

According to the question,

Heat spent during the conversion of sample of water at 100° C to steam is,

$\Delta Q = 54\,\text{cal} = 54\times4.18$ J

$= 225.72$ J

Normal pressure, $p = 1.013\times10^5\,Nm^{-2}$

Net work done during the conversion would be given as

$\Delta W = p\Delta V$

$= p[V_{steam} - V_{water}]$

Here, $V_{steam} = 167.1\,cc = 167.1\times10^{-6}\,m^3$

$V_{water} = 0.1\,g = 0.1\,cc = 0.1\times10^{-6}\,m^3$

$\therefore\ \Delta W = 1.013\times10^5\,[(167.1 - 0.1)\times10^{-6}]$

$= 1.013\times167\times10^{-1}$

$= 16.917$ J

Now, by the first law of thermodynamics,

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

where, ΔU is the change in internal energy of the sample.

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

Substituting the values in the above equation, we get

$\Delta U = 225.72 - 16.917 = 208.7$ J

03 During an isothermal expansion, a confined ideal gas does –150 J of work against its surroundings. This implies that **[CBSE AIPMT 2011]**

(a) 300 J of heat has been added to the gas
(b) no heat is transferred because the process is isothermal
(c) 150 J of heat has been added to the gas
(d) 150 J of heat has been removed from the gas

Ans. ***(c)***

Concept Apply first law of thermodynamics.

According to first law of thermodynamics

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

For isothermal process, $\Delta U = 0$

So, $\Delta Q = -\Delta W$

Given, $\Delta W = -150$ J

So, $\Delta Q = +150$ J

When Q is positive, the heat is added to the gas.

04 If ΔU and ΔW represent the increase in internal energy and work done by the system respectively in a thermodynamical process, which of the following is true? **[CBSE AIPMT 2010]**

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

Ans. ***(a)***

From first law of thermodynamics

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

For adiabatic process, $\Delta Q = 0$

$\because\ \Delta Q = 0$

So, $\Delta U = -\Delta W$

05 The internal energy change in a system that has absorbed 2 kcal of heat and done 500 J of work is **[CBSE AIPMT 2009]**

(a) 8900 J (b) 6400 J
(c) 5400 J (d) 7900 J

Ans. *(d)*

According to first law of thermodynamics

$$\Delta Q = U + W$$

or $\Delta U = Q - W$

ΔU = change in internal energy

Q = heat given to system

W = work done

$\therefore \quad \Delta U = 2 \times 4.2 \times 1000 - 500$

$= 8400 - 500 = 7900$ J

06 If Q, E and W denote respectively the heat added, change in internal energy and the work done in a closed cycle process, then **[CBSE AIPMT 2008]**

(a) $W = 0$ (b) $Q = W = 0$
(c) $E = 0$ (d) $Q = 0$

Ans. *(c)*

For a cyclic process, $\Delta U = 0$ or $E = 0$

07 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 AIPMT 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

Ans. *(a)*

An isothermal process is a constant temperature process. In this process, T = constant or $\Delta T = 0$.

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

$\Rightarrow \quad \Delta Q = \Delta W \qquad (\Delta U = 0)$

$\Delta U = nC_V \, \Delta T = 0$

An adiabatic process is defined as one with no heat transfer into or out of a system. Therefore, $Q = 0$. From the first law of thermodynamics.

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

or $\Delta U = - W \qquad [\Delta Q = 0]$

08 110 J of heat is added to a gaseous system, whose internal energy is 40 J, then the amount of external work done is **[CBSE AIPMT 1993]**

(a) 150 J (b) 70 J (c) 110 J (d) 40 J

Ans. *(b)*

Concept Apply first law of thermodynamics to calculate the required work done.

From first law of thermodynamics

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

where, ΔQ = heat given

ΔU = change in internal energy

ΔW = work done

Here, $\Delta Q = 110$ J

$\Delta U = 40$ J

$\therefore \quad \Delta W = \Delta Q - \Delta U = 110 - 40 = 70$ J

09 First law of thermodynamics is a consequence of conservation of **[CBSE AIPMT 1988]**

(a) work (b) energy
(c) heat (d) All of these

Ans. *(b)*

According to the first law of thermodynamics, when some quantity of heat (dQ) is supplied to a system capable of doing external work, then the quantity of heat absorbed by the system (dQ) is equal to the sum of the increase in the internal energy of the system (dU) due to rise in temperature and the external work done by the system (dW) in expansion,

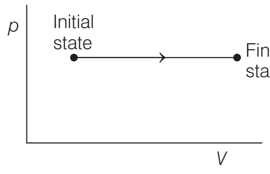
i.e. $dQ = dU + dW$

This law, which is basically the law of conservation of energy applies to every process in nature.

TOPIC 2

Thermodynamic Process

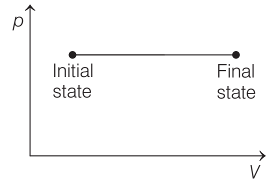
10 The p-V diagram for an ideal gas in a piston cylinder assembly undergoing a thermodynamic process is shown in the figure. The process is **[NEET (Oct.) 2020]**



(a) adiabatic (b) isochoric
(c) isobaric (d) isothermal

Ans. *(c)*

pV-diagram for an ideal gas is given as



From the pV diagram, it is clear that pressure of ideal gas in the piston cylinder is constant during thermodynamic process. Hence, this process is isobaric.

11 Two cylinders A and B of equal capacity are connected to each other *via* a stop cock. A contains an ideal gas at standard temperature and pressure. B is completely evacuated. The entire system is thermally insulated. The stop cock is suddenly opened. The process is **[NEET (Sep.) 2020]**

(a) adiabatic (b) isochoric
(c) isobaric (d) isothermal

Ans. *(a)*

Since, the entire system is thermally insulated. Thus, their will be no transfer of heat between the system and the surrounding. Hence, when the stop cock is suddenly opened, a sudden process of expansion will takes place with no heat transfer. Thus, the given process will be adiabatic, as it is a process that occurs without transferring heat or mass between a thermodynamic system and its surroundings.

Hence, correct option is (a).

12 In which of the following processes, heat is neither absorbed nor released by a system? **[NEET (National) 2019]**

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

Ans. *(a)*

In an adiabatic process, the system is completely insulated from the surroundings. Thus, heat is neither absorbed nor released by the system to the surroundings. So, $\Delta Q = 0$.

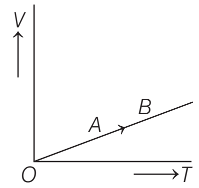
Sudden processes are adiabatic like bursting of cycle tyre, etc.

If the pressure of gas is kept constant, then the process is called isobaric, i.e. $\Delta p = 0$.

If the temperature of the system remains constant, then it is called isothermal process, i.e. $\Delta T = 0$.

If the volume of gas is constant in a system, then it is called isochoric process, i.e. $\Delta V = 0$.

13 The volume (V) of a monoatomic gas varies with its temperature (T), as shown in the graph. The ratio of work done by the gas, to the heat absorbed by it, when it undergoes a change from state A to state B, is **[NEET 2018]**



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

(c) $\frac{2}{5}$ (d) $\frac{2}{7}$

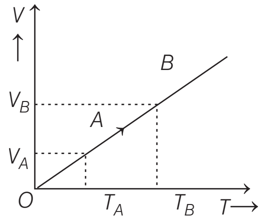
Ans. ***(c)***

According to the given graph,

Volume (V) $\propto$ Temperature (T)

or $\frac{V}{T} = \text{constant}$

Thus, the process is isobaric.



$\therefore$ Work done, $\Delta W = p\Delta V$

$$= nR\Delta T = nR(T_B - T_A) \quad \text{...(i)}$$

Heat absorbed $\Delta Q = nC_p\Delta T$

$$= nC_p(T_B - T_A) \quad \text{...(ii)}$$

As, $C_p = \frac{\gamma R}{\gamma - 1}$, $\left(\text{where, } \gamma = 1 + \frac{2}{f}\right)$

For a monoatomic gas, $f = 3$

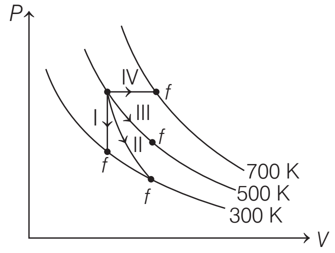
$$\Rightarrow \quad C_p = \left(R + \frac{3}{2}R\right) = \frac{5}{2}R$$

Substituting the value of C_p in Eq. (ii), we get

$$\Delta Q = n\left(\frac{5}{2}R\right)(T_B - T_A)$$

Hence, $\frac{\Delta W}{\Delta Q} = \frac{nR(T_B - T_A)}{n\left(\frac{5}{2}R\right)(T_B - T_A)} = \frac{2}{5}$

14 Thermodynamic processes are indicated in the following diagram **[NEET 2017]**



Match the following :

	Column-I		Column-II
P.	Process I	a.	Adiabatic
Q.	Process II	b.	Isobaric
R.	Process III	c.	Isochoric
S.	Process IV	d.	Isothermal

(a) P→ a, Q→ c, R→ d, S→ b

(b) P→ c, Q→ a, R→ d, S→ b

(c) P→ c, Q→ d, R→ b, S→ a

(d) P→ d, Q→ b, R→ a, S→ c

Ans. ***(b)***

In isochoric process, the curve is parallel to y-axis because volume is constant. Isobaric is parallel to x-axis because pressure is constant. Along the curve, it will be isothermal because temperature is constant.

So, $\text{P} \rightarrow \text{c} \Rightarrow \text{Q} \rightarrow \text{a} \Rightarrow \text{R} \rightarrow \text{d}$

$$\Rightarrow \text{S} \rightarrow \text{b}$$

15 A gas is compressed isothermally to half its initial volume. The same gas is compressed separately through an adiabatic process until its volume is again reduced to half. Then **[NEET 2016]**

(a) compressing the gas through adiabatic process will require more work to be done.

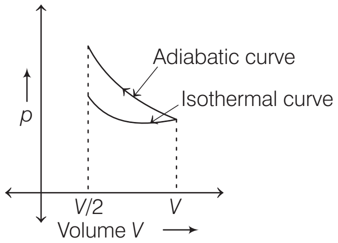
(b) compressing the gas isothermally or adiabatically will require the same amount of work.

(c) which of the case (whether compression through isothermal or through adiabatic process) requires more work will depend upon the atomicity of the gas.

(d) compressing the gas isothermally will require more work to be done.

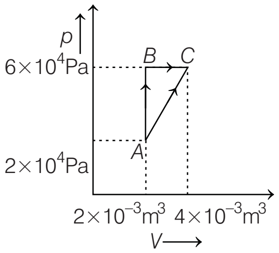
Ans. ***(a)***

The solution of this question can be understood by plotting a p-V graph for the compression of a gas isothermally and adiabatically simultaneously to half of its initial volume. *i.e.*



Since, the isothermal curve is less steeper than the adiabatic curve. So, area under the p-V curve for adiabatic process has more magnitude than isothermal curve. Hence, work done in adiabatic process will be more than in isothermal process.

16 Figure below shows two paths that may be taken by a gas to go from a state A to a state C. **[CBSE AIPMT 2015]**



In process AB, 400 J of heat is added to the system and in process BC, 100 J of heat is added to the system. The heat absorbed by the system in the process AC will be

(a) 380 J (b) 500 J (c) 460 J (d) 300 J

Ans. ***(c)***

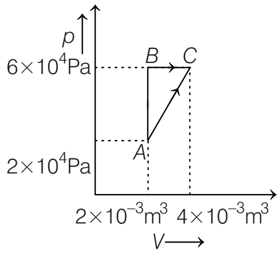
Since, initial and final points are same

So, $\Delta U_{A \to B \to C} = \Delta U_{A \to C}$ ...(i)

Also $A \to B$ is isochoric process

So $dW_{A \to B} = 0$ and $dQ = dU + dW$

So, $dQ_{A \to B} = dU_{A \to B} = 400 \text{ J}$



Next $B \to C$ is isobaric process

So, $dQ_{B \to C} = dU_{B \to C} + dW_{B \to C}$

$$= dU_{B \to C} + p\Delta V_{B \to C}$$

$$\Rightarrow \quad 100 = dU_{B \to C} + 6\times10^4(2\times10^{-3})$$

$$\Rightarrow \quad dU_{B\to C} = 100-120 = -20 \text{ J}$$

From Eq. (i),

$$\because \quad \Delta U_{A\to B\to C} = \Delta U_{A\to C}$$

$$\Rightarrow \quad \Delta U_{A\to B} + \Delta U_{B\to C} = dQ_{A\to C} - dW_{A\to C}$$

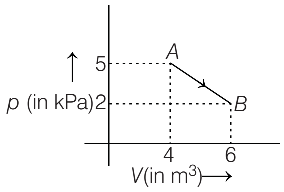
$$\Rightarrow 400 + (-20) = dQ_{A\to C} - (p\Delta V_A + \text{Area of } \Delta ABC)$$

$$\Rightarrow dQ_{A\to C} = 380 + \begin{pmatrix} 2\times10^4\times2\times10^{-3} \\ +\frac{1}{2}\times2\times10^{-3}\times4\times10^4 \end{pmatrix}$$

$$= 380 + (40+40)$$

$$dQ_{A\to C} = 460 \text{ J}$$

17 One mole of an ideal diatomic gas undergoes a transition from A to B along a path AB as shown in the figure. **[CBSE AIPMT 2015]**

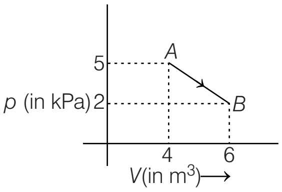


The change in internal energy of the gas during the transition is

(a) 20 kJ (b) – 20 kJ (c) 20 J (d) – 12 kJ

Ans. ***(b)***

For a diatomic gas,



$$C_V = \frac{5}{2}R$$

The change in internal energy of gas in the transition from A to B is

$$\Delta U = nC_V dT = n\left(\frac{5R}{2}\right)(T_B - T_A)$$

$$= nR\frac{5}{2}\left(\frac{p_BV_B}{nR} - \frac{p_AV_A}{nR}\right)$$

$$= \frac{5}{2}(2\times10^3\times6 - 5\times10^3\times4)$$

$$= \frac{5}{2}\times(-8\times10^3) = -\frac{4\times10^4}{2} = -20 \text{ kJ}$$

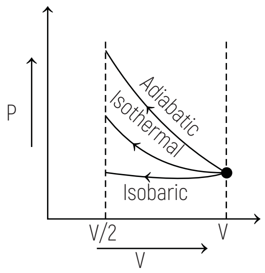
18 An ideal gas is compressed to half its initial volume by means of several process. Which of the process results in the maximum work done on the gas? **[CBSE AIPMT 2015]**

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

Ans. ***(a)***

Given, ideal gas is compressed to half its initial volume i.e.

$$V_0 = \frac{V}{2}$$



The isochoric process is one in which volume is kept constant, meaning that work done by the system will be zero. i.e.

$$W_{\text{isochoric}} = 0$$

As we know, work done on the gas = Area under curve, i.e.

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

19 A monoatomic gas at a pressure p, having a volume V expands isothermally to a volume 2 V and then adiabatically to a volume 16 V. The final pressure of the gas is $\left(\textbf{take } \gamma = \frac{5}{3}\right)$ **[CBSE AIPMT 2014]**

(a) $64p$ (b) $32p$
(c) $\frac{p}{64}$ (d) $16p$

Ans. ***(c)***

For isothermal expansion process

$$pV = p' \times 2V \qquad [\therefore V' = 2V]$$

$$p' = \frac{p}{2}$$

For adiabatic expansion,

$$pV^\gamma = \text{constant} \quad \Rightarrow$$

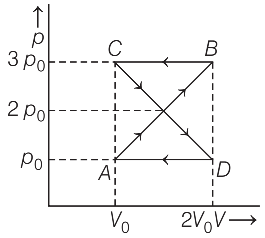
$$p'V'^\gamma = p''V''^\gamma$$

$$\Rightarrow \quad \frac{p}{2}(2V)^{5/3} = p''(16V)^{5/3}$$

$$\Rightarrow \quad p'' = \frac{p}{2}\left[\frac{2V}{16V}\right]^{5/3} = \frac{p}{2}\left(\frac{1}{8}\right)^{5/3}$$

$$= \frac{p}{2}\left(\frac{1}{32}\right) = p/64$$

20 A thermodynamic system undergoes cyclic process $ABCDA$ as shown in figure. The work done by the system in the cycle is **[CBSE AIPMT 2014]**



(a) p_0V_0 (b) $2p_0V_0$
(c) $\frac{p_0V_0}{2}$ (d) zero

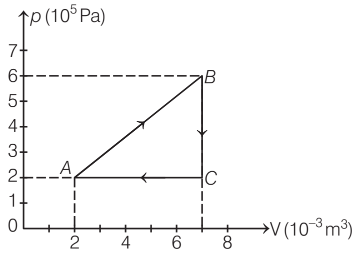
Ans. ***(d)***

Work done in the cyclic process = Area bounded by the closed configuration

$$= \text{Area of closed configuration}$$

$$= \frac{1}{2}\times V_0 \times p_0 - \frac{1}{2}\times V_0 \times p_0 = 0 \text{ (zero)}.$$

21 A gas is taken through the cycle $A \to B \to C \to A$, as shown. What is the net work done by the gas? **[NEET 2013]**



(a) 2000 J (b) 1000 J
(c) Zero (d) –2000 J

Ans. ***(b)***

According to question,

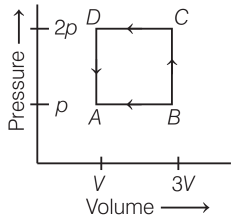
Net work done = Area enclosed in pV curve i.e. ΔABC

Area of ΔABC

$$= \frac{1}{2}\times5\times10^{-3}\times4\times10^5 \text{ J}$$

$$= 10^3 \text{ J} = 1000 \text{ J}$$

22 A thermodynamic system is taken through the cycle $ABCD$ as shown in figure. Heat rejected by the gas during the cycle is **[CBSE AIPMT 2012]**



(a) $2pV$ (b) $4pV$ (c) $\frac{1}{2}pV$ (d) pV

Ans. ***(a)***

For given cyclic process,

$$\Delta U = 0 \Rightarrow Q = W$$

Also, $W = -$ area enclosed by the curve

$$= -AB \times AD$$

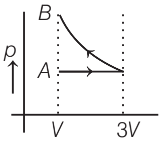
$$= -(2p - p)(3V - V)$$

$$= -p \times 2V$$

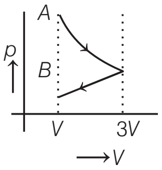
$\therefore$ Heat rejected $= 2pV$

23 One mole of an ideal gas goes from an initial state A to final state B *via* two processes. It first undergoes isothermal expansion from volume V to $3V$ and then its volume is reduced from $3V$ to V at constant pressure. The correct p-V diagram representing the two processes is **[CBSE AIPMT 2012]**

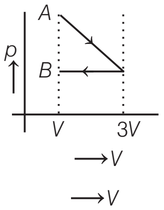
(a)



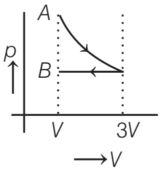
(b)



(c)



(d)



Ans. ***(d)***

According to question, firstly gas expands from volume V to $3V$ and after this volume is reduced from $3V$ to V at constant pressure.

In isothermal expansion, p-V curve is rectangular hyperbola.

24 In thermodynamic processes which of the following statements is not true ? **[CBSE AIPMT 2009]**

(a) In an adiabatic process the system is insulated from the surroundings

(b) In an isochoric process pressure remains constant

(c) In an isothermal process the temperature remains constant

(d) In an adiabatic process $pV^{\gamma} =$ constant

Ans. ***(b)***

For an adiabatic process, there should not be any exchange of heat between the system and its surroundings. All walls of the container must be perfectly insulated. In adiabatic changes, gases obey Poisson's law, i.e., $pV^{\gamma} =$ constant. In an isochoric process, volume remains constant and for isobaric process, pressure remains constant.

25 Which of the following processes is reversible? **[CBSE AIPMT 2005]**

(a) Transfer of heat by radiation

(b) Electrical heating of a nichrome wire

(c) Transfer of heat by conduction

(d) Isothermal compression

Ans. ***(d)***

(a) It is the process by which heat is transmitted from one place to another without heating the intervening medium. Hence, it is not a reversible process.

(b) Nichrome wire is made of alloy and has high resistance. When current is passed through it, heat is produced. So, here electrical energy is converted into heat energy. Hence, it is not a reversible process.

(c) It is the process by which heat is transmitted from one point to another through a substance in the direction of fall of temperature without the actual movement of the particles of the substances themselves. Hence, it cannot be reversible.

(d) Isothermal compression is reversible, for example-Carnot cycle, Heat engine.

Thus, choice (d) is correct.

26 One mole of an ideal gas at an initial temperature of T K does $6R$ 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 AIPMT 2004]**

(a) $(T + 2.4)$ K

(b) $(T - 2.4)$ K

(c) $(T + 4)$ K

(d) $(T - 4)$ K

Ans. ***(d)***

In an adiabatic process,

$$Q = 0$$

So, from Ist law of thermodynamics,

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

As $\Delta Q = 0$

so, $W = -\Delta U = -nC_V \Delta T$

$$= -n\left(\frac{R}{\gamma - 1}\right)(T_f - T_i)$$

$$= \frac{nR}{\gamma - 1}(T_i - T_f) \qquad \text{...(i)}$$

Given, work done, $W = 6R$ J, $n = 1$ mol,

$$R = 8.31 \text{ J/mol-K}, \gamma = \frac{5}{3}, T_i = T \text{ K}$$

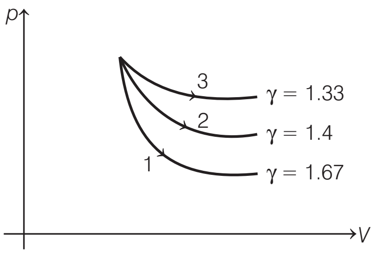
Substituting given values in Eq. (i), we get

$$\therefore \quad 6R = \frac{R}{(5/3 - 1)}(T - T_f)$$

$$\Rightarrow \quad 6R = \frac{3R}{2}(T - T_f) \Rightarrow T - T_f = 4$$

$$\therefore \quad T_f = (T - 4) \text{ K}$$

Adiabatic expansions of mono, dia and polyatomic gases are shown below.
1 → monoatomic 2 → diatomic 3 → polyatomic



27 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 $2V$ at constant pressure p is **[CBSE AIPMT 1998]**

(a) $\frac{R}{(\gamma - 1)}$ (b) pV (c) $\frac{pV}{(\gamma - 1)}$ (d) $\frac{\gamma pV}{(\gamma - 1)}$

Ans. ***(c)***

Change in internal energy of a gas having atomicity γ is given by

$$\Delta U = \frac{1}{(\gamma - 1)}(p_2V_2 - p_1V_1)$$

Given, $V_1 = V, V_2 = 2V$

So, $\Delta U = \frac{1}{\gamma - 1}[p \times 2V - p \times V]$

$$= \frac{1}{\gamma - 1} \times pV = \frac{pV}{\gamma - 1}$$

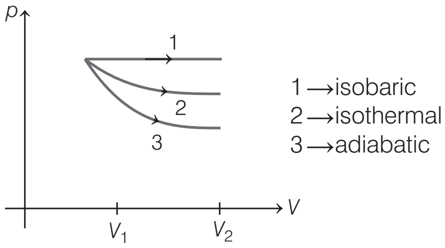
28 A sample of gas expands from volume V_1 to V_2. The amount of work done by the gas is greatest when the expansion is

[CBSE AIPMT 1997]

(a) adiabatic
(b) isobaric
(c) isothermal
(d) Equal in all above cases

Ans. ***(b)***

The *p*-*V* diagram for isobaric, isothermal and adiabatic processes of an ideal gas is shown in graph below



In thermodynamics, for some change in volume, the work done is maximum for the curve having maximum area enclosed with the volume axis.

Area enclosed by the curve

$$\propto \text{(Slope of curve)}$$

Note

$$(\text{slope})_{\text{isobaric}} < (\text{slope})_{\text{isothermal}} < (\text{slope})_{\text{adiabatic}}$$

$$\Rightarrow (\text{Area})_{\text{isobaric}} > (\text{Area})_{\text{isothermal}} > (\text{Area})_{\text{adiabatic}}$$

Hence, work done is maximum in isobaric process.

$$(\text{Slope})_{\text{adiabatic}} = -\gamma\left(\frac{p}{V}\right)$$

and $(\text{Slope})_{\text{isothermal}} = -\frac{p}{V}$

$\therefore$ $(\text{Slope})_{\text{adiabatic}} = \gamma \times (\text{slope})_{\text{isothermal}}$

Slope of adiabatic curve is always steeper than that of isothermal curve.

29 An ideal gas undergoing adiabatic change has the following pressure-temperature relationship

[CBSE AIPMT 1996]

(a) $p^{\gamma-1}T^{\gamma}$ = constant
(b) $p^{\gamma}T^{\gamma-1}$ = constant
(c) $p^{\gamma}T^{1-\gamma}$ = constant
(d) $p^{1-\gamma}T^{\gamma}$ = constant

Ans. ***(d)***

The adiabatic relation between *p* and *V* for a perfect gas is

$$pV^{\gamma} = k \qquad \text{...(i)}$$

From standard gas equation

$$pV = RT \quad \text{or} \quad V = \frac{RT}{p}$$

Putting value of *V* in Eq. (i)

$$p\left(\frac{RT}{p}\right)^{\gamma} = k$$

or $\quad p^{1-\gamma}T^{\gamma} = \frac{k}{R^{\gamma}}$ = another constant

i.e., $\quad p^{1-\gamma}T^{\gamma}$ = constant

30 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 AIPMT 1993]

(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*

Ans. ***(b)***

A change in pressure and volume of a gas without any change in its temperature is called an isothermal change. In such a change, there is a free exchange of heat between the gas and its surroundings.

$\therefore \quad T$ = constant, $\Delta T = 0$

So, internal energy (U) remains constant 0.

31 Which of the following is not thermodynamical function ?

[CBSE AIPMT 1993]

(a) Enthalpy
(b) Work done
(c) Gibb's energy
(d) Internal energy

Ans. ***(b)***

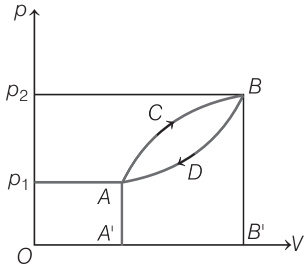
The thermodynamic state of a homogeneous system may be represented by certain specific thermodynamic variables such as pressure *p*, volume *V*, temperature *T* and entropy *S*. Out of these four variables, any two are independent and when they are known the others may be determined. Thus, there are only two independent variables and the others may be considered their functions. For complete knowledge of the system certain relations are required and for this purpose we introduce some functions of variables *p*, *V*, *T* and *S* known as thermodynamic functions. There are four principal thermodynamic functions

(i) Internal energy (U)
(ii) Helmholtz function (F)
(iii) Enthalpy (H)
(iv) Gibb's energy (G)

Hence, work done is not thermodynamic function.

32 A thermodynamic system is taken from state *A* to *B* along *ACB* and is brought back to *A* along *BDA* as shown in the *p*-*V* diagram. The net work done during the complete cycle is given by the area

[CBSE AIPMT 1992]



(a) $p_1ACBp_2p_1$
(b) $ACBB'A'A$
(c) $ACBDA$
(d) $ADBB'A'A$

Ans. ***(c)***

Work done during path *ACB*

= area $ACBB'A'A$

Work done during path *BDA*

= area $BDAA'B'B$

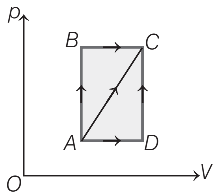
$\therefore$ Work done during going from *ACB* and then to *BDA* path is

= area $ACBB'A'A$ – area $BDAA'B'B$

= area $ACBDA$

Net work done in cyclic process is given by area under the cycle.

33 A thermodynamic process is shown in the figure. The pressure and volumes corresponding to some points in the figure are



$p_A = 3 \times 10^4$ pa,, $V_A = 2 \times 10^{-3}$ m³
$p_B = 8 \times 10^4$ pa, $V_B = 5 \times 10^{-3}$ m³

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

[CBSE AIPMT 1991]

(a) 560 J
(b) 800 J
(c) 600 J
(d) 640 J

Ans. ***(a)***

For path AB, applying first law of thermodynamics

$$dQ = dU + dW \text{ or } dQ = U_B - U_A + dW$$

or $\quad 600 = U_B - U_A + 0$

(for isochoric process $dV = 0$ so, $dW = 0$)

$$U_B - U_A = 600 \qquad \text{...(i)}$$

For path BC,

$$dQ = dU + dW$$

$\therefore \quad 200 = U_C - U_B + p_B(V_C - V_B)$

(as BC is isobaric process)

$\therefore \quad 200 = U_C - U_B + 8 \times 10^4 (5 \times 10^{-3} - 2 \times 10^{-3})$

or $\quad 200 = U_C - U_B + 240$

$\therefore \quad U_C - U_B = -40\text{ J} \qquad \text{...(ii)}$

For AC, change in internal energy can be calculated by adding Eqs. (i) and (ii),

$$= U_C - U_A$$
$$= U_C - U_B + U_B - U_A$$
$$= -40 + 600 = 560\text{ J}$$

TOPIC 3

Heat Engine, Second Law of Thermodynamics and Carnot Engine

33 The efficiency of a Carnot engine depends upon **[NEET (Oct.) 2020]**

(a) the temperature of the sink only

(b) the temperatures of the source and sink

(c) the volume of the cylinder of the engine

(d) the temperature of the source only

Ans. ***(b)***

Efficiency of Carnot engine is given as

$$\eta = 1 - \frac{T_2}{T_1}$$

where, T_2 = temperature of sink

and $\quad T_1$ = temperature of source.

Hence, η depends upon the temperature of source and sink both.

34 The efficiency of an ideal heat engine working between the freezing point and boiling point of water, is **[NEET 2018]**

(a) 6.25% (b) 20% (c) 26.8% (d) 12.5%

Ans. ***(c)***

Efficiency of an ideal heat engine is given as

$$\eta = 1 - \frac{T_2}{T_1}$$

where, T_1 is the temperature of the source and T_2 is the temperature of the sink.

Here, $\quad T_1 = 100 + 273 = 373\text{ K}$

$$T_2 = 0 + 273 = 273\text{ K}$$

$$\Rightarrow \quad \eta = 1 - \frac{273}{373}$$

$$= \frac{373 - 273}{373} = \frac{100}{373} = 0.268$$

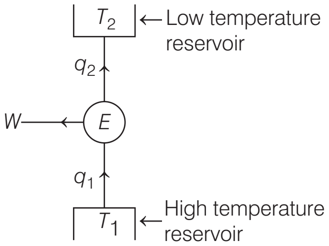
$$\therefore \quad \eta\,\% = 0.268 \times 100 = 26.8\,\%$$

35 A Carnot engine having an efficiency of $\frac{1}{10}$ as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is **[NEET 2017]**

(a) 1 J (b) 90 J (c) 99 J (d) 100 J

Ans. ***(b)***

Consider schematic diagram for a Carnot engine as shown below.



In case of engine,

$$\text{engine efficiency} = \frac{\text{work}}{\text{heat absorbed}} = \frac{W}{q_1}$$

$$\therefore \quad \frac{W}{q_1} = \frac{1}{10}$$

$$\Rightarrow \quad \frac{10\text{ J}}{q_1} = \frac{1}{10} \quad \text{or} \quad q_1 = 100\text{ J}$$

When this engine is reversed, it takes in work W and heat q_2 from cold reservoir and ejects 100 J of heat to hot reservoir.

$\therefore \quad W + q_2 = q_1$

$\Rightarrow \quad 10 + q_2 = 100 \quad \text{or} \quad q_2 = 90\text{ J}$

36 A refrigerator works between 4°C and 30°C. It is required to remove 600 calories of heat every second in order to keep the temperature of the refrigerated space constant. The power required is

(Take, 1 cal = 4.2 Joules) **[NEET 2016]**

(a) 23.65 W (b) 236.5 W

(c) 2365 W (d) 2.365 W

Ans. ***(b)***

Given, temperature of source,

$$T = 30°\text{C} = 30 + 273 \Rightarrow T_1 = 303\text{ K}$$

Temperature of sink, $T_2 = 4°\text{C} = 4 + 273$

$$T_2 = 277\text{ K}$$

As, we know that

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2} \Rightarrow \frac{Q_2 + W}{Q_2} = \frac{T_1}{T_2}$$

$$\{\because W = Q_1 - Q_2\}$$

where Q_2 is the amount of heat drawn from the sink (at T_2), W is workdone on working substance, Q_1 is amount of heat rejected to source (at room temperature T_1).

$\Rightarrow \quad WT_2 + T_2Q_2 = T_1Q_2$

$\Rightarrow \quad WT_2 = T_1Q_2 - T_2Q_2$

$\Rightarrow \quad WT_2 = Q_2(T_1 - T_2)$

$$\Rightarrow \quad W = Q_2\left(\frac{T_1}{T_2} - 1\right)$$

$$\Rightarrow \quad W = 600 \times 4.2 \times \left(\frac{303}{277} - 1\right)$$

$$W = 600 \times 4.2 \times \left(\frac{26}{277}\right)$$

$$W = 236.5\text{ Joules}$$

$$\text{Power} = \frac{\text{Work done}}{\text{Time}} = \frac{W}{t} = \frac{236.5}{1}$$

$$= 236.5\text{ W}$$

37 The temperature inside a refrigerator is t_2 °C and the room temperature is t_1 °C. The amount of heat delivered to the room for each joule of electrical energy consumed ideally will be **[NEET 2016]**

(a) $\frac{t_1}{t_1 - t_2}$ (b) $\frac{t_1 + 273}{t_1 - t_2}$

(c) $\frac{t_2 + 273}{t_1 - t_2}$ (d) $\frac{t_1 + t_2}{t_1 + 273}$

Ans. ***(b)***

For a refrigerator, we know that

$$\frac{Q_1}{W} = \frac{Q_1}{Q_1 - Q_2} = \frac{T_1}{T_1 - T_2}$$

where,

Q_1 = amount of heat delivered to the room

W = electrical energy consumed

T_1 = room temperature = $t_1 + 273$

T_2 = temperature of sink = $t_2 + 273$

$$\therefore \quad \frac{Q_1}{1}=\frac{t_1+273}{t_1+273-(t_2+273)}$$

$$\Rightarrow \quad Q_1=\frac{t_1+273}{t_1-t_2}$$

38 A Carnot engine, having an efficiency of $\eta=\frac{1}{10}$ as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is **[CBSE AIPMT 2015]**

(a) 100 J (b) 99 J
(c) 90 J (d) 1 J

Ans. ***(c)***

As, $Q_1+W=Q_2$

Given, $\eta=\frac{1}{10}$

Now, using $\eta=1-\frac{T_1}{T_2}$

So, $\frac{1}{10}=1-\frac{T_1}{T_2} \Rightarrow \frac{T_1}{T_2}=\frac{9}{10}$

Now $\frac{Q_1}{Q_2}=\frac{T_1}{T_2} \Rightarrow \frac{Q_1}{Q_1+W}=\frac{9}{10}$

$\Rightarrow \quad 10Q_1=9Q_1+9W$

$\Rightarrow \quad Q_1=9W=9\times10=90\text{ J}$

39 The coefficient of performance of a refrigerator is 5. If the temperature inside freezer is $-20°$C, the temperature of the surroundings to which it rejects heat is **[CBSE AIPMT 2015]**

(a) 31°C (b) 41°C
(c) 11°C (d) 21°C

Ans. ***(a)***

Key Concept Coefficient of performance (β) of a refrigerator is defined as the ratio of quantity of heat removed per cycle (Q_2) to the work done on the working substance per cycle to remove this heat.

Given, coefficient of performance of a refrigerator, $\beta=5$

Temperature of surface, i.e. inside freezer,

$$T_2=-20°\text{ C}=-20+273=253\text{K}$$

Temperature of surrounding, i.e. heat rejected outside $T_1=?$

So, $\beta=\frac{T_2}{T_1-T_2} \Rightarrow 5=\frac{253}{T_1-253}$

$\Rightarrow \quad 5T_1-1265=253$

$\Rightarrow \quad 5T_1=1518$

$$T_1=\frac{1518}{5}=303.6\text{ K}$$

$$T_1=303.6-273=31°\text{ C}$$

40 An engine has an efficiency of $\frac{1}{6}$. When the temperature of sink is reduced by 62°C, its efficiency is doubled. Temperature of the source is **[CBSE AIPMT 2007]**

(a) 124°C (b) 37°C (c) 62°C (d) 99°C

Ans. ***(d)***

Efficiency of engine is given by

$$\eta=1-\frac{T_2}{T_1}$$

T_2 = temperature of sink

T_1 = temperature of source

$$\therefore \quad \frac{T_2}{T_1}=1-\eta=1-\frac{1}{6}=\frac{5}{6} \qquad \text{...(i)}$$

In other case,

$$\frac{T_2-62}{T_1}=1-\eta=1-\frac{2}{6}=\frac{2}{3} \qquad \text{...(ii)}$$

or $T_2-62=\frac{2}{3}T_1=\frac{2}{3}\times\frac{6}{5}T_2$ [Using Eq. (i)]

or $\frac{1}{5}T_2=62$

$\therefore \quad T_2=310\text{ K}$

$=310-273°\text{C}=37°\text{ C}$

Here, $T_1=\frac{6}{5}T_2=\frac{6}{5}\times310$

$=372\text{ K}=372-273$

$=99°\text{C}$

41 A Carnot engine whose sink is at 300 K has an efficiency of 40%. By how much should the temperature of source be increased so as to increase its efficiency by 50% of original efficiency ? **[CBSE AIPMT 2006]**

(a) 275 K (b) 325 K (c) 250 K (d) 380 K

Ans. ***(c)***

The efficiency of Carnot engine is defined as the ratio of work done to the heat supplied i.e.

$$\eta=\frac{\text{Work done}}{\text{Heat supplied}}=\frac{W}{Q_1}=\frac{Q_1-Q_2}{Q_1}$$

$$=1-\frac{Q_2}{Q_1}=1-\frac{T_2}{T_1}$$

Here, T_1 is the temperature of source, T_2 is the temperature of sink, Q_1 is heat absorbed and Q_2 heat rejected

As given, $\eta=40\%=\frac{40}{100}=0.4$ and $T_2=300\text{ K}$

So $\quad 0.4=1-\frac{300}{T_1}$

$$\Rightarrow \quad T_1=\frac{300}{1-0.4}=\frac{300}{0.6}$$

$=500\text{ K}$

Let temperature of the source be increased by x K, then efficiency becomes

$$\eta'=40\%+50\%\text{ of }\eta$$

$$=\frac{40}{100}+\frac{50}{100}\times0.4$$

$$=0.4+0.5\times0.4=0.6$$

Hence, $\quad 0.6=1-\frac{300}{500+x}$

$$\Rightarrow \quad \frac{300}{500+x}=0.4$$

$$\Rightarrow \quad 500+x=\frac{300}{0.4}=750$$

$$\therefore \quad x=750-500=250\text{ K}$$

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).

42 An ideal gas heat engine operates in Carnot cycle between 227°C and 127°C. It absorbs 6×10^4 cal of heat at higher temperature. Amount of heat converted to work is **[CBSE AIPMT 2005]**

(a) 2.4×10^4 cal (b) 6×10^4 cal
(c) 1.2×10^4 cal (d) 4.8×10^4 cal

Ans. ***(c)***

According to the Carnot cycle in heat engine

$$\frac{Q_2}{Q_1}=\frac{T_2}{T_1}$$

Given, heat absorbed, $Q_1=6\times10^4$ cal,

Temperature of source,

$$T_1=227+273=500\text{ K}$$

Temperature of sink,

$$T_2=127+273=400\text{ K}$$

$$\therefore \quad \frac{Q_2}{6\times10^4}=\frac{400}{500}$$

$\Rightarrow$ Heat rejected, $Q_2=\frac{4}{5}\times6\times10^4$

$=4.8\times10^4$ cal

Now, heat converted to work

$$W=Q_1-Q_2=6.0\times10^4-4.8\times10^4$$

$=1.2\times10^4$ cal

43 An ideal gas heat engine operates in a Carnot cycle between 227°C and 127°C. It absorbs 6 kcal at the higher temperature. The amount of heat (in kcal) converted into work is equal to **[CBSE AIPMT 2003]**

(a) 1.6 (b) 1.2 (c) 4.8 (d) 3.5

Ans. *(b)*

The efficiency of heat engine is $\eta = 1 - \frac{T_2}{T_1}$

or $\frac{W}{Q_1} = 1 - \frac{T_2}{T_1}$

T_2 = Temperature of sink
T_1 = Temperature of source
W = Work done

Given, Q_1 = heat absorbed from the source

$= 6$ kcal

$$T_1 = 227 + 273 = 500\text{ K}$$

and $T_2 = 127 + 273 = 400\text{ K}$

Hence, $\frac{W}{6} = 1 - \frac{400}{500}$

or $\frac{W}{6} = \frac{100}{500}$

or $W = 1.2$ kcal

Thus, amount of heat converted into work is 1.2 kcal.

44 The efficiency of Carnot engine is 50% and temperature of sink is 500 K. If the temperature of source is kept constant and its efficiency is to be raised to 60%, then the required temperature of the sink will be **[CBSE AIPMT 2002]**

(a) 600 K (b) 500 K (c) 400 K (d) 100 K

Ans. *(c)*

Efficiency of the Carnot engine is given by

$$\eta = 1 - \frac{T_2}{T_1} \quad \text{...(i)}$$

where, T_1 = temperature of source
T_2 = temperature of sink

Given, $\eta = 50\% = 0.5$, $T_2 = 500$ K

Substituting in Eq. (i), we have

$$0.5 = 1 - \frac{500}{T_1} \quad \text{or} \quad \frac{500}{T_1} = 0.5$$

$\therefore$ $T_1 = \frac{500}{0.5} = 1000$ K

Now, the temperature of sink is changed to T_2' and the efficiency becomes 60% i.e., 0.6.

Using Eq. (i), we get

$$0.6 = 1 - \frac{T_2'}{1000}$$

or $\frac{T_2'}{1000} = 1 - 0.6 = 0.4$ or

$$T_2' = 0.4 \times 100 = 400\text{ K}$$

Carnot engine is not a practical engine because many ideal situations have been assumed while designing this engine which cannot be obtained practically.

45 The temperatures of source and sink of a heat engine are 127°C and 27°C respectively. An inventor claims its efficiency to be 26%, then, **[CBSE AIPMT 2001]**

(a) it is impossible
(b) it is possible with high probability
(c) it is possible with low probability
(d) Data is insufficient

Ans. *(a)*

Efficiency of heat engine is,

$$\eta = 1 - \frac{T_2}{T_1} \quad \text{or} \quad \eta = \frac{T_1 - T_2}{T_1}$$

T_2 = temperature of sink
T_1 = temperature of source

Given, $T_1 = 273 + 127 = 400$ K

$$T_2 = 273 + 27 = 300\text{ K}$$

$\therefore$ $\eta = \frac{400 - 300}{400} = \frac{100}{400} = 0.25 = 25\%$

Hence, 26% efficiency is impossible for a given heat engine.

46 An engine takes heat from a reservoir and converts its 1/6 part into work. By decreasing temperature of sink by 62°C, its efficiency becomes double. The temperatures of source and sink must be **[CBSE AIPMT 2000]**

(a) 90°C, 37°C (b) 99°C, 37°C
(c) 372°C, 37°C (d) 206°C, 37°C

Ans. *(b)*

If T_1 is temperature of source and T_2 the temperature of sink, the efficiency of engine

$$\eta = \frac{\text{Work done }(W)}{\text{Heat taken }(Q_1)} = 1 - \frac{T_2}{T_1}$$

$\therefore$ $1 - \frac{T_2}{T_1} = \frac{1}{6}$ ...(i)

When temperature of sink is reduced by 62°C, then temperature of sink

$$T_2' = T_2 - 62$$

$\therefore$ $\eta' = 1 - \frac{T_2'}{T_1}$

As according to question efficiency becomes double

So, $\eta' = 2\eta = \frac{2}{6} = \frac{1}{3}$

$\therefore$ $\frac{1}{3} = 1 - \frac{T_2 - 62}{T_1}$ ...(ii)

From Eq. (i) $\frac{T_2}{T_1} = \frac{5}{6}$ ...(iii)

From Eq. (ii) $\frac{T_2 - 62}{T_1} = \frac{2}{3}$ ...(iv)

Dividing Eq. (iii) by Eq. (iv)

$$\frac{T_2}{T_2 - 62} = \frac{5}{4}$$

$\Rightarrow$ $4T_2 = 5T_2 - 310$

$\Rightarrow$ $T_2 = 310$ K

and from Eq. (iii), we have

$$\frac{310}{T_1} = \frac{5}{6} \Rightarrow T_1 = 372\text{ K}$$

Hence, $T_1 = 372\text{ K} = 372 - 273 = 99°\text{C}$

and $T_2 = 310\text{ K} = 310 - 273 = 37°\text{C}$

As kinetic energy of a gas depends on its atomicity.

47 The efficiency of a Carnot engine operating between temperatures of 100°C and −23°C will be **[CBSE AIPMT 1997]**

(a) $\frac{100 - 23}{273}$ (b) $\frac{100 + 23}{373}$
(c) $\frac{100 + 23}{100}$ (d) $\frac{100 - 23}{100}$

Ans. *(b)*

Efficiency of Carnot engine is given by

$$\eta = 1 - \frac{T_2}{T_1} = \frac{T_1 - T_2}{T_1} \quad \text{...(i)}$$

Given, T_1 = temperature of reservoir

$= 100 + 273 = 373$ K

T_2 = temperature of sink

$= -23 + 273 = 250$ K

Substituting in Eq. (i), we get

$$\therefore \quad \eta = \frac{373 - 250}{373} = \frac{123}{373}$$

$$= \frac{100 + 23}{373}$$