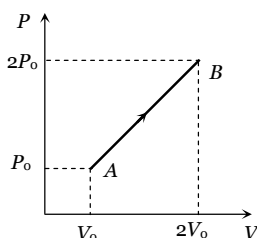


Thermodynamics

SET Self Evaluation Test -14

1. The P - V diagram of 2 gm of helium gas for a certain process $A \rightarrow B$ is shown in the figure. what is the heat given to the gas during the process $A \rightarrow B$

- (a) $4P_0V_0$
 (b) $6P_0V_0$
 (c) $4.5P_0V_0$
 (d) $2P_0V_0$



2. A certain mass of gas at 273 K is expanded to 81 times its volume under adiabatic condition. If $\gamma = 1.25$ for the gas, then its final temperature is [Pb. PET 1997]

- (a) -235°C (b) -182°C
 (c) -91°C (d) 0°C

3. In an adiabatic process 90 J of work is done on the gas. The change in internal energy of the gas is [CPMT 1996]

- (a) -90 J
 (b) $+90\text{ J}$
 (c) 0 J
 (d) Depends on initial temperature

4. If a Carnot's engine functions at source temperature 127°C and at sink temperature 87°C , what is its efficiency [DCE 1997]

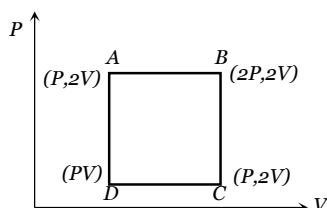
- (a) 10% (b) 25%
 (c) 40% (d) 50%

5. In the case of diatomic gas, the heat given at constant pressure is that part of energy which is used for the expansion of gas, is

- (a) $\frac{2}{5}$ (b) $\frac{3}{7}$
 (c) $\frac{2}{7}$ (d) $\frac{5}{7}$

6. An ideal monoatomic gas is taken round the cycle ABCDA shown in the PV diagram in the given fig. The work done during the cycle is [UPSEAT 1998]

- (a) $\frac{1}{2}PV$
 (b) $2PV$
 (c) PV
 (d) Zero



7. A gas is compressed adiabatically till its temperature is doubled. The ratio of its final volume to initial volume will be [BHU 1997]

- (a) $1/2$ (b) More than $1/2$
 (c) Less than $1/2$ (d) Between 1 and 2

8. A tyre filled with air (27°C , and 2 atm) bursts, then what is temperature of air ($\gamma = 1.5$)

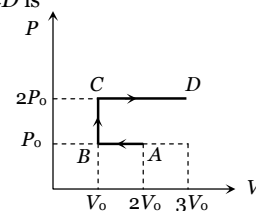
- (a) -33°C (b) 0°C
 (c) 27°C (d) 240°C

9. A gas expands adiabatically at constant pressure such that its temperature $T \propto \frac{1}{\sqrt{V}}$, the value of C_p / C_v of gas is

- [RPMT 2002; MHCET 2004]
 (a) 1.30 (b) 1.50
 (c) 1.67 (d) 2.00

10. P - V diagram of an ideal gas is as shown in figure. Work done by the gas in process ABCD is

- (a) $4P_0V_0$
 (b) $2P_0V_0$
 (c) $3P_0V_0$
 (d) P_0V_0



11. An engineer claims to have made an engine delivering 10 kW power with fuel consumption of 1 g s^{-1} . The calorific value of fuel is 2 kcal/g . His claim

- (a) Is non-valid (b) Is valid
 (c) Depends on engine (d) Depends on load

12. An ideal gas heat engine operates in a Carnot cycle between 27°C and 127°C . It absorbs 6 kcal at the higher temperature. The amount of heat (in kcal) converted into work is equal to [CBSE PMT 2003]

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

13. A gas expands with temperature according to the relation $V = kT^{2/3}$. What is the work done when the temperature changes by 30°C

- (a) $10R$ (b) $20R$
 (c) $30R$ (d) $40R$

14. An ideal gas ($\gamma = 1.5$) is expanded adiabatically. How many times has the gas to be expanded to reduce the root mean square velocity of molecules 2.0 times

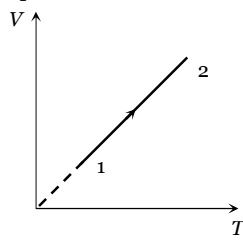
(a) 4 times (b) 16 times
(c) 8 times (d) 2 times

15. Three samples of the same gas A , B and C ($\gamma = 3/2$) have initially equal volume. Now the volume of each sample is doubled. The process is adiabatic for A isobaric for B and isothermal for C . If the final pressures are equal for all three samples, the ratio of their initial pressures are

(a) $2\sqrt{2} : 2 : 1$ (b) $2\sqrt{2} : 1 : 2$
(c) $\sqrt{2} : 1 : 2$ (d) $2 : 1 : \sqrt{2}$

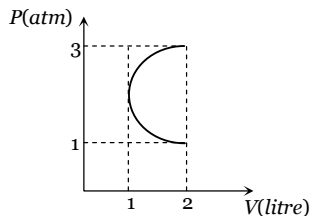
16. Volume versus temperature graph of two moles of helium gas is as shown in figure. The ratio of heat absorbed and the work done by the gas in process 1-2 is

(a) 3
(b) $\frac{5}{2}$
(c) $\frac{5}{3}$
(d) $\frac{7}{2}$



17. In the P - V diagram shown in figure ABC is a semicircle. The work done in the process ABC is

(a) Zero
(b) $\frac{\pi}{2} \text{ atm} - \text{lt}$
(c) $-\frac{\pi}{2} \text{ atm} - \text{lt}$
(d) $4 \text{ atm} - \text{lt}$



18. Heat is supplied to a diatomic gas at constant pressure. The ratio of $\Delta Q : \Delta U : \Delta W$ is

(a) 5 : 3 : 2 (b) 5 : 2 : 3
(c) 7 : 5 : 2 (d) 7 : 2 : 5

19. A gas undergoes a change of state during which 100 J of heat is supplied to it and it does 20 J of work. The system is brought back to its original state through a process during which 20 J of heat is released by the gas. The work done by the gas in the second process is

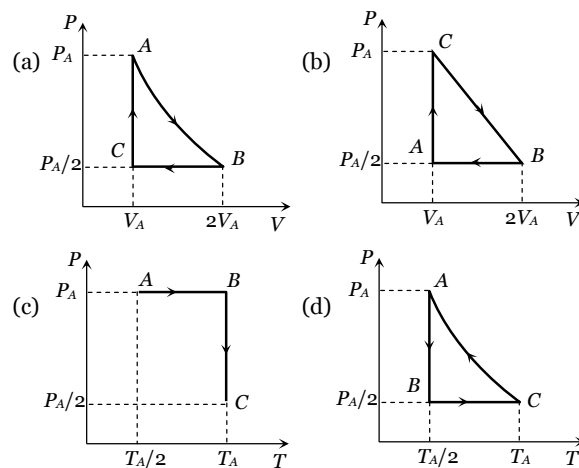
(a) 60 J (b) 40 J
(c) 80 J (d) 20 J

20. N moles of an ideal diatomic gas are in a cylinder at temperature T . Suppose on supplying heat to the gas, its temperature remain constant but n moles get dissociated into atoms. Heat supplied to the gas is

(a) Zero (b) $\frac{1}{2} nRT$
(c) $\frac{3}{2} nRT$ (d) $\frac{3}{2} (N - n)RT$

21. Three moles of an ideal gas ($C_p = \frac{7}{2}R$) at pressure P_A

and temperature T_A is isothermally expanded to twice its initial volume. It is then compressed at constant pressure to its original volume. Finally the gas is compressed at constant volume to its original pressure P_A . The correct P - V and P - T diagrams indicating the process are



22. A cylinder of mass 1 kg is given heat of 20000 J at atmospheric pressure. If initially temperature of cylinder is 20°C , then work done by the cylinder will be (Given that Specific heat of cylinder = 400 J kg^{-1} , Coefficient of volume expansion = $9 \times 10^{-5} \text{ }^\circ\text{C}^{-1}$, Atmospheric pressure = 10^5 N/m^2 and density of cylinder 9000 kg/m^3)

(a) 0.02 J (b) 0.05 J
(c) 0.08 J (d) 0.1 J

23. In a thermodynamic process pressure of a fixed mass of a gas is changed in such a manner that the gas releases 30 joules of heat and 10 joules of work was done on the gas. If the initial internal energy of the gas was 30 joules, then the final internal energy will be

(a) 2 J (b) -18 J
(c) 10 J (d) 58 J

24. In an adiabatic change, the pressure P and temperature T of a monoatomic gas are related by the relation $P \propto T^c$, where c equals

[CBSE PMT 1994;

BHU 1997; AIIMS 2001; MH CET 2000]

(a) 5/3 (b) 2/5
(c) 3/5 (d) 5/2

25. The internal energy of an ideal gas increases during an isothermal process when the gas is

[SCRA 1998]

(a) Expanded by adding more molecules to it
(b) Expanded by adding more heat to it
(c) Expanded against zero pressure
(d) Compressed by doing work on it

AS Answers and Solutions

(SET -14)

1. (b) Change in internal energy from $A \rightarrow B$ is

$$\Delta U = \frac{f}{2} \mu R \Delta T = \frac{f}{2} (P_f V_f - P_i V_i)$$

$$= \frac{3}{2} (2P_0 \times 2V_0 - P_0 \times V_0) = \frac{9}{2} P_0 V_0$$

Work done in process $A \rightarrow B$ is equal to the Area covered by the graph with volume axis i.e.,

$$W_{A \rightarrow B} = \frac{1}{2} (P_0 + 2P_0) \times (2V_0 - V_0) = \frac{3}{2} P_0 V_0$$

$$\text{Hence, } \Delta Q = \Delta U + \Delta W = \frac{9}{2} P_0 V_0 + \frac{3}{2} P_0 V_0 = 6 P_0 V_0$$

2. (b) For adiabatic process $TV^{\gamma-1} = \text{constant}$

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

$$\Rightarrow T_2 = \left(\frac{1}{81} \right)^{1.25-1} \times 273 = \left(\frac{1}{81} \right)^{0.25} \times 273$$

$$= \frac{273}{3} = 91 \text{ K} \rightarrow -182^\circ \text{C}$$

3. (b) For adiabatic process $\Delta Q = 0$

$$\text{From } \Delta Q = \Delta U + \Delta W \Rightarrow 0 = \Delta U - 90 \Rightarrow \Delta U = +90 \text{ J}$$

4. (d) $\eta = \frac{T_1 - T_2}{T_1} = \frac{(127 + 273) - (87 + 273)}{(127 + 273)}$
- $$= \frac{400 - 360}{400} = 0.1 \rightarrow 10\%$$

5. (c) $\Delta W = \text{energy used for expansion} = PdV = RdT$
 $\Delta Q = \text{heat supplied to diatomic gas at constant } P$
 $= C_p dT = \frac{7}{2} RdT$ ($\because C_p = \frac{7}{2} R$) $\therefore \frac{\Delta W}{\Delta Q} = \frac{RdT}{\frac{7}{2} RdT} = \frac{2}{7}$

6. (c)

7. (c) $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2} \right)^{\gamma-1} = 2 \Rightarrow \left(\frac{V_2}{V_1} \right)^{\gamma-1} = \frac{1}{2} \Rightarrow \frac{V_2}{V_1} = \left(\frac{1}{2} \right)^{\frac{1}{\gamma-1}} < \frac{1}{2}$
- $$\Rightarrow V_2 < \frac{V_1}{2}$$

8. (a) $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} \Rightarrow \frac{T_2}{(273+27)} = \left(\frac{1}{2} \right)^{\frac{1.5-1}{1.5}} = \left(\frac{1}{2} \right)^{\frac{1}{3}} = \frac{1}{2.5}$
- $$\Rightarrow T_2 = \frac{T_1}{2.5} = \frac{(273+27)}{2.5} = 238 \text{ K} = -34.8^\circ \text{C}$$

9. (b) $TV^{\gamma-1} = \text{constant} \Rightarrow T \propto V^{1-\gamma}$
- According to question $T \propto V^{\frac{1}{2}}$
- Hence $1 - \gamma = -\frac{1}{2} \Rightarrow \gamma = \frac{3}{2} = 1.5$

10. (c) $W_{AB} = -P_0 V_0$, $W_{BC} = 0$ and $W_{CD} = 4P_0 V_0$
- $$\Rightarrow W_{ABCD} = -P_0 V_0 + 0 + 4P_0 V_0 = 3P_0 V_0$$

11. (a) Power = $10 \text{ KW} = 10000 \text{ J/s} = \frac{10000}{4.2} = 2.38 \text{ k cal/gm}$

But the calorific value of fuel is only 2 k cal/gm . Hence claim is invalid.

12. (c) Efficiency of a carnot engine is given by $\eta = 1 - \frac{T_2}{T_1}$
- or $\frac{W}{Q} = 1 - \frac{T_2}{T_1} \Rightarrow \frac{W}{6} = 1 - \frac{(273+127)}{(273+227)} \Rightarrow W = 1.2 \text{ k cal}$

13. (b) $W = \int PdV = \int \frac{RT}{V} dV$

$$\text{Since } V = kT^{2/3} \Rightarrow dV = \frac{2}{3} kT^{-1/3} dT$$

$$\text{Eliminating } K, \text{ we find } \frac{dV}{V} = \frac{2}{3} \frac{dT}{T}$$

$$\text{Hence } W = \int_{T_1}^{T_2} \frac{2}{3} \frac{RT}{T} dT = \frac{2}{3} R(T_2 - T_1) = \frac{2}{3} R(30) = 20 \text{ R}$$

14. (b) $v_{rms} = \sqrt{\frac{3RT}{M}} \Rightarrow v_{rms} \propto \sqrt{T}$

v_{rms} is to reduce two times i.e. temperature of the gas will have to reduce four times or $\frac{T'}{T} = \frac{1}{4}$

During adiabatic process $TV^{\gamma-1} = T'V'^{\gamma-1}$

$$\Rightarrow \frac{V'}{V} = \left(\frac{T}{T'} \right)^{\frac{1}{\gamma-1}} = (4)^{\frac{1}{1.5-1}} = (4)^2 = 16 \Rightarrow V' = 16V$$

15. (b) Let the initial pressure of the three samples be P_A, P_B and P_C , then $P_A(V)^{3/2} = (2V)^{3/2} P$, $P_B = P$ and

$$P_C(V) = P(2V)$$

$$\Rightarrow P_A : P_B : P_C = (2)^{3/2} : 1 : 2 = 2\sqrt{2} : 1 : 2$$

16. (b) $V-T$ graph is a straight line passing through origin. Hence, $V \propto T$ or $P = \text{constant}$

$$\therefore \Delta Q = nC_p \Delta T \text{ and } \Delta U = nC_v \Delta T$$

$$\text{Also } \Delta W = \Delta Q - \Delta U = \mu(C_p - C_v) \Delta T$$

$$\therefore \frac{\Delta Q}{\Delta W} = \frac{nC_p \Delta T}{n(C_p - C_v) \Delta T} = \frac{C_p}{C_p - C_v} = \frac{1}{1 - \frac{C_v}{C_p}}$$

$$\frac{C_v}{C_p} = \frac{3}{5} \text{ for helium gas. Hence } \frac{\Delta Q}{\Delta W} = \frac{1}{1 - 3/5} = \frac{5}{2}$$

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17. (b) W_{AB} is negative (volume is decreasing) and W_{BC} is positive (volume is increasing) and since, $|W_{BC}| > |W_{AB}|$
 \therefore net work done is positive and area between semicircle which is equal to $\frac{\pi}{2} atm - lt$.

18. (c) $\Delta Q = \mu C_p \Delta T = \frac{7}{2} \mu R \Delta T \quad \left(C_p = \frac{7}{2} R \right)$

$$\Delta U = \mu C_v \Delta T = \frac{5}{2} \mu R \Delta T \quad \left(C_v = \frac{5}{2} R \right)$$

and $\Delta W = \Delta Q - \Delta U = \mu R \Delta T$

$$\Rightarrow \Delta Q : \Delta U : \Delta W = 7 : 5 : 2$$

19. (a) In a cyclic process $\Delta U = 0 \Rightarrow \Delta Q = \Delta W$
 $\Rightarrow (100 - 20) = 20 + W_2 \Rightarrow W_2 = 60 J$
20. (b) Since the gas is enclosed in a vessel, therefore, during heating process, volume of the gas remains constant. Hence, no work is done by the gas. It means heat supplied to the gas is used to increase its internal energy only.

Initial internal energy of the gas is $U_1 = N \left(\frac{5}{2} R \right) T$

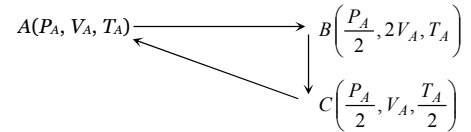
Since n moles get dissociated into atoms, therefore, after heating, vessel contains $(N - n)$ moles of diatomic gas and $2n$ moles of a mono-atomic gas. Hence the internal energy for the gas, after heating, will be equal to

$$U_2 = (N - n) \left(\frac{5}{2} R \right) T + 2n \left(\frac{3}{2} R \right) T = \frac{5}{2} NRT + \frac{1}{2} nRT$$

Hence, the heat supplied = increase in internal energy

$$= (U_2 - U_1) = \frac{1}{2} nRT$$

21. (a) Let the process start from initial pressure P_A , volume V_A and temperature T_A .



- (i) Isothermal expansion ($PV = \text{constant}$) at temperature T_A to twice the initial volume V_A
 (ii) Compression at constant pressure $\frac{P_A}{2}$ to original volume V_A (i.e. $V \propto T$)
 (iii) Isochoric process (at volume V_A) to initial condition (i.e. $P \propto T$)

22. (b) $\Delta Q = mc \Delta T \Rightarrow \Delta T = \frac{20000 J}{1 \text{ kg} \times (400 J / \text{kg}^\circ\text{C})} = 50^\circ\text{C}$

$$\Rightarrow T_{\text{Final}} = 70^\circ\text{C}$$

Hence $W = P_{\text{atm}} \Delta V = P_{\text{atm}} V_0 \gamma \Delta T$

$$= (10^5 \text{ N} / \text{m}^2) \left(\frac{1}{9 \times 10^3} \text{ m}^3 \right) (9 \times 10^{-5} / ^\circ\text{C}) (50^\circ\text{C}) = 0.05 J$$

23. (c) $\Delta Q = \Delta U + \Delta W = (U_f - U_i) + \Delta W$

$$\Rightarrow -30 = (U_f - 30) - 10 \Rightarrow U_f = 10 J$$

24. (d) $T^\gamma P^{1-\gamma} = \text{constant} \Rightarrow P \propto T^{\frac{\gamma}{\gamma-1}}$

Comparing above equation with given equation

$$P \propto T^C \Rightarrow C = \frac{\gamma}{\gamma-1} = \frac{5/3}{5/3-1} = \frac{5}{2}$$

25. (a) Internal energy of an ideal gas is given by

$$U = \frac{f}{2} \mu RT = \frac{f}{2} \left(\frac{N}{N_A} \right) RT \Rightarrow U \propto NT.$$

In isothermal process $T = \text{constant} \Rightarrow U \propto N$.

i.e. internal energy increases by increasing number of molecules (N).
