KTG & THERMODYNAMICS

Contents

Syllabus

Ideal gas laws ; Specific heats (C_V and C_p for monoatomic and diatomic gases) ; Isothermal and adiabatic processes, bulk modulus of gases ; Equivalence of heat and work ; First law of thermodynamics and its applications (only for ideal gases) ; Blackbody radiation ; absorptive and emissive powers ; Kirchhoff's law ; Wien's displacement law, Stefan's law.

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EXERCISE # 1

PART - I : OBJECTIVE QUESTIONS

*** Marked Questions are having more than one correct option.**

SECTION (A) : KINETIC THEORY OF GASES

A-1. When an ideal gas is compressed isothermally then its pressure increases because :
(A) its potential energy decreases
(B) its kinetic energy increases and molecules move apart
(C) its number of collisions per unit area with walls of container increases
(D) molecular energy increases

A-2. Which of the following is correct for the molecules of a gas in thermal equilibrium ?
(A) All have the same speed
(B) All have different speeds which remain constant
(C) They have a certain constant average speed
(D) They do not collide with one another.

A-3.* Consider a collision between an argon molecule and a nitrogen molecule in a mixture of argon and nitrogen kept at room temperature. Which of the following are possible ?
(A) The kinetic energies of both the molecules decrease.
(B) The kinetic energies of both the molecules increase
(C) The kinetic energy of the argon molecule increases and that of the nitrogen molecules decrease.
(D) The kinetic energy of the nitrogen molecules increases and that of the argon molecule decrease.

A-4.* For an ideal gas molecules the following quantities having zero average values are.
(A) velocity (B) momentum (C) kinetic energy (D) density

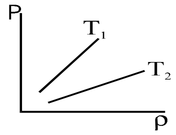
A-5. In a sample of an ideal gas the average momentum of a molecule depends on
(A) pressure (B) mass of gas (C) number of moles (D) none of these

Section (B) : Root mean square speed, Kinetic Energy and Equation of state

B-1. The temperature at which the r.m.s velocity of oxygen molecules equal that of nitrogen molecules at 100ºC is nearly:
(A) 426.3 K (B) 456.3 K (C) 436.3 K (D) 446.3 K

B-2. A gas behaves more closely like an ideal gas at
(A) low pressure and low temperature (B) low pressure and high temperature
(C) at all pressure and temperature (D) none of these

B-3. Figure shows graphs of pressure vs density for an ideal gas at two temperatures T_1 and T_2.



(A) $T_1 > T_2$ (B) $T_1 = T_2$

(C) $T_1 < T_2$ (D) any of the three is possible

B-4. Suppose a container is evacuated to leave just one molecule of a gas in it. Let ν_{mp} and ν_{av} represent the most probable speed and the average speed of the gas, then

(A) $\nu_{mp} > \nu_{av}$ (B) $\nu_{mp} < \nu_{av}$ (C) $\nu_{mp} = \nu_{av}$ (D) none of these

B-5. The average speed of nitrogen molecules in a gas is v. If the temperature is doubled and the N_2 molecule dissociate into nitrogen atoms, then the average speed will be

(A) v (B) $v\sqrt{2}$ (C) 2 v (D) 4v

B-6. The quantity $\frac{2U}{fkT}$ represents (where U = internal energy of gas)

(A) mass of the gas (B) kinetic energy of the gas
(C) number of moles of the gas (D) number of molecules in the gas

B-7. In a mixture of nitrogen and helium kept at room tempertaure. As compared to a helium molecule nitrogen molecule hits the wall

(A) With greater average speed (B) with smaller average speed
(C) with greater average kinetic energy (D) with smaller average kinetic energy.

B-8. Keeping the number of moles, volume and pressure the same, which of the following are the same for all ideal gas ?

(A) rms speed of a molicule (B) density (C) temperature
(D) average of magnitude of momentum.

Section (C) : Maxwell's distribution of speed

C-1. Three closed vessels A, B, and C are at the same temperature T and contain gases which obey the Maxwell distribution of speed . Vessel A contains only O_2, B only N_2 and C a mixture of equal quantities of O_2 and N_2. If the average speed of O_2 molecules in vessel A is V_1, that of the N_2 molecules in vessel B is V_2, the average speed of the O_2 molecules in vessel C will be :

(A) $(V_1 + V_2)/2$ (B) V_1 (C) $(V_1V_2)^{1/2}$ (D) $\frac{V_1}{2}$

Section (D) : Law of equipartition and internal energy

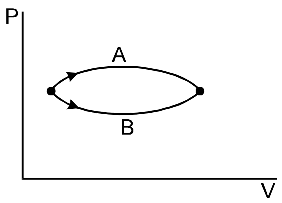
D-1. The pressure of an ideal gas is written as $E = \frac{3PV}{2}$. Here E stands for

(A) total translational kinetic energy (B) rotational kinetic energy
(C) average translational kinetic energy (D) total kinetic energy.

D-2. The quantities which remains same for all ideal gases at the same temperature is/are ?

(A) the kinetic energy of equal moles of gas
(B) the kinetic energy of equal mass of gas
(C) the number of molecules of equal moles of gas
(D) the number of molecules of equal mass of gas

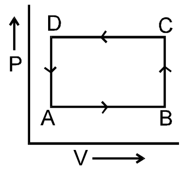
D-3. Refer to fig. Let ΔU_1 and ΔU_2 be the changes in internal energy of the system in the processes A and B then

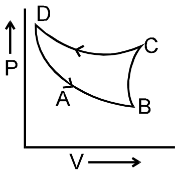


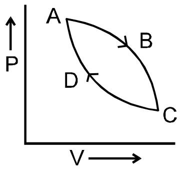
(A) $\Delta U_1 > \Delta U_2$ (B) $\Delta U_1 = \Delta U_2$ (C) $\Delta U_1 < \Delta U_2$ (D) $\Delta U_1 \neq \Delta U_2$

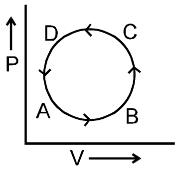
Section (E) : Calculation of work

E-1. In the following figures (1) to (4), variation of volume by change of pressure is shown. A gas is taken along the path ABCDA. The change in internal energy of the gas will be:

(1) 

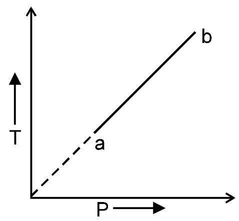
(2) 

(3) 

(4) 

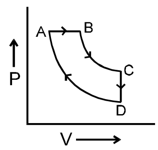
(A) positive in all cases from (1) to (4)
(B) positive in cases (1), (2) and (3) but zero in case (4)
(C) negative in cases (1), (2) and (3) but zero in case (4)
(D) zero in all the four cases.

E-2. An ideal gas changes from state a to state b as shown in Fig. What is the work done by the gas in the process ?

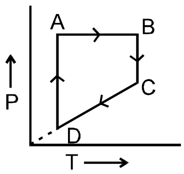


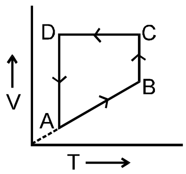
(A) zero (B) positive (C) negative (D) infinite

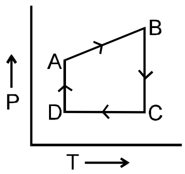
E-3.* A cyclic process ABCD is shown in the P–V diagram. (BC and DA are isothermal)

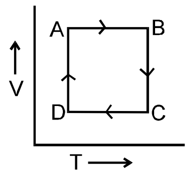


Which of the following curves represents the same process?

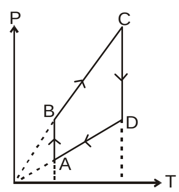
(A) 

(B) 

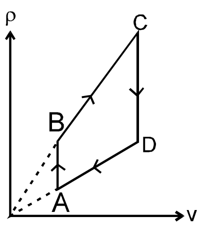
(C) 

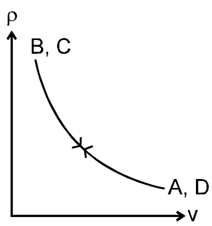
(D) 

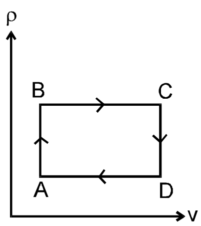
E-4. Pressure versus temperature graph of an ideal gas is as shown in figure.

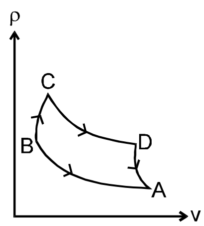


Corresponding density (ρ) versus volume (v) graph will be :

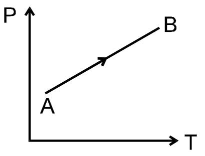
(A) 

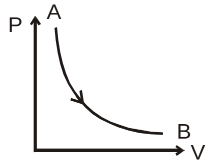
(B) 

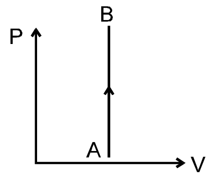
(C) 

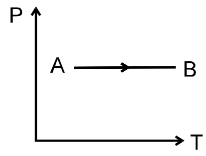
(D) 

E-5. The process $\Delta U = 0$, for an ideal gas can be best represented in the form of a graph :

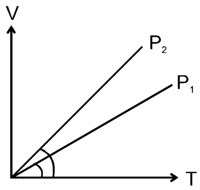
(A) 

(B) 

(C) 

(D) 

E-6. In the following V-T diagram what is the relation between P_1 and P_2 :



(A) $P_2 = P_1$

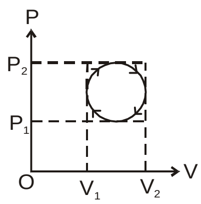
(B) $P_2 > P_1$

(C) $P_2 < P_1$

(D) cannot be predicted

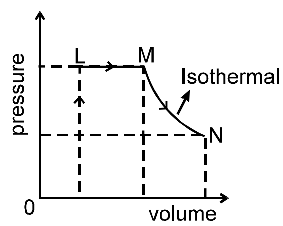
E-7. In an isothermal expansion of an ideal gas. Select wrong statement:
(A) there is no change in the temperature of the gas
(B) there is no change in the internal energy of the gas
(C) the work done by the gas is equal to the heat supplied to the gas
(D) the work done by the gas is equal to the change in its internal energy

E-8. In a cyclic process shown on the P – V diagram the magnitude of the work done is :

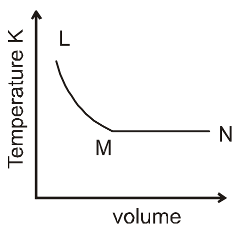


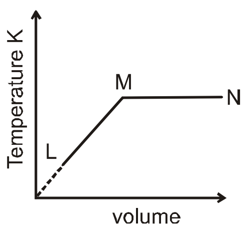
(A) $\pi\left(\frac{P_2 - P_1}{2}\right)^2$ (B) $\pi\left(\frac{V_2 - V_1}{2}\right)^2$ (C) $\frac{\pi}{4}(P_2 - P_1)(V_2 - V_1)$ (D) $\pi(P_2V_2 - P_1V_1)$

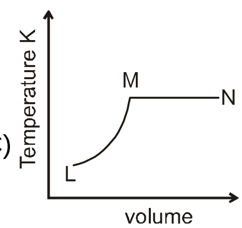
E-9. A fixed mass of an ideal gas undergoes changes of pressure and volume starting at L, as shown in Figure.

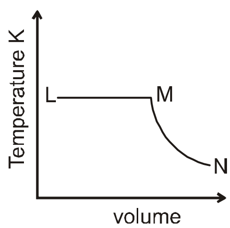


Which of the following is correct :

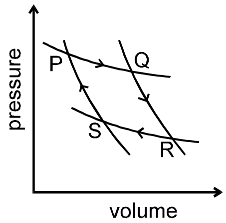
(A) 

(B) 

(C) 

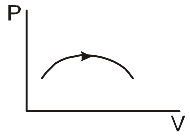
(D) 

E-10. A fixed mass of gas undergoes the cycle of changes represented by PQRSP as shown in Figure. In some of the changes, work is done on the gas and in others, work is done by the gas. In which pair of the changes work is done on the gas?



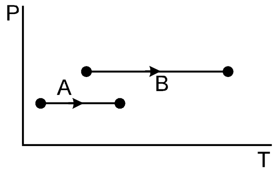
(A) PQ and RS (B) PQ and QR (C) OR and RS (D) RS and SP.

E-11. In figure, P-V curve of an ideal gas is given. During the process, the cumulative work done by the gas



(A) continuously increases
(B) continuously decreases
(C) first increases then decreases
(D) first decreases then increases

E-12. In given figure, let W_1 and W_2 be the workdone by the system in process A and B respectively then (initial and final volumes in both process remains same)



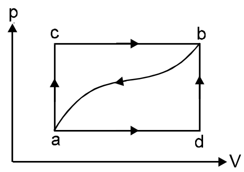
(A) $\Delta W_1 > \Delta W_2$ (B) $\Delta W_1 = \Delta W_2$ (C) $\Delta W_1 < \Delta W_2$

(D) Nothing can be said about the relation between ΔW_1 and ΔW_2

E-13. A mass of an ideal gas undergoes a reversible isothermal compression. Its molecules will then have compared with initial state, the same
(i) root mean square velocity (ii) mean mometum
(iii) mean kinetic energy
(A) (i), (ii), (iii) correct (B) (i), (ii) correct
(C) (ii), (iii) correct (D) (i) correct

Section (F) : First law of thermodynamics

F-1. When a system is taken from state 'a' to state 'b' along the path 'acb', it is found that a quantity of heat Q = 200 J is absorbed by the system and a work W = 80J is done by it. Along the path 'adb', Q = 144J. The work done along the path 'adb' is



(A) 6J (B) 12 J (C) 18 J (D) 24 J

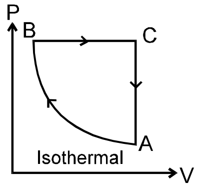
F-2. In the above question, if the work done on the system along the curved path 'ba' is 52J, heat abosrbed is
(A) – 140 J (B) – 172 J (C) 140 J (D) 172 J

F-3. In above question, if U_a = 40J, value of U_b will be
(A) – 50 J (B) 100 J (C) – 120 J (D) 160 J

F-4. In above question, if $U_d = 88$ J, heat absorbed for the path 'db' is
(A) – 72 J (B) 72 J (C) 144 J (D) – 144 J

F-5*. For an ideal gas, the initial pressure and volume are equal to the final pressure and volume.
(A) The initial temperature must be equal to the final temperature
(B) The initial internal energy must be equal to the final internal energy.
(C) The net heat given to an ideal gas in the process must be zero
(D) The net work done by an ideal gas in the process may be zero

F-6.* A cyclic process of an ideal monoatomic gas is shown in figure. The correct statement is (are) :

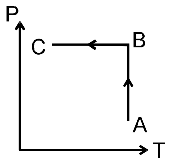


(A) Work done by gas in process AB is more than that of the process BC.
(B) net heat energy has been supplied to the system.
(C) temperature of the gas is maximum in state B.
(D) in process CA, heat energy is rejected out by system.

F-7*. A system undergoes a cyclic process in which it absorbs Q_1 heat and gives out Q_2 heat. The efficiency of the process is η and work done is W. Select correct statement:

(A) $W = Q_1 - Q_2$ (B) $\eta = \frac{W}{Q_1}$ (C) $\eta = \frac{Q_2}{Q_1}$ (D) $\eta = 1 - \frac{Q_2}{Q_1}$

F-8. Ideal gas is taken through process shown in figure:



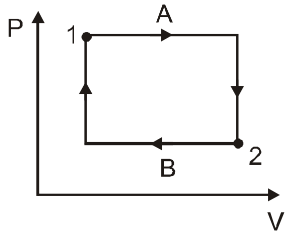
(A) In process AB, work done by system is positive
(B) In process AB, heat is rejected out of the system.
(C) In process AB, internal energy increases
(D) In process AB internal energy decreases and in process BC internal energy increases.

F-9. In isothermal process if heat is released from an ideal gas then,
(A) the internal energy of the gas will increase
(B) the gas will do positive work
(C) the gas will do negative work
(D) the given process is not possible

F-10.* The pressure P and volume V of an ideal gas both decreases in a process.
(A) The work done by the gas is negative
(B) The work done by the gas is positive
(C) The temperature of the gas must decrease
(D) Heat supplied to the gas is equal to the change in internal energy.

F-11.* An ideal gas can be taken from initial state 1 to final state 2 by two different process. Let ΔQ and W represent the heat given and work done by the system. Then which quantities is/are same in both process (where ΔU = internal energy of gas)
(A) ΔQ (B) W (C) ΔU (D) ΔQ - W

F-12.* In given figure, let ΔU_1 and ΔU_2 be change in internal energy in process A and B respectively. ΔQ and W be the net heat given and net work done by the system in the process A + B, then



(A) $\Delta U_1 + \Delta U_2 = 0$ (B) $\Delta U_1 - \Delta U_2 = 0$
(C) $\Delta Q - W = 0$ (D) $\Delta Q + W = 0$

Section (G) : Specific heat capacities of gases

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

(A) $\frac{2}{5}$ (B) $\frac{3}{5}$ (C) $\frac{3}{7}$ (D) $\frac{5}{7}$

G-2. The value of the ratio C_p/C_v for hydrogen is 1.67 at 30 K but decreases to 1.4 at 300 K as more degrees of freedom become active. During this rise in temperature,
(A) C_p remains constant but C_v increases
(B) C_p decreases but C_v increases
(C) Both C_p and C_v decrease by the same amount
(D) Both C_p and C_v increase by the same amount

G-3. Boiling water is changing into steam. Under this condition, the specific heat of water is
(A) zero (B) one (C) Infinite (D) less than one

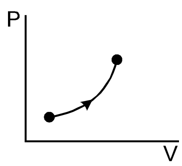
G-4. Supposing the distance between the atoms of a diatomic gas to be constant, its specific heat at constant volume per mole (gram mole) is

(A) $\frac{5}{2}R$ (B) $\frac{3}{2}R$ (C) R (D) $\frac{7}{2}R$

G-5. For an ideal gas, the heat capacity at constant pressure is larger than than that at constant volume because
(A) positive work is done during expansion of the gas by the external pressure
(B) positive work is done during expasion by the gas against external pressure
(C) positive work is done during expansion by the gas against intermolecular forces of attraction
(D) more collisions occur per unit time when volume is kept constant.

G-6. A gas has :
(A) one specific heat only (B) two specific heats only
(C) infinite number of specific heats (D) no specific heat

G-7. If molar heat capacity of the given process (as shown in figure) is C, then



(A) $C < C_V$ (B) $C = 0$ (C) $C > C_v$ (D) $C = C_v$

G-8. For small coefficient of expansion in case of solid,
(A) $C_p - C_v = R$ (B) $C_p - C_v = 2R$
(C) C_p is slightly greater than C_v (D) C_p is slightly less than C_v

G-9.* Specific heat of a substance can be :-
(A) finite (B) infinite (C) zero (D) negative

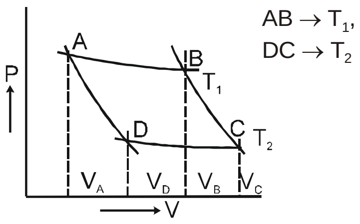
Section (H) : Adiabatic process and free expansion

H-1. A gas is contained in a metallic cylinder fitted with a piston. The gas is suddenly compressed by pushing piston downward and is maintained at this position. After this process, as time passes the pressure of the gas in the cylinder

(A) increases (B) decreases (C) remains constant

(D) increases or decreases depending on the nature of the gas.

H-2. In the following P–V diagram of an ideal gas, AB and CD are isothermal where as BC and DA are adiabatic process. The value of V_B/V_C is



(A) $= V_A/V_D$ (B) $< V_A / V_D$ (C) $> V_A / V_D$ (D) cannot say

H-3.* A gas kept in a container, if the container is of finite conductivity, then the process

(A) must be very nearly adiabatic (B) must be very nearly isothermal

(C) may be very nearly adiabatic (D) may be very nearly isothermal

H-4.* Oxygen, nitrogen and helium gas are kept in three identical adiabatic containers P, Q and R respectively at equal pressure. When the gases are pushed to half their original volumes. (initial temperature is same)

(A) The final temperature in the three containers will be the same.

(B) The final pressures in the three containers will be the same.

(C) The pressure of oxygen and nitrogen will be the same but that of helium will be different.

(D) The temperature of oxygen and nitrogen will be the same but that of helium will be different

H-5.* An ideal gas of one mole is kept in a rigid container of negligible heat capacity. If 25 J of heat is supplied the gas temperature raises by 2^0C. Then the gas may be

(A) helium (B) argon (C) oxygen (D) carbon dioxide

H-6. Two samples 1 and 2 are initially kept in the same state. The sample 1 is expanded through an isothermal process where as sample 2 through an adiabatic process upto the same final volume. The final temperature in process 1 and 2 are T_1 and T_2 respectively, then

(A) $T_1 > T_2$ (B) $T_1 = T_2$ (C) $T_1 < T_2$

(D) The relation between T_1 and T_2 cannot be deduced.

H-7. Let P_1 and P_2 be the final pressure of the samples 1 and 2 respectively in the previous question then :

(A) $P_1 < P_2$ (B) $P_1 = P_2$ (C) $P_1 > P_2$

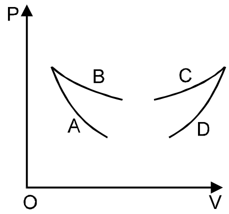
(D) The relation between P_1 and P_2 cannot be deduced.

H-8. Let ΔW_1 and ΔW_2 be the work done by the systems 1 and 2 respectively in the previous question then :

(A) $\Delta W_1 > \Delta W_2$ (B) $\Delta W_1 = \Delta W_2$ (C) $\Delta W_1 < \Delta W_2$

(D) The relation between W_1 and W_2 cannot be deduced.

H-9. Four curves A, B, C and D are drawn in the Fig. for a given amount of gas. The curves which represent adiabatic and isothermal changes are



(A) C and D respectively (B) D and C respectively

(C) A and B respectively (D) B and A respectively

H-10. When an ideal gas undergoes an adiabatic change causing a temparture change ΔT
(i) there is no heat gained or lost by the gas
(ii) the work done by the gas is equal to change in internal energy
(iii) the change in internal energy per mole of the gas is $C_v \Delta T$, where C_v is the molar heat capacity at constnat volume.
(A) (i), (ii), (iii) correct (B) (i), (ii) correct (C) (i), (iii) correct (D) (i) correct

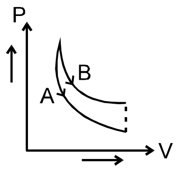
H-11.* The following sets of values for C_v and C_p of a gas have been reported by different students. The units are cal mole^{-1} K^{-1}. Which of these sets is most reliable ?
(A) $C_v = 3$, $C_p = 5$ (B) $C_v = 4$, $C_p = 6$ (C) $C_v = 3$, $C_p = 2$ (D) $C_v = 3$, $C_p = 4.2$

H-12. The adiabatic bulk modulus of hydrogen gas ($\gamma = 1.4$) at NTP is :
(A) 1×10^5 N/m^2 (B) 1×10^{-5} N/m^2 (C) 1.4 N/m^2 (D) 1.4×10^5 N/m^2

H-13. A given quantity of a gas is at pressure P and absolute temperature T. The isothermal bulk modulus of the gas is:
(A) $\frac{2}{3}P$ (B) P (C) $\frac{3}{2}P$ (D) 2P

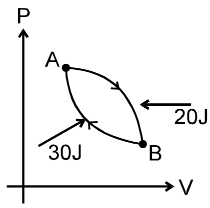
H-14.* When an enclosed perfect gas is subjected to an adiabatic process:
(A) Its total internal energy does not change
(B) Its temperature does not change
(C) Its pressure varies inversely as a certain power of its volume
(D) The product of its pressure and volume is directly proportional to its absolute temperature.

H-15. In figure, A and B are two adiabatic curves for two different gases. Then A and B corresponds to :



(A) Ar and He respectively (B) He and H_2 respectively
(C) O_2 and H_2 respectively (D) H_2 and He respectively

H-16. In a cyclic process shown in the figure an ideal gas is adiabatically taken from B and A, the work done on the gas during the process $B \rightarrow A$ is 30 J, when the gas is taken from $A \rightarrow B$ the heat absorbed by the gas is 20 J. The change in internal energy of the gas in the process $A \rightarrow B$ is :



(A) 20 J (B) – 30 J (C) 50 J (D) – 10 J

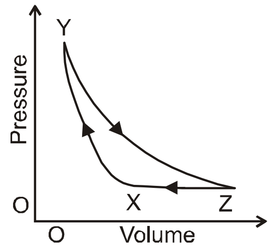
H-17. An ideal gas is allowed to expand freely against a vacuum in a rigid insulated container. The gas undergoes:
(A) an increase in its internal energy
(B) a decrease in its internal energy
(C) neither an increase nor decrease in temperature or internal energy
(D) an increase in temperature

H-18. For free expansion of a gas in an adiabatic container which of the following is true ?
(A) Q = W = 0 and $\Delta U = 0$ (B) Q = 0, W > 0 and $\Delta U = Q$
(C) W = 0, Q > 0 and $\Delta U = Q$ (D) W = 0, Q < 0 and $\Delta U = 0$

H-19. In an adiabatic process on a gas with $\gamma = 1.4$, the pressure is increased by 0.5%. The volume decreases by about

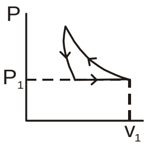
(A) 0.36% (B) 0.5% (C) 0.7& (D) 1%

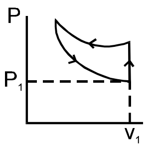
H-20. In given figure, a fixed mass of an ideal gas undergoes the change represented by XYZX below. Which one of the following sets could describe these of changes ?

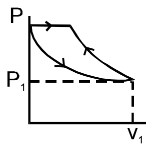


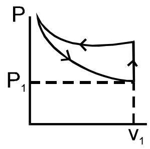
	X Y	Y Z	Z X
(A)	isothermal expansion	adiabatic compression	compression at constant pressure
(B)	adiabatic expansion	isothermal compression	pressure reduction constant volume
(C)	isothermal compression	adiabatic expansion	compression at constant pressure
(D)	adiabatic compression	isothermal expansion	compression at constant pressure

H-21. A certain mass of an ideal gas is at pressure P_1 and volume V_1. It is compressed isothermally and then allowed to expand adiabatically until its pressure returns to P_1. The gas is then allowed to expand its original volume. Which of the following P-V graphs are these process correctly shown?

(A) 

(B) 

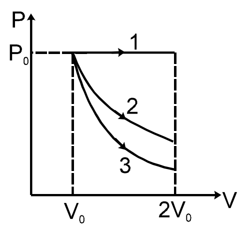
(C) 

(D) 

H-22. Starting with the same initial conditions, an ideal gas expands from volume V_1 to V_2 in three different ways. The work done by the gas is W_1 if the process is isothermal, W_2 if isobaric and W_3 if adiabatic, then :

(A) $W_2 > W_1 > W_3$ (B) $W_2 > W_3 > W_1$ (C) $W_1 > W_2 > W_3$ (D) $W_1 > W_3 > W_2$

H-23. In figure, an ideal gas is expanded from volume V_0 to $2V_0$ under three different processes. Process 1 is isobaric, process 2 is isothermal and process 3 is adiabatic. Let $\Delta U_1, \Delta U_2$ and ΔU_3 be the change in internal energy of the gas is these three processes. Then :



(A) $\Delta U_1 > \Delta U_2 > \Delta U_3$ (B) $\Delta U_1 < \Delta U_2 < \Delta U_3$

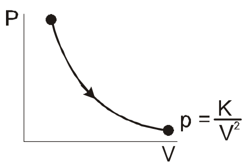
(C) $\Delta U_2 < \Delta U_1 < \Delta U_3$ (D) $\Delta U_2 < \Delta U_3 < \Delta U_1$

H-24. The internal energy of an ideal gas is equal to negative of the work done by the system, then

(A) The process must be adiabatic (B) The process must be isothermal

(C) The process must be isobaric (D) The temperature must decrease

H-25. The molar heat capacity for the process shown in fig. is



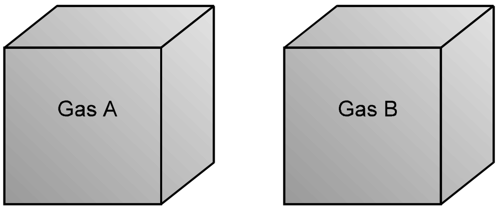
(A) $C = C_V$ (B) $C = C_P$ (C) $C > C_V$ (D) $C < C_V$

PART - II : MISLLANEOUS QUESTIONS

1. COMPREHENSION

Comprehension # 1

Two closed identical conducting containers are found in the laboratory of an old scientist. For the verification of the gas some experiments are performed on the two boxes and the results are noted.



Experiment 1.

When the two containers are weighed $W_A = 225$ g , $W_B = 160$ g and mass of evacuated container $W_C = 100$ g.

Experiment 2.

When the two containers are given same amount of heat same temperature rise is recorded. The pressure changes found are
$\Delta P_A = 2.5$ atm. $\Delta P_B = 1.5$ atm.

Required data for unknown gas :

Mono (molar mass)	He 4g	Ne 20g	Ar 40 g	Kr 84 g	Xe 131 g	Rd 222 g
Dia (molar mass)	H_2 2g	F_2 19 g	N_2 28g	O_2 32g	Cl_2 71 g	

1. Identify the type of gas filled in container A and B respectively.
(A) Mono, Mono (B) Dia, Dia (C) Mono, Dia (D) Dia, Mono.

2. Identify the gas filled in the container A and B.
(A) N_2, Ne (B) He, H_2 (C) O_2 , Ar (D) Ar, O_2

3. Total number of molecules in 'A' (here N_A = Avagadro number)
(A) $\frac{125}{64}N_A$ (B) 3.125 N_A (C) $\frac{125}{28}N_A$ (D) 31.25 N_A

4. The initial internal energy of the gas in container 'A', If the container were at room temperature 300K initially
(A) 1406.25 cal (B) 1000 cal (C) 2812.5 cal (D) none of these

Comprehension # 2

A mono atomic ideal gas is filled in a non conducting container. The gas can be compressed by a movable non conducting piston. The gas is compressed slowly to 12.5% of its initial volume.

5. The percentage increase in the temperature of the gas is
(A) 400% (B) 300% (C) – 87.5% (D) 0%

6. The ratio of initial adiabatic bulk modulus of the gas to the final value of adiabatic bulk modulus of the gas is
(A) 32 (B) 1 (C) 1/32 (D) 4

7. The ratio of work done by the gas to the change in internal energy of the gas is

(A) 1 (B) –1 (C) ∞ (D) 0

Comprehension # 3

An ideal gas initially at pressure p_0 undergoes a free expansion (expansion against vacuum under adiabatic conditions) until its volume is 3 times its initial volume. The gas is next adiabatically compressed back to its original volume. The pressure after compression is $3^{2/3}$ p_0.

8. The pressure of the gas after the free expansion is :

(A) $\frac{p_0}{3}$ (B) $p_0^{1/3}$ (C) p_0 (D) $3p_0$

9. The gas

(A) is monoatomic. (B) is diatomic. (C) is polyatomic.

(D) type is not possible to decide from the given information.

10. What is the ratio of the average kinetic energy per molecule in the final state to that in the initial state ?

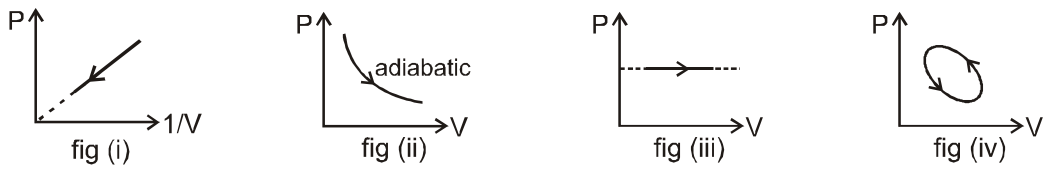
(A) 1 (B) $3^{2/3}$ (C) $3^{1/3}$ (D) $3^{1/6}$

2. MATCH THE COLUMN

1. An ideal monoatomic gas undergoes different types of processes which are described in column-I. Match the corresponding effects in column-II. The letters have usual meaning.

Column-I	Column-II
(A) $P = 2V^2$	(p) If volume increases then temperature will also increases.
(B) PV^2 = constant	(q) If volume increases then temperature will decreases.
(C) $C = C_V + 2R$	(r) For expansion, heat will have to be supplied to the gas.
(D) $C = C_V - 2R$	(s) If temperature increases then work done by gas is positive.

2. The figures given below show different processes (relating pressure P and volume V) for a given amount for an ideal gas. W is work done by the gas and ΔQ is heat absorbed by the gas.



Column-I	Column-II
(A) In Figure (i)	(p) $\Delta Q > 0$.
(B) In Figure (ii)	(q) $W < 0$.
(C) In Figure (iii)	(r) $\Delta Q < 0$.
(D) In Figure (iv) (for complete cycle)	(s) $W > 0$.

3. ASSERTION / REASON

13. **STATEMENT-1 :** An ideal gas is enclosed within a container fitted with a piston. When volume of this enclosed gas is increased at constant temperature, the pressure exerted by the gas on the piston decreases.
STATEMENT-2 : In the above situation the rate of molecules striking the piston decreases. If the rate at which molecules of a gas having same average speed striking a given area of the wall decreases, the pressure exerted by gas on the wall decreases.
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True

14. **STATEMENT-1 :** Different gases at the same condition of temperature and pressure have same root mean square speed.
STATEMENT-1 : Average K.E. of gas is directly proportional to temperature in kelvin
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True

15. **STATEMENT-1 :** The root mean square speed of molecules of a gas having Maxwell's distribution of speed is higher than their most probable speed, at any temperature.
STATEMENT-2 : A very small number of molecules of a gas molecules possess very large speed.
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True

16. **STATEMENT-1 :** Most probable speed is the speed possessed by maximum fraction of molecules at the same temperature.
STATEMENT-2 : On collision, more and more molecules acquire higher speed at the same temperature.
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True

17. **STATEMENT-1 :** Two different gases having same temperature always have molecules with same r.m.s speed.
STATEMENT-2 : The average translational KE per molecule for each gas is $\frac{3}{2}KT$ (where K = Boltzmann constant, T = temperature in kelvin)-
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True

18. **STATEMENT-1 :** The pressure of a gas filled in a cylinder fitted with an immovable piston is increased by raising its temperature.
STATEMENT-2 : On raising the temperature, greater momentum is transferred to the wall of the container per second.
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True

19. **STATEMENT -1 :** It is possible for both the pressure and volume of a monoatomic ideal gas of a given amount to change simultaneously without causing the internal energy of the gas to change.
STATEMENT-2: The internal energy of an ideal gas of a given amount remains constant if temperature does not change. It is possible to have a process in which pressure and volume are changed such that temperature remains constant.
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True

20. **STATEMENT-1 :** We can not change the temperature of a body without giving (or taking) heat to (or from) it.
STATEMENT-2 : According to principle of conservation of energy, total internal energy of system should remain conserved.
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True
(E) Both Statements are False

21. **STATEMENT-1 :** If an electric fan be switched on in a closed room, the air of the room will be cooled.
STATEMENT-2 : Fan air decreases the temperature of the room.
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True
(E) Both Statements are False

22. **STATEMENT-1 :** Heat supplied to a system with constant volume is used to increase only the internal energy of the system.
STATEMENT-2: According to first law of thermodynamics $dQ = U + W$ and W is zero for constant volume.
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True

23. **STATEMENT-1 :** Two conducting bodies at different temperatures, if brought in thermal contact in isolated container do not necessary settle to the mean temperature.
STATEMENT-2 : The two bodies may have different heat capacities.
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True

24. **STATEMENT-1 :** Work done by a gas in isothermal expansion is more than the work done by the gas in an adiabatic expansion. (In both cases initial parameters are same and expanded to same final volume)
STATEMENT-2 : Temperature remains constant in isothermal expansion and not in adiabatic expansion.
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True

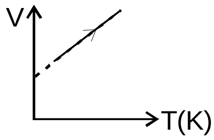
25. **STATEMENT-1:** Equal moles of helium and oxygen gases are given equal quantities of heat at constant volume. There will be a greater rise in the temperature of helium as compared to that of oxygen.
STATEMENT-2: The molecular weight of oxygen is more than the molecular weight of helium.
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True

26. **STATEMENT-1 :** The ratio of $\frac{C_p}{C_v}$ for an ideal diatomic gas is more than that for an ideal monoatomic gas(where C_p and C_v have usual meaning).
STATEMENT-2 : The atoms of monoatomic gas have less degrees of freedom as compared to molecules of the diatomic gas.
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True

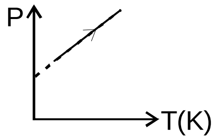
4. TRUE / FALSE

27. **State true and false**

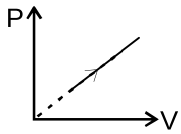
(i) The process represents isobaric process.



(ii) The process represents isochoric process.



(iii) The process represents isothermal process.



(iv) Two isothermal curves will never intersect.

5. FILL IN THE BLANKS

28. **Fill in the blanks :**

(i) One mole of a monoatomic ideal gas is mixed with one mole of a diatomic ideal gas. The molar specific heat of the mixture at constant volume is ......

(ii) During an experiment, an ideal gas is found to obey an additional law $P^2 V$ = constant. The gas is initially at a temperature T and volume V. When it expands to a volume 2V, the temperature becomes ....

(iii) An ideal gas with pressure P_i, volume V and temperature T is expanded isothermally to a volume 2V and a final pressure P_i. If the same gas is expanded adiabatically to a volume 2V, the final pressure is P_a. The ratio of the specific heat of the gas is 1.67. The ratio $\frac{P_a}{P_i}$ is ....

(iv) A container of volume 1 m^3 is divided into two equal parts by a partition. One part has an ideal gas at 300 K and the other part is vacuum. The whole system is thermally isolated from the surroundings. When the partition is removed, the gas expands to occupy the whole volume. Its temperature will now be ....

EXERCISE # 2

PART - I : MIXED OBJECTIVE

** Marked Questions are having more than one correct option.*

Single choice type

1. P_i, V_i are initial pressure and volumes and V_f is final volume of a gas in a thermodynamic process respectively. If PV^n = constant, then the amount of work done by gas is : ($\gamma = C_p/C_v$).
Assume same, initial state & same final volume in all processes.

(A) minimum for $n = \gamma$ (B) minimum for n = 1 (C) minimum for n = 0 (D) minimum for $n = \frac{1}{\gamma}$

2. The value of $C_p - C_v$ is 1.09 R for a gas sample in state A and is 1.00 R in state B. Let T_A, T_B denote the temperature and p_A and p_B denote the pressure of the states A and B respectively. Then
(A) $p_A < p_B$ and $T_A > T_B$ (B) $p_A > p_B$ and $T_A < T_B$ (C) $p_A = p_B$ and $T_A < T_B$ (D) $p_A > p_B$ and $T_A < T_B$

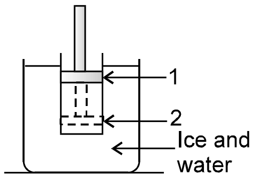
3. Find the amount of work done to increase the temperature of one mole of ideal gas by 30ºC. if it is expanding under the condition $V \propto T^{2/3}$ (R = 8.31 J/mol - K) :
(A) 16.62 J (B) 166.2 J (C) 1662 J (D) 1.662 J

4. A gas undergoes a process in which its pressure P and volume V are related as VP^n = constant. The bulk modulus of the gas in the process is :
(A) nP (B) $P^{1/n}$ (C) P/n (D) P^n

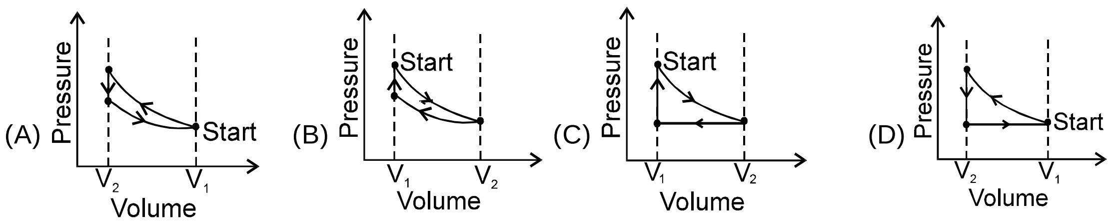
5. $V = k\left(\frac{P}{T}\right)^{0.33}$ where k is constant. It is an,

(A) isothermal process (B) adiabatic process (C) isochoric process (D) isobaric process

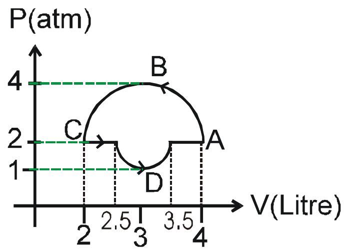
6. Figure shows a conducting cylinder containing gas and closed by a movable piston. The cylinder is submerged in an ice-water mixture. The piston is quickly pushed down from position (1) to position (2). The piston is held at position (2) until the gas is again at 0°C and then is slowly raised back to position (1).



P-V diagram for the above process will be



7. Find work done by the gas in the process shown in figure :

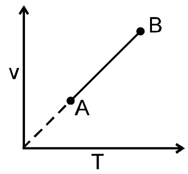


(A) $\frac{5}{2}\pi$ atm L (B) $\frac{5}{2}$ atm L (C) $-\frac{3}{2}\pi$ atm L (D) $-\frac{5}{4}\pi$ atm L

8. Two different ideal diatomic gases A and B are initially in the same state. A and B are then expanded to same final volume through adiabatic and isothermal process respectively. If P_A, P_B and T_A, T_B represents the final pressure and temperatures of A and B respectively then:

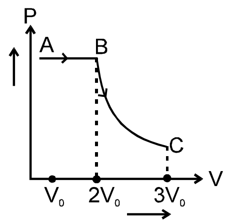
(A) $P_A < P_B$ and $T_A < T_B$ (B) $P_A > P_B$ and $T_A > T_B$
(C) $P_A > P_B$ and $T_A < T_B$ (D) $P_A < P_B$ and $T_A > T_B$

9. An ideal monoatomic gas undergoes the process AB as shown in the figure. If the heat supplied and the work done in the process are ΔQ and W respectively. The ratio ΔQ : W is :



(A) 2.50 (B) 1.67 (C) 0.67 (D) 0.40

10. One mole of a gas is subjected to two process AB and BC, one after the other as shown in the figure. BC is represented by PV^n = constant. We can conclude that (where T = temperature, W = work done by gas, V = volume and U = internal energy).



(A) $T_A = T_B = T_C$ (B) $V_A < V_B$, $P_B < P_C$ (C) $W_{AB} < W_{BC}$ (D) $U_A < U_B$

11. The molar heat capacity C for an ideal gas going through a process is given by C = $\frac{a}{T}$, where 'a' is a constant. If $\gamma = \frac{C_p}{C_v}$, the work done by one mole of gas during heating from T_0 to ηT_0 will be:

(A) $a\,\ell n\,\eta$ (B) $\frac{1}{a\ell n\eta}$ (C) $a\ell n\eta - \left(\frac{\eta-1}{\gamma-1}\right)RT_0$ (D) $a\ell n\eta - (\gamma-1)RT_0$

12. One mole of an ideal gas undergoes a process in which $T = T_0 + aV^3$, where T_0 and 'a' are positive constants and V is volume. The volume for which pressure will be minimum is

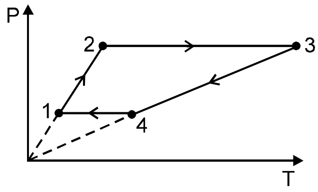
(A) $\left(\frac{T_0}{2a}\right)^{1/3}$ (B) $\left(\frac{T_0}{3a}\right)^{1/3}$ (C) $\left(\frac{a}{2T_0}\right)^{2/3}$ (D) $\left(\frac{a}{3T_0}\right)^{2/3}$

13. In the above question, minimum pressure attainable is

(A) $\frac{3}{4}\left(a^{5/3}R^{2/3}T_0^{2/3}\right)2^{1/3}$ (B) $\frac{3}{2}\left(a^{2/3}RT_0^{2/3}\right)3^{1/2}$

(C) $\frac{3}{2}\left(a^{1/2}R^{2/3}T_0^{3/4}\right)4^{1/3}$ (D) $\frac{3}{2}\left(a^{1/3}RT_0^{2/3}\right)2^{1/3}$

14. Three moles of an ideal monoatomic gas perform a cycle shown in figure. The gas temperatures in different states are T_1 = 400 K, T_2 = 800 K, T_3 = 2400 K, and T_4 = 1200 K. The work done by the gas during the cycle is :- $\left[R = \frac{25}{3} J/mol - k\right]$



(A) 5 kJ (B) 10 kJ (C) 15 kJ (D) 20 kJ

15. In a certain gas, the ratio of the speed of sound and root mean square speed is $\sqrt{\frac{5}{9}}$. The molar heat capacity of the gas in a process given by PT = constant is
(Take R = 2 cal/mole K). Treat the gas as ideal.

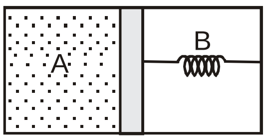
(A) $\frac{R}{2}$ (B) $\frac{3R}{2}$ (C) $\frac{5R}{2}$ (D) $\frac{7R}{2}$

16. The molar heat capacity at constant presure of nitrogen gas at STP is nearly 3.5 R. Now when the temperature is increased, it gradually increases and approaches 4.5 R. The most appropriate reason for this behaviour is that at high temperatures

(A) nitrogen does not behave as an ideal gas (B) nitrogen molecules dissociate in atoms
(C) the molecules collides more frequently (D) molecular vibration gradually become effective

More than one choice type

17. A thermally insulated chamber of volume $2V_0$ is divided by a frictionless piston of area S & mass m into two equal parts A and B.Part A has an ideal gas at pressure P_0 and temperature T_0 and in part B is vacuum. A massless spring of force constant K is connected with the piston and the wall of the container as shown. Initially the spring is undeformed. The gas in chamber A is allowed to expand. Let in equilibrium the spring is compressed by x_0 . Then :



(A) Pressure of the gas at equilibrium is $\frac{Kx_0}{S}$

(B) Work done by the gas is $\frac{1}{2}Kx_0^2$

(C) Increase in internal energy of the gas is $\frac{1}{2}Kx_0^2$

(D) Temperature of the gas is decreased

18. For an ideal gas :

(A) the change in internal energy in a constant pressure process from temperature T_1 to T_2 is equal to $nC_v(T_2 - T_1)$, where C_v is the molar specific heat at constant volume and n the number of moles of the gas.

(B) the change in internal energy of the gas and the work done by the gas are equal in magnitude in an adiabatic process.

(C) the internal energy does not change in an isothermal process.

(D) no heat is added or removed in an adiabatic process.

PART - II : SUBJECTIVE QUESTIONS

Section (A) : Kinetic Theory of Gases

A-1. Find the average momentum of molecules of hydrogen gas in a container at temperature 300 K.

A-2. A cubical container having each side as ℓ is filled with a gas having N molecules in the container. Mass of each molecule is m. If we assume that at every instant half of the molecules are moving towards the positive x-axis and half of the molecules are moving towards the negative x-axis. Two walls of the container are perpendicular to the x-axis. Find the force acting on the two walls given? Assume that all the molecules are moving with speed v_0 .

Section (B) : Root mean square speed, Kinetic Energy and equation of state

B-1. The speeds of three molecules are 3V, 4V and 5V respectively. Find their rms speed.

B-2. At room temperature (300 K) , the rms speed of the molecules of a certain diatomic gas is found to be 1930 m/s. Can you guess name of the gas ? Find the temperature at which the rms speed is double of the speed in part one (R = 25/3 J/mol – k)

B-3. The average translational kinetic energy of nitrogen gas molecules is 0.02 eV ($1 \text{ eV} = 1.6 \times 10^{-19}$ J). Calculate the temperature of the of gas. Boltzmann constant $k = 1.38 \times 10^{-23}$ J/K.

B-4. A gas is filled in a rigid container at pressure P_0. If the mass of each molecule is halved keeping the total number of molecules same and their r.m.s. speed is doubled then find the new pressure.

B-5. The molecules of a given mass of gas have r.m.s. speed 200 ms^{-1} at 27ºC and 10^5 Nm^{-2} pressure. When the absolute temperature is doubled and the pressure is halved, then find rms speed of the molecules of the same gas.

B-6. Find the number of molecules in 10 cm^3 of an ideal gas at 0ºC and at a pressure of 2×10^{-5} mm of mercury. Take density of Hg = 13.6 g/cc and g = 10 m/s^2, R = 25/3 J/mol–K

B-7. Butane gas burns in air according to the following reaction,

$$2\,C_4H_{10} + 13\,O_2 \longrightarrow 10\,H_2O + 8\,CO_2.$$

Suppose the initial and final temperatures are equal and high enough so that all reactants and products act as perfect gases. Two moles of butane are mixed with 13 moles of oxygen and then completely reacted. Find the final pressure (if the volume remains unchanged and the pressure before reaction is P_0)?

B-8. An ideal gas expands in such a way that its pressure and volume are related by the equation : PV^2 = constant. Find whether the gas is heated or cooled :

Note : Heated here means temperature rises, and not heat energy supplied. Similarly cooled implies reduction in temperature, and not heat rejected by the system (gas)

B-9. Equal masses of air are sealed in two vessels, one of volume V_0 and the other of volume $2V_0$. If the first vessel is maintained at a temperature 300 K and the other at 600 K, find the ratio of the pressures in the two vessels.

B-10. Find the number of air molecules present in an electric bulb of volume 200 cc was sealed during manufacturing at a pressure of 2×10^{-3} mm of mercury at 31ºC. Avogadro constant = 6×10^{23} per mol, density of mercury = 13600 kg/m^3 and g = 10 m/s^2. [R = 25/3 J / mol – k]

B-11. A cylinder contains gas at 2×10^5 Pa and 47ºC. The cylinder is steadily heated. Neglecting any change in its volume, find the temperature at which the cylinder will break if the walls of cylinder can bear a maximum pressure of 8×10^5 Pa.

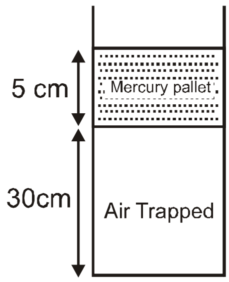
B-12. The temperature and pressure at Manali are 10ºC and 72.0 cm of mercury and at Mumbai these are 40ºC and 76.0 cm of mercury. Find the ratio of air density at Manali to the air density at Mumbai.

B-13. An air bubble of radius 3.0 mm is formed at the bottom of a 5 m deep river. Calculate the radius of the bubble as it comes to the surface. Atmospheric pressure = 1.0×10^5 Pa and density of water = 1000 kg/m^3, g = 10 m/s^2. (Assume temperature remains constant in this process.)

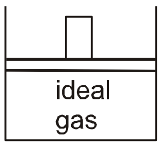
B-14. At a pressure of 3 atm air (treated as an ideal gas) is pumped into the tubes of a cycle rickshaw. The volume of each tube at given pressure is 0.004 m^3. One of the tubes gets punctured and the volume of the tube reduces to 0.0008 m^3. Find the number moles of air have leaked out? Assume that the temperature remains constant at 300 K . (R = 25/3 J mol^{-1} K^{-1})

B-15. A vessel contains 0.5 g of hydrogen and 0.8 g of oxygen. The volume of vessel is $\frac{5}{28}$ m^3 while its temperature is maintained at 300 K. Find the pressure of the mixture. (Assuming no reaction takes place between hydrogen and oxygen) ($M_{H_2} = 2$, $M_{O_2} = 32$ & $R = \frac{25}{3}$ J/mol–K)

B-16. In given figure, A uniform cylindrical tube closed at one end, contains a pallet of mercury 5 cm long. When the tube is kept vertically with the closed end downward, the length of the air column trapped is 30 cm. Now the tube is inverted so that the closed end goes up find the new length of the air column trapped. Atmospheric pressure = 75 cm of mercury. (Assume temperature remains constant in this process)



B-17. Vessel fitted with a frictionless piston of mass 2 kg and a cross-sectional area 10 cm^2 as shown in the figure. Initially the length of gas coluomn is 40 cm. Now the vessel is taken into spaceship revolving round the earth as a satellite. The air pressure in the spaceship is maintained at 100 kPa. Find the length of the gas column in the cylinder (Assuming in both cases temperature remains same).



Section (C) : Maxwell's distribution of speed

C-1. Find the temperature at which average speed of oxygen molecule be sufficient so as to escape from the earth? (Escape speed from the earth is 11.0 km/sec, R = 25/3 J-mol^{-1}K^{-1}) .

C-2. Find the average magnitude of linear momentum of a helium molecule in a sample of helium gas at 150 π K. Mass of a helium molecule = (166/3) × 10^{-27} kg and R = 25/3 J-mol^{-1} K^{-1}

C-3. The mean speed of the molecules of a hydrogen sample equals the mean speed of the molecules of helium sample. Calculate the ratio of the temperature of the hydrogen sample to the temperature of the helium sample.

C-4. Find the ratio of the mean speed of hydrogen molecules to the mean speed of nitrogen molecules in a sample containing a mixture of the two gases.

Section (D) : Law of equipartition and internal energy

D-1. 16 g of oxygen at 37°C is mixed with 14 g of nitrogen at 27°C. Find the temperature of the mixture?

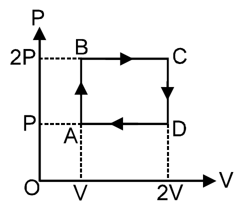
D-2. 0.040 g of He is kept in a closed container initially at 100.0°C. The container is now heated. Neglecting the expansion of the container, calculate the temperature at which the internal energy is increased by 12 J.

$$\left[R = \frac{25}{3} J - mol^{-1} - k^{-1}\right]$$

D-3. Show that the internal energy of the air (treated as an ideal gas) contained in a room remains constant as the temperature changes between day and night. Assume that the atmospheric pressure around remains constant and the air in the room maintains this pressure by communicating with the surrounding through the windows etc.

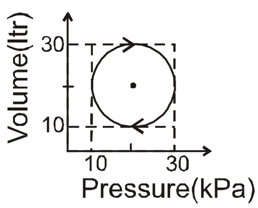
Section (E) : Calculation of work

E-1. An ideal monoatomic gas is taken round the cycle ABCDA as shown in the P–V diagram. Find the work done by the gas during the cycle?



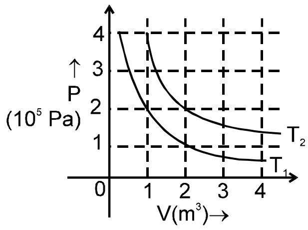
E-2. One mole of a gas expands with temperature T such that its volume, V = kT^2, where k is a constant. If the temperature of the gas changes by 60° C then find the work done by the gas? (R = 25/3 J/mol-K).

E-3. Find the work done by gas going through a cyclic process shown in figure?



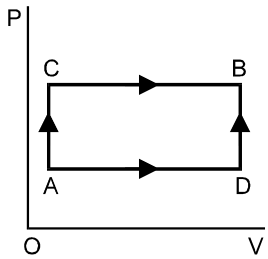
E-4. An ideal gas is compressed at constant pressure of 10^5 Pa until its volume is halved. If the initial volume of the gas as 3.0 × 10^{-2} m^3, find the work done on the gas?

E-5. The following graph shows two isotherms for a fixed mass of an ideal gas. Find the ratio of r.m.s. speed of the molecules at temperatures T_1 amd T_2 ?



Section (F) : First Law of thermodynamics

F-1. In given figure, when a thermodynamic system is taken from state A to state B via path ACB, 100 cal of heat given to the system and 60 cal work is done by the gas. Along the path ADB, the work done by the gas is 20 cal. Find the heat flowing into the system in this case?



F-2. A system absorbs 1000 cal of heat and does 1675 J work. If J = 4.18 J/cal, then find the change in internal energy of the system ?

F-3. A cylinder fitted with a piston contains an ideal monoatomic gas at a temperature of 400 K. The piston is held fixed while heat ΔQ is given to the gas, It is found the temperature of the gas has increased by 20 K. In an isobaric process the same ΔQ heat is supplied slowly to it. Find the change in temperature in the second process?

F-4. 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 and 8 J of work is done on the gas. If initial internal energy of the gas was 30 J, what will be the final internal energy ?

F-5. A diatomic gas does 80 J of work when expanded isobarically. Find the heat given to the gas during this process ?

F-6. The average degree of freedom per molecule for a gas is 6. The gas performs 25 J of work when it expands at constant pressure. Find the heat absorbed by the gas?

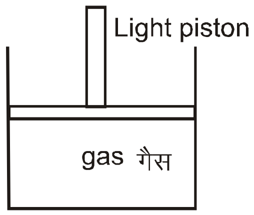
F-7. Ideal diatomic gas is taken through a process dQ = 2dU, where dQ is heat supplied and dU is change in internal energy of system. Find the work done by the gas?

F-8. A gas under constant pressure of 4.5×10^5 Pa when subjected to 800 kJ of heat, changes the volume from 0.5 m^3 to 2.0 m^3. Find the change in internal energy of the gas?

F-9. When 1 g of water at 0ºC and 1×10^5 N m^{-2} pressure is converted into ice of volume 1.091 cm^3, find the work done by water? (ρ_w = 1 gm/cm^3)

F-10. An ideal gas is taken through a cyclic thermodynamic process through four steps. The amounts of heat involved in these steps are Q_1 = 5960 J, Q_2 = – 5585 J, Q_3 =– 2980 J and Q_4 = 3645 J respectively. The corresponding works involved are W_1 = 2200 J, W_2 = – 825 J, W_3 = – 1100 J and W_4 respectively.
(i) Find the value of W_4.
(ii) What is the efficiency of the cycle ?

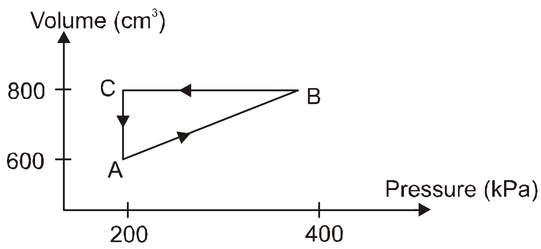
F-11. In given figure, gas is slowly heated for sometime. During the process , the increase in internal energy of the gas is 10 J and the piston is found to move out by 25 cm, then find the amount of heat supplied. The area of cross-section of cylinder = 40 cm^2 and atmospheric pressure = 100 kPa



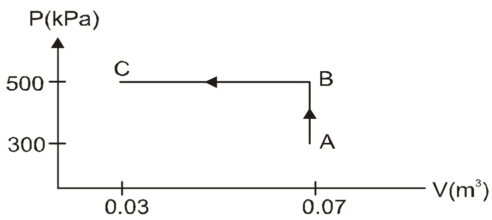
F-12. A gas is initially at a pressure of 100 kPa and its volume is $2.0m^3$. Its pressure is kept constant and the volume is changed from $2.0m^3$ to $2.5m^3$. Its volume is now kept constant and the pressure is increased from 100 kPa to 200 kPa. The gas is brought back to its initial state, the pressure varying linearly with its volume. (a) Whether the net heat is supplied or extracted from the gas in the complete cycle? (b) How much heat was supplied or extracted?

F-13. Find the change in the internal energy of 2kg of water as it is heated from 0ºC to 4ºC. The specific heat capacity of water is 4200 J/kg-K and its densities at 0ºC and 4ºC are 999.9kg/m^3 and 1000 kg/m^3 respectively. Atmospheric pressure = 10^5 Pa.

F-14. In given figure, An ideal gas a gas is taken through a cyclic process ABCA, calcualte the value of mechanical equivalent of heat (J) when 4.8 cal of heat is given in the process ?



F-15. An ideal gas is taken through the process ABC as shown in figure. If the internal energy of the substance decreases by 10000 J and a heat of 7159 cal is released to the system, calculate the value of mechanical equivalent of heat (J).



Section (G) : Specific heat capacities of gases

G-1. If γ be the ratio of specific heats (C_p & C_v) for a perfect gas, Find the number of degrees of freedom of a molecule of the gas?:

G-2. 70 calories of heat is required to raise the temperature of 2 moles of an ideal gas at constant pressure from 30 °C to 35 °C. Find the amount of heat required (in calories) to raise the temperature of the same gas through the same range (30 °C to 35 °C) at constant volume?

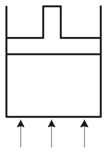
G-3. Internal energy of two moles of an ideal gas at a temperature of 127ºC is 1200 R. Then find the molar specific heat of the gas at constant pressure?

G-4. Ideal monoatomic gas is taken through a process $dQ = 2dU$. Find the molar heat capacity (in terms of R) for the process ? (where dQ is heat supplied and dU is change in internal energy)

G-5. Find the molar heat capacity (in terms of R) of a monoatomic ideal gas undergoing the process : $PV^{1/2}$ = constant ?

G-6 A vessel containing diatomic ideal gas (molecular weight = M g/mol) is moving on a floor. The vessel is stopped suddenly, if the initial speed of vessel is v then find the rise in temperature (Assuming that the mechanical energy lost has gone into the internal energy of the gas, R = Gas constant)

G-7. In given figure a cylindrical vessel contains nitrogen and closed by a 20 kg frictionless piston. If cylinder is slowly heated for sometime and 77 J of heat is supplied to the gas then find the displacement of piston during the process. (Area of cross-section of piston = 200 cm^2, atmospheric pressure = 100s kPa, g = 10m/s^2)



G-8. Calculater the value of mechanical equivalent of heat from the following data. Specific heat capacity of air at constant volume and at constant pressure are 4.93 cal/mol–K and 6.90 cal/mol–K respectively. Gas constant R = 8.3 J/mol–K.

G-9. Find the change in internal energy of 2 moles of an ideal gas when its temperature is increased by 75 K (a) keeping the pressure constant, (b) keeping the volume constant and (c) adiabatically. $\left(\gamma = \frac{C_P}{C_V} = \frac{7}{5}\right)$

$\left[R = \frac{25}{3} J/mol - k\right]$

G-10. When 100 J of heat is given to an ideal gas it expands from 200 cm^3 to 400 cm^3 at a constant pressure of 3×10^5 Pa. Calculate (a) the change in internal energy of the gas, (b) the number of moles in the gas if the initial temperature is 400 K, (c) the molar heat capacity C_p at constant pressure and (d) the molar heat capacity C_v at constant volume. $\left[R = \frac{25}{3} J/mol - k\right]$

G-11. If Q amount of heat is given to a diatomic ideal gas in a process in which the gas perform a work $\frac{2Q}{3}$ on its surrounding. Find the molar heat capacity (in terms of R) for the process.

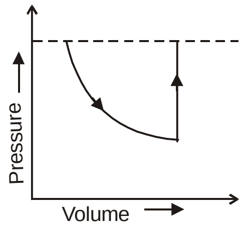
G-12. An ideal gas is taken through a process in which pressure and volume vary as $P = kV^2$. Show that the molar heat capacity of the gas for the process is given by $C = C_v + \frac{R}{3}$.

G-13. An ideal gas ($C_p/C_v = \gamma$) is taken through a process in which the pressure and the volume vary as $P = kV^a$, where k = constant. Find the value of a for which the molar specific heat capacity in the process is zero.

G-14. When the state of a system changes form A to B adiabatically the work done on the system is 322 Joule. If the state of the same system is changed from A to B by another process, and heat required is 50 calories of heat is required then find work done on the system in this process? (J = 4.2 J/cal)

Section (H) : Adiabatic process and free expansion

H-1. In given figure, a sample of an ideal gas initially having internal energy U_1 is allowed to expand adiabatically performing work W. Heat Q is then supplied to it, keeping the volume constant at its new value, until the pressure rised to its original value. The internal energy is then U_2.



Find the increase in internal energy $(U_2 - U_1)$?

H-2. One mole of an ideal monoatomic gas $\left(\gamma = \frac{5}{3}\right)$ is mixed with one mole of a diatomic gas $\left(\gamma = \frac{7}{5}\right)$. ($\gamma$ denotes the ratio of specific heat at constant pressure, to that at constant volume) find γ for the mixture?

H-3. The temperature of 5 mol of a gas which was held at constant volume was changed from 100ºC to 120ºC. The changes in internal energy was found to be 80 J. Find the molar heat capacity of the gas at constant volume?

H-4. The pressure and density of a diatomic gas $\left(\gamma = \frac{7}{5}\right)$ change adiabatically from (P, d) to (P′, d′). If $\frac{d'}{d}$ = 32, then find the value of $\frac{P'}{P}$?

H-5. An ideal gas ($\gamma = \frac{5}{3}$) is suddenly compressed from 640 cm^3 to 80 cm^3. If the initial pressure is P then find the final pressure?

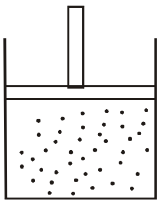
H-6. In an adiabatic process, the pressure is increased by $\frac{2}{3}\%$. If $\gamma = \frac{3}{2}$, then find the decreases in volume (approximately)?

H-7. For a gas, γ = 9/7. What is the number of degrees of freedom of the molecules of this gas ?

H-8. A gas at NTP is suddenly compressed to one-fourth of its original volume. If γ is supposed to be 3/2, then find final pressure?

H-9 An ideal gas at pressure 4×10^5 Pa and temperature 400 k occupies 100 cc. It is adiabatically expanded to double of its original volume. Calculate (a) the final pressure, (b) final temperature and (c) work done by the gas in the process (γ = 1.5) :

H-10 In fig, the walls of the container and the piston are adiabatic. The initial pressure, volume and temperture of the gas are 200 K Pa, 800 cm^3 and 100 K resp. Find the pressure and the temperature of the gas if it is (a) slowly compressed (b) suddenly compressed to 200 cm^3 (γ = 1.5).



H-11. A container of volume 1 m^3 is divided into two equal parts by a partition. One part has an ideal gas at 300 K and the other part is vacuum. The whole system is thermally isolated from the surroundings. When the partition is removed, the gas expands to occupy the whole volume. Its temperature will now become ________.

H-12. A mixture contains 1 mole of Argon (C_p = 2.5R, C_v = 1.5 R) and 1 mole of oxygen (C_p = 3.5 R, C_v = 2.5 R). Calculate the value of C_p, C_v and γ for the mixture.

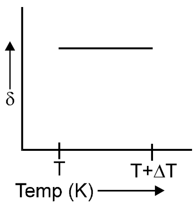
EXERCISE # 3

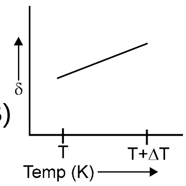
PART-I IIT-JEE (PREVIOUS YEARS PROBLEMS)

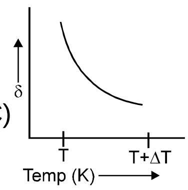
*** Marked Questions are having more than one correct option.**

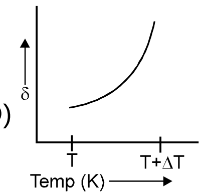
1. A vertical cylinder of cross sectional area 0.1 m^2 closed at both ends is fitted with a frictionless piston of mass M dividing the cylinder into two parts. Each part contains one mole of an ideal gas in equilibrium at 300 K. The volume of the upper part is 0.1 m^3 and the volume of the lower part is 0.05 m^3. What force must be applied to the piston so that the volume of the two parts remain unchanged when the temperature is increased to 500 K? use R = $\frac{25}{3}$ J-mol^{-1} K^{-1}. **[REE - 2000]**

2. An ideal gas is initially at temperature T and volume V. Its volume is increased by ΔV due to an increase in temperature ΔT, pressure remaining constant. The quantity $\delta = \frac{\Delta V}{V\Delta T}$ varies with temperature as: **[JEE (Scr.) 2000, 3/105]**

(A) 

(B) 

(C) 

(D) 

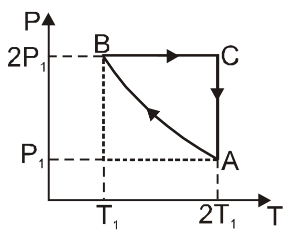
3. A monoatomic ideal gas, initially at temperature T_1, is enclosed in a cylinder fitted with a frictionless piston. The gas is allowed to expand adiabatically to a temperature T_2 by releasing the piston suddenly. If L_1 and L_2 are the lengths of gas column before and after expansion respectively, then T_1/T_2 is given by: **[JEE 2000, 3/105]**

(A) $\left(\frac{L_1}{L_2}\right)^{2/3}$ (B) $\frac{L_1}{L_2}$ (C) $\frac{L_2}{L_1}$ (D) $\left(\frac{L_2}{L_1}\right)^{2/3}$

4. Starting the same initial conditions, an ideal gas expands from volume V_1 to V_2 in three different ways, the work done by the gas is W_1 if the process is purely isothermal, W_2 if purely isobaric and W_3 if purely adiabatic, then: **[JEE 2000, 3/105]**

(A) $W_2 > W_1 > W_3$ (B) $W_2 > W_3 > W_1$ (C) $W_1 > W_2 > W_3$ (D) $W_1 > W_3 > W_2$

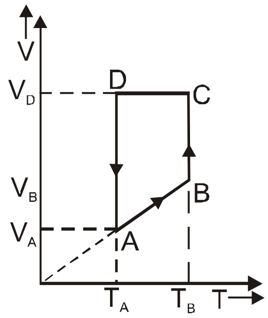
5. Two moles of an ideal monatomic gas is taken through a cycle ABCA as shown in the P-T diagram. During the process AB, pressure and temperature of the gas vary such that PT = constant. If T_1 = 300 K, calculate:



(a) The work done on the gas in the process AB and
(b) The heat absorbed or released by the gas in each of the processes. Give answer in terms of the gas constant R. **[JEE (Scr.) 2000, 10/100]**

6. One mole of an ideal gas is heated isobarically from the freezing point to the boiling point of water at atmospheric pressure. Find out the work done by the gas and the change in its internal energy. The amount of heat involved is 1 kJ. [R = $\frac{25}{3}$ J/mol–k] **[REE 2000]**

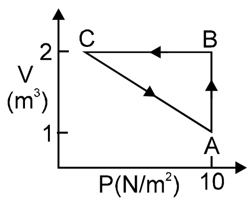
7. A monoatomic ideal gas of two moles is taken through a cyclic process starting from A as shown in figure. The volume ratios are $\frac{V_B}{V_A} = 2$ and $\frac{V_D}{V_A} = 4$ .If the temperature T_A at A is 27°C, calculate :



(a) the temperature of the gas at point B,
(b) heat absorbed or released by the gas in each process,
(c) the total work done by the gas during the complete cycle.
Express your answer in terms of the gas constant R. **[JEE 2001,(1 + 4 + 5)/100]**

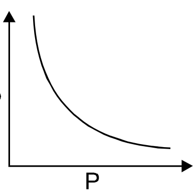
8. 4 moles of a monatomic gas are at pressure 3 x 10^5 Nm^{-2} and temperature 100 K (state A). It is heated isobarically to temperature 400 K (state B). Next it undergoes isothermal expansion to pressure 1 x 10^5 Nm^{-2} (state C). It is then cooled isobarically to 100 K (state D). Finally it is compressed isothermally to return to state A. Draw P-T, P-V and V-T diagrams for the whole process. [R = $\frac{25}{3}$ J / mole – k] **[REE 2001]**

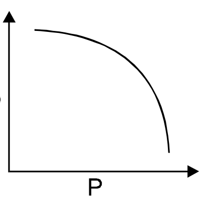
9. An ideal gas is taken through the cycle A $\rightarrow$ B $\rightarrow$ C $\rightarrow$ A as shown in the fig. If the net heat supplied to the gas in the cycle is 5 J,the work done by the gas in the process C $\rightarrow$ A is : **[JEE (Scr.) 2002, 3/90, –1]**

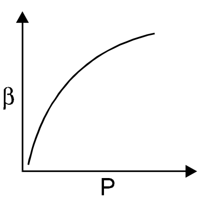


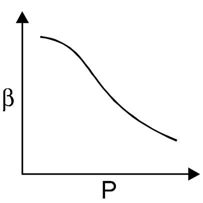
(A) – 5 J (B) – 10 J (C) – 15 J (D) – 20 J

10. Which of the following graphs correctly represents the variation of $\beta = -(dV/dP)/V$ with P for an ideal gas at constant temperature ? **[JEE (Scr.) 2002, 3/90, –1]**

(A) 

(B) 

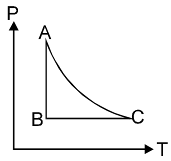
(C) 

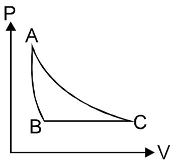
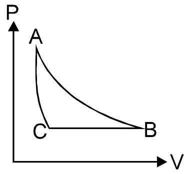
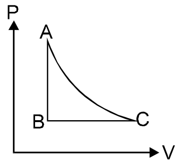
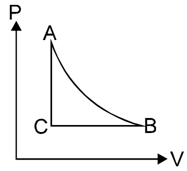
(D) 

11. A cubical box of side 1 meter contains helium gas (atomic weight 4) at a pressure of 100 N/m^2. During an observation time of 1 second, an atom travelling with the root-mean-square speed parallel to one of the edges of the cube, was found to make 500 hits with a particular wall, without any collision with other atoms. Take R = $\frac{25}{3}$ J/mol-K and k = 1.38 × 10^{-23} J/K.

(a) Evaluate the temperature of the gas.
(b) Evaluate the average kinetic energy per atom.
(c) Evaluate the total mass of helium gas in the box. **[JEE (Mains), 2002, 5/60]**

12. An ideal gas under goes a cyclic process as shown in the given P–T diagram, where the process AC is adiabatic. The process is also represented by : **[JEE (Scr.) 2003, 3/84, –1]**



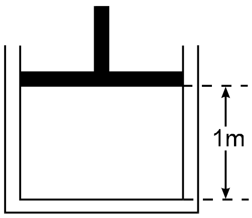
(A)  (B)  (C)  (D) 

13. An insulated box containing a monoatomic gas of molar mass M moving with a speed v_0 is suddenly stopped. Find the increment in gas temperature as a result of stopping the box. **[JEE (Mains) 2003, 2/60]**

14. An ideal gas initially at a state (P_1, V_1) is allowed to expand isothermally to a state (P_2, V_2). Then the gas is compressed adiabatically to its initial volume V_1. Let the final pressure be P_3 and the work done by the gas during the whole process be W, then **[JEE(Scr.) 2004,3/84, –1]**

(A) $P_3 > P_1$ and $W < 0$ (B) $P_3 > P_1$ and $W > 0$
(C) $P_3 < P_1$ and $W > 0$ (D) $P_3 < P_1$ and $W < 0$

15. An ideal diatomic gas is enclosed in a cylindrical chamber of uniform cross-section $1m^2$. The cylinder is fitted with a movable frictionless piston of negligible mass. When the gas is at equilibrium temperature T = 300 K, the piston is at a height h = 1m (as shown in figure). Find the height of the piston when the equilibrium temperature is raised to 400K at constant pressure. Now the piston is brought back to its original height without any loss of heat. What is the final temperature of the gas? (you may leave the answer in fractional form.) **[JEE (Mains) 2004, 2/60]**



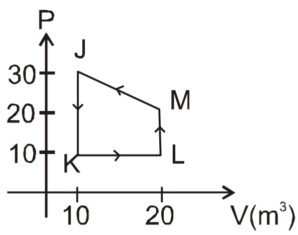
16. An ideal gas is filled in a closed rigid and thermally insulated container. A coil of 100Ω resistor carrying current 1A for 5 minutes supplies heat to the gas. The change in internal energy of the gas is : **[JEE (Scr.) 2005, 3/84, –1]**

(A) 10 KJ (B) 20 KJ (C) 30 KJ (D) 0 KJ

17. 1 calorie is the heat required to increase the temperature of 1 gm of water by 1°C from

(A) 13.5°C to 14.5°C at 76 mm of Hg
(B) 14.5 °C to 15.5°C at 760 mm of Hg
(C) 6.5 °C to 7.5°C at 76 mm of Hg
(D) 98.5 °C to 99.5°C at 760 mm of Hg **[JEE (Scr) 2005, 3/84, –1]**

18. Match the following for the given process : **[JEE 2006, 6/184]**



(A) Process J → K	(p) W > 0
(B) Process K → L	(q) W < 0
(C) Process L → M	(r) Q > 0
(D) Process M → J	(s) Q < 0

19. **STATEMENT - 1**

The total translational kinetic energy of all the molecules of a given mass of an ideal gas is 1.5 times the product of its pressure and its volume. **[JEE 2007; 3/162)]**

because

STATEMENT - 2

The molecules of a gas collide with each other and the velocities of the molecules change due to the collision.

(A) Statement-1 is True, Statement-2 is True; Statement-2 **is** a correct explanation for Statement-1
(B) Statement-1 is True, Statement-2 is True; Statement-2 **is NOT** a correct explanation for Statement-1
(C) Statement-1 is True, Statement-2 is False
(D) Statement-1 is False, Statement-2 is True.

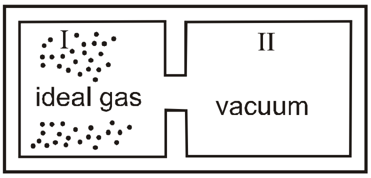
20. An ideal gas is expanding such that PT^2 = constant. The coefficient of volume expansion of the gas is

(A) $\frac{1}{T}$ (B) $\frac{2}{T}$ (C) $\frac{3}{T}$ (D) $\frac{4}{T}$ **[JEE 2008' 3/163]**

21. **Column I** contains a list of processes involving expansion of an ideal gas. Match this with **Column II** describing the thermodynamic change during this process. Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS. **[JEE 2008' 6/163]**

Column I

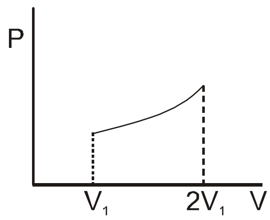
(A) An insulated container has two chambers separated by a valve. Chamber I contains an ideal gas and the Chamber II has vacuum. The valve is opened.



(B) An ideal monoatomic gas expands to twice its original volume such that its pressure $P \propto \frac{1}{V^2}$, where V is the volume of the gas.

(C) An ideal monoatomic gas expands to twice its original volume such that its pressure $P \propto \frac{1}{V^{4/3}}$, where V is its volume

(D) An ideal monoatomic gas expands such that its pressure P and volume V follows the behaviour shown in the graph



Column II

(p) The temperature of the gas decreases

(q) The temperature of the gas increases or remains constant

(r) The gas loses heat

(s) The gas gains heat

22. C_v and C_p denote the molar specific heat capacities of a gas at constant volume and constant pressure, respectively. Then **[JEE, 2009, 4/160, –1]**

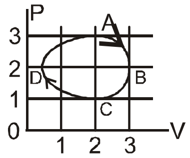
(A) $C_p - C_v$ is larger for a diatomic ideal gas than for a monoatomic ideal gas

(B) $C_p + C_v$ is larger for a diatomic ideal gas than for a monoatomic ideal gas

(C) C_p / C_v is larger for a diatomic ideal gas than for a monoatomic ideal gas

(D) $C_p \cdot C_v$ is larger for a diatomic ideal gas than for a monoatomic ideal gas

23. The figure shows the P-V plot of an ideal gas taken through a cycle ABCDA. The part ABC is a semi-circle and CDA is half of an ellipse. Then, **[JEE, 2009, 4/160, –1]**



(A) the process during the path $A \to B$ is isothermal

(B) heat flows out of the gas during the path $B \to C \to D$

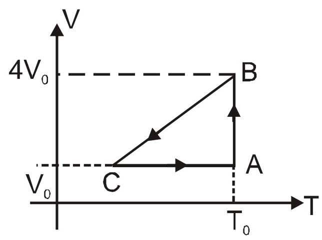
(C) work done during the path $A \to B \to C$ is zero

(D) positive work is done by the gas in the cycle ABCDA

24. A real gas behaves like an ideal gas if its **[JEE, 2010, 3/163, –1]**

(A) pressure and temperature are both high
(B) pressure and temperature are both low
(C) pressure is high and temperature is low
(D) pressure is low and temperature is high

25. One mole of an ideal gas in initial state A undergoes a cyclic process ABCA, as shown in the figure. Its pressure at A is P_0. Choose the correct option(s) from the following : **[JEE, 2010, 3/163]**



(A) Internal energies at A and B are the same
(B) Work done by the gas in process AB is $P_0V_0 \ \ell n\ 4$

(C) Pressure at C is $\frac{P_0}{4}$
(D) Temperature at C is $\frac{T_0}{4}$

26. A diatomic ideal gas is compressed adiabatically to $\frac{1}{32}$ of its initial volume. If the initial temperature of the gas is T_i (in Kelvin) and the final temperature is aT_i, the value of a is : **[JEE, 2010, 3/163]**

PART-II AIEEE (PREVIOUS YEARS PROBLEMS)

* ***Marked Questions are having more than one correct option.***

1. Which statement is incorrect ? **[AIEEE - 2002, 4/300]**
(1) All reversible cycles have same efficiency
(2) Reversible cycle has more efficiency than an irreversible one
(3) Carnot cycle is a reversible one
(4) Carnot cycle has the maximum efficiency in all cycles

2. Cooking gas containers are kept in a lorry moving with uniform speed. The temperature of the gas molecules inside will : **[AIEEE - 2002, 4/300]**
(1) increase (2) decrease
(3) remain same (4) decrease for some, while increase for others

3. At what temperature is the rms velocity of a hydrogen molecule equal to that of an oxygen molecule at 47° C ? **[AIEEE - 2002, 4/300]**
(1) 80 K (2) –73 K (3) 3 K (4) 20 K

4. Even Carnot engine cannot give 100% efficiency because we cannot : **[AIEEE - 2002, 4/300]**
(1) prevent radiation (2) find ideal sources
(3) reach absolute zero temperature (4) eliminate friction

5. 1 mole of a gas with $\gamma = 7/5$ is mixed with 1 mole of a gas with $\gamma = 5/3$, then the value of γ for the resulting mixture is : **[AIEEE - 2002, 4/300]**
(1) 7/5 (2) 2/5 (3) 24/16 (4) 12/7

6. "Heat cannot be itself flow from a body at lower temperature to a body at higher temperature" is a statement or consequence of : **[AIEEE - 2003, 4/300]**
(1) second law of thermodynamics (2) conservation of momentum
(3) conservation of mass (4) first law of thermodynamics

7. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its absolute temperature. The ratio C_p/C_v for the gas is : **[AIEEE - 2003, 4/300]**
(1) 4/3 (2) 2 (3) 5/3 (4) 3/2

8. Which of the following parameters does not characterise the thermodynamic state of matter?
[AIEEE - 2003, 4/300]
(1) Temperature (2) Pressure (3) Work (4) Volume

9. A Carnot engine takes 3×10^6 cal of heat from a reservoir at 627ºC and gives it to a sink at 27ºC. The work done by the engine is : **[AIEEE - 2003, 4/300]**
(1) 4.2×10^6 J (2) 8.4×10^6 J (3) 16.8×10^6 J (4) zero

10. One mole of ideal monoatomic gas ($\gamma = 5/3$) is mixed with one mole of diatomic gas ($\gamma = 7/5$). What is γ for the mixture? γ denotes the ratio of specific heat at constant pressure, to that at constant volume.
[AIEEE - 2004, 4/300]
(1) 3/2 (2) 23/15 (3) 35/23 (4) 4/3

11. Which of the following statements is correct for any thermodynamic system? **[AIEEE - 2004, 4/300]**
(1) The internal energy changes in all processes
(2) Internal energy and entropy are state functions
(3) The change in entropy can never be zero
(4) The work done in an adiabatic process is always zero

12. Two thermally insulated vessels 1 and 2 are filled with air at temperature (T_1, T_2), volume (V_1, V_2) and pressure (P_1, P_2) respectively. If the valve joining the two vessels is opened, the temperature inside the vessel at equilibrium will be : **[AIEEE - 2004, 4/300]**

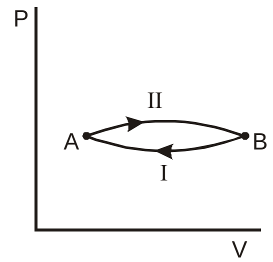
(1) $T_1 + T_2$ (2) $(T_1 + T_2)/2$ (3) $\frac{T_1T_2(P_1V_1+P_2V_2)}{P_1V_1T_2+P_2V_2T_1}$ (4) $\frac{T_1T_2(P_1V_1+P_2V_2)}{P_1V_1T_1+P_2V_2T_2}$

13*. Which of the following is incorrect regarding the first law of thermodynamics? **[AIEEE - 2005, 4/300]**
(1) It is not applicable to any cycle process
(2) It is a restatement of the principle of conservation of energy
(3) It introduces the concept of the internal energy
(4) It introduces the concept of the entropy

14. A gaseous mixture consists of 16 g of helium and 16 g of oxygen. The ratio $\frac{C_p}{C_v}$ of the mixture is :

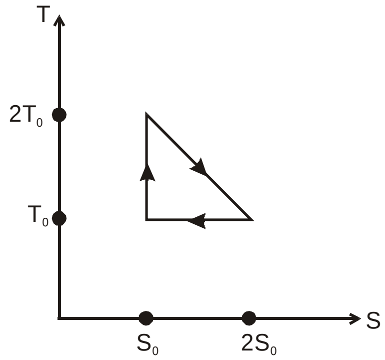
(1) 1.59 (2) 1.62 (3) 1.4 (4) 1.54 **[AIEEE - 2005, 4/300]**

15. A system goes from A to B via two processes I and II as shown in figure. If ΔU_1 and ΔU_2 are the changes in internal energies in the processes I and II respectively, then : **[AIEEE - 2005, 4/300]**



(1) $\Delta U_1 = \Delta U_2$
(2) relation between ΔU_1 and ΔU_2 cannot be determined
(3) $\Delta U_2 > \Delta U_1$
(4) $\Delta U_2 < \Delta U_1$

16. The temperature-entropy diagram of a reversible engine cycle is given in the figure. Its efficiency is :



[AIEEE - 2005, 4/300]

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

17. Two rigid boxes containing different ideal gases are placed on a table. Box A contains one mole of nitrogen at temperature T_0, while box B contains one mole of helium at temperature $(7/3)T_0$. The boxes are then put into thermal contact with each other, and heat flows between them until the gases reach a common final temperature. (Ignore the heat capacity of boxes). Then, the final temperature of the gases, T_f in terms of T_0 is : **[AIEEE - 2006, 4½/180]**

(1) $T_f = \frac{3}{7}T_0$ (2) $T_f = \frac{7}{3}T_0$ (3) $T_f = \frac{3}{2}T_0$ (4) $T_f = \frac{5}{2}T_0$

18. The work of 146 kJ is performed in order to compress one kilo mole of a gas adiabatically and in this process the temperature of the gas increases by 7 °C. The gas is **[AIEEE - 2006, 3/180]**

($R = 8.3$ J mol^{-1} K^{-1})

(1) diatomic
(2) triatomic
(3) mixture of monoatomic and diatomic
(4) monoatomic

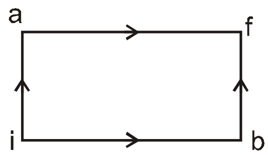
19. A Carnot engine, having an efficiency of $\eta = 1/10$ as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is :**[AIEEE - 2007, 3/120]**

(1) 99 J
(2) 90 J
(3) 1 J
(4) 100 J

20. If C_p and C_V denote the specific heats of nitrogen per unit mass at constant pressure and constant volume respectively, then **[AIEEE - 2007, 3/120]**

(1) $C_p - C_v = R/28$
(2) $C_p - C_v = R/14$
(3) $C_p - C_v = R$
(4) $C_p - C_v = 28R$

21. When a system is taken from state i to state f along the path iaf, it is found that Q = 50 cal and W = 20 cal. Along the path ibf Q = 36 cal. W along the path ibf is : **[AIEEE - 2007, 3/120]**



(1) 6 cal
(2) 16 cal
(3) 66 cal
(4) 14 cal

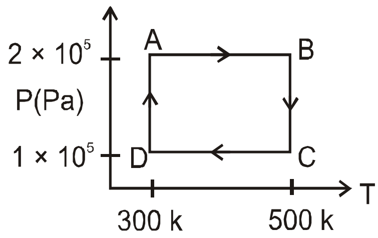
22. An insulated container of gas has two chambers separated by an insulating partition. One of the chambers has volume V_1 and contains ideal gas at pressure p_1 and temperature T_1. The other chamber has volume V_2 and contains ideal gas at pressure p_2 and temperature T_2. If the partition is removed without doing any work on the gas, the final equilibrium temperature of the gas in the container will be - **[AIEEE - 2008, 3/105]**

(1) $\dfrac{T_1T_2(p_1V_1+p_2V_2)}{p_1V_1T_2+p_2V_2T_1}$
(2) $\dfrac{p_1V_1T_1+p_2V_2T_2}{p_1V_1+p_2V_2}$
(3) $\dfrac{p_1V_1T_2+p_2V_2T_1}{p_1V_1+p_2V_2}$
(4) $\dfrac{T_1T_2(p_1V_1+p_2V_2)}{p_1V_1T_1+p_2V_2T_2}$

Directions : Question number 20, 21 and 22 are based on the following paragraph.

Two moles of helium gas are taken over the cycle ABCDA, as shown in the P-T diagram.

[AIEEE - 2009, 4×3/144]



23. Assume the gas to be ideal the work done on the gas in taking it from A to B is :

(1) 200 R (2) 300 R (3) 400 R (4) 500 R

24. The work done on the gas in taking it from D to A is

(1) –414 R (2) + 414 R (3) – 690 R (4) + 690 R

25. The net work done on the gas in the cycle ABCDA is:

(1) Zero (2) 276 R (3) 1076 R (4) 1904 R

26. One kg of a diatomic gas is at a pressure of 8×10^4 N/m^2. The density of the gas is 4 kg/m^3. What is the energy of the gas due to its thermal rnotion? **[AIEEE - 2009, 4/144]**

(1) 5×10^4J (2) 6×10^4J (3) 7×10^4J (4) 3×10^4J

27. A diatomic ideal gas is used in a Carnot engine as the working substance. If during the adiabatic expansion part of the cycle the volume of the gas increases from V to 32 V, the efficiency of the engine is :

[AIEEE - 2010, 4/144, –1]

(1) 0.5 (2) 0.75 (3) 0.99 (4) 0.25

EXERCISE # 1

PART - I : OBJECTIVE QUESTIONS

A-1.	(C)	**A-2.**	(C)	**A-3.***	(CD)	**A-4.***	(AB)	**A-5.**	(D)	**B-1.**	(A)	**B-2.**	(B)
B-3.	(A)	**B-4.**	(C)	**B-5.**	(C)	**B-6.**	(D)	**B-7.**	(B)	**B-8.**	(C)	**C-1.**	(B)
D-1.	(A)	**D-2.**	(C)	**D-3.**	(B)	**E-1.**	(D)	**E-2.**	(A)	**E-3.***	(AB)	**E-4.**	(B)
E-5.	(B)	**E-6.**	(C)	**E-7.**	(D)	**E-8.**	(C)	**E-9.**	(B)	**E-10.**	(D)	**E-11.**	(A)
E-12.	(C)	**E-13.**	(A)	**F-1.**	(D)	**F-2.**	(B)	**F-3.**	(D)	**F-4.**	(B)	**F-5*.**	(ABD)
F-6.*	(BD)	**F-7.***	(ABD)	**F-8.**	(B)	**F-9.**	(C)	**F-10.***	(AC)	**F-11.***	(CD)	**F-12.***	(AC)
G-1.	(D)	**G-2.**	(D)	**G-3.**	(C)	**G-4.**	(A)	**G-5.**	(B)	**G-6.**	(C)	**G-7.**	(C)
G-8.	(C)	**G-9.***	(ABCD)	**H-1.**	(B)	**H-2.**	(A)	**H-3.***	(CD)	**H-4.***	(CD)	**H-5.***	(AB)
H-6.	(A)	**H-7.**	(C)	**H-8.**	(A)	**H-9.**	(C)	**H-10.**	(C)	**H-11.***	(AB)	**H-12.**	(D)
H-13.	(B)	**H-14.***	(CD)	**H-15.**	(B)	**H-16.**	(B)	**H-17.**	(C)	**H-18.**	(A)	**H-19.**	(A)
H-20.	(D)	**H-21.**	(A)	**H-22.**	(A)	**H-23.**	(A)	**H-24.**	(A)	**H-25.**	(D)		

PART - II : MISLLANEOUS QUESTIONS

1.	(C)	**2.**	(D)	**3.**	(B)	**4.**	(C)	**5.**	(B)	**6.**	(C)	**7.**	(B)
8.	(A)	**9.**	(A)	**10.**	(B)	**11.**	(A) p,r,s (B) q (C) p,r,s (D) q,r						
12.	(A) p, s (B) s (C) p, s (D) q, r					**13.**	(A)	**14.**	(D)	**15.**	(B)	**16.**	(C)
17.	(D)	**18.**	(A)	**19.**	(A)	**20.**	(E)	**21.**	(E)	**22.**	(A)	**23.**	(A)
24.	(B)	**25.**	(B)	**26.**	(D)	**27.**	**(i)**	False	**(ii)**	False	**(iii)**	**False**	
(iv)	True	**28.**	**(i)**	2R	**(ii)**	$\sqrt{2}T$	**(iii)**	$\frac{1}{2^{0.67}}$	**(iv)**	temperature remains constant			

EXERCISE # 2

PART - I : MIXED OBJECTIVE

1.	(A)	**2.**	(D)	**3.**	(B)	**4.**	(C)	**5.**	(C)	**6.**	(A)	**7.**	(D)
8.	(A)	**9.**	(A)	**10.**	(D)	**11.**	(C)	**12.**	(A)	**13.**	(D)	**14.**	(D)
15.	(D)	**16.**	(D)	**17.**	(AD)	**18.**	(ABCD)						

PART - II : SUBJECTIVE QUESTIONS

A-1. zero **A-2.** $\left(\frac{mv_0^2}{\ell}\right)$N **B-1.** $\sqrt{\frac{50}{3}}$ V **B-2.** H_2, 1200 K **B-3.** $\frac{32000}{207}$ K

B-4. $2P_0$ **B-5.** $200\sqrt{2}$ ms^{-1} **B-6.** 7.2×10^{11} **B-7.** $\frac{6P_0}{5}$ **B-8.** cooled

B-9. 1 : 1 **B-10.** $\frac{1224}{95} \times 10^{15}$ **B-11.** 1280 K **B-12.** $\frac{5634}{5377}$ **B-13.** $3\left(\frac{3}{2}\right)^{1/3}$ mm

B-14. $\frac{112}{250}$ mole **B-15.** 3850 N/m^2 **B-16.** $\frac{240}{7}$ cm **B-17.** 48 cm

C-1. $\frac{1452\pi}{25} \times 10^3$ K **C-2.** $\frac{\sqrt{83}}{3} \times 10^{-23}$ kg-m/s **C-3.** 1 : 2 **C-4.** $\sqrt{14}$ **D-1.** 32ºC

D-2. 196ºC **D-3.** $U = \frac{fnRT}{2} = \frac{f}{2}PV = \frac{f}{2}P_{atm} \cdot V_{room}$ = constant. **E-1.** PV **E-2.** 1000 J

E-3. -100πJ **E-4.** 1500 J **E-5.** $1 : \sqrt{2}$ **F-1.** 60 cal **F-2.** + 2505 J **F-3.** 12 K

F-4. 18 J **F-5.** 280 J **F-6.** 100 J **F-7.** $\frac{dQ}{2}$ **F-8.** 125 KJ **F-9.** 0.0091 J

F-10. **(i)** 765 J **(ii)** $\frac{208}{1921}$ **F-11.** 110 J **F-12.** (a) extracted (b) 25000 J

F-13. (33600 + 0.02) J **F-14.** $\frac{25}{6}$ J/cal **F-15.** $\frac{30000}{7159}$ = 4.19 J/cal

G-1. $\frac{2}{\gamma - 1}$ **G-2.** 50 cal. **G-3.** 2.5 R **G-4.** 3R **G-5.** $\frac{7}{2}$R **G-6** $\frac{Mv^2}{5R}$

G-7. 0.01 m **G-8.** 4.2 J/cal. **G-9.** 3125 J

G-10. (a) 40 J (b) $\frac{9}{500}$ moles (c) $\frac{125}{9}$ J/mol–K (d) $\frac{50}{9}$ J/mol–K]

G-11. 7.5 R **G-12.** $PV^{-2} = k$ **G-13.** $-\gamma$ **G-14.** 112 joule **H-1.** Q – W

H-2. $\frac{3}{2}$ **H-3.** 0.8 JK^{-1} **H-4.** 128 **H-5.** 32P **H-6.** 4/9 % **H-7.** 7

H-8. 8 atmosphere **H-9** (a) $\sqrt{2} \times 10^5$ Pa (b) $200\sqrt{2}$ K (c) $20(2 - \sqrt{2})$ J

H-10 (a) 800 kPa, 100 K (b) 1600 kPa, 200 K **H-11.** 300 K **H-12.** 3R, 2R, 1.5

EXERCISE # 3

PART-I IIT-JEE (PREVIOUS YEARS PROBLEMS)

1. 200R **2.** (C) **3.** (D) **4.** (A) **5.** (a) 1200R

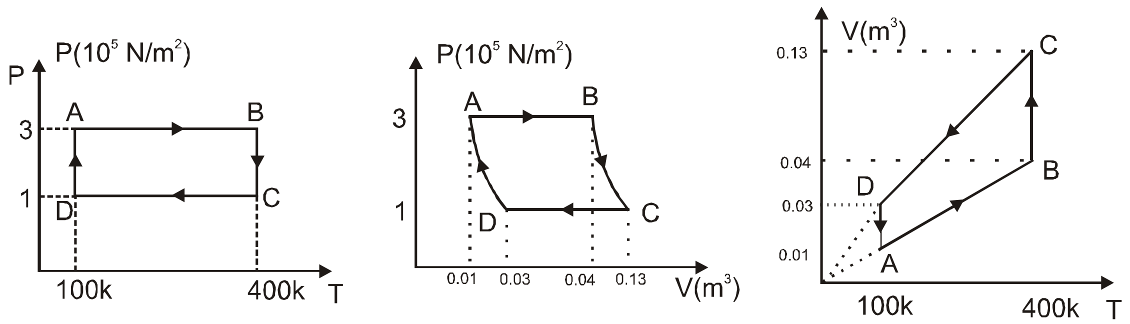
(b) for process AB, $\Delta Q = -2100R$, for process BC, $\Delta Q = 1500R$, for process CA, $\Delta Q = 1200\ell n2\ R$

6. $\frac{2500}{3}$ J, $\frac{500}{3}$ J **7.** (a) 600 K

(b) during AB, Q = 1500R; during BC, Q = 1200 ℓn2R; during CD, Q = – 900R;during DA, Q = – 1200 ℓn2 R

(c) W = 600R

8.



9. (A) **10.** (A) **11.** (a) 160 K (b) 3.312×10^{-21} J (c) 3×10^{-4} kg

12. No option is correct. This was bonus in JEE. [Marks allotted to all appeared candidates]

13. $\Delta T = \frac{Mv_0^2}{3R}$ **14.** (A) **15.** (a) 4/3 m (b) $400\left(\frac{4}{3}\right)^{0.4}$ **16.** (C)

17. (B) **18.** (A) $\rightarrow$ (s), (B) $\rightarrow$ (p) and (r), (C) $\rightarrow$ (r), (D) $\rightarrow$ (q) and (s). **19.** (B) **20.** (C)

21. (A) $\rightarrow$ (q); (B) $\rightarrow$ (p, r); (C) $\rightarrow$ p,s; (D) $\rightarrow$ (q, s) **22.** (BD) **23.** (BD) **24.** (D)

25. (AB) **26.** a = 4

PART-II AIEEE (PREVIOUS YEARS PROBLEMS)

1.	(1)	**2.**	(3)	**3.**	(4)	**4.**	(3)	**5.**	(3)	**6.**	(1)	**7.**	(4)
8.	(3)	**9.**	(2)	**10.**	(1)	**11.**	(2)	**12.**	(3)	**13*.**	(1, 4)	**14.**	(2)
15.	(1)	**16.**	(C)	**17.**	(3)	**18.**	(1)	**19.**	(2)	**20.**	(1)	**21.**	(1)
22.	(1)	**23.**	(3)	**24.**	(2)	**25.**	(2)	**26.**	(1)	**27.**	(2)		