Chapter # 11 (Heat and Thermodynamics)

1. What are the main postulates of kinetic theory of gases?

Ans: Main Postulates:

(i) A finite volume of gas consists of very large number of molecules.

(ii) The size of molecules is much smaller than the separation between molecules.

(iii) The gas molecules are in random motion and may change their direction of motion after every collision.

(iv) Collision between gas molecules themselves and with the wall of container are assumed to be perfectly elastic.

(v) Molecules exert no force on each other except during a collision.

2. Prove that $T \propto <\frac{1}{2}mv^2>$ OR $T \propto <K.E>$

Ans: Proof:

According to ideal gas law:

$$PV = nRT \quad \text{_____ (i)}$$

$$n = \frac{N}{N_A}$$

Put in equation (i),

$$PV = \frac{NRT}{N_A}$$

$$PV = NkT \quad \text{_____(ii)}$$

Here $k = \frac{R}{N_A}$. Its value is $1.38 \times 10^{-23}\ JK^{-1}$.

$$P = \frac{2}{3}\frac{N}{V}<\frac{1}{2}mv^2>$$

$$PV = \frac{2N}{V}<\frac{1}{2}mv^2> \quad \text{_____ (iii)}$$

Put value of $PV = NkT$ in (iii),

$$NkT = \frac{2N}{3}<\frac{1}{2}mv^2>$$

$$T = \frac{2}{3k}<\frac{1}{2}mv^2>$$

$$T = \text{constant} <\frac{1}{2}mv^2>$$

$$T \propto <\frac{1}{2}mv^2>$$

$$T \propto <K.E>$$

3. Define Boyle's law. How it can be derived the expression of gas.

Ans: Boyle's Law:

The volume of a give mass of a gas at constant temperature is inversely proportional to the pressure applied to the gas.

From kinetic molecular theory of gasses,

$$P = \frac{2}{3}\frac{N}{V}<\frac{1}{2}mv^2>$$

$$PV = \frac{2N}{3}<\frac{1}{2}mv^2>$$

Since, temperature is constant so, K.E is also constant.

$$PV = \text{constant}$$

$$P = \text{constant}\left(\frac{1}{V}\right)$$

$$P \propto \frac{1}{V}$$

4. Define Charles's law. How it can be derived the expression of gas.

Ans: Charles's Law:

The volume of given mass of a gas is directly proportional to the absolute temperature when the pressure is kept constant.

From kinetic molecular theory of gasses,

$$P = \frac{2}{3}\frac{N}{V}<\frac{1}{2}mv^2>$$

$$V = \frac{2}{3}\frac{N}{P}<\frac{1}{2}mv^2>$$

As pressure is constant,

$$V = \text{constant} <\frac{1}{2}mv^2>$$

$$V \propto <\frac{1}{2}mv^2> \propto T$$

$$V \propto T$$

5. Define internal energy. How can we increase internal energy?

Ans: Internal Energy:

The sum of all forms of molecular energies (kinetic and potential) of a substance is called internal energy.

How can we increase internal energy?

We can increase internal energy by two methods:

- By heating
- By doing mechanical work

6. State first law of thermodynamics and give its mathematical form.

Ans: Statement:

When the heat Q is added to a system, this energy appears as an increase in the internal ΔU stored in the system plus the work done W by the system on its surroundings.

$$Q = \Delta U + W$$

7. What is isothermal process?

Ans: Isothermal Process:

A process in which the temperature of the system is constant is called isothermal process.

Mathematical:

$$Q = \Delta U + W$$

As, temperature is constant, $(\Delta U = 0)$

$$Q = W$$

8. What is adiabatic process?

Ans: Adiabatic Process:

A process in which no heat enters or leaves the system is called adiabatic process.

Mathematical:

$$Q = \Delta U + W$$

As no heat enters, $(Q = 0)$

$$0 = \Delta U + W$$

Adiabatic Compression $(W = - \Delta U)$

Adiabatic Expansion $(-W = \Delta U)$

Examples:

- The rapid escape of air from a burst tyre.
- Cloud formation in the atmosphere

9. Define molar specific heat. Also discuss its types.

Ans: Molar Specific Heat:

Molar specific heat of the substance is the heat required to raise the temperature of one mole of a substance through 1K.

Molar specific heat at constant Pressure (C_P)	Molar specific heat at constant volume (C_V)
• The molar specific heat at constant pressure is the amount of heat required to raise the temperature of one mole of the gas through 1K at constant pressure. • It is represented by C_P • Its unit is $JMol^{-1}K^{-1}$	• The molar specific heat at constant volume is the amount of heat required to raise the temperature of one mole of the gas through 1K at constant volume. • It is represented by C_V • Its unit is $JMol^{-1}K^{-1}$

10. Differentiate between reversible and irreversible process.

Ans:

Reversible Process	Irreversible Process
• The process which can be retraced in exactly reverse order without producing any change in the surroundings is called reversible process. • Slow compression of a gas in a cylinder • The process of liquefaction and evaporation	• The process which cannot be retraced in exactly reverse order without producing any change in the surroundings is called irreversible process. • Work done against friction • Explosion

11. State second law of thermodynamics.

Ans: Statement:

It is impossible to make a heat engine which converts all the heat absorbed from a hot reservoir into work without rejecting any heat to sink

$$W = Q_1 - Q_2$$

12. Write down two statements of Carnot's Engine. Also write down its four steps.

Ans: Carnot's Engine:

- No heat engine can be more efficient than a Carnot engine separating between the same two temperatures.
- All Carnot's engines operating between the same two temperatures have the same efficiency, irrespective of the nature of working substance.

Steps of Carnot's Cycle:

(i) Isothermal expansion
(ii) Adiabatic expansion
(iii) Isothermal compression
(iv) Adiabatic Compression

13. What is triple point of water?

Ans: Triple point of water:

The temperature at which water, ice and water vapours are in equilibrium state which is obtained at particular temperature and pressure is called triple point of water.

$$T = (273.16)\frac{Q_1}{Q_2}$$

14. Name the four strokes of petrol engine.

Ans: Four strokes of petrol engine:

- Intake stroke
- Compression stroke
- Power stroke
- Exhaust stroke

15. Why spark plug is not needed in a diesel engine?

Ans: No spark plug is needed in the diesel engine. Diesel is sprayed into cylinder at maximum compression. Because air is at high temperature after compression the fuel mixture ignites on contact with air in cylinder and pushes the piston outward.

16. What is entropy? Give its mathematical form. Also write its unit.

Ans: Entropy:

It is the measure of disorder of molecules of a system.

It is denoted by ΔS.

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

Unit: Its unit is JK^{-1}.

Sign Convention:

- When heat is added to system, entropy increases. Then entropy is positive.
- When heat is taken out from system, entropy decreases. Then entropy is negative.

Exercise Short Questions

1. Why the average velocity of the molecules in a gas container is zero but the average of the squares of velocities is not zero?

Ans: Average of velocity of molecule:

The motion of gas molecules is random motion. The number of molecules along positive x – axis is equal to the number of molecules along negative x – axis. This is true for y – axis and z – axis.

$$\langle V \rangle = \frac{V - V}{2} = 0$$

Average of velocity of molecule: -

But the average of square of velocities is not zero because square of a negative value is also positive.

$$\langle V^2 \rangle = \frac{V^2 + (-V)^2}{2} \neq 0$$

2. Why does the pressure of gas in a car tyre increases when it is driven through some distance?

Ans: Reason:

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 K.E of molecules because $P \propto K.E$. So, the pressure of gas molecules increases.

3. A system undergoes from state P_1V_1 to P_2V_2 as shown in fig. 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, $\Delta U = 0$

4. A 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?

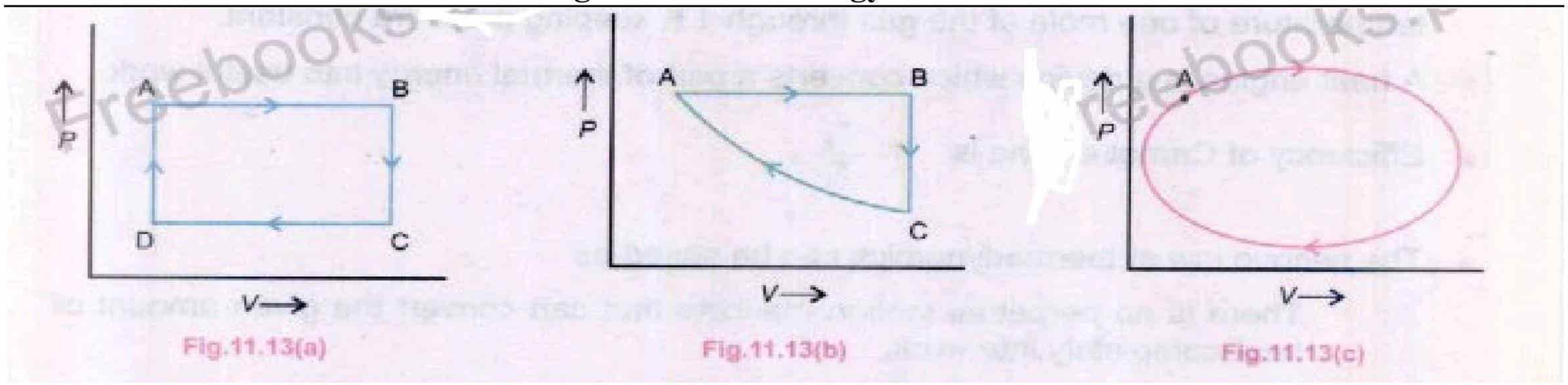

Fig.11.13(a) Fig.11.13(b) Fig.11.13(c)

Ans: As in each case, the system comes back to its initial state, therefore the internal energy remains constant.

So, $\Delta U = 0$

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

Ans: C_P is always greater than C_V.

Reason: -

When a gas is heated at constant volume.

- all the heat is absorbed is used to increase temperature through 1K.

When a gas is heated at constant pressure.

- A part of heat is used to do work on piston.
- Rest of heat is used to increase the temperature through 1K.

That is why the molar specific heat at constant pressure (C_P) is greater than molar specific heat at constant volume (C_V).

6. Give 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 on system is called "Adiabatic Process"

$$Q = \Delta U + W$$

For adiabatic process $Q = 0$

$$0 = \Delta U + W$$

$$W = -\Delta U \text{ (Adiabatic Expansion)}$$

$$\Delta U = -W \text{ (Adiabatic Comprssion)}$$

So, by doing so whole mechanical energy is converted into heat energy.

Examples: -

- Rapid escape of air from a burst tyre.
- Rapid expansion and compression of air through which sound wave is passing.
- Cloud formation in the atmosphere.

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 mechanical energy.

Example: -

In an adiabatic process, when a gas expands, work is done on the surrounding by using internal energy. Due to which internal energy decreases.

$$W = - \Delta U$$

Gases can be liquefied by this process.

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

Ans: No, it is impossible to construct a heat engine that will not expel heat into atmosphere.

Reason: -

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).

If it is possible, then it will violation of second law of thermodynamics.

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

Ans: Yes, the temperature of the milk rises.

Reason: -

As we know that,

$$T \propto K.E$$

When we rapidly shake the thermos flask we do some work on it. This work done increases the K.E of molecules of milk. Hence, the temperature of milk increases.

10. What happens to the temperature of the room? When an air conditioner is left running on a table in the middle of the room?

Ans: The temperature of the room increases slightly.

Reason: -

When an air conditioned is left running on a table in the middle of the room, it absorbs as well as reject heat in the same room at the constant rate. So, the temperature of room is unchanged . But due to the working of compressor some heat is produced due to friction which increases the temperature of the room slightly.

11. Can the mechanical energy be converted completely into heat energy? If so give an example.

Ans: Yes, mechanical energy can be converted completely into heat energy.

Example: -

When brakes are applied to stop the running car, then the car stops due to friction and all the mechanical energy supplied to the car is converted into heat due to friction.

Also, during isothermal compression then work done on the system is converted into heat energy.

$$Q = \Delta U + W$$

$\Delta U = 0$ (For inothermal Process)

$$Q = W$$

$$W = Q$$

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

Ans: Yes, the entropy of the system increases due to friction.

Reason: -

As the entropy of the system is given as.

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

Due to friction, some mechanical energy is dissipated as heat to overcome friction. Its mean heat is added up into the system which increases the entropy of the system.

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 the system and surroundings increases.

Example: -

When ice melts, it involves the increase in entropy. Ice absorbs temperature from the surroundings and changes its state (Solid to liquid). Thus, entropy increases.

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

As ΔQ is Positive (+ ve). So, the entropy increases.

14. An adiabatic change is the one in which

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

Ans: (a) No heat is added to or taken out of the system.

15. Which one of the following process in 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: (d) A chemical explosion is irreversible.

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 them

Ans: (b) Highest Efficiency