Chapter 12

Thermodynamics

Solutions

SECTION - A

Objective Type Questions

(Zeroth Law of Thermodynamics; Heat, Internal Energy and Work)

1. In thermodynamics the Zeroth law is related to

   (1) Work done (2) Thermal equilibrium (3) Entropy (4) Diffusion

Sol. Answer (2)

Zeroth law related to thermal equilibrium.

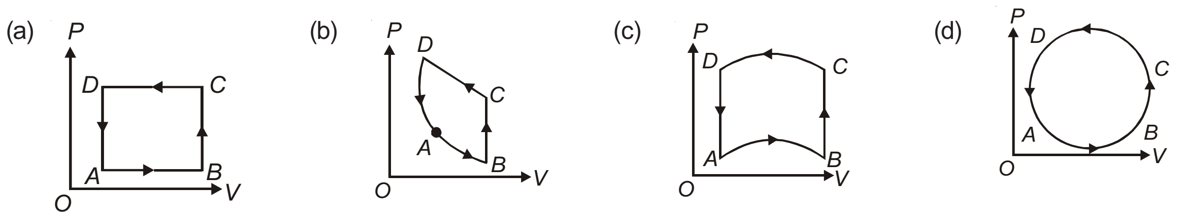
2. For a cyclic process

   (1) $\Delta U = 0$ (2) $\Delta Q = 0$ (3) $W = 0$ (4) Both (1) & (3)

Sol. Answer (1)

Since initial and final points are at same, temperature so $\Delta U = 0$

3. In following figures (a) to (d), variation of volume by change of pressure is shown in figure. The gas is taken along the path *ABCDA*. Change in internal energy of the gas will be



   (1) Positive in all cases from (a) to (d)

   (2) Positive in cases (a), (b) and (c) but zero in case (d)

   (3) Negative in cases (a), (b) and (c) but zero in case (d)

   (4) Zero in all the four cases

Sol. Answer (4)

$\Delta U = 0$ in all cases because cyclic process.

(First Law of Thermodynamics)

4. Which of the following laws of thermodynamics defines internal energy?

(1) Zeroth law (2) Second law (3) First law (4) Third law

Sol. Answer (3)

Internal energy is defined in first law

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

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

5. Select the correct statement for work, heat and change in internal energy.

(1) Heat supplied and work done depend on initial and final states

(2) Change in internal energy depends on the initial and final states only

(3) Heat and work depend on the path between the two points

(4) All of these

Sol. Answer (4)

All statements are correct.

6. Morning breakfast gives 5000 cal to a 60 kg person. The efficiency of person is 30%. The height upto which the person can climb up by using energy obtained from breakfast is

(1) 5 m (2) 10.5 m (3) 15 m (4) 16.5 m

Sol. Answer (2)

$\because \quad W = \eta JQ \quad$ So, $mgh = \eta JQ$

$$h = \frac{\eta JQ}{mgh} = \frac{\left(\frac{30}{100}\right)\times 4.2\times 5000}{60\times 10} = 10.5\text{ m}$$

7. In a thermodynamic process pressure of a fixed mass of a gas is changed in such a manner that the gas releases 20 J of heat when 8 J of work was done on the gas. If the initial internal energy of the gas was 30 J, then the final internal energy will be

(1) 2 J (2) 18 J (3) 42 J (4) 58 J

Sol. Answer (2)

We know by 1st Law of Thermodynamics

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

$-20\text{ J} = \Delta U - 8\text{ J}$

$\because \quad \Delta U = U_{final} - U_{initial}$

$\Delta U = -12\text{ J}$

So, $U_{final} = U_{initial} + \Delta U$

$= 30 + (-12) = 18\text{ J}$

8. A perfect gas goes from state A to state B by absorbing 8×10^5 joule and doing 6.5×10^5 joule of external work. If it is taken from same initial state A to final state B in another process in which it absorbs 10^5 J of heat, then in the second process work done

(1) On gas is 10^5 J (2) On gas is 0.5×10^5 J

(3) By gas is 10^5 J (4) By gas is 0.5×10^5 J

Sol. Answer (2)

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

$8 \times 10^5 = \Delta U + 6.5 \times 10^5$

$1.5 \times 10^5 \text{ J} = \Delta U$

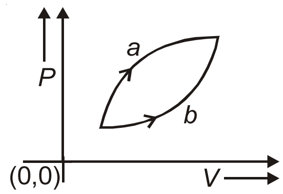
Again using $\Delta Q = \Delta U + W$ for the second case ΔU will stay the same.

Now, $10^5 = 1.5 \times 10^5 + \Delta W$

$-0.5 \times 10^5 = \Delta W$

negative sign indicates work is being done on the gas.

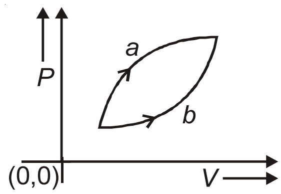
9. Figure shows two processes *a* and *b* for a given sample of gas. If ΔQ_1, ΔQ_2 are the amount of heat absorbed by the system in the two cases; and ΔU_1, ΔU_2 are changes in internal energy respectively, then



(1) $\Delta Q_1 = \Delta Q_2$; $\Delta U_1 = \Delta U_2$ (2) $\Delta Q_1 > \Delta Q_2$; $\Delta U_1 > \Delta U_2$

(3) $\Delta Q_1 < \Delta Q_2$; $\Delta U_1 < \Delta U_2$ (4) $\Delta Q_1 > \Delta Q_2$; $\Delta U_1 = \Delta U_2$

Sol. Answer (4)



$\because$ Initial and final states are same.

$\therefore$ $\Delta U_1 = \Delta U_2$

Area under '*a*' > area under '*b*' *i.e.*, $\Delta W_1 > \Delta W_2$

$\therefore$ Heat absorbed by *a* > heat absorbed by *b*

$\Delta Q_1 > \Delta Q_2$

10. A sample of an ideal gas undergoes an isothermal expansion. If *dQ*, *dU* and *dW* represent the amount of heat supplied, the change in internal energy and the work done respectively, then

(1) dQ = +ve, dU = +ve, dW = +ve (2) dQ = +ve, dU = 0, dW = +ve

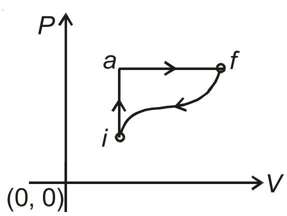
(3) dQ = +ve, dU = +ve, dW = 0 (4) dQ = –ve, dU = –ve, dW = –ve

Sol. Answer (2)

dQ = positive, dU = zero, dW = positive

$\because$ $dQ = dU + dW$

11. In the diagram shown Q_{iaf} = 80 cal and W_{iaf} = 50 cal. If W = –30 cal for the curved path *fi,* value of Q for path *fi,* will be



(1) 60 cal (2) 30 cal (3) –30 cal (4) –60 cal

Sol. Answer (4)

From process *iaf*

Find ΔU first, $\Delta Q = \Delta W + \Delta U$

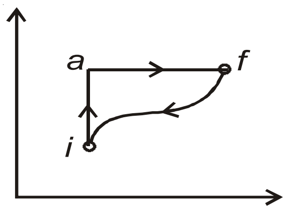
$80 = 50 + \Delta U$

$30 \text{ cal} = \Delta U$

Use this ΔU for process if

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

$\Delta Q = -30 + (-30) = -60$ cal



(Specific Heat Capacity)

12. Select the incorrect relation. (Where symbols have their usual meanings)

(1) $C_P = \dfrac{\gamma R}{\gamma - 1}$ (2) $C_P - C_V = R$ (3) $\Delta U = \dfrac{P_f V_f - P_i V_i}{1-\gamma}$ (4) $C_V = \dfrac{R}{\gamma - 1}$

Sol. Answer (3)

$\Delta U = \dfrac{P_f V_f - P_i V_i}{\gamma - 1}$ is the correct relation.

13. Select the incorrect statement about the specific heats of a gaseous system.

(1) Specific heat at no exchange condition, $C_A = 0$ (2) Specific heat at constant temperature, $C_T = \infty$

(3) Specific heat at constant pressure, $C_P = \dfrac{\gamma R}{\gamma - 1}$ (4) Specific heat at constant volume, $C_V = \dfrac{R}{\gamma}$

Sol. Answer (4)

The correct value of $C_V = \dfrac{R}{\gamma - 1}$

14. A certain amount of an ideal monatomic gas needs 20 J of heat energy to raise its temperature by 10°C at constant pressure. The heat needed for the same temperature rise at constant volume will be

(1) 30 J (2) 12 J (3) 200 J (4) 215.3 J

Sol. Answer (2)

$\Delta Q = nC_P \Delta T$

$20 = nC_P \times 10$ ...(1)

$\Delta U = nC_V \Delta T$

$\Delta U = n\dfrac{C_P}{\gamma}\Delta T$ $\{\because \gamma_{mono} = 5/3\}$

$\Delta U = 12$ J

15. The specific heat of a gas in a polytropic process is given by

(1) $\dfrac{R}{\gamma - 1} + \dfrac{R}{N-1}$ (2) $\dfrac{R}{1-\gamma} + \dfrac{R}{1-N}$ (3) $\dfrac{R}{\gamma - 1} - \dfrac{R}{N-1}$ (4) $\dfrac{R}{1-\gamma} - \dfrac{R}{1-N}$

Sol. Answer (3)

$\because \quad C = C_V + \dfrac{R}{1-N} = \dfrac{R}{\gamma - 1} - \dfrac{R}{N-1}$

16. If during an adiabatic process the pressure of mixture of gases is found to be proportional to square of its absolute temperature. The ratio of C_P/C_V for mixture of gases is

(1) 2 (2) 1.5 (3) 1.67 (4) 2.1

Sol. Answer (1)

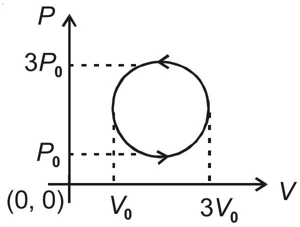
$P \propto T^2$

PT^{-2} = constant compare with $PT^{\left(\frac{\gamma}{1-\gamma}\right)} = \text{constant}$

$$\frac{C_P}{C_V} = \gamma = 2$$

(Thermodynamic State Variables and Equation of State)

17. Work done in the cyclic process shown in figure is



(1) $4P_0V_0$ (2) $-4P_0V_0$ (3) $-\frac{22}{7}P_0V_0$ (4) $-13P_0V_0$

Sol. Answer (3)

Cyclic process is anticlockwise then

Work done = –(Area of P-V graph)

$$W = -\pi R_1 R_2$$

$$= -\pi\left(\frac{3P_0 - P_0}{2}\right) \times \left(\frac{3V_0 - V_0}{2}\right)$$

$$= \frac{-22}{7}P_0V_0$$

18. A gas undergoes a change at constant temperature. Which of the following quantities remain fixed?

(1) Pressure (2) Entropy

(3) Heat exchanged with the system (4) All the above may change

Sol. Answer (4)

When temperature change = 0 then,

$P_1V_1 = P_2V_2$ = constant

Rest may change.

19. For a certain process, pressure of diatomic gas varies according to the relation $P = aV^2$, where a is constant. What is the molar heat capacity of the gas for this process?

(1) $\frac{17R}{6}$ (2) $\frac{6R}{17}$ (3) $\frac{13R}{6}$ (4) $\frac{16R}{7}$

Sol. Answer (1)

$P = aV^2$

$PV^{-2} = a$ Compare with PV^N = constant then $N = -2$

Polytropic process

$$\because \quad C = C_V + \frac{R}{1-N}$$

$$= \frac{R}{\gamma - 1} + \frac{R}{1-N} \qquad \left\{\gamma \text{ of diatomic} = \frac{7}{5}\right\}$$

$$= \frac{R}{\left(\frac{7}{5} - 1\right)} + \frac{R}{1-(-2)}$$

$$= \frac{5R}{2} + \frac{R}{1+2} = \frac{17R}{6}$$

(Thermodynamic Processes)

20. For an adiabatic expansion of an ideal gas the fractional change in its pressure is equal to

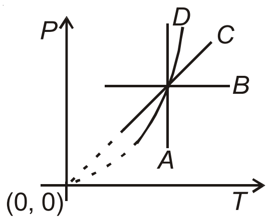
(1) $-\gamma\frac{V}{dV}$ (2) $-\frac{dV}{\gamma V}$ (3) $\frac{dV}{V}$ (4) $-\gamma\frac{dV}{V}$

Sol. Answer (4)

$\because$ PV^γ = constant So, $P \propto V^{-\gamma}$

Then, $\frac{\Delta P}{P} = -\gamma\left(\frac{dV}{V}\right)$

21. Following figure shows *P*-*T* graph for four processes *A*, *B*, *C* and *D*. Select the correct alternative.



(1) *A* – Isobaric process (2) *B* – Adiabatic process

(3) *C* – Isochoric process (4) *D* – Isothermal process

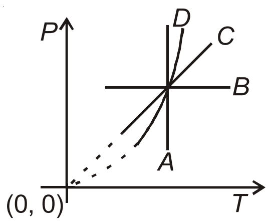
Sol. Answer (3)

(A) Temperature is constant – isothermal

(B) Pressure is constant – Isobaric

(C) Pressure $\propto$ Temperature – Isochoric process

(D) $P^{1-\gamma}T^\gamma$ = constant – Adiabatic process



22. An ideal gas with adiabatic exponent γ is heated at constant pressure. It absorbs *Q* amount of heat. Fraction of heat absorbed in increasing the temperature is

(1) γ (2) $\frac{1}{\gamma}$ (3) $1-\frac{1}{\gamma}$ (4) 2γ

Sol. Answer (2)

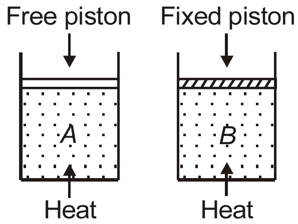
Heat absorbed in increasing temperature = $\Delta U = \Delta Q - \Delta W = nC_V\Delta T$

Fraction of heat absorbed = $\dfrac{\text{Heat absorbed}}{\text{Total heat}}$

$$= \frac{nC_V\Delta T}{nC_P\Delta T}$$

$$= \frac{C_V}{C_P} = \frac{1}{\gamma}$$

23. Two cylinders contain same amount of ideal monatomic gas. Same amount of heat is given to two cylinders. If temperature rise in cylinder A is T_0 then temperature rise in cylinder B will be



(1) $\dfrac{4}{3}T_0$ (2) $2T_0$ (3) $\dfrac{T_0}{2}$ (4) $\dfrac{5}{3}T_0$

Sol. Answer (4)

Cylinder A

Free piston *i.e.*, at constant pressure

Cylinder B

Fixed piston *i.e.*, at constant volume

$\Delta Q = \Delta U$

$nC_P\Delta T = nC_V\Delta T'$

$C_PT_0 = C_V(\Delta T)'$

$$\Delta T' = \frac{C_P}{C_V}T_0 = \gamma T_0 = \frac{5}{3}T_0$$

24. A mass of dry air at N.T.P. is compressed to $\dfrac{1}{32}$ th of its original volume suddenly. If $\gamma = 1.4$, the final pressure would be

(1) 32 atm (2) 128 atm (3) $\dfrac{1}{32}$ atm (4) 150 atm

Sol. Answer (2)

Process carried out suddenly so process is adiabatic.

$\Rightarrow$ $PV^\gamma = K$

$P_1V_1^\gamma = P_2V_2^\gamma$

$$P_2 = P_1\left(\frac{V_1}{V_2}\right)^{\gamma}$$

$$P_2 = (1\,\text{atm})\left(\frac{V_1}{V_1/32}\right)^{7/5}$$

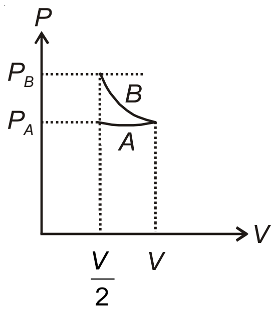
P_2 = 1 atm × $(2^5)^{7/5}$

= 128 atm

25. Two samples *A* and *B* of a gas initially at the same temperature and pressure, are compressed from volume *V* to $\frac{V}{2}$ (*A* isothermally and *B* adiabatically). The final pressure

(1) $P_A > P_B$ (2) $P_A = P_B$ (3) $P_A < P_B$ (4) $P_A = 2P_B$

Sol. Answer (3)



i.e., $P_A < P_B$

26. The adiabatic elasticity of a diatomic gas at NTP is

(1) Zero (2) 1×10^5 N/m^2 (3) 1.4×10^5 N/m^2 (4) 2.75×10^5 N/m^2

Sol. Answer (3)

Adiabatic elasticity = $\gamma P = \frac{7}{5} \times 1.01 \times 10^5$

$= 1.414 \times 10^5$ N/m^2

27. For an isometric process

(1) $\Delta W = -\Delta U$ (2) $\Delta Q = \Delta U$ (3) $\Delta Q = \Delta W$ (4) $\Delta Q = -\Delta U$

Sol. Answer (2)

For an isometric process, (*i.e.*, isochoric) workdone = zero

So $\Delta Q = \Delta U$

28. A mixture of gases at NTP for which γ = 1.5 is suddenly compressed to $\frac{1}{9}$th of its original volume. The final temperature of mixture is

(1) 300°C (2) 546°C (3) 420°C (4) 872°C

Sol. Answer (2)

$$TV^{\gamma-1} = \text{constant}$$

$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

$$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$T_2 = (273\text{ K})\left[\frac{V_1}{V/9}\right]^{1.5-1}$$

$$T_2 = (273\text{ K}) \times 3$$

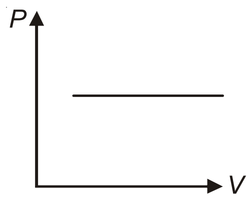
$$= 819\text{ K}$$

$$= 546°\text{C}$$

29. In which process P-V diagram is a straight line parallel to the volume axis?

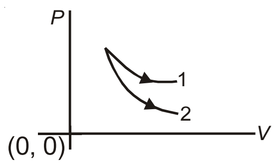
(1) Isochoric (2) Isobaric (3) Isothermal (4) Adiabatic

Sol. Answer (2)



Process having a constant pressure, so isobaric process.

30. The P-V plots for two gases during adiabatic processes are shown in the figure. The graphs 1 and 2 should correspond respectively to



(1) O_2 and He (2) He and O_2 (3) O_2 and CO (4) N_2 and O_2

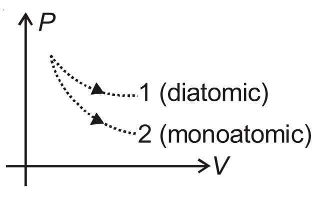
Sol. Answer (1)

PV^{γ} = constant [equation of graphs]

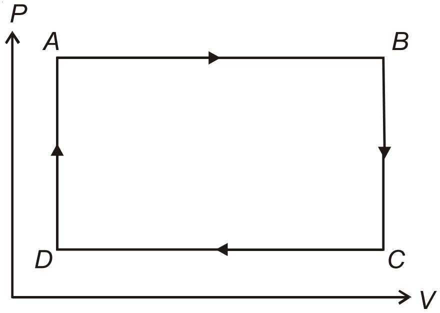
So for more γ less the rate of change or slope of graph and γ is less for diatomic.

So graph 1 for O_2

Graph 2 for He.



31. The pressure and volume of a gas are changed as shown in the P-V diagram in this figure. The temperature of the gas will



(1) Increase as it goes from A to B

(2) Increase as it goes from B to C

(3) Remain constant during these changes

(4) Decrease as it goes from D to A

Sol. Answer (1)

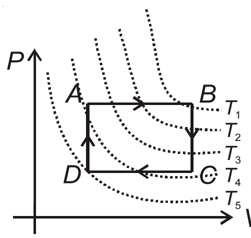
In the process $A \rightarrow B$

Pressure is constant.

$$PV = nRT$$

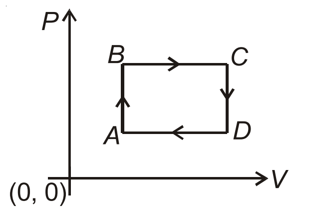
So $V \propto T$

and volume is increasing so temperature also increases.

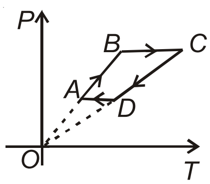


$T_5 > T_4 > T_3 > T_2 > T_1$

32. The figure shows P-V diagram of a thermodynamic cycle. Which corresponding curve is correct?



(1)



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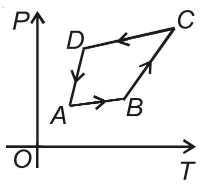

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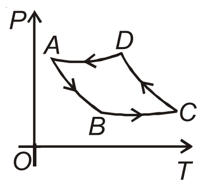
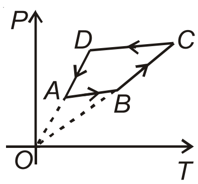


(4)

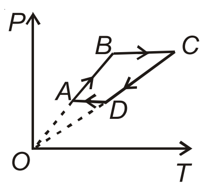


Sol. Answer (1)

$A \rightarrow B$ V = constant

$\because$ $PV = RT$

$$P = \frac{R}{V}T$$



Compare with $y = mx$

P-T graph is a straight line which must passes from origin

$A \rightarrow B$ volume constant, P-increasing, T-increasing.

$B \rightarrow C$ pressure constant, volume - increasing, temperature - increasing

$B \rightarrow C$ P = constant, origin P-T graph is a straightline parallel to v-axis

$C \rightarrow D$ V = constant then

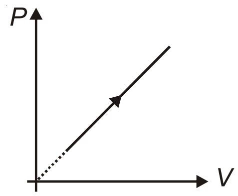
$$P = \frac{R}{V}T$$

P-T graph is straight line must passes from origin

$D \rightarrow A$ P = constant

P-T graph is a straightline parallel to T-axis.

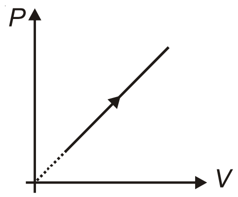
33. During the thermodynamic process shown in figure for an ideal gas



(1) $\Delta T = 0$ (2) $\Delta Q = 0$ (3) $W < 0$ (4) $\Delta U > 0$

Sol. Answer (4)

For a straight P-V graph line $P \propto V$



If pressure increases, volume increases then T also increases $[PV \propto T]$

So $\Delta T \neq 0$

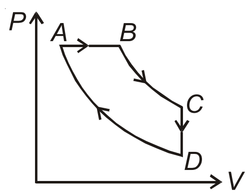
Volume increasing so work is positive, $W > 0$

and temperature also increasing so $\Delta Q > 0$

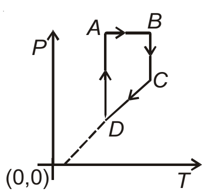
$\because$ $\Delta Q = \Delta U + \Delta W$

So $\Delta U > 0$

34. For P-V diagram of a thermodynamic cycle as shown in figure, process BC and DA are isothermal. Which of the corresponding graphs is correct?



(1)



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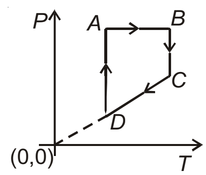

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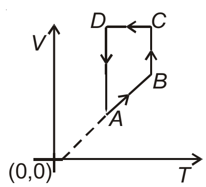
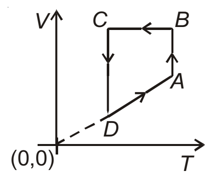
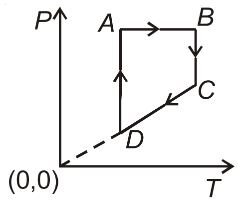


(4)



Sol. Answer (2)

From $A \longrightarrow B$, volume increasing, pressure constant



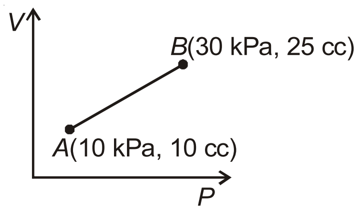
$B \longrightarrow C$, Pressure $\propto \dfrac{1}{\text{Volume}} \Rightarrow$ Temperature constant

Same for $D \longrightarrow A$

$C \longrightarrow D$ pressure decreasing, volume constant

So $P \propto T$

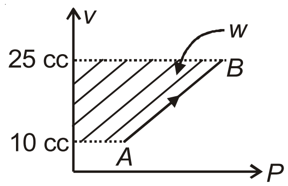
35. Work done for the process shown in the figure is



(1) 1 J (2) 1.5 J (3) 4.5 J (4) 0.3 J

Sol. Answer (4)

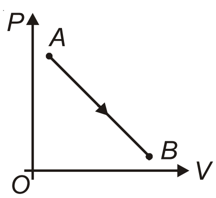
Area under graph and V axis = work done

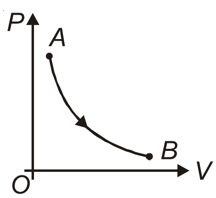


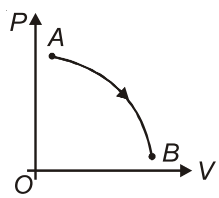
$$= \frac{1}{2} \times (30 + 10) \times 10^3 \times (25 - 10) \times 10^{-6}$$

= 0.3 J

36. During which of the following thermodynamic process represented by PV diagram the heat energy absorbed by system may be equal to area under PV graph?

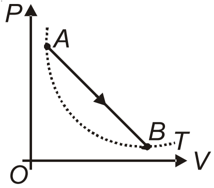
(1) 

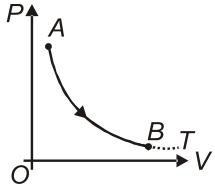
(2) 

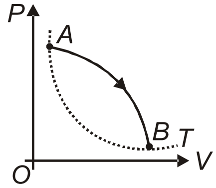
(3) 

(4) All of these

Sol. Answer (4)







$\because$ T is constant in all cases.

37. In a thermodynamic process two moles of a monatomic ideal gas obeys $P \propto V^{-2}$. If temperature of the gas increases from 300 K to 400 K, then find work done by the gas (where R = universal gas constant).

(1) 200 R (2) –200 R (3) –100 R (4) –400 R

Sol. Answer (2)

$P \propto V^{-2}$

PV^2 = constant Compare with PV^N = constant then N = 2

$$W = \mu\left(\frac{R}{1-N}\right)\Delta T$$

$$W = \frac{\mu R}{1-N}(T_2 - T_1)$$

$$= \frac{2 \times R(400-300)}{(1-2)}$$

= –200 R

(Heat Engines, Carnot engine, Refrigerators and Heat Pumps)

38. If the efficiency of a carnot engine is η, then the coefficient of performance of a heat pump working between the same temperatures will be

(1) $1 - \eta$ (2) $\frac{1-\eta}{\eta}$ (3) $\frac{1}{\eta}$ (4) $1 + \frac{1}{\eta}$

Sol. Answer (3)

Coefficient of performance of heat pump = $\frac{1}{\text{efficiency of Carnot engine}} = \frac{1}{\eta}$

39. In a Carnot engine, when heat is absorbed from the source, temperature of source

(1) Increases (2) Decreases

(3) Remains constant (4) Cannot say

Sol. Answer (3)

Even when heat is taken out temperature stays the same. *i.e.*, heat capacity of surface is infinite.

40. A Carnot engine working between 300 K and 600 K has a work output of 800 J per cycle. The amount of heat energy supplied to engine from the source in each cycle is

(1) 800 J (2) 1600 J (3) 3200 J (4) 6400 J

Sol. Answer (2)

W = 800 J

$$\frac{W}{Q} = 1 - \frac{T_2}{T_1}$$

$$\frac{800}{Q} = 1 - \frac{300}{600}$$

1600 J = Q

41. An ideal heat engine operates on Carnot cycle between 227°C and 127°C. It absorbs 6×10^4 cal at the higher temperature. The amount of heat converted into work equals to

(1) 4.8×10^4 cal (2) 3.5×10^4 cal (3) 1.6×10^4 cal (4) 1.2×10^4 cal

Sol. Answer (4)

$$\frac{W}{6\times10^4} = 1 - \frac{400}{500}$$

$W = 1.2 \times 10^4$ cal

42. The maximum possible efficiency of a heat engine is

(1) 100%

(2) $\frac{T_1}{T_2}$

(3) $\frac{T_1}{T_2} + 1$

(4) Dependent upon the temperature of source (T_1) and sink (T_2) and is equal to $\left(1 - \frac{T_2}{T_1}\right)$

Sol. Answer (4)

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

So it depends on source and sink temperature.

43. A frictionless heat engine can be 100% efficient only if its exhaust temperature is

(1) Equal to its input temperature (2) Less than its input temperature

(3) 0 K (4) 0°C

Sol. Answer (3)

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

If exhaust temperature zero kelvin then η = 100%.

44. A reversible engine and an irreversible engine are working between the same temperatures. The efficiency of the

(1) Two engines are same (2) Reversible engine is greater

(3) Irreversible engine is greater (4) Two engines cannot be compared

Sol. Answer (2)

Efficiency of reversible engine is greater, because there is no loss of heat.

45. Which of the following can be coefficient of performance of refrigerator?

(1) 1 (2) 0.5 (3) 9 (4) All of these

Sol. Answer (4)

$$\beta = \frac{1-\eta}{\eta}$$

$$\beta = \frac{1}{\eta} - 1$$

η is less than 1 so $\frac{1}{\eta} > 1$

$\Rightarrow \quad \frac{1}{\eta} - 1 > 0$

$\Rightarrow \quad \beta > 0$

46. The temperature inside and outside a refrigerator are 273 K and 300 K respectively. Assuming that the refrigerator cycle is reversible, for every joule of work done, the heat delivered to the surrounding will be nearly

(1) 11 J (2) 22 J (3) 33 J (4) 50 J

Sol. Answer (1)

$$\eta = 1 - \frac{T_2}{T_1} ; \eta = 1 - \frac{273}{300} = \frac{9}{100}$$

$$\beta = \frac{1-\eta}{\eta} = \frac{100}{9} - 1 = \frac{91}{9} \sim 11\,\text{J}$$

$$\beta = \frac{Q}{W}$$

For W = 1 J

$Q = \beta$

Q = 11 J

47. By opening the door of a refrigerator placed inside a room you

(1) Can cool the room to certain degree

(2) Can cool it to the temperature inside the refrigerator

(3) Ultimately warm the room slightly

(4) Can neither cool nor warm the room

Sol. Answer (3)

Ultimately warm the room because work is being done by the refrigerator.

48. A Carnot engine whose sink is at 300 K has an efficiency of 40%. By how much should the temperature of source be increased to as to increase its efficiency by 50% of original efficiency?

(1) 150 K (2) 250 K (3) 300 K (4) 450 K

Sol. Answer (2)

$$\frac{40}{100} = 1 - \frac{300}{T_1}$$

$T_1 = 500\,\text{K}$

50% increase in efficiency

$$\frac{150}{100} \times 0.4 = 0.6$$

new efficiency = 0.6 = $\frac{60}{100}$

$$\frac{60}{100} = 1 - \frac{300}{T_1}$$

$T_1 = 750\,\text{K}$

Difference between 2 Temperatures = 250 K

(Second Law of Thermodynamics)

49. Entropy of a system decreases
    (1) When heat is supplied to a system at constant temperature
    (2) When heat is taken out from the system at constant temperature
    (3) At equilibrium
    (4) In any spontaneous process

Sol. Answer (2)

Entropy of a system decreases when heat is taken out of the system at constant temperature.

(Miscellaneous)

50. Internal energy of a non-ideal gas depends on
    (1) Temperature (2) Pressure (3) Volume (4) All of these

Sol. Answer (4)

Depends on Temperature, Pressure, Volume.

SECTION - B

Objective Type Questions

(Heat, Internal Energy and Work)

1. A container is filled with 20 moles of an ideal diatomic gas at absolute temperature T. When heat is supplied to gas temperature remains constant but 8 moles dissociate into atoms. Heat energy given to gas is
   (1) $4RT$ (2) $6RT$ (3) $3RT$ (4) $5RT$

Sol. Answer (1)

Heat supplied = $\Delta U = U_{\text{final}} - U_{\text{initial}}$

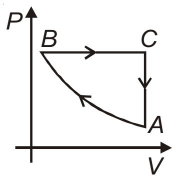
$$U_{\text{initial}} = \frac{5}{2}\times 20\times RT, U_{\text{final}} = \frac{5}{2}\times(20-8)RT + \frac{3}{2}\times(2\times 8)RT$$

$$\Delta U = \frac{1}{2}\times 8\times RT$$

$= 4RT$

$\Rightarrow$ Heat energy given is $4RT$.

2. A cyclic process on an ideal monatomic gas is shown in figure. The correct statement is



   (1) Work done by gas in process AB is more than that in the process BC
   (2) Net heat energy has been supplied to the system
   (3) Temperature of the gas is maximum at state B
   (4) In process CA, heat energy is absorbed by system

Sol. Answer (2)

It is a cyclic system $\Rightarrow \Delta U = 0$

and work done is (+)ive, so heat is supplied to system.

(First Law of Thermodynamics)

3. A triatomic, diatomic and monatomic gas is supplied same amount of heat at constant pressure, then

(1) Fractional energy used to change internal energy is maximum in monatomic gas

(2) Fractional energy used to change internal energy is maximum in diatomic gas

(3) Fractional energy used to change internal energy is maximum in triatomic gases

(4) Fractional energy used to change internal energy is same in all the three gases

Sol. Answer (3)

$$\frac{\Delta U}{\Delta Q} = \frac{nC_V \Delta T}{nC_P \Delta T} = \frac{C_V}{C_P} = \frac{1}{\gamma}$$

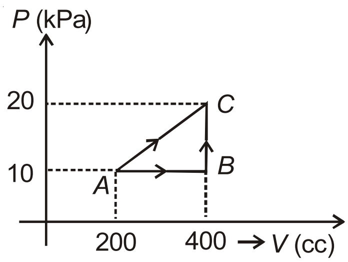
$$\left(\frac{\Delta U}{\Delta Q}\right)_{mono} = \frac{1}{\gamma_{mono}} = \frac{3}{5}$$

$$\left(\frac{\Delta U}{\Delta Q}\right)_{dia} = \frac{1}{\gamma_{dia}} = \frac{5}{7}$$

$$\left(\frac{\Delta U}{\Delta Q}\right)_{tria} = \frac{1}{\gamma_{tria}} = \frac{3}{4}$$

Fractional energy used to change internal energy is maximum in Triatomic gas.

4. If a gas is taken from A to C through B then heat absorbed by the gas is 8 J. Heat absorbed by the gas in taking it from A to C directly is



(1) 8 J (2) 9 J (3) 11 J (4) 12 J

Sol. Answer (2)

When taken through ABC [ΔU + work = heat absorbed]

Heat absorbed = area under graph + ΔU = 8

$$\Delta U = 8 - \frac{10 \times 200}{1000} = 6$$

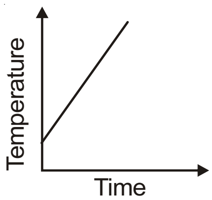
when taken directly to C

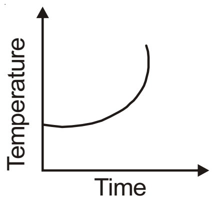
$W + \Delta U = Q$

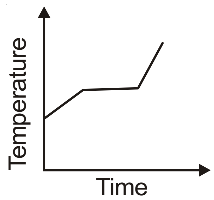
$$\left[\frac{10 \times 200}{1000} + \frac{1}{2} \times \frac{2000}{1000}\right] + 6 = Q \Rightarrow Q = 9 \text{ J}$$

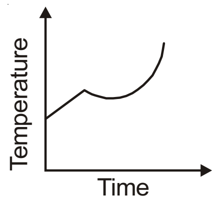
(Specific Heat Capacity)

5. Liquid oxygen at 50 K is heated to 300 K at constant pressure of 1 atm. The rate of heating is constant. Which one of the following graphs represents the variation of temperature with time?

(1) 

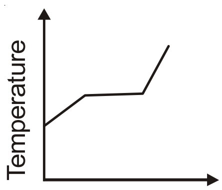
(2) 

(3) 

(4) 

Sol. Answer (3)

Liquid oxygen when heated will observe a rise in temperature as well as change in state one time, which can be represented as



6. 105 calories of heat is required to raise the temperature of 3 moles of an ideal gas at constant pressure from 30°C to 35°C. The amount of heat required in calories to raise the temperature of the gas through the range (60°C to 65°C) at constant volume is $\left(\gamma = \frac{C_p}{C_v} = 1.4\right)$

(1) 50 cal (2) 75 cal (3) 70 cal (4) 90 cal

Sol. Answer (2)

At constant pressure heat absorbed = $\Delta Q = nC_P\Delta T$ ...(1)

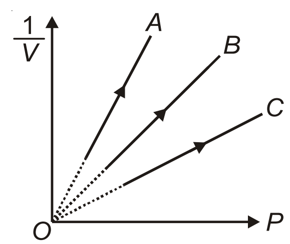
At constant volume heat absorbed = $\Delta U = nC_V\Delta T$ ...(2)

Dividing (1) by (2),

$$\frac{\Delta Q}{\Delta U} = \frac{C_P}{C_V} = \gamma = 1.4 \Rightarrow \frac{105}{\Delta U} = 1.4$$

$\therefore \quad \Delta U_V = 75$ cal

7. Figure shows the isotherms of a fixed mass of an ideal gas at three temperatures T_A, T_B and T_C, then



(1) $T_A > T_B > T_C$ (2) $T_A < T_B < T_C$ (3) $T_B < T_A < T_C$ (4) $T_A = T_B = T_C$

Sol. Answer (2)

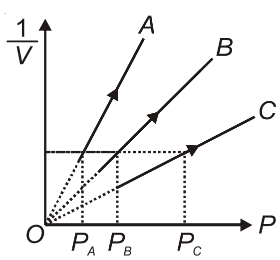
$\because \quad PV = RT$

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

$\because$ For constant $\frac{1}{V}$ So, $P \propto T$

$\because \quad P_C > P_B > P_A$ then

$T_C > T_B > T_A$



8. A gas may expand either adiabatically or isothermally. A number of P–V curves are drawn for the two processes over different range of pressure and volume. It will be found that

(1) An adiabatic curve and an isothermal curve may intersect

(2) Two adiabatic curves do not intersect

(3) Two isothermal curves do not intersect

(4) All of these

Sol. Answer (4)

Slope for isothermal and adiabatic are not same so they will intersect.

(Thermodynamic State Variables and Equation of State)

9. A hydrogen cylinder is designed to withstand an internal pressure of 100 atm. At 27°C, hydrogen is pumped into the cylinder which exerts a pressure of 20 atm. At what temperature does the danger of explosion first sets in?

(1) 500 K (2) 1500 K (3) 1000 K (4) 2000 K

Sol. Answer (2)

Constant volume process

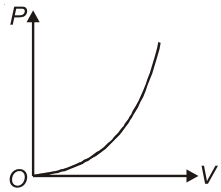
$PV = nRT$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{20}{300} = \frac{100}{T_2}$$

$T_2 = 1500$ K

10. The variation of pressure P with volume V for an ideal diatomic gas is parabolic as shown in the figure. The molar specific heat of the gas during this process is



(1) $\frac{9R}{5}$ (2) $\frac{17R}{6}$ (3) $\frac{3R}{4}$ (4) $\frac{8R}{5}$

Sol. Answer (2)

$P = aV^{-2}$ So, PV^2 = constant then $N = 2$

$$C = \frac{R}{\gamma - 1} - \frac{R}{1 - N} \qquad \because \gamma = 1.4$$

$$C = \frac{17R}{6}$$

11. When 1 kg of ice at 0°C melts to water at 0° C, the resulting change in its entropy, taking latent heat of ice to be 80 cal/°C is

(1) 293 cal/K (2) 273 cal/K (3) 8×10^4 cal/K (4) 80 cal/K

Sol. Answer (1)

$\because$ Change in entropy= $\dfrac{\Delta Q}{T} = \dfrac{m.L_f}{T}$

$$\Delta S = \frac{1000 \times 80}{273} = 293 \text{ cal/K}$$

(Thermodynamic Processes)

12. For an isobaric process, the ratio of ΔQ (amount of heat supplied) to the ΔW (work done by the gas) is $\left(\gamma = \dfrac{C_P}{C_V}\right)$

(1) γ (2) $\gamma - 1$ (3) $\dfrac{\gamma}{\gamma+1}$ (4) $\dfrac{\gamma}{\gamma-1}$

Sol. Answer (4)

For isobaric process $\Delta Q = nC_p\Delta T$ and $\Delta W = nR\Delta T$

So, $\dfrac{\Delta Q}{\Delta W} = \dfrac{C_P}{R} = \dfrac{C_P}{C_P - C_V} = \dfrac{1}{1 - \dfrac{C_V}{C_P}} = \dfrac{\gamma}{\gamma - 1}$ $\left[\because \dfrac{C_P}{C_V} = \gamma\right]$

13. 3 moles of an ideal gas are contained within a cylinder by a frictionless piston and are initially at temperature T. The pressure of the gas remains constant while it is heated and its volume doubles. If R is molar gas constant, the work done by the gas in increasing its volume is

(1) $\dfrac{3}{2}RT\ln 2$ (2) $3RT \ln 2$ (3) $\dfrac{3}{2}RT$ (4) $3RT$

Sol. Answer (4)

$W = P\Delta V$

$= PV$

$= nRT$

$= 3RT$

14. Two moles of a gas at temperature T and volume V are heated to twice its volume at constant pressure. If $\dfrac{C_p}{C_v} = \gamma$ then increase in internal energy of the gas is

(1) $\dfrac{RT}{\gamma-1}$ (2) $\dfrac{2RT}{\gamma-1}$ (3) $\dfrac{2RT}{3(\gamma-1)}$ (4) $\dfrac{2T}{\gamma-1}$

Sol. Answer (2)

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

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

$$\frac{\gamma}{\gamma-1}\Delta W - \Delta W = \Delta U$$

$$\Delta U = \Delta W\left(\frac{1}{\gamma-1}\right) = \frac{(P.\Delta V)}{\gamma-1} = \frac{nRT}{\gamma-1} = \frac{2RT}{\gamma-1}$$

15. To an ideal triatomic gas 800 cal heat energy is given at constant pressure. If vibrational mode is neglected, then energy used by gas in work done against surroundings is

(1) 200 cal (2) 300 cal (3) 400 cal (4) 60 cal

Sol. Answer (1)

Heat at constant pressure

$\Delta Q = nC_P\Delta T$

Heat for doing work

$\Delta W = nR\Delta T$

Then $\dfrac{\Delta W}{\Delta Q} = \dfrac{nR\Delta T}{nC_P\Delta T}$

$$\frac{\Delta W}{800} = \left(\frac{\gamma - 1}{\gamma}\right)$$

$$\frac{\Delta W}{800} = 1 - \frac{1}{\gamma}$$

$$\frac{\Delta W}{800} = 1 - \frac{3}{4}$$

ΔW = 200 cal

16. A closed cylindrical vessel contains N moles of an ideal diatomic gas at a temperature T. On supplying heat, temperature remains same, but n moles get dissociated into atoms. The heat supplied is

(1) $\frac{5}{2}(N-n)RT$ (2) $\frac{5}{2}nRT$ (3) $\frac{1}{2}nRT$ (4) $\frac{3}{2}nRT$

Sol. Answer (3)

Heat supplied = $\Delta U = U_{\text{final}} - U_{\text{initial}}$

Total internal energy initially = $\frac{5}{2}NRT$ [Only diatomic gas is present]

Total internal energy when

'n' moles get dissociated = $\frac{5}{2}(N-n)RT + \frac{3}{2}(2n)RT$ [diatomic and monoatomic both are present]

$$\Delta U = \left\{\frac{5}{2}(N-n)RT + \frac{3}{2}(2n)RT\right\} - \frac{5}{2}NRT$$

Solving this we get

$$\Delta U = \frac{1}{2}nRT$$

$\therefore$ Heat supplied is $\frac{1}{2}nRT$.

17. An ideal monatomic gas at 300 K expands adiabatically to 8 times its volume. What is the final temperature?

(1) 75 K (2) 300 K (3) 560 K (4) 340 K

Sol. Answer (1)

Adiabatic expansion

γ for monoatomic gas $= \frac{5}{3}$

$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

$$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$= 300\left(\frac{V_1}{8V_1}\right)^{5/3} = \frac{300}{4} = 75\text{ K}$$

18. Slope of isotherm for a gas (having $\gamma = \frac{5}{3}$) is 3×10^5 N/m^2. If the same gas is undergoing adiabatic change then adiabatic elasticity at that instant is

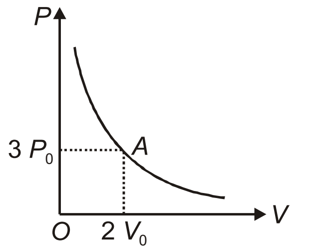
(1) 3×10^5 N/m^2 (2) 5×10^5 N/m^2 (3) 6×10^5 N/m^2 (4) 10×10^5 N/m^2

Sol. Answer (2)

Adiabatic elasticity = γP

$$= \frac{5}{3} \times 3 \times 10^5 = 5 \times 10^5\text{ N/m}^2$$

19. The variation of pressure P with volume V for an ideal monatomic gas during an adiabatic process is shown in figure. At point A the magnitude of rate of change of pressure with volume is



(1) $\frac{3P_0}{5V_0}$ (2) $\frac{5P_0}{3V_0}$ (3) $\frac{3P_0}{2V_0}$ (4) $\frac{5P_0}{2V_0}$

Sol. Answer (4)

PV^γ = constant

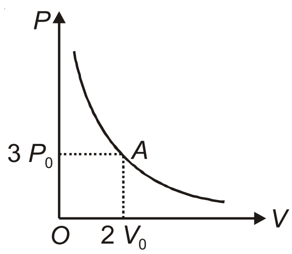
$P \propto V^{-\gamma}$

$$\frac{dP}{P} = -\gamma\frac{dV}{V}$$

$$\frac{dP}{dV} = \gamma\frac{P}{V}$$

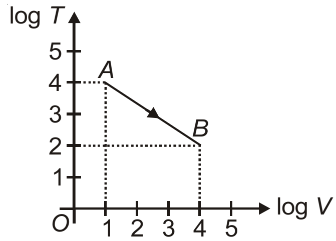
$$= \frac{5}{3} \times \frac{3P_0}{2V_0}$$

$$= \frac{5P_0}{2V_0}$$



Then $\left(\frac{dP}{dV}\right) = \frac{5P_0}{2V_0}$

20. Figure shows, the adiabatic curve on a log T and log V scale performed on ideal gas. The gas is



(1) Monatomic (2) Diatomic

(3) Polyatomic (4) Mixture of monatomic and diatomic

Sol. Answer (1)

$TV^{\gamma-1} = K$

$\log T + (\gamma - 1)\log V = 0$

$\log T = -(\gamma - 1)\log V$

$y = -(\gamma - 1)x$

$\frac{y}{x} = -(\gamma - 1) = \text{ slope } = \frac{2-4}{4-1}$

$\Rightarrow \; -(\gamma - 1) = -\frac{2}{3}$

$\gamma = \frac{5}{3}$

$\therefore$ Monoatomic.

21. A diatomic gas undergoes a process represented by $PV^{1.3}$ = constant. Choose the incorrect statement

(1) The gas expands by absorbing heat from the surroundings

(2) The gas cools down during expansion

(3) The work done by surroundings during expansion of the gas is negative

(4) None of these

Sol. Answer (4)

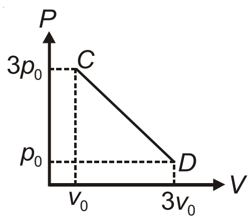
$PV^{1.3} = K$

$W = \frac{P_2V_2 - P_1V_1}{1-N}$ $\because$ $N > 1$, so W is negative.

Heat supplied by surrounding heat goes to do work.

$\therefore$ Down when expands.

22. The process CD is shown in the diagram. As system is taken from C to D, what happens to the temperature of the system?



(1) Temperature first decreases and then increases (2) Temperature first increases and then decreases

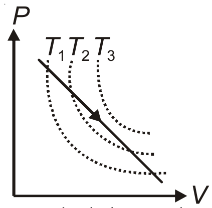
(3) Temperature decreases continuously (4) Temperature increases continuously

Sol. Answer (2)

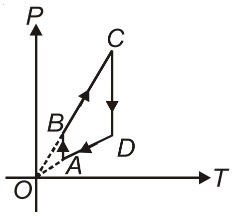
$T_3 > T_2 > T_1$

So from $C \rightarrow D$

Temperature first increases then decreases.



23. A P-T graph is shown for a cyclic process. Select correct statement regarding this



(1) During process CD, work done by gas is negative

(2) During process AB, work done by the gas is positive

(3) During process BC internal energy of system increases

(4) During process BC internal energy of the system decreases

Sol. Answer (3)

In process BC (isochoric process) where ΔT is (+)ve.

So $\Delta U = nC_V\Delta T$

$\because$ ΔT is positive $\Rightarrow$ U increases

24. An ideal gas of volume V and pressure P expands isothermally to volume 16 V and then compressed adiabatically to volume V. The final pressure of gas is [γ = 1.5]

(1) P (2) $3P$ (3) $4P$ (4) $6P$

Sol. Answer (3)

Isothermal expansion

$P_1V_1 = P_2V_2$

$PV = 16\ V \times P'$

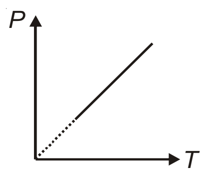
$\frac{P}{16} = P'$

$P_1V_1^\gamma = P_2V_2^\gamma$ [adiabatic compression]

$P'(16\ V)^{1.5} = P''\ (V)^{1.5}$

$\frac{P}{16} \times 16^{1.5} = P'' = 4P$

25. The pressure P of an ideal diatomic gas varies with its absolute temperature T as shown in figure. The molar heat capacity of gas during this process is [R is gas constant]



(1) 1.7 R (2) 3.25 R (3) 2.5 R (4) 4.2 R

Sol. Answer (3)

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

26. An ideal gas expands according to the law P^2V = constant. The internal energy of the gas

(1) Increases continuously
(2) Decreases continuously
(3) Remain constant
(4) First increases and then decreases

Sol. Answer (1)

$P^2V = K$

or $PV^{-2} = K$

$N = -2$

$C = C_V + \frac{R}{1-N}$ = positive quantity

$C > 0$

$W > 0$ [gas is expanding]

$\because$ $PV^{-2} = K$ so TV^{-3} = constant

$\Rightarrow$ T will increases if V increases.

$\Rightarrow$ $\Delta T > 0$

So $\Delta U = \eta C \Delta T > 0$

It will increase continuously.

27. Neon gas of a given mass expands isothermally to double volume. What should be the further fractional decrease in pressure, so that the gas when adiabatically compressed from that state, reaches the original state?

(1) $1 - 2^{-2/3}$
(2) $1 - 3^{1/3}$
(3) $2^{1/3}$
(4) $3^{2/3}$

Sol. Answer (1)

$P_1V_1 = P_2V_2$ [for isothermal]

$PV = P' \times 2V$

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

$P_1V_1^{\gamma} = P_2V_2^{\gamma}$ [for adiabatic]

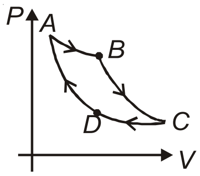
$\frac{P}{2} \times (2V)^{5/3} = P_2(V)^{5/3}$ [γ for neon = 5/3]

$P = P_2 . (2)^{-2/3}$

Fractional decrease $= \frac{P_2 - P}{P_2} = \frac{P_2 - P_2.(2)^{-2/3}}{P_2} = 1 - 2^{-2/3}$

(Heat Engines, Carnot engine, Refrigerators and Heat Pumps)

28. Carnot cycle is plotted in *P-V* graph. Which portion represents an isothermal expansion?



(1) *AB* (2) *BC* (3) *CD* (4) *DA*

Sol. Answer (1)

AB is isothermal expansion. *BC* is adiabatic expansion

CD is isothermal compression

ΔA = adiabatic compression.

29. Efficiency of a heat engine working between a given source and sink is 0.5. Coefficient of performance of the refrigerator working between the same source and the sink will be

(1) 1 (2) 0.5 (3) 1.5 (4) 2

Sol. Answer (1)

$$\eta = \frac{1}{1+\beta}$$

$$0.5 = \frac{1}{1+\beta} \Rightarrow \beta = 1$$

30. A heat engine rejects 600 cal to the sink at 27°C. Amount of work done by the engine will be

(Temperature of source is 227°C & J = 4.2 J/cal)

(1) 1680 J (2) 840 J (3) 2520 J (4) None of these

Sol. Answer (1)

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

$$1-\frac{300}{500} = \frac{W}{Q_1}$$

$$\frac{W}{Q_1} = \frac{2}{5}$$

$$Q_1 = \frac{5W}{2}$$

$\because \; W = Q_1 - Q_2$

Then $Q_2 = Q_1 - W$

$$Q_2 = \frac{5W}{2} - W = \frac{3W}{2}$$

Then $W = \frac{2Q_2}{3} = \frac{2\times 600}{3}$ = 400 cal = 400 × 4.2 J = 1680 J

SECTION - C

Previous Years Questions

1. 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]**

(1) 104.3 J (2) 208.7 J (3) 84.5 J (4) 42.2 J

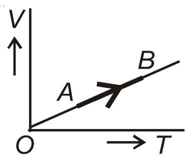
Sol. Answer (2)

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

$\Rightarrow$ $54 \times 4.18 = \Delta U + 1.013 \times 10^5(167.1 \times 10^{-6} - 0)$

$\Rightarrow$ $\Delta U = 208.7$ J

2. The volume (V) of a monatomic 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]**



(1) $\frac{2}{5}$ (2) $\frac{2}{3}$ (3) $\frac{2}{7}$ (4) $\frac{1}{3}$

Sol. Answer (1)

Given process is isobaric, $dQ = nC_p dT$

$$dQ = n\left(\frac{5}{2}R\right)dT$$

$$dW = PdV = nRdT$$

Required ratio $= \dfrac{dW}{dQ} = \dfrac{nRdT}{n\left(\frac{5}{2}R\right)dT} = \dfrac{2}{5}$

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

(1) 26.8% (2) 20% (3) 12.5% (4) 6.25%

Sol. Answer (1)

Efficiency of ideal heat engine, $\eta = \left(1 - \frac{T_2}{T_1}\right)$

T_2 : Sink temperature

T_1 : Source temperature

$$\%\eta = \left(1 - \frac{T_2}{T_1}\right) \times 100 = \left(1 - \frac{273}{373}\right) \times 100$$

$$= \left(\frac{100}{373}\right) \times 100 = 26.8\%$$

4. 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]

(1) 1 J (2) 90 J

(3) 99 J (4) 100 J

Sol. Answer (2)

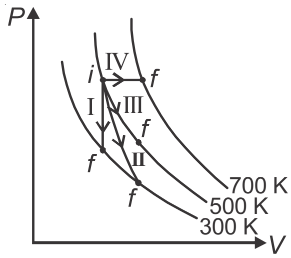
$$\beta = \frac{1-\eta}{\eta} = \frac{1-\frac{1}{10}}{\frac{1}{10}} = \frac{\frac{9}{10}}{\frac{1}{10}}$$

$\beta = 9$

$\beta = \frac{Q_2}{W}$

$Q_2 = 9 \times 10 = 90$ J

5. Thermodynamic processes are indicated in the following diagram.



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

[NEET-2017]

(1) P $\rightarrow$ a, Q $\rightarrow$ c, R $\rightarrow$ d, S $\rightarrow$ b (2) P $\rightarrow$ c, Q $\rightarrow$ a, R $\rightarrow$ d, S $\rightarrow$ b

(3) P $\rightarrow$ c, Q $\rightarrow$ d, R $\rightarrow$ b, S $\rightarrow$ a (4) P $\rightarrow$ d, Q $\rightarrow$ b, R $\rightarrow$ a, S $\rightarrow$ c

Sol. Answer (2)

Process, I = Isochoric

II = Adiabatic

III = Isothermal

IV = Isobaric

6. One mole of an ideal monatomic gas undergoes a process described by the equation PV^3 = constant. The heat capacity of the gas during this process is **[NEET (Phase-2)-2016]**

(1) $\frac{3}{2}R$ (2) $\frac{5}{2}R$

(3) $2R$ (4) R

Sol. Answer (4)

PV^3 = constant polytropic process with $n = 3$

$$C = C_V + \frac{R}{1-n}$$

$$= \frac{R}{r-1} + \frac{R}{1-n} = \frac{R}{\frac{5}{3}-1} + \frac{R}{1-3} = R$$

7. 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 (Phase-2) - 2016]**

(1) $\frac{t_1}{t_1 - t_2}$

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

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

(4) $\frac{t_1 + t_2}{t_1 + 273}$

Sol. Answer (2)

$$K = \frac{Q_2}{W} = \frac{1}{\frac{t_1}{t_2} - 1}$$

$$Q_2 = \frac{t_2 W}{t_1 - t_2}$$

$$Q_1 = Q_2 + W = \frac{t_2 W}{t_1 - t_2} + W$$

$$= \frac{t_1 W}{t_1 - t_2} = \frac{t_1 + 273}{t_1 - t_2}$$

8. 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 J)

[NEET-2016]

(1) 2365 W

(2) 2.365 W

(3) 23.65 W

(4) 236.5 W

Sol. Answer (4)

T_2 = 4°C = 277 K

T_1 = 303 K

Q_2 = 600 cal

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

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

W = 236.5 W

9. 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]**

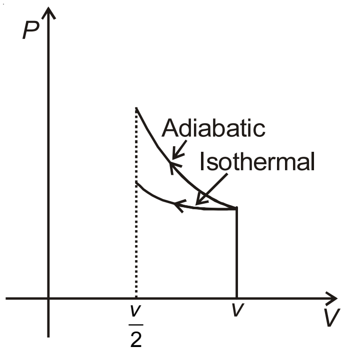
(1) Which of the case (whether compression through isothermal or through adiabatic process) requires more work will depend upon the atomicity of the gas

(2) Compressing the gas isothermally will require more work to be done

(3) Compressing the gas through adiabatic process will require more work to be done

(4) Compressing the gas isothermally or adiabatically will require the same amount of work

Sol. Answer (3)



10. 4.0 g of a gas occupies 22.4 litres at NTP. The specific heat capacity of the gas at constant volume is 5.0 JK^{-1} mol^{-1}. If the speed of sound in this gas at NTP is 952 ms^{-1}, then the heat capacity at constant pressure is (Take gas constant R = 8.3 JK^{-1} mol^{-1}) **[Re-AIPMT-2015]**

(1) 8.5 JK^{-1} mol^{-1} (2) 8.0 JK^{-1} mol^{-1} (3) 7.5 JK^{-1} mol^{-1} (4) 7.0 JK^{-1} mol^{-1}

Sol. Answer (2)

11. 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 **[Re-AIPMT-2015]**

(1) 21°C (2) 31°C (3) 41°C (4) 11°C

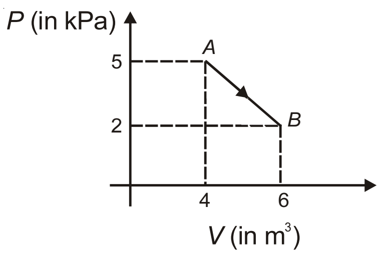
Sol. Answer (2)

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

(1) Isothermal (2) Adiabatic (3) Isobaric (4) Isochoric

Sol. Answer (2)

13. One mole of an ideal diatomic gas undergoes a transition from A to B along a path AB as shown in the figure



The change in internal energy of the gas during the transition is **[AIPMT-2015]**

(1) –12 kJ (2) 20 kJ

(3) –20 kJ (4) 20 J

Sol. Answer (3)

$$\Delta U = nC_V\Delta T$$

$$= n\left(\frac{R}{\gamma-1}\right)(T_2 - T_1)$$

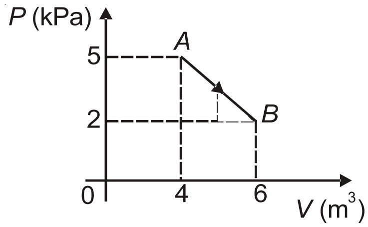
$$= \frac{n[RT_2 - RT_1]}{\gamma-1}$$

$$= \frac{n(P_2V_2 - P_1V_1)}{\gamma-1}$$

$$= \frac{1(2\times6\times10^3 - 5\times4\times10^3)}{7/5-1}$$

$$= \frac{-8\times10^3}{2/5} = -20\times10^3$$

$$= -20 \text{ kJ}$$



14. 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 **[AIPMT-2015]**

(1) 1 J (2) 100 J

(3) 99 J (4) 90 J

Sol. Answer (4)

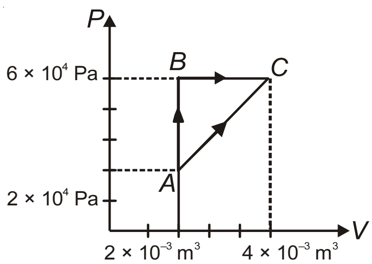
$$\because \quad \beta = \frac{1}{\eta} - 1 = \frac{Q_2}{W}$$

$$\frac{1}{(1/10)} - 1 = \frac{Q_2}{10}$$

$$(10-1) = \frac{Q_2}{10}$$

$$Q_2 = 90 \text{ J}$$

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



(1) 300 J (2) 380 J

(3) 500 J (4) 460 J

Sol. Answer (4)

In process ABC

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

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

$\Delta U = (400 + 100) - (6 \times 10^4 \times 2 \times 10^{-3})$

$\Delta U = 500 - 120$

$\Delta U = 380$ J

In process AC

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

$$= 380 + \left[\frac{1}{2} \times (2 \times 10^4 + 6 \times 10^4) \times 2 \times 10^{-3}\right]$$

$= 380 + 80$

$= 460$ J

16. A monoatomic gas at a pressure P, having a volume V expands isothermally to a volume $2V$ and then adiabatically to a volume $16V$. the final pressure of the gas is: (take $\gamma = 5/3$) **[AIPMT-2014]**

(1) $64P$ (2) $32P$ (3) $P/64$ (4) $16P$

Sol. Answer (3)

In isothermal process

$P_1V_1 = P_2V_2$

$PV = P_2(2V)$

$$P_2 = \frac{P}{2} \qquad ...(1)$$

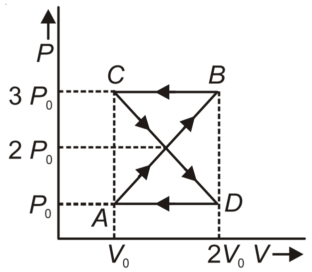
In adiabatic process

$P_2V_2^{\gamma} = P_3V_3^{\gamma}$

$$\left(\frac{P}{2}\right)(2V)^{\gamma} = P_3(16V)^{\gamma}$$

$$P_3 = \frac{P}{2}\left(\frac{2v}{16V}\right)^{\gamma} = \frac{P}{2}\left(\frac{1}{8}\right)^{5/3} = \frac{P}{64}$$

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

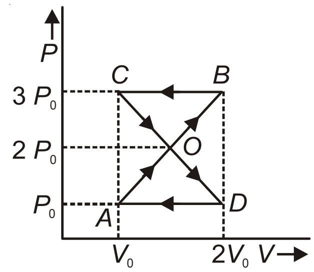


(1) $P_0 V_0$ (2) $2P_0 V_0$

(3) $\frac{P_0V_0}{2}$ (4) Zero

Sol. Answer (4)

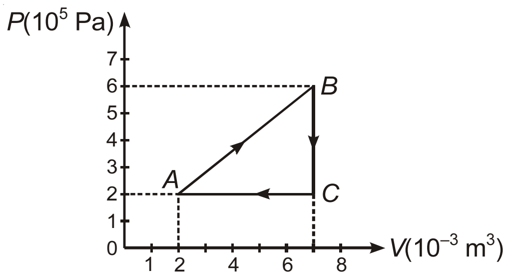
W = area enclosed by $AODA$ + by area enclosed $OBCO$



$$= \left[\frac{1}{2}\times(2V_0 - V_0)\times P_0\right] + \left[-\frac{1}{2}(2V_0 - V_0)P_0\right]$$

$= 0$ $\begin{cases} AODA \text{ is a clockwise} \\ \text{while } DBCO \text{ is anticlockwise} \end{cases}$

18. 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]

(1) 1000 J (2) Zero (3) – 2000 J (4) 2000 J

Sol. Answer (1)

$\because$ Cyclic curve is clockwise *i.e.*, W = +ve

W = area enclosed

$$= \frac{1}{2}\times 5\times 10^{-3}\times 4\times 10^5$$

= 1000 J

19. The molar specific heats of an ideal gas at constant pressure and volume are denoted by C_p and C_v respectively. If $\gamma = \frac{C_p}{C_v}$ and R is the universal gas constant, then C_v is equal to **[NEET-2013]**

(1) $\frac{R}{(\gamma - 1)}$ (2) $\frac{(\gamma - 1)}{R}$ (3) γR (4) $\frac{1+\gamma}{1-\gamma}$

Sol. Answer (1)

$$\gamma = \frac{C_p}{C_v}$$

We know $C_p - C_v = R$

So $C_v = \frac{R}{\gamma - 1}$

20. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its temperature. The ratio of $\frac{C_p}{C_v}$ for the gas is: **[NEET-2013]**

(1) 2 (2) $\frac{5}{3}$ (3) $\frac{3}{2}$ (4) $\frac{4}{3}$

Sol. Answer (3)

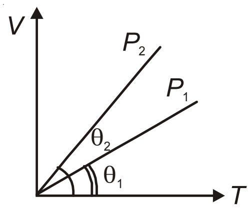
$P \propto T^3$

PT^{-3} = constant

Compare with $PT^{\left(\frac{\gamma}{1-\gamma}\right)} = \text{constant}$

Then, $\frac{\gamma}{1-\gamma} = -3 \Rightarrow \gamma = \frac{3}{2}$

21. In the given (V – T) diagram, what is the relation between pressures P_1 and P_2? **[NEET-2013]**



(1) $P_2 > P_1$ (2) $P_2 < P_1$

(3) Cannot be predicted (4) $P_2 = P_1$

Sol. Answer (2)

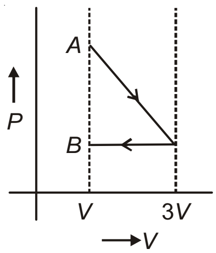
$\because$ $PV = RT$

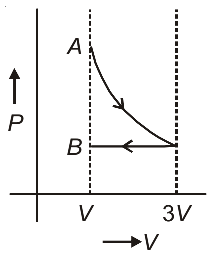
$\frac{V}{T} = \frac{R}{P} = \tan\theta$ $\left\{\because \text{ Slope of } V\text{-}T \text{ graph } m = \tan\theta = \frac{V}{T}\right\}$

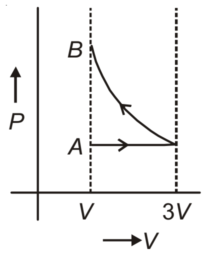
i.e., $P = \frac{1}{\tan\theta}$

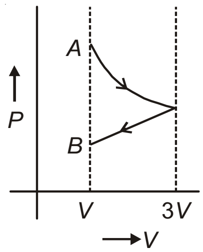
$\theta_2 > \theta_1$ so $\tan\theta_2 > \tan\theta_1$ $\Rightarrow P_2 < P_1$, then $P_2 < P_1$

22. 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 **[AIPMT (Prelims)-2012]**

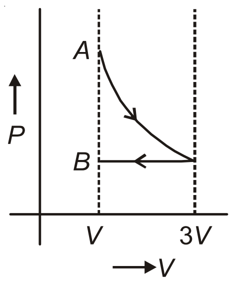
(1) 

(2) 

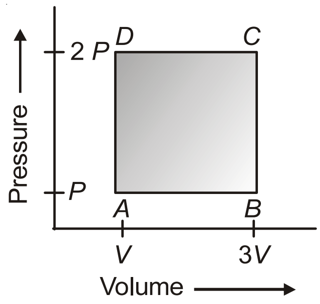
(3) 

(4) 

Sol. Answer (2)



23. A thermodynamic system is taken through the cycle *ABCD* as shown in figure. Heat rejected by the gas during the cycle is **[AIPMT (Prelims)-2012]**

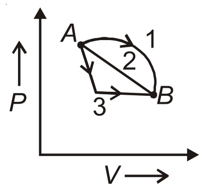


(1) $\frac{1}{2}PV$ (2) PV (3) $2\ PV$ (4) $4\ PV$

Sol. Answer (3)

Heat rejected = workdone by surrounding = area of *PV* graph = $P \times 2V = 2PV$

24. An ideal gas goes from state *A* to state *B* via three different processes as indicated in the *P*-*V* diagram



If Q_1, Q_2, Q_3 indicate the heat absorbed by the gas along the three processes and ΔU_1, ΔU_2, ΔU_3 indicate the change in internal energy along the three processes respectively, then **[AIPMT (Mains)-2012]**

(1) $Q_1 > Q_2 > Q_3$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$

(2) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$

(3) $Q_1 = Q_2 = Q_3$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$

(4) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$

Sol. Answer (1)

$Q_1 > Q_2 > Q_3$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$

25. During an isothermal expansion, a confined ideal gas does –150 J of work against its surroundings. This implies that **[AIPMT (Prelims)-2011]**

(1) 150 J of heat has been added to the gas

(2) 150 J of heat has been removed from the gas

(3) 300 J of heat has been added to the gas

(4) No heat is transferred because the process is isothermal

Sol. Answer (2)

It implies 150 J heat has been removed from the gas.

26. A mass of diatomic gas (γ = 1.4) at a pressure of 2 atmospheres is compressed adiabatically so that its temperature rises from 27°C to 927°C. The pressure of the gas in the final state is **[AIPMT (Mains)-2011]**

(1) 256 atm (2) 8 atm

(3) 28 atm (4) 68.7 atm

Sol. Answer (1)

$P^{1-\gamma}T^{\gamma} = C$ then, $PT^{\left(\frac{\gamma}{1-\gamma}\right)} = \text{constant}$

$$\frac{P_2}{P_1} = \left(\frac{T_1}{T_2}\right)^{\gamma/1-\gamma}$$

$$\frac{P_2}{2} = \left(\frac{300}{1200}\right)^{1.4/1-1.4}$$

$$\frac{P_2}{2} = \left(\frac{1}{4}\right)^{-7/2}$$

$$P_2 = 2^6 = 256 \text{ atm}$$

27. 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? **[AIPMT (Prelims)-2010]**

(1) $\Delta U = -\Delta W$, in a isothermal process
(2) $\Delta U = -\Delta W$, in a adiabatic process
(3) $\Delta U = \Delta W$, in a isothermal process
(4) $\Delta U = \Delta W$, in a adiabatic process

Sol. Answer (2)

In adiabatic process $Q = 0$

So $\Delta U = -\Delta W$ $[\because \Delta Q = \Delta W + \Delta U]$

28. If C_p and C_v denote the specific heats (per unit mass) of an ideal gas of molecular weight M, where R is the molar gas constant **[AIPMT (Mains)-2010]**

(1) $C_p - C_v = R/M^2$
(2) $C_p - C_v = R$
(3) $C_p - C_v = R/M$
(4) $C_p - C_v = MR$

Sol. Answer (3)

$$C_p - C_v = \frac{R}{M}$$

Because C_p & C_v are given per unit mass

And $C_p - C_v = R$ is for 1 mole

So here we use R/M where M is molecular mass.

29. A monoatomic gas at pressure P_1 and V_1 is compressed adiabatically to $\frac{1}{8}$th its original volume. What is the final pressure of the gas? **[AIPMT (Mains)-2010]**

(1) $64\ P_1$
(2) P_1
(3) $16\ P_1$
(4) $32\ P_1$

Sol. Answer (4)

$\because$ $PV^{\gamma} = \text{constant}$

$$P_2 = P_1\left(\frac{V_1}{V_2}\right)^{\gamma} = P(8)^{5/3} = 32P_1$$

30. In thermodynamic processes which of the following statements is not true? **[AIPMT (Prelims)-2009]**

(1) In an isochoric process pressure remains constant

(2) In an isothermal process the temperature remains constant

(3) In an adiabatic process PV^{γ} = constant

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

Sol. Answer (1)

In isochoric processes volume remains constant.

31. The internal energy change in a system that has absorbed 2 Kcals of heat and done 500 J of work is **[AIPMT (Prelims)-2009]**

(1) 6400 J (2) 5400 J

(3) 7900 J (4) 8900 J

Sol. Answer (3)

$2 \times 4.2 \times 1000 = dU + 500 \Rightarrow dU = 7900$ J

32. If Q, E and W denote respectively the heat added, change in internal energy and the work done in a closed cycle process, then **[AIPMT (Prelims)-2008]**

(1) $Q = 0$ (2) $W = 0$ (3) $Q = W = 0$ (4) $E = 0$

Sol. Answer (4)

E = change in U and in cyclic process $\Delta U = 0$

$\Rightarrow E = 0$

33. At 10°C the value of the density of a fixed mass of an ideal gas divided by its pressure is x. At 110°C this ratio is **[AIPMT (Prelims)-2008]**

(1) $\frac{283}{383}x$ (2) x (3) $\frac{383}{283}x$ (4) $\frac{10}{110}x$

Sol. Answer (1)

$\frac{\rho}{P} = x$ at 10°C

$\frac{M}{PV} = x$

$\frac{\text{Molecular mass} \times \text{number of moles}}{R \times T} = x$

$\Rightarrow \frac{1}{T} \propto x$

$\frac{383}{283} = \frac{x}{x'}$

$x' = \frac{283}{383}x$

34. An engine has an efficiency of 1/6. When the temperature of sink is reduced by 62°C, its efficiency is doubled. Temperature of the source is **[AIPMT (Prelims)-2007]**

(1) 99°C (2) 124°C (3) 37°C (4) 62°C

Sol. Answer (1)

$$\frac{1}{3}=1-\frac{(T_L-62)}{T_H}$$

$$\frac{1}{3}=1-\frac{5}{6}+\frac{62}{T_H} \qquad \left[\frac{T_L}{T_H}=\frac{5}{6}\right]$$

T_H = 372° K = 99°C

T_L = 37°C

35. 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? **[AIPMT (Prelims)-2006]**

(1) 275 K (2) 325 K

(3) 250 K (4) 380 K

Sol. Answer (3)

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

Where T_2 = Sink Temperature
T_1 = Source Temperature

Temperature of sink is given to be 300 K.

η = 0.4

So $0.4=1-\dfrac{300}{T_1}$

$\Rightarrow$ T_1 = 500 K

Now, η is increased by 50%.

$$\Rightarrow \quad \eta'=\frac{150}{100}\times\eta=\frac{15}{10}\times 0.4=0.6$$

To maintain same sink temperature new source temperature is

$$0.6=1-\frac{300}{T_1}$$

T_1 = 750 K

$\therefore$ Increase in temperature = 750 – 500 = 250 K

36. The molar specific heat at constant pressure of an ideal gas is $\frac{7}{2}R$. The ratio of specific heat at constant pressure to that at constant volume is : **[AIPMT (Prelims)-2006]**

(1) $\frac{7}{5}$ (2) $\frac{8}{7}$

(3) $\frac{5}{7}$ (4) $\frac{9}{7}$

Sol. Answer (1)

$$C_P=\frac{7}{2}R=\frac{\gamma R}{\gamma-1} \quad\Rightarrow\quad \gamma=\frac{7}{5}$$

37. Which of the following processes is reversible ? **[AIPMT (Prelims)-2005]**

(1) Transfer of heat by radiation (2) Electrical heating of a nichrome wire

(3) Transfer of heat by conduction (4) Isothermal compression

Sol. Answer (4)

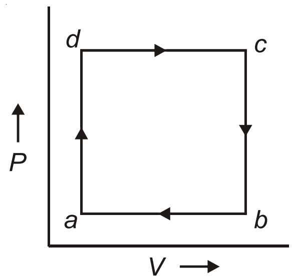
Isothermal compression takes place slowly at constant pressure, also ΔU is zero so it is a reversible process.

38. 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 **[AIPMT (Prelims)-2005]**

(1) 2.4×10^4 cal (2) 6×10^4 cal (3) 1.2×10^4 cal (4) 4.8×10^4 cal

Sol. Answer (3)

39. A system is taken from state *a* to state *c* by two paths *adc* and *abc* as shown in the figure. The internal energy at *a* is U_a = 10 J. Along the path *adc* the amount of heat absorbed δQ_1 = 50 J and the work obtained δW_1 = 20 J whereas along the path *abc* the heat absorbed δQ_2 = 36 J. The amount of work along the path *abc* is



(1) 6 J (2) 10 J (3) 12 J (4) 36 J

Sol. Answer (1)

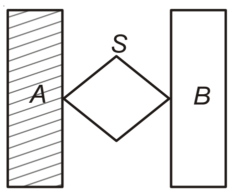
$$dQ_{1\,adc} = 50 = dU_{adc} + 20$$

$$\Rightarrow dU_{adc} = 30 = dU_{abc}$$

$$dQ_{abc} = 36 = 30 + dW_{abc}$$

$$\Rightarrow dW_{abc} = 6 \text{ J}$$

40. Consider two insulated chambers (A, B) of same volume connected by a closed knob, S. 1 mole of perfect gas is confined in chamber A. What is the change in entropy of gas when knob S is opened? R = 8.31 J mol^{-1}K^{-1}.



(1) 1.46 J/K (2) 3.46 J/K (3) 5.46 J/K (4) 7.46 J/K

Sol. Answer (3)

$$\Delta S = 2.303\, nR \log_e \frac{V_2}{V_1}$$

If initially volume is taken as V, then final volume = ZV, as volume of both chambers is given to be same.

$$\Rightarrow \Delta S = 2.303 \times 1 \times 8.31 \times \log_e \frac{2V}{V}$$

$$\Delta S \cong 5.46 \text{ J/K}$$

41. A Carnot engine has efficiency 25%. It operates between reservoirs of constant temperatures with temperature difference of 80°C. What is the temperature of the low-temperature reservoir?

(1) –25°C (2) 25°C (3) –33°C (4) 33°C

Sol. Answer (3)

$$\eta = 1 - \frac{T_L}{T_H}$$

$$\frac{1}{4} = 1 - \frac{T_L}{T_H}$$

$$T_H = \frac{4}{3}T_L$$

Also, $T_H - T_L = 80$

$\Rightarrow$ $T_L = 240$ K = –33°C

42. In an adiabatic change, the pressure and temperature of a monatomic gas are related as $P \propto T^c$, where c equals

(1) $\frac{3}{5}$ (2) $\frac{5}{3}$ (3) $\frac{2}{5}$ (4) $\frac{5}{2}$

Sol. Answer (4)

$$P \propto T^C \Rightarrow PT^{-C} = K$$

And compare with $PT^{\left(\frac{\gamma}{1-\gamma}\right)} = \text{constant}$ [condition from adiabatic process]

Then, $-C = \dfrac{\gamma}{1-\gamma}$

$$C = -\frac{5/3}{1-5/3} = -\frac{5/3}{-2/3} = \frac{5}{2}$$

43. An ideal Carnot engine, whose efficiency is 40%, receives heat at 500 K. If its efficiency is 50%, then the intake temperature for the same exhaust temperature is

(1) 800 K (2) 900 K

(3) 600 K (4) 700 K

Sol. Answer (3)

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

$$\frac{40}{100} = 1 - \frac{T_2}{500}$$

$T_2 = 300$ K

If $\eta = 50\%$

$$\frac{50}{100} = 1 - \frac{300}{T_1}$$

$\Rightarrow$ $T_1 = 600$ K

44. A monatomic gas initially at 18°C is compressed adiabatically to one eighth of its original volume. The temperature after compression will be

(1) 1164 K (2) 144 K (3) 18 K (4) 887.4 K

Sol. Answer (1)

$\because$ $TV^{\gamma-1}$ = constant

$$T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = T_2$$

$291 \times (8)^{2/3} = T_2$

$T_2 = 291 \times 4 = 1164$ K

45. An ideal gas, undergoing adiabatic change, has which of the following pressure temperature relationship?

(1) $P^{\gamma}T^{1-\gamma}$ = constant (2) $P^{1-\gamma}T^{\gamma}$ = constant

(3) $P^{\gamma-1}T^{\gamma}$ = constant (4) $P^{\gamma}T^{\gamma-1}$ = constant

Sol. Answer (2)

$$PV^{\gamma} = \text{constant}$$

$$P\left(\frac{T}{P}\right)^{\gamma} = \text{constant} \qquad \left\{\begin{array}{l} \because\ PV = RT \\ \quad V = \left(\dfrac{RT}{P}\right) \end{array}\right\}$$

$$P^{1-\gamma}.T^{\gamma} = \text{constant}$$

46. 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

(1) Adiabatic (2) Equal in all cases (3) Isothermal (4) Isobaric

Sol. Answer (4)

Work done is maximum in isobaric proces, $W = P.\Delta V = P(V_2 - V_1) = nR(T_2 - T_1)$

47. The efficiency of a Carnot engine operating with reservoir temperature of 100°C and – 23°C will be

(1) $\dfrac{373+250}{373}$ (2) $\dfrac{373-250}{373}$ (3) $\dfrac{100+23}{100}$ (4) $\dfrac{100-23}{100}$

Sol. Answer (2)

$$\eta = 1-\frac{T_2}{T_1} \qquad \left[\begin{array}{l} \text{Where} \\ T_2 - \text{sink temperature} \\ T_1 - \text{reservoir temperature} \end{array}\right]$$

$$\eta = \frac{373-250}{373}$$

48. 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?

(1) $\Delta U = -W$ in an isothermal process (2) $\Delta U = W$ in an isothermal process

(3) $\Delta U = -W$ in an adiabatic process (4) $\Delta U = W$ in an adiabatic process

Sol. Answer (3)

As Q = zero for adiabatic process

So $\Delta U = -W$ for adiabatic process

49. 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

(1) $\dfrac{PV}{(\gamma-1)}$ (2) PV (3) $\dfrac{R}{(\gamma-1)}$ (4) $\dfrac{\gamma PV}{(\gamma-1)}$

Sol. Answer (1)

$$\Delta U = nC_V\Delta T = n\left(\frac{R}{\gamma-1}\right)\Delta T = \frac{nR(T_2-T_1)}{\gamma-1} = \frac{nRT_2-nRT_1}{\gamma-1} = \frac{P(2V-V)}{\gamma-1} = \frac{PV}{\gamma-1}$$

50. An ideal gas at 27°C is compressed adiabatically to 8/27 of its original volume. The rise in temperature is (Take $\gamma = 5/3$)

(1) 275 K (2) 375 K (3) 475 K (4) 175 K

Sol. Answer (2)

$\because \quad TV^{\gamma-1}$ = constant

$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

$$T_1\times\left[\frac{V_1}{V_2}\right]^{\gamma-1} = T_2$$

$$300\times\left[\frac{27}{8}\right]^{5/3-1} = T_2$$

$$300\times\left[\frac{3}{2}\right]^{2} = T_2$$

$$300\times\frac{9}{4} = T_2$$

675 K = T_2

$\therefore \quad \Delta T$ = 675 – 300 = 375 K

51. Two Carnot engines A and B are operated in series. The engine A receives heat from the source at temperature T_1 and rejects the heat to the sink at temperature T. The second engine B receives the heat at temperature T and rejects to its sink at temperature T_2. For what value of T the efficiencies of the two engines are equal?

(1) $\dfrac{T_1+T_2}{2}$ (2) $\dfrac{T_1-T_2}{2}$ (3) T_1T_2 (4) $\sqrt{T_1T_2}$

Sol. Answer (4)

$\eta_A = \eta_B$

$$\left(\frac{T_L}{T_H}\right)_A = \left(\frac{T_L}{T_H}\right)_B$$

$$\frac{T}{T_1} = \frac{T_2}{T}$$

$$T^2 = T_1T_2 \Rightarrow T = \sqrt{T_1T_2}$$

52. The (W/Q) of a Carnot engine is 1/6. Now the temperature of sink is reduced by 62°C, then this ratio becomes twice, therefore the initial temperature of the sink and source are respectively

(1) 33°C, 67°C (2) 37°C, 99°C (3) 67°C, 33°C (4) 97K, 37K

Sol. Answer (2)

$$\frac{1}{6}=1-\frac{T_L}{T_H} \quad ...(1)$$

$$2\times\left(\frac{1}{6}\right)=1-\left(\frac{T_L-62}{T_H}\right)$$

$$\frac{1}{3}=1-\frac{(T_2-62)}{T_H}$$

$$\frac{1}{3}=1-\frac{5}{6}+\frac{62}{T_H}$$

T_H = 372°K = 99°C

T_L = 37°C

53. A scientist says that the efficiency of his heat engine which works at source temperature 127°C and sink temperature 27°C is 26%, then

(1) It is impossible
(2) It is possible but less probable
(3) It is quite probable
(4) Data are incomplete

Sol. Answer (1)

$$\eta=1-\frac{T_L}{T_H}=1-\frac{300}{400}=25\%$$

54. The efficiency of Carnot engine is 50% and temperature of sink is 500 K. If temperature of source is kept constant and its efficiency raised to 60%, then the required temperature of sink will be

(1) 100 K (2) 600 K (3) 400 K (4) 500 K

Sol. Answer (3)

$$\frac{1}{2}=1-\frac{500}{T_H} \qquad \frac{6}{10}=1-\frac{T_L}{10^3}$$

$$T_H=10^3 \qquad T_L=4\times10^2=400\text{ K}$$

55. 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

(1) 4.8
(2) 3.5
(3) 1.6
(4) 1.2

Sol. Answer (4)

$$\frac{W}{Q_1}=1-\frac{T_L}{T_H}$$

$$\frac{W}{6}=1-\frac{400}{500}=1.2\text{ J}$$

56. 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

(1) (T + 2.4) K
(2) (T – 2.4) K
(3) (T + 4) K
(4) (T – 4) K

Sol. Answer (4)

$$W = \frac{-nR(T_2 - T_1)}{\gamma - 1} = -dU \qquad \left[\gamma = \frac{5}{3}\right]$$

$$\Rightarrow \quad T_{\text{final}} = (T - 4)\,\text{K}$$

57. The amount of heat energy required to raise the temperature of 1 g of Helium at NTP, from T_1 K to T_2 K is

(1) $\frac{3}{2}N_a k_B (T_2 - T_1)$ (2) $\frac{3}{4}N_a k_B (T_2 - T_1)$ (3) $\frac{3}{4}N_a k_B \left(\frac{T_2}{T_1}\right)$ (4) $\frac{3}{8}N_a k_B (T_2 - T_1)$

Sol. Answer (4)

$$Q = \eta \cdot \frac{f}{2} R(dT)$$

$$= \frac{3}{8} N_a K_B (T_2 - T_1) = Q$$

58. Which of the following relations does not give the equation of an adiabatic process, where terms have their usual meaning?

(1) $P^{\gamma}.T^{1-\gamma}$ = constant (2) $P^{1-\gamma}T^{\gamma}$ = constant (3) PV^{γ} = constant (4) $TV^{\gamma-1}$ = constant

Sol. Answer (1)

It is $P^{1-\gamma}T^{\gamma} = K$

59. According to C.E. van der Waal, the interatomic potential varies with the average interatomic distance (R) as

(1) R^{-1} (2) R^{-2} (3) R^{-4} (4) R^{-6}

Sol. Answer (4)

According to van der Waal's formulae, interatomic potential is inversely proportion to R^6.

So, $U \propto R^{-6}$

60. In a vessel, the gas is at a pressure P. If the mass of all the molecules is halved and their speed is doubled, then the resultant pressure will be

(1) $4P$ (2) $2P$ (3) P (4) $P/2$

Sol. Answer (2)

$$P = \frac{1}{3}MnV^2$$

$$P' = \frac{1}{3} \times \frac{M}{2} n(2V)^2 = 2 \times \frac{1}{3}MnV^2 = 2P$$

61. The mean free path of collision of gas molecules varies with its diameter (d) of the molecules as

(1) d^{-1} (2) d^{-2} (3) d^{-3} (4) d^{-4}

Sol. Answer (2)

$$\lambda \propto \frac{1}{d^2}$$

62. At 0 K, which of the following properties of a gas will be zero?

(1) Volume (2) Density (3) Kinetic energy (4) Potential energy

Sol. Answer (3)

at 0 K $V_{rms} = 0$ so K.E. = 0

63. The value of critical temperature in terms of van der Waals' constants *a* and *b* is given by

(1) $T_C = \frac{8a}{27Rb}$ (2) $T_C = \frac{27a}{8Rb}$

(3) $T_C = \frac{a}{2Rb}$ (4) $T_C = \frac{a}{27Rb}$

Sol. Answer (1)

$$T_C = \frac{8a}{27Rb}$$

64. The degrees of freedom of a triatomic gas is

(Consider moderate temperature)

(1) 6 (2) 4 (3) 2 (4) 8

Sol. Answer (1)

Degree of freedom = 3 rotational + 3 translational + 0 vibrational [*T* is moderate] = 6

65. To find out degree of freedom, the expression is

(1) $f = \frac{2}{\gamma - 1}$ (2) $f = \frac{\gamma + 1}{2}$ (3) $f = \frac{2}{\gamma + 1}$ (4) $f = \frac{1}{\gamma + 1}$

Sol. Answer (1)

$\because \quad C_V = \frac{fR}{2}$

Then, $f = \frac{2C_V}{R} = \frac{2C_V}{C_P - C_V} = \frac{2}{\frac{C_P}{C_V} - 1} = \frac{2}{\gamma - 1}$

66. The equation of state for 5 g of oxygen at a pressure *P* and temperature *T*, when occupying a volume *V*, will be (where *R* is the gas constant)

(1) $PV = \frac{5}{32}RT$ (2) $PV = 5RT$

(3) $PV = \frac{5}{2}RT$ (4) $PV = \frac{5}{16}RT$

Sol. Answer (1)

$$\because \quad PV = nRT = \left(\frac{m}{M}\right)RT$$

$$PV = \frac{5}{32}RT$$

SECTION - D

Assertion - Reason Type Questions

1. A : Work done by a gas in isothermal expansion is more than the work done by the gas in the same expansion adiabatically.

   R : Temperature remains constant in isothermal expansion and not in adiabatic expansion.

Sol. Answer (2)

A : is true

R : is true, but not correct explanation

correct explanation is, in isothermal expansion.

$\because \quad \Delta T = 0$ so $\Delta U = 0$

$\Rightarrow \quad \Delta Q = \Delta W$

all the heat goes in doing work.

Whereas in adiabatic process

Heat goes to work as well as in increasing internal energy.

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

2. A : Efficiency of heat engine can never be 100%.

   R : Second law of thermodynamics puts a limitation on the efficiency of a heat engine.

Sol. Answer (1)

A : is true

R : is true, and correct explanation

3. A : Heat absorbed in a cyclic process is zero.

   R : Work done in a cyclic process is zero.

Sol. Answer (4)

A : is false, in cyclic process only $\Delta U = 0$, $\Delta Q = \Delta W$.

R : is false, work done is not zero only change in internal energy is zero.

4. A : Coefficient of performance of a refrigerator is always greater than 1.

   R : Efficiency of heat engine is greater than 1.

Sol. Answer (4)

A : is false.

R : is false

Because efficiency of heat engine can never be equal to greater to 1.

$\eta \not\geq 1$

$\because$ all the heat cannot be converted to work.

and coefficient of performane of refrigerator

$$\beta = \frac{1-\eta}{\eta} = \frac{1}{\eta} - 1$$

$\because \quad \eta < 1$ so β may be less than 1.

5. A : Adiabatic expansion causes cooling.

R : In adiabatic expansion, internal energy is used up in doing work.

Sol. Answer (1)

A : is true

R : is true, and correct explanation

6. A : The specific heat of an ideal gas is zero in an adiabatic process.

R : Specific heat of a gas is process independent.

Sol. Answer (3)

A : is true

R : is false

Because specific heat depends on the process.

7. A : The change in internal energy does not depend on the path of process.

R : The internal energy of an ideal gas is independent of the configuration of its molecules.

Sol. Answer (2)

A : is true

R : is true, but not the correct explanation, because internal energy depends on the temperature of the gas.

8. A : Heat supplied to a gaseous system in an isothermal process is used to do work against surroundings.

R : During isothermal process there is no change in internal energy of the system.

Sol. Answer (1)

A : true

R : true and correct explanation

9. A : In nature all thermodynamic processes are irreversible.

R : During a thermodynamic process it is not possible to eliminate dissipative effects.

Sol. Answer (1)

A : is true

R : is true and correct explanation

10. A : During a cyclic process work done by the system is zero.

R : Heat supplied to a system in the cyclic process converts into internal energy of the system.

Sol. Answer (4)

A : is false, in cyclic process, work done is not zero, internal energy change is zero.

R : is false, heat supplied converts to work as initial state is equal to final state.

$\therefore$ No change in internal energy.

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