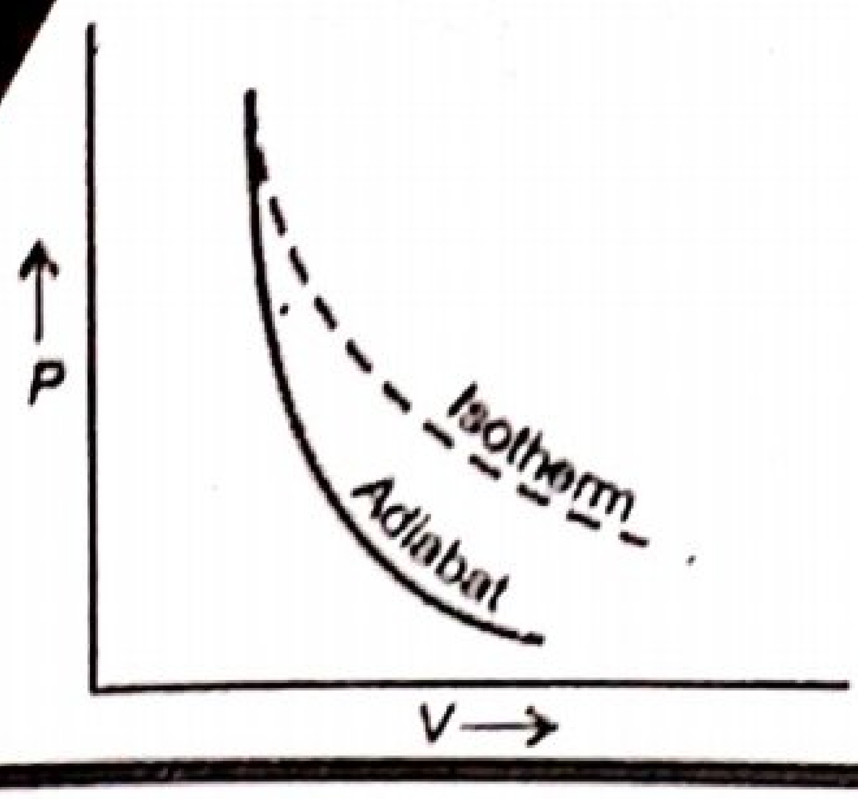


Chapter 11

HEAT AND THERMODYNAMICS

KEY POINTS

inetic Molecular Theory of Gases:

$T \propto < K.E >$

From the Kinetic theory of gases $P = \frac{1}{3}\rho < v^2 >$.

$P \propto < K.E >$

irst Law of Thermodynamics:

When heat is transformed into other forms of energy total heat energy remains constant.

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

Were ΔQ is +ve when heat is added and vice versa.

ΔW is –ve when work is done on the system and vice versa.

Isothermal process is that in which temperature remains constant.

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

Isothermal process is the process in which Boyle's law holds good.

Adiabatic process is that in which no heat enters or leaves the system such that

$\Delta Q = 0$ So $W = -\Delta U$

nternal Energy:

- The sum of all forms of molecular energy present in a thermodynamics system is called its internal energy.

Molar Specific heat at Constant Volume:

- Molar specific heat at constant volume is the amount of heat required to raise the temperature of one mole of the gas through 1K keeping volume constant.

Molar Specific Heat at Constant Pressure:

- Molar specific heat at constant pressure is the amount of heat required to raised the temperature of one mole of the gas through 1K keeping pressure constant.

Heat Engine:

- A heat engine is a device which converts a part of thermal energy into useful work.
  There are four major parts of every engine.
  - Cylinder
  - Piston
  - Crank shaft

➢ Connecting rod

Petrol engine and diesel engine:

- There are four successive processes in each cycle of a both engines.

(i) Charging stroke or intake stroke

(ii) Compression stroke

(iii) Power stroke

(iv) Exhaust stroke

- There is one cylinder in motorbikes engine
- Efficiency of petrol engine is about 25% to 30%.
- Diesel engine has no spark plug.
- Efficiency of diesel engine is about 35% to 40%.

Carnot Heat Engine

- Sadi Carnot proposed it in 1840. (ideal Engine).
- Efficiency of Carnot engine is $1-\frac{T_2}{T_1}$.

Reversible and irreversible processes:

- Sequence of processes carried out in such a manner that the values of thermodynamic variables are retraced at the end of processes then this process is called reversible process. Otherwise called irreversible.
- Liquefaction, evaporation and compression performed slowly are reversible processes.
- All changes that occur suddenly or involve friction or dissipation of energy through conduction, convection or radiation are irreversible processes.

Second Law Thermodynamics:

- The second law of thermodynamics can be stated as

i. There is no perpetual motion machine that can convert the given amount of heat completely into work.

ii. The total entropy of any system plus that of its environment increases as a result of any natural process.

iii. Kelvin Statement: "It is impossible to construct a heat engine which converts all heat energy absorbed from source without having a sink."

Entropy:

- Entropy changes ΔS due to heat transfer ΔQ at absolute temperature T is given by

$$\Delta S = \pm \frac{\Delta Q}{T}$$

- Its unit is J / K.
- Entropy may remain constant for a reversible process.
- Entropy increases for all irreversible processes.

TOPICAL MULTIPLE CHOICE QUESTIONS

Topic 11.1: Kinetic Theory of Gases

1) **Fahrenheit and centigrade thermometers have same reading at**
(a) -100^0 (b) 32^0
(c) -40^0 (d) 273^0

2) **Temperature of -273^0C on Kelvin scale is**
(a) 100K (b) 373K
(c) 0 K (d) 273K

3) **Pressure of a gas can be written as**
(a) $P = \frac{1}{3}\rho v^2$ (b) $P = \frac{NkT}{V}$
(c) $P = \frac{2}{3}\frac{N}{V} < 1/2mv^2 >$ (d) all of these

4) **The translation K.E per molecule of an ideal gas is given by**
(a) $\frac{2}{3}kT$ (b) $\frac{3}{2}kT$
(c) $\frac{3}{2}kT^2$ (d) $\frac{3}{2kT}$

5) **The collisions among the gas molecules and with the walls of container are assumed to be**
(a) perfectly elastic (b) elastic
(c) inelastic (d) None of them

6) **The application of kinetic theory can be studied in**
(a) diffusion of gases (b) Brownian motion
(c) both a & b (d) none of these

7) **Which of the following thermometers has only positive degrees of temperature?**
(a) Celsius (b) Fahrenheit
(c) Kelvin (d) none

8) **Charles law can be written as mathematically**
(a) $V \propto T$ (b) $V \propto \frac{1}{T}$
(c) $P \propto T$ (d) $P \propto \frac{1}{T}$

9) **The temperature of a normal human body is 98.6^0F. This temperature on centigrade scale is**
(a) 0^0C (b) 37^0C
(c) 73^0C (d) 37.6^0C

(10) **Pressure of a gas is written**
(a) $1/3\ \rho<v>$ (b) $2/3\ \rho<v^2>$
(c) $1/3\ \rho<v^2>$ (d) $3/2\ \rho<v^2>$

(11) **The direction of flow of heat between two bodies depends upon**
(a) thermal conductivity (b) specific heat
(c) internal energies (d) temperature difference

(12) **Pressure of gas depends upon**
(a) molecular speed (b) number of molecules
(c) mass of molecules (d) all of them

(13) **According to Boyle's law the volume is**
(a) inversely proportional to temperature
(b) directly proportional to pressure
(c) inversely proportional to pressure
(d) directly proportional to temperature

(14) **The value of Boltzman's constant is**
(a) $1.38 \times 10^{-34} JK^{-1}$
(b) $1.38 \times 10^{-23} JK^{-1}$
(c) $1.38 \times 10^{-32} JK^{-1}$
(d) $1.38 \times 10^{-27} JK^{-1}$

(15) **The unit of pressure**
(a) Ns
(b) Nm^{-1}
(c) Nm^{-2}
(d) Nm^{-3}

(16) **A diatomic gas contains**
(a) translational K.E
(b) vibrational K.E
(c) rotational K.E
(d) all of these

(17) **At constant pressure the graph between volume and absolute temperature**
(a) parabola
(b) straight line
(c) hyperbola
(d) ellipse

(18) **In Boyle's law, if the pressure is three times then the volume of a gas becomes**
(a) one half
(b) three times
(c) one third
(d) double

(19) **The relation between Celsius and Fahrenheit scale is given by**
(a) $T_c = \frac{5}{9}(T_F + 32)$
(b) $T_c = \frac{9}{5}(T_F + 32)$
(c) $T_c = \frac{9}{5}(T_F - 32)$
(d) $T_c = \frac{5}{9}(T_F - 32)$

(20) **On Kelvin scale the normal body temperature is given by**
(a) 210K
(b) 320K
(c) 310K
(d) 373K

(21) **The K.E of the molecules of an ideal gas at absolute zero will be**
(a) zero
(b) low
(c) high
(d) remain same

(22) **The relation PV = RT hold good for**
(a) one kilogram of gas
(b) one meter cubic volume of gas
(c) one mole of gas
(d) one gram of gas

(23) **The relationship between heat and other form of energy is called**
(a) thermal equilibrium
(b) thermodynamics
(c) thermal energy
(d) none of these

Topic 11.2:

Internal Energy

(24) **The internal energy of a body is maximum when its temperature is**
(a) 0K
(b) 273K
(c) -273K
(d) -273^0C

(25) **The sum of all molecular energies of a substance is called**
(a) K.E
(b) P.E
(c) internal energy
(d) chemical energy

(26) **The molecules of an ideal gas are mere mass points which exerts**
(a) maximum force on one another
(b) no force on one another
(c) equal force
(d) none of these

(27) **When we heat a substance, energy associated with its atoms or molecules is**
(a) increase (b) remain same
(c) decrease (d) none of these

(28) **Internal energy depends upon**
(a) final state (b) initial state
(c) both a & b (d) none of these

(29) **The internal energy of an ideal gas depends upon only**
(a) pressure (b) temperature
(c) volume (d) all of these

(30) **By rubbing the objects together, their internal energy**
(a) increases (b) decreases
(c) remains constant (d) becomes zero

(31) **A gas does 10J of external work in adiabatic process while expanding, then the change is internal energy is**
(a) 10J (b) 20J
(c) -10J (d) 0J

(32) **When some amount of heat energy enter a system**
(a) it increase its internal energy (b) it decrease its internal energy
(c) the internal energy remains constant (d) none of these

(33) **The sum of all forms of molecular energy present in a thermodynamic system is called its**
(a) Environmental energy (b) Temperature
(c) Heat (d) Internal energy

Topic 11.3:

Work and Heat

(34) **Work done by the system on its environment is taken as**
(a) positive (b) negative
(c) neutral (d) none of these

(35) **The work done can also be calculated by the area of the curve under**
(a) P-V graph (b) V-T graph
(c) P-T graph (d) P-1/V graph

(36) **The relation for the work done by the system can be expressed as**
(a) $W=A\Delta V$ (b) $W=P\Delta V$
(c) $W=A\Delta P$ (d) $W=P\Delta A$

(37) **The dimension of work done on the system**
(a) $[ML^{-1}T^{-2}]$ (b) $[ML^{2}T^{-2}]$
(c) $[MLT^{-2}]$ (d) $[ML^{-1}T^{-1}]$

Topic 11.4:

First Law of Thermodynamics

(38) **The process in which the volume of the gas remain same is called**
(a) isobaric (b) isothermal
(c) isochoric (d) adiabatic

(39) **First law of Thermodynamics is restatement of law of conservation of**
(a) mass (b) energy
(c) momentum (d) heat

(40) **Examples of first law of thermodynamics**
(a) working of bicycle pump (b) Human metabolism
(d) All of these

(41) **The cloud formation is the example of**
(a) isothermal process
(b) adiabatic process
(c) isobaric process
(d) isochoric process.

(42) **The process in which no heat can enter or leave the system is called**
(a) isothermal process
(b) adiabatic process
(c) isobaric process
(d) isochoric process

(43) **The relation for the 1st law of thermodynamics can be expressed as**
(a) $\Delta U = \Delta W - Q$
(b) $\Delta W = \Delta U - Q$
(c) $Q = \Delta U - \Delta W$
(d) $Q = \Delta U + W$

(44) **The isothermal process obeys**
(a) Charle's law
(b) Boyle's law
(c) Stefen's law
(d) Pascal's law

(45) **The curve representing an isothermal process is called**
(a) an isotherm
(b) an adiabat
(c) an isobar
(d) an isochoric

(46) **An adiabatic compression causes the temperature of the gas**
(a) to increases
(b) to decreases
(c) remain constant
(d) become zero

(47) **The rapid expansion and compression of air through which a sound wave is passing, obeys**
(a) isothermal process
(b) isochoric process
(c) adiabatic process
(d) isobaric process

(48) **In relation** $PV^{\gamma} = \text{constant}$ **the** γ **is given by**
(a) $\frac{C_v}{C_p}$
(b) $\frac{C_p}{C_v}$
(c) $C_p - C_v$
(d) $C_v - C_p$

(49) **Compressed air coming out of punctured football becomes cooler because of**
(a) isothermal expansion
(b) adiabatic expansion
(c) energy dissipation
(d) adiabatic compression

Topic 11.5:

Molar Specific Heat of Gas

(50) **The amount of heat required to raise the temperature of one mole of substance through 1 Kelvin is called**
(a) Specific heat
(b) molar specific heat
(c) specific heat at constant volume
(d) Heat capacity

51) **The amount of heat required to raise the temperature of one mole of substance through 1 Kelvin at constant pressure is called**
(a) Specific heat
(b) molar heat capacity at constant pressure
(c) molar specific heat capacity at constant pressure
(d) Heat capacity at constant pressure

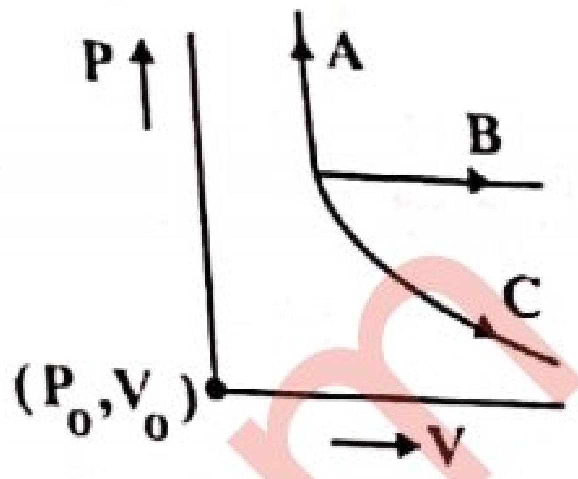
52) **If 1 mole of an ideal gas is heated at constant pressure then**
(a) $Q_P = C_V \Delta T$
(b) $Q_P = C_P \Delta T$
(c) $Q_V = C_V \Delta T$
(d) $Q_V = C_P \Delta T$

(53) The difference between the molar specific heat at constant pressure and volume is called
(a) molar gas constant
(b) universal gas constant
(c) pressure constant
(d) Boltzman constant

(54) The amount of heat required to raise the temperature of one kg of substance through 1 ^{0}C is called
(a) Specific heat
(b) molar heat capacity
(c) heat of fusion
(d) latent heat of fusion

(55) The value of universal gas constant is
(a) 8.314 J mol^{-1} K^{-1}
(b) 81.34 J mol^{-1} K^{-1}
(c) 0.8134 J mol^{-1} K^{-1}
(d) 8134 J mol^{-1} K^{-1}

(56) Which of the following processes is isochoric?



(a) A
(b) B
(c) C
(d) all of these

(57) For 1 mole of gas the relation $P\Delta V=$
(a) $R\Delta T$
(b) $R\Delta V$
(c) $R\Delta P$
(d) $P\Delta T$

(58) Mathematically, the molar specific heat at constant pressure can be expressed as
(a) $C_p = \dfrac{Q_p}{\Delta T}$
(b) $C_p = \dfrac{\Delta T}{Q_p}$
(c) $C_p = \dfrac{T}{\Delta Q_p}$
(d) $C_p = \Delta Q_p \times T$

Topic 11.6:

Reversible and Irreversible processes

(59) Work done against friction is a
(a) reversible process
(b) irreversible process
(c) adiabatic process
(d) isobaric process

(60) All changes which occur suddenly or which involve friction or dissipation of energy are
(a) Reversible
(b) adiabatic
(c) isothermal
(d) irreversible

(61) The dissipation of energy through conduction, convection and radiation are
(a) reversible process
(b) irreversible process
(c) isothermal process
(d) isobaric process

(62) If a process cannot be traced in the backward direction by reversing the controlling factors, it is called
(a) irreversible process
(b) reversible process
(c) adiabatic process
(d) isothermal process

(63) A succession of events which brings the system back to its initial condition is called
(a) cycle
(b) irreversible process
(c) isothermal process
(d) adiabatic process

Topic 11.7:

Heat Engine

(64) Basic part or parts of a heat engine
(a) source
(b) sink
(c) working substance
(d) All of above

(65) Heat engine converts thermal energy to ________
(a) Mechanical work
(b) electrical energy
(c) hydro energy
(d) solar energy

SHORT QUESTIONS

(From Textbook Exercise)

11.1 Why is the average velocity of the molecules in a gas zero but the average of the square of velocities is not zero?

Ans: The molecules in a gas are in a state of random motion. The number of molecules along positive x-axis is equal to the number of molecules along negative x-axis. This is also true for y-axis and z-axis.

$$<V_x> = \frac{V_x - V_x}{2} = 0$$

Similarly,

$$<V_y> = 0$$

And,

$$<V_z> = 0$$

But the average of square of velocities is not zero because square of a negative Value is also positive:

$$\frac{(Vx)^2 + (-Vx)^2}{2} = \frac{2Vx^2}{2} = Vx^2$$

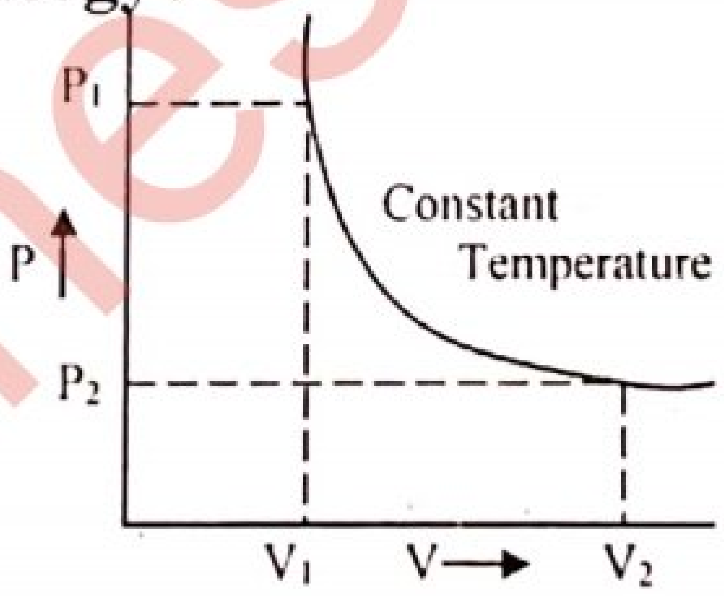
11.2 Why does the pressure of a gas in a car tyre increase when it is driven through some distance?

Ans: When the car is driven through some distance, then the work has to be done to overcome friction and a part of work done is converted into heat. As a result, temperature of a gas increases and hence kinetic energy of molecules increase because,

Pressure $\propto$ K.E.

So, pressure of gas molecules increase.

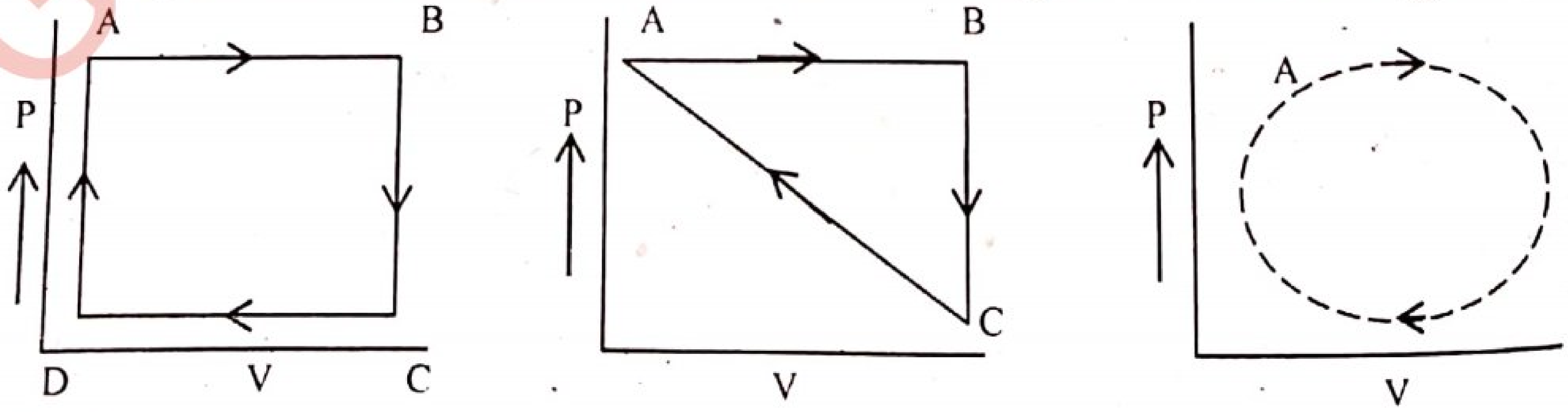
11.3 A system undergoes form state $P_1 V_1$ to state $P_2 V_2$ as shown in fig 11.12. What will be the change in internal energy?



Ans: As the temperature of the system remains constant. Therefore, the internal energy of the system remains same.

Therefore, $\Delta U = 0$

11.4 Variation of volume by pressure is given in Fig 11.13. A gas is taken along the paths ABCDA, ABCA and A to A. What will be the change in internal energy?



$\Delta U = ?$

Ans: As in each case, the system comes back to its initial state, therefore the internal energy remains constant. So, $\Delta U = 0$

11.5 Specific heat of a gas at constant pressure is greater than specific heat at constant volume. Why?

Ans: When a gas is heated at constant pressure, then part of heat is used in doing work and part of heat is used in increasing the internal energy or temperature of the gas.

When a gas is heated at constant volume, then whole of the heat supplied is used up in increasing the internal energy of the system. That's why specific heat at constant pressure is greater than specific heat at constant volume.

Since, $C_p - C_v = R$

$C_p > C_v$

11.6 Given an example of a process in which no heat is transferred to or from the system but the temperature of the system changes.

Ans: The process in which no heat enters or leaves the system is called 'Adiabatic Process.' When a gas expands adiabatically, work is done at the cost of internal energy.

$W = -\Delta U$

As a result, the temperature of the system falls.

11.7 Is it possible to convert internal energy into mechanical energy? Explain with an example.

Ans: Yes, it is possible to convert internal energy into work in an "Adiabatic process", when a gas expands, work is done at the cost of internal energy.

$W = -\Delta U$

- In steam engine, the energy of molecules of the steam is used up in running the engine.

11.8 Is it possible to construct a heat engine that will not expel heat into the atmosphere?

Ans: No, it is not possible to construct a heat engine that will not expel heat into the atmosphere. According to second law of thermodynamics, in order to convert heat into work, a part of heat has to be rejected to the sink, (cold reservoir)

11.9 A thermos flask containing milk as a system is shaken rapidly. Does the temperature of milk rise?

Ans: When a thermos flask containing milk is shaken rapidly then kinetic energy of the milk molecules increase due to the work done on the system. As, no heat can leave the system therefore, the temperature of milk rises.

As $T \propto \langle K.E \rangle$

11.10 What happens to the temperature of the room, when an air conditioner is le running on a table in the middle of the room?

Ans: When an air conditioner is left running on the table in the middle of the room, the temperatu of the room increase. The heat absorbed by the air conditioner from the room is expelled in t same room by compressor. The work done in running the air conditioner is also converted in heat energy. Therefore, the temperature of the room rises.

11.11 Can the mechanical energy be converted completely into heat energy? If so given example.

Ans: Yes, it is possible to convert mechanical energy completely into heat energy for exam When brakes are applied to stop a running car, then the car stops due to friction mechanical energy supplied is completely converted into heat energy due to friction. Also when a gas is compressed adiabatically, the work done is used to increase internal energy which appears as heat energy.

$-W = \Delta U$

11.12 Does entropy of a system increases or decreases due to friction?

Ans: The entropy of a system increase due to friction. because the useful energy is dissipated as heat to overcome friction. As the unavailability of useful energy increase, therefore, entropy also increases.

11.13 Give an example of a natural process that involves an increase in entropy.

Ans: In every natural process, the heat flows from a body at high temperature to a body at lower temperature. Therefore, entropy of a system and surrounding increases. e.g., When ice melts due to high temperature "T", then the change in entropy is:

$$\Delta S = \frac{\Delta Q}{T}$$

As, ΔQ is positive (+Ve). So, ΔS is positive and consequently, entropy increases.

11.14 An adiabatic change is the one in which

a. No heat is added to or taken out of a system
b. No change of temperature takes place
c. Boyle's law is applicable
d. Pressure and volume remains constant

Ans: The correct answer is a.

11.15 Which one of the following process is irreversible?

a. Slow compressions of an elastic spring
b. Slow evaporation of a substance in an isolated vessel?
c. Slow compression of a gas
d. A chemical explosion

Ans: Statement d is a irreversible process.

11.16 An ideal reversible heat engine has

a. 100% efficiency
b. Highest efficiency
c. An efficiency which depends on the nature of working substance
d. None of these

Ans: Statement 'b' is correct answer.

SHORT QUESTIONS

(From past papers 2012-2017)

(Federal Board)

(1) Human metabolism provides an example of law of conservation of energy Explain on the basis of the 1st law of thermodynamics. **(FDR 2012)**

(2) How does diesel engine work? **(FDR 2012)**

(3) A thermos flask containing milk as a system is shaken rapidly. Does the temperature of milk rise? **(FDR 2012)**

(4) Specific heat of gas at constant pressure is greater than specific heat at constant volume. Why? **(FDR 2013)**

(5) Writhe the postulates of kinetic theory of gases. **(FDR 2014)**

(6) A heat engine performs 100 J of work and at the same time rejects 400 J of heat energy to the cold reservoirs. What is the efficiency of the engine? **(FDR 2014)**

(7) Thermal pollution is an inevitable consequence of 2nd law of thermodynamics. How? **(FDR 2015)**

(8) For diatomic gases $\gamma=1.4$, show that the specific heat at constant pressure 'C_p' and the specific heat at constant volume 'C_v' are $\frac{7}{2}R$ and $\frac{5}{2}R$ respectively, where 'R' is the general gas constant **(FDR 2016)**

(9) Why do we say that molar specific heat at constant pressure is greater than molar specific heat at constant Volume? ($C_p > C_v$) **(FDR 2017)**

(10) A steam engine has a boiler that operates at 450 k. The heat changes water to steam, which drives the piston. If the exhaust temperature of the outside air is about 300 k then calculate maximum efficiency of this steam engine? **(FDR 2017)**