

Unit 10

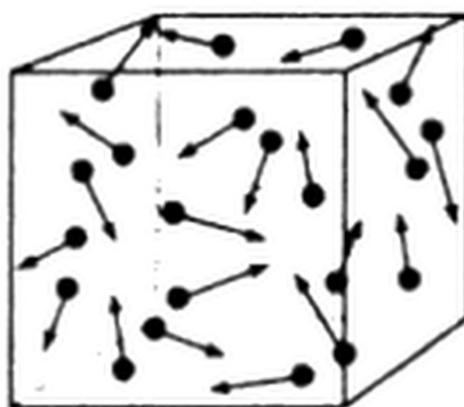
THERMODYNAMICS

Q.1 State the postulates of kinetic molecular theory of gases.

Answer

Kinetic theory of gases

- The behavior of gases is well described by the kinetic theory.
- It relates macroscopic properties (T, P, and V etc.) of gases to microscopic properties (K.E etc.)
- It provides a mathematical model to study the behavior of gases.



Postulates

- A finite, volume of gas consists of very large number of molecules.
- The size of the molecules is much smaller than the separation between molecules.
- The gas molecules are in random motion and may change their direction of motion after every collision.
- Collisions between gas molecules themselves and with walls of container are assumed to be perfect elastic.
- Molecules do not exert force on each other except during a collision.

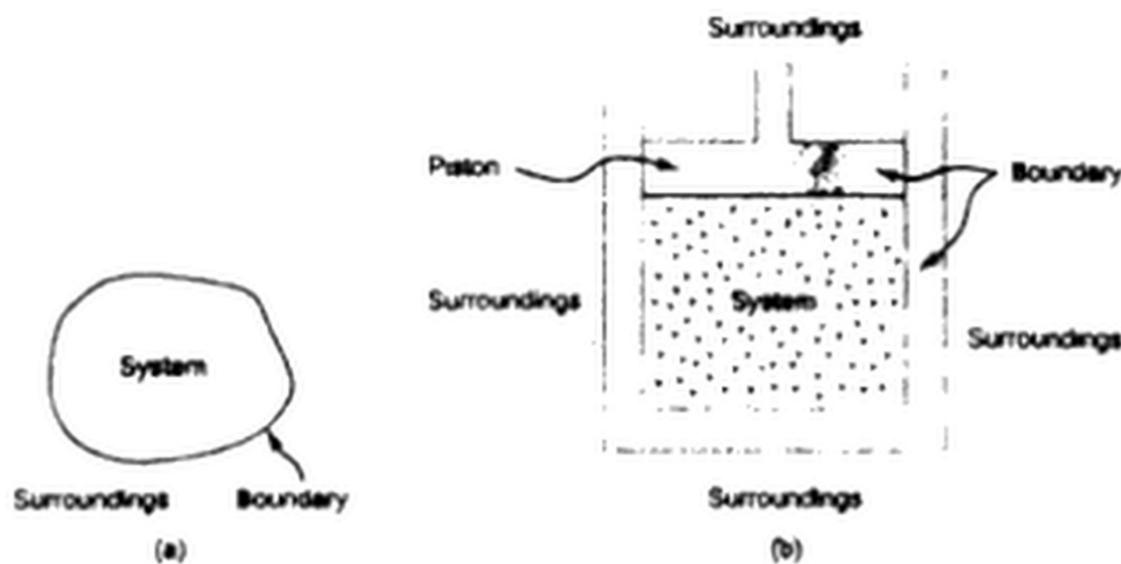
Q.2 Discuss the term "Thermodynamics". Also describe the terms: System, Surrounding, Boundary and State variables?

Answer

Thermodynamics

Thermodynamics deals with the science of "motion" (dynamics) and/or the transformation of "heat" (thermo) and energy into various other energy-containing forms.

The flow of energy is of great importance to engineers involved in the design of the power generation and process industries. Thermodynamics provides an understanding of the nature and degree of energy transformations, so that these can be understood and suitably utilized.



System

A system is a region containing energy and/or matter that is separated from its surroundings by arbitrarily imposed walls or boundaries.

In a thermodynamic analysis, the system is the subject of the investigation.

Closed system (control mass): energy, but not matter, can be exchanged with the environment. Examples: a tightly capped cup of coffee.

Open system (control volume): Both energy and matter can be exchanged with the environment. Example: an open cup of coffee.

Isolated system

Neither energy nor mass can be exchanged with the environment. In fact, no interactions with the environment are possible at all. Example: coffee in a closed, well-insulated thermos bottle.

Surrounding

Everything external to the system is the surroundings.

Boundary

A boundary is a closed surface surrounding a system through which energy and mass may enter or leave the system.

State variables

State Variables are Path Independent: meaning that the change in the value of the state variable will be the same no matter what path you take between the two states.

This is not true of either the work W or the heat Q .

If a system is carried through a cycle that returns it to its original state, then a variable will only be a state variable if variable returns to its original value.

State Variables are only measurable when the system is in Equilibrium.

Examples of State Variables: Temperature, Pressure, Volume, Entropy, Enthalpy, Internal Energy, Mass, Density.

Q.3 Write a note on Internal Energy and show that it is independent of the path.

Answer

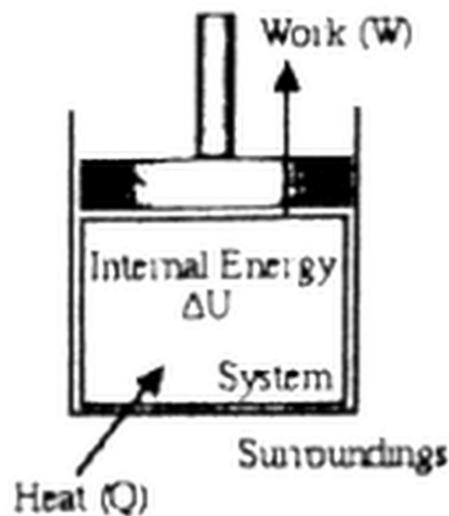
Internal energy

The sum of all the forms of molecular energies (such as kinetic or potential energy) of a substance is called internal energy.

Explanation

It is the study of thermodynamics. An ideal gas is usually considered as a working substance. The molecules of an ideal gas are mere mass points which exert no force on one another.

So, the internal energy of an ideal gas system is generally the translational K.E of the molecules. Since $T \propto \langle K.E \rangle$, thus the internal energy of an ideal gas is directly proportional to its temperature.



Energy Equation for Stationary Closed Systems

$$Q - W = \Delta U \quad [\text{KJ}]$$

Where Q is the Heat Transferred to the System.

W is the Work Done by the System.

ΔU is the Change of Internal Energy.

Dividing each term by the system mass m [kg], we obtain the specific form of the Energy Equation

$$Q - W = \Delta U \quad [\text{KJ/Kg}]$$

Q4. How can we increase the internal energy?

1. By heating

When we heat a substance, energy associated with its atoms or molecules is increased i.e. heat is converted to internal energy.

2. By doing mechanical work

When two objects are rubbed together, their internal energy increases because of mechanical work. The increase in temperature of the object indicates an increase in the internal energy.

Note

Similarly, when an object slides over any surface and comes to rest because of frictional forces, the mechanical work done on or by the system is partially converted into internal energy.

Internal energy in a state function

In thermodynamics, internal energy is function of state. Consequently, it does not depend on the path but depends on initial and final states of the system.

Explanation

Consider the system which undergoes a pressure and volume change from P_a and V_a to P_b and V_b respectively, regardless of the process by which the system changes from initial to final state. By experiment it has been seen that the change in internal energy is always the same and is independent of the paths C_1 and C_2 . Internal energy is similar to the gravitational P.E, so like the gravitational P.E we take the change in internal energy and not its absolute value, which is important.

Q5 Discuss transfer of energy into work and heat. Also calculate the work done by a thermodynamic system during the volume change.

Answer**Work and Heat**

Both heat and work correspond to transfer of energy by some means. This idea was first applied to the steam engine where it was natural to transfer heat in and get work out.

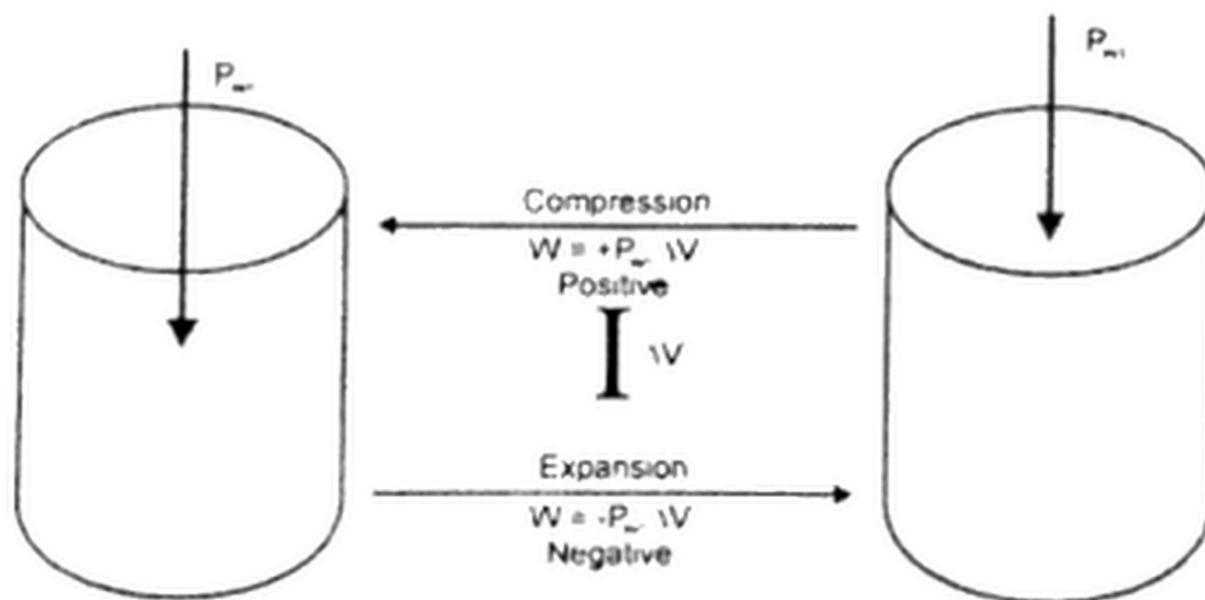
Positive work done

Work done by the system (gas) on its environment is considered as positive.

Negative work done

Work done by the environment on the system is considered as negative.

If an amount of heat Q enters the system it either appears as an increase in internal energy of the system or is used up in doing work by the system on its environment.



Expression for work

Consider a gas enclosed in a cylinder with a movable frictionless piston of cross-sectional area ' A '. In equilibrium, the system occupies volume ' V ' and exerts a pressure ' P ' on the walls of the cylinder and its piston. As pressure is defined, force per unit area i.e.,

$$P = \frac{F}{A}$$

Or $F = PA$

This is the force exerted by gas on piston.

The gas expands through ΔV very slowly so that it remains in the equilibrium. As the piston moves up through a small distance $= d = \Delta y$

Work done by gas is

$$W = F\Delta y$$

$$W = P\Delta y$$

Since $A\Delta y = \Delta V$ (change in volume)

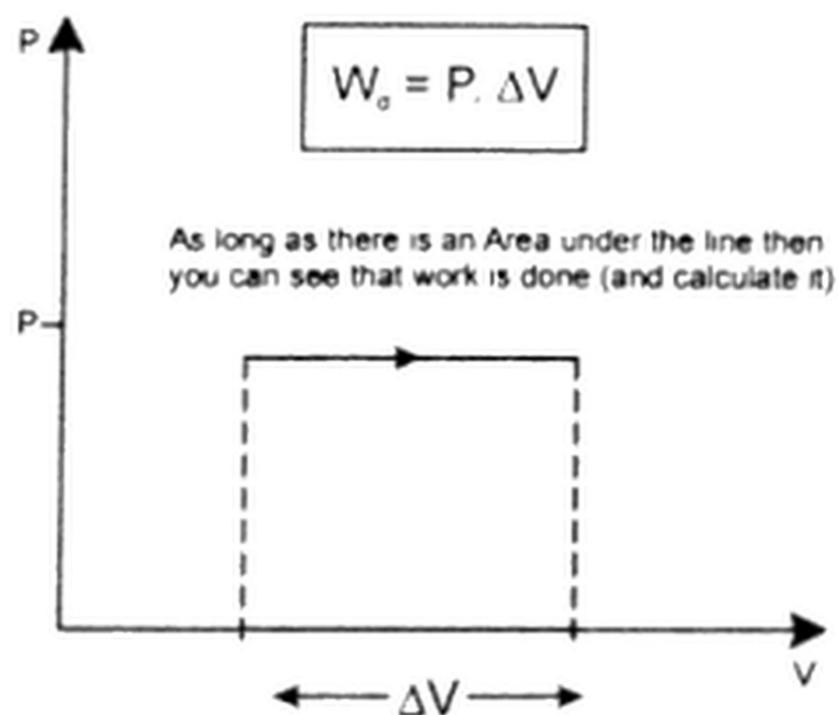
$$W = P \Delta V$$

This is the work done by gas on the piston.

We can express work in terms of directly measurable quantities.

Graphical representation

Work done can be calculated from the area under P–V graph.



By the details of change in internal energy and the mechanical work done, we can describe the general principals which deal with heat energy transformation into mechanical energy. This principal is known as the law of thermodynamics.

Q.6 Explain the first law of Thermodynamics and its consequences?

Answer

First law of thermodynamics

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

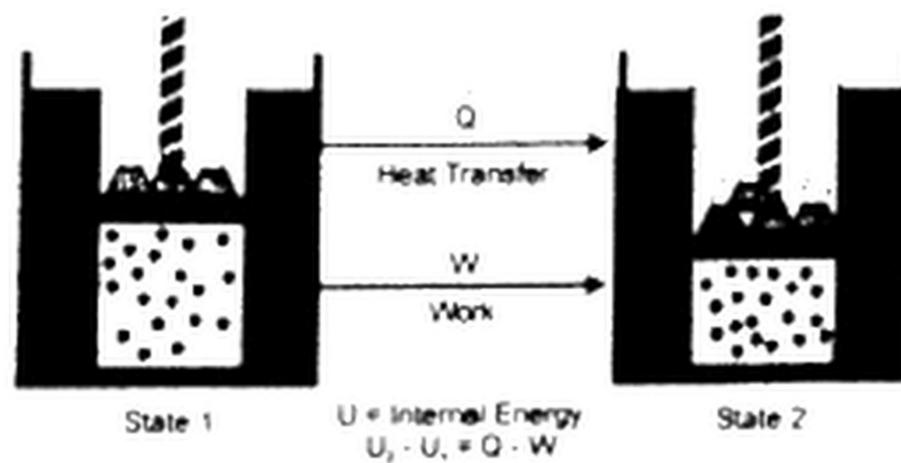
Mathematically

$$Q = \Delta U + W$$

Explanation

When heat is added to a system;

- There is an increase in the internal energy from U_1 to U_2 due to rise in temperature, an increase in pressure or change in its state.



If at the same time, a substance is allowed to expand, then W is the work done on its environment.

$$Q = (U_2 - U_1) + W$$

OR $Q = \Delta U + W$ (1)

Thus, the change in internal energy $\Delta U = U_2 - U_1$

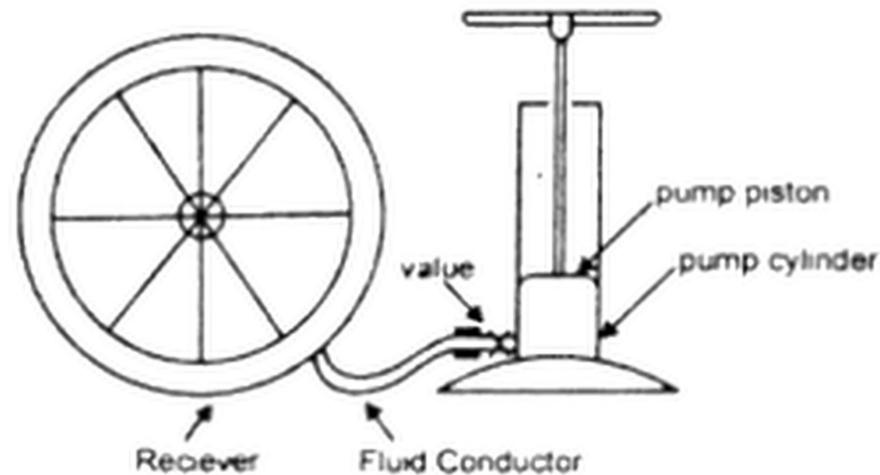
From eq. (1)

$$\Delta U = Q - W \quad \dots\dots\dots (2)$$

Examples of first law of thermodynamics

Bicycle pump

A bicycle pump provides a good example. When we pump on the handle rapidly, it becomes hot due to mechanical work done on the gas, in this way; it increases its internal energy.



Note

The arrangement consists of

- Bicycle pump with a blocked outlet.
- A thermocouple connected through the blocked outlet to note the temperature of the air.
- When piston is rapidly pushed, thermometer shows a temperature rise due to increase of internal energy of the air.
- The push force does work on the air, thereby increasing its internal energy, by the increase in temperature of the air.

Human metabolism

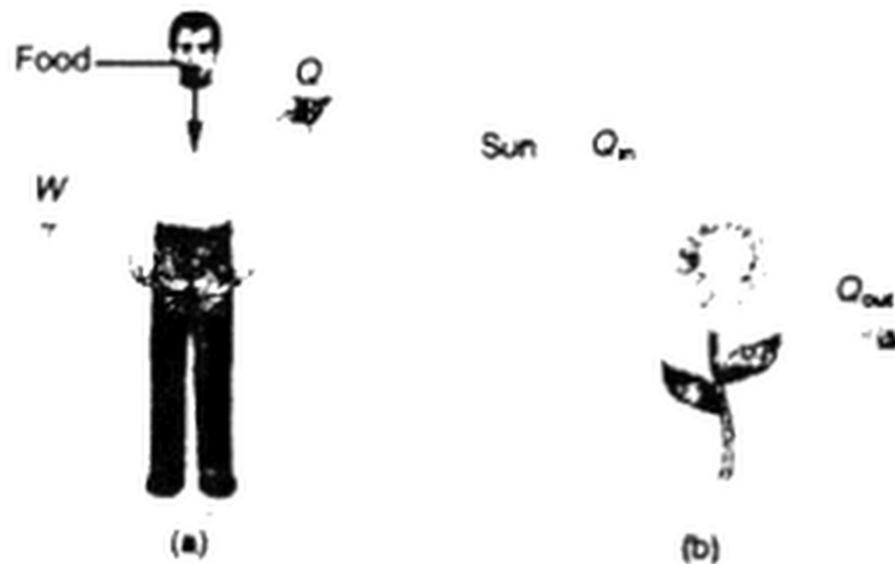
- Human metabolism also provides an example of energy conversion.
- Human being and other animals do work when they walk, run, or move heavy objects. Work requires energy.

- Energy is also needed for growth to make new cells and to replace old cells that have died.
- Work done will result in decrease in internal energy of the body.
- According to 1st law of thermodynamics, to an organism of human body.

$$\Delta U = Q - W$$

- Hence, the body temperature or internal energy is maintained by the food we eat.

$$\Delta U = -Q - W + \text{food energy} \quad \Delta U = \text{stored food energy}$$



Note (metabolism)

Energy transforming processes that occur within an organism are named as metabolism.

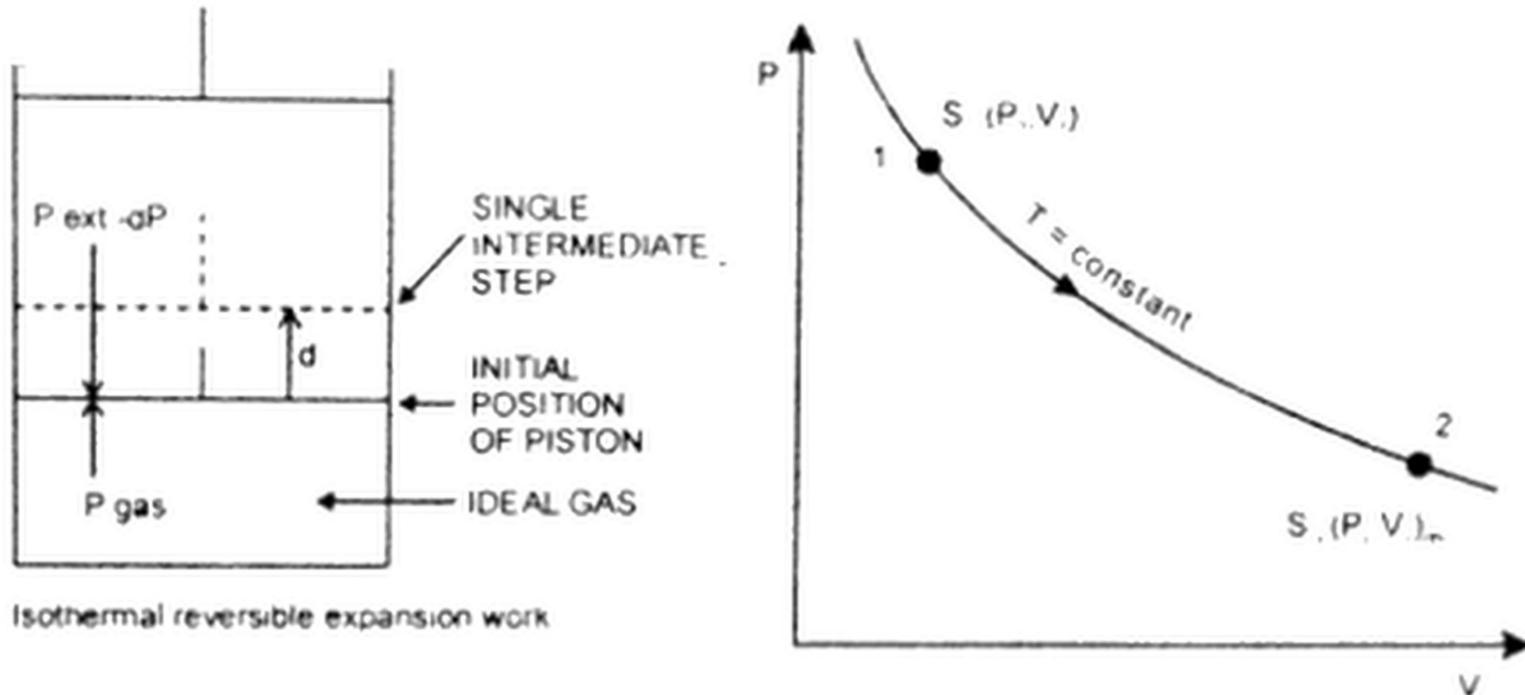
Q.7 Discuss the Applications of first law of thermodynamics

Applications of first law of thermodynamics

1) Isothermal process

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

In isothermal process the condition for the application of the Boyle's Law is fulfilled. Therefore, when gas expands or compresses isothermally, the product of its pressure and volume during the process remain constant.



Explanation

If P_1 and V_1 are the initial pressure and volume where as P_2 and V_2 are pressure and volume after the isothermal change takes place. Then

$$P_1 V_1 = P_2 V_2$$

As the internal energy of an ideal gas depends only on its temperature, which in this case is constant.

Therefore,

$$\Delta U = 0$$

Hence first law of thermodynamics reduces to

$$Q = \Delta U + W$$

$$Q = U + W$$

$$Q = W$$

2) Isothermal expansion

If a gas expands and does external work W , an amount of heat Q has to be supplied to the gas in order to produce an isothermal change since, transfer of heat from one place to another requires time, hence to keep temperature of the gas constant, the expansion must take place slowly.

Isotherm

The curve representing an isothermal process is called isotherm.

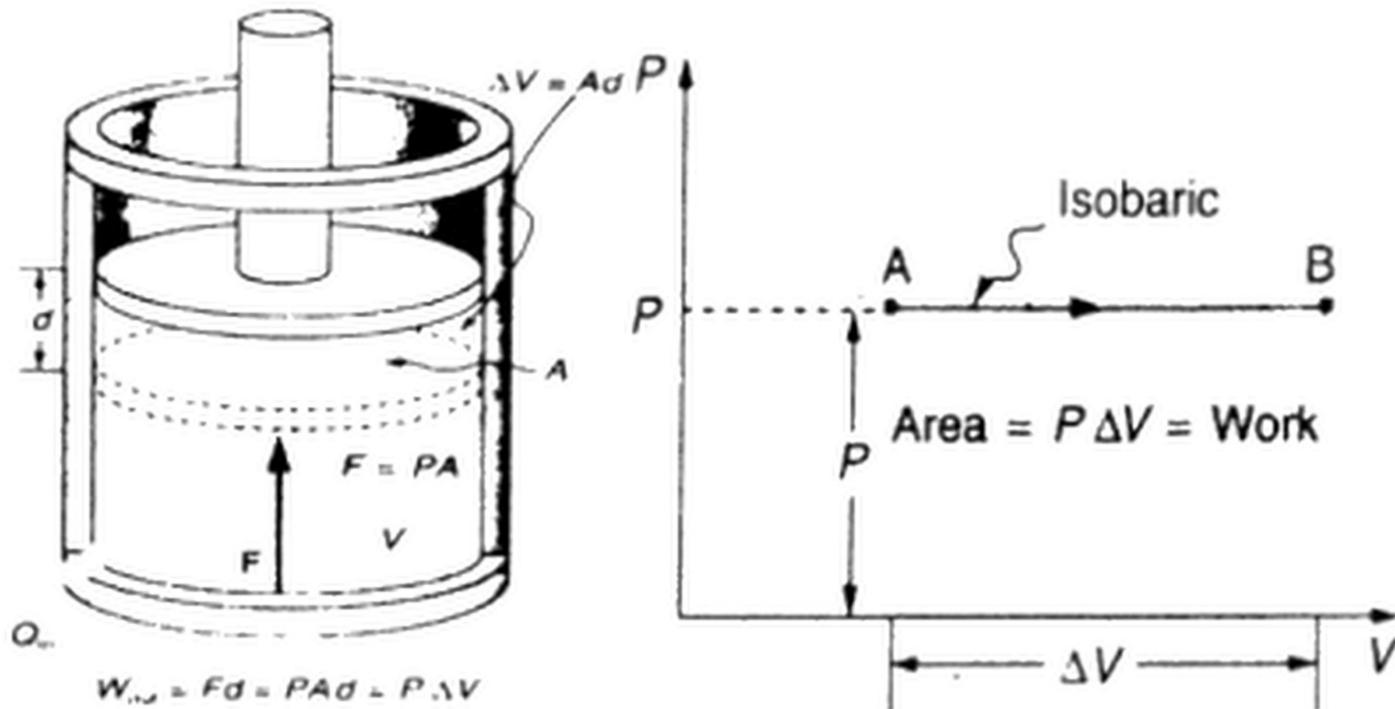
3) Isobaric Process

An isobaric process is one where the pressure of the system (often a gas) stays constant.

'Iso' means the same, and 'baric' means pressure. Pressure is related to the amount of force that the molecules apply to the walls of the container.

Explanation

Imagine that you have a gas inside a movable piston and you heat that gas up. By heating the gas up you make the molecules move faster, which would normally increase the pressure. But at the same time the piston expands, increasing the volume and giving the molecules more room to move. Since the walls of the container are now bigger, the pressure can stay the same even though the molecules are moving faster. That makes it an isobaric process.



$$\Delta V = 0$$

So, $W = p\Delta V = 0$

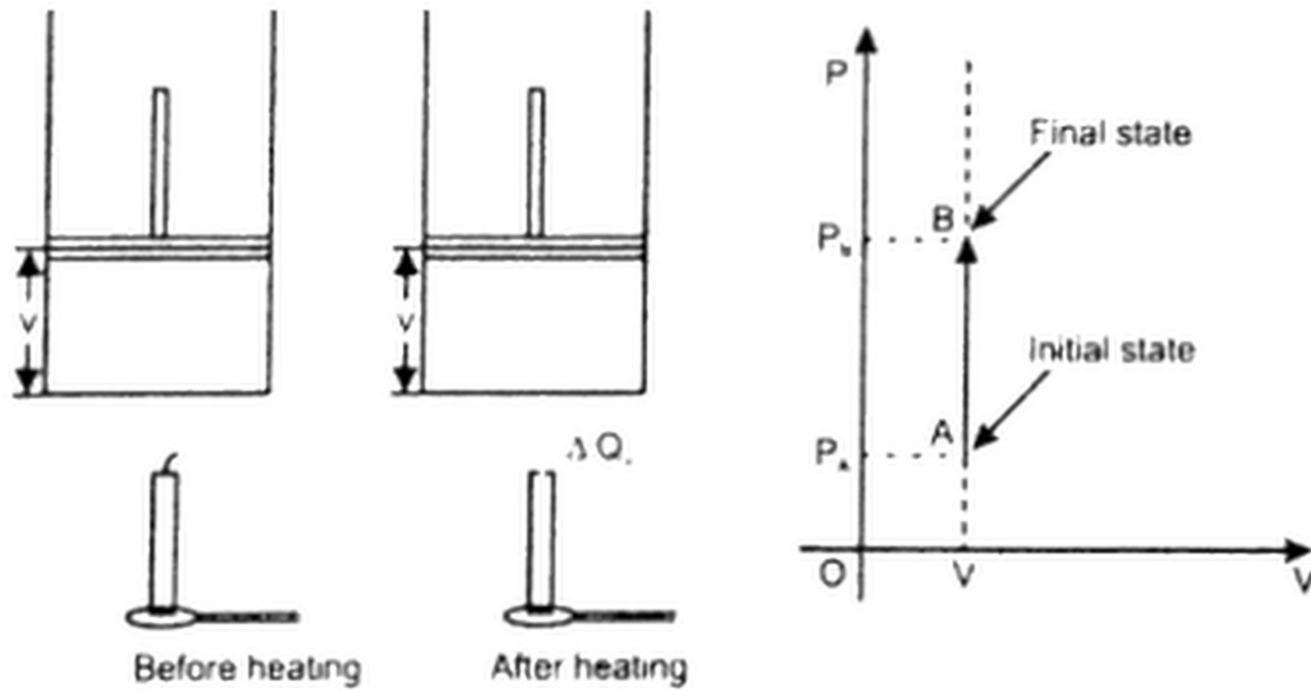
4) Isochoric Process

An isochoric process is one where the volume of the system stays constant.

Explanation

Again, 'iso' means the same and 'choric' means volume. Volume is the amount of space the material takes up. So, this would be like heating a gas in a solid, non-expandable container. The molecules would move faster and the pressure would increase, but the size of the container stays the same.

$$W = p \Delta V = p(V_2 - V_1)$$



4) Adiabatic Process

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

Explanation

Since in adiabatic process no heat enters or leaves the system i.e., $Q = 0$

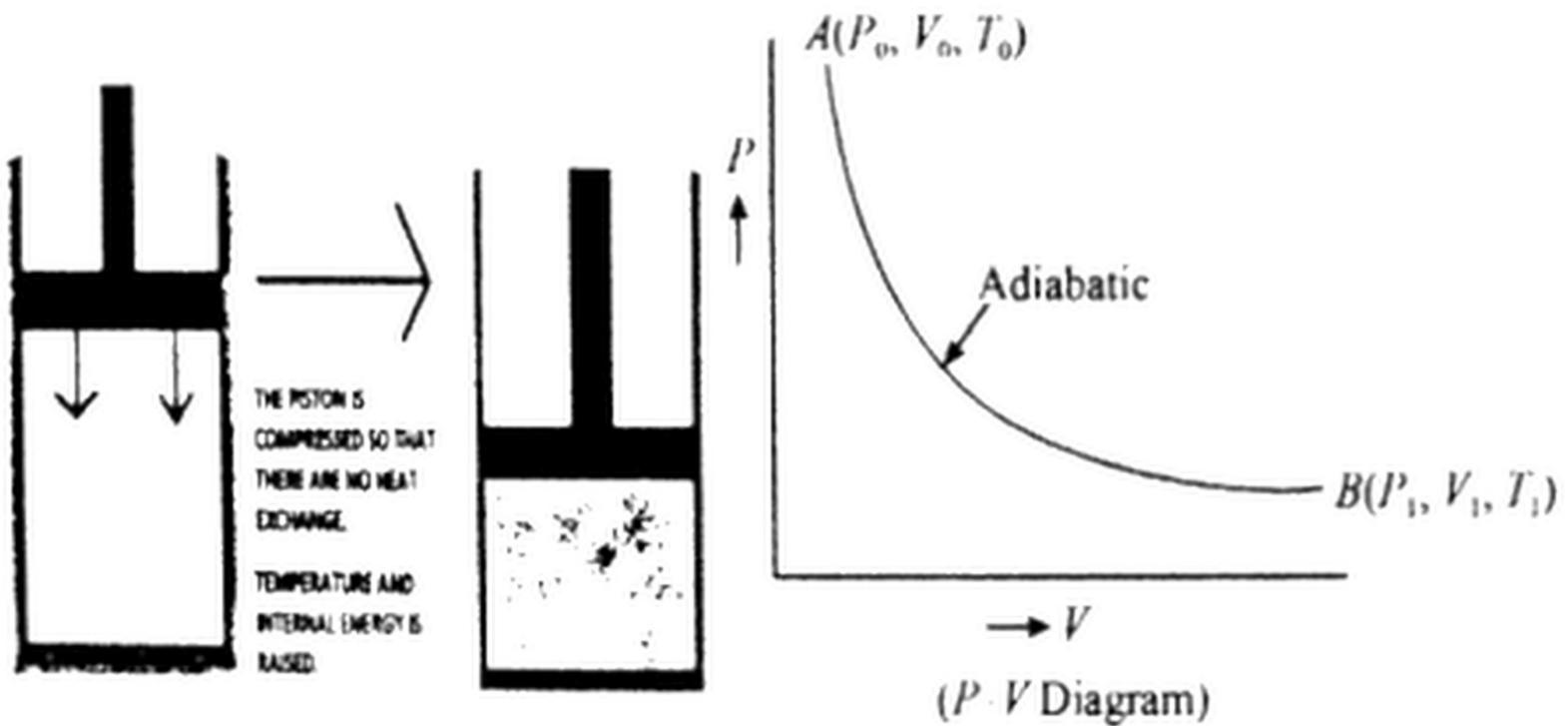
Hence the first law of thermodynamics becomes

$$Q = \Delta U + W$$

$$0 = \Delta U + W$$

Or

$$W = -\Delta U$$



Adiabatic expansion

If gas expands and does external work, it does so at the expense of internal energy of its molecules and hence, the temperature of the gas falls.

Adiabatic compression

If gas is compressed, work is done on the gas, it increases the temperature of the gas.

$$-W = \Delta U$$

Condition for adiabatic change

Adiabatic change occurs when the gas expands or is compressed rapidly. Particularly when the gas is contained in an isolated cylinder. In case of adiabatic changes, as the temperature of the gas does not remain constant,

So, $PV^\lambda = \text{constant}$

Where, λ is the ratio of the molar specific heat of the gas at constant pressure to the molar specific heat at constant volume i.e.

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

Adiabat

The curve representing an adiabatic process is called an adiabat. An adiabat is steeper than an isotherm.

Examples of Adiabatic Process

The examples of adiabatic processes are

- 1) The rapid escape of air from a burst tyre.
- 2) The rapid expansion and compression of air through which a sound wave is passing.
- 3) Cloud formation in the atmosphere.

Q8 (a) Define the following terms:

(i) molar specific heat (ii) Molar specific heat at constant volume (C_v)

(iii) molar specific heat at constant pressure (C_p)

(b) Prove that $C_p - C_v = R$

Answer

Specific heat

The amount of heat required to raise the temperature of one kilogram of a substance up to one Kelvin is called specific heat.

Mole

One kilogram of different substances contains different number of molecules. Sometimes it is preferred to consider a quantity called mole. One mole of any substance contains same number of molecules.

Molar Specific Heat of a Gas

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

Note

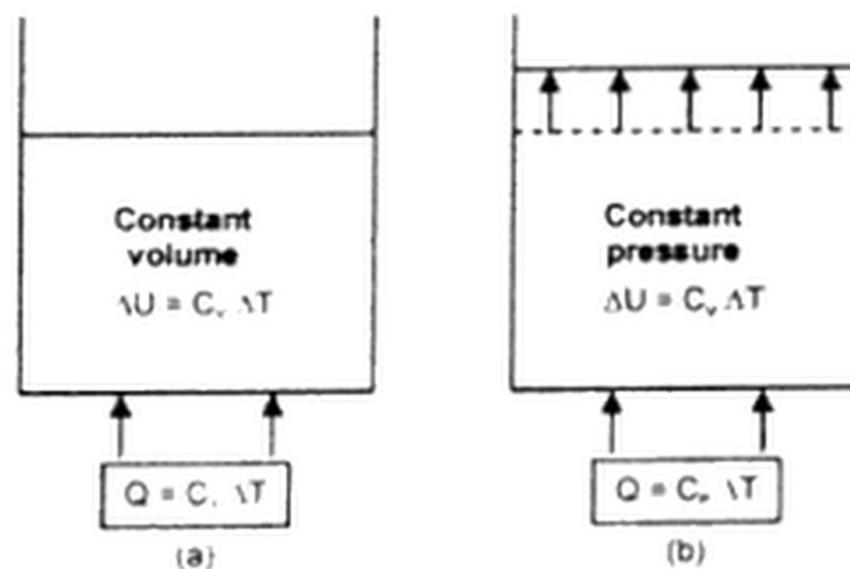
In case of solids and liquids the change of volume and hence work done against external pressure during a change of temperature is negligibly small.

But gases suffer variation in pressure as well as in volume with the rise in temperature. Hence, to study the effect of heating the gases, either pressure or volume is kept constant. We can define molar specific heat of a gas in two ways.

i) Molar specific heat at constant volume

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 symbolized by C_v . Its SI unit is $\text{J Mole}^{-1} \text{K}^{-1}$.



ii) Molar specific heat at constant pressure

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 symbol C_p .

i) Derivation of $C_p - C_v = R$

At constant volume

If one mole of an ideal gas is heated at constant volume so that its temperature rises by ΔT then the heat transferred Q_v is given by

$$Q_v = C_v \Delta T \quad \dots\dots (1)$$

Applying first law of thermodynamics.

$$C_v \Delta T = \Delta U + W$$

$$C_v \Delta T = \Delta U + P \Delta V \quad [\because W = P \Delta V]$$

Since volume remains constant, so $\Delta V = 0$

Hence $C_v \Delta T = \Delta U$

Or $C_v \Delta T = C_v \Delta U$

Thus the first law of thermodynamics

$$C_v \Delta T = \Delta T$$

Or $\Delta U = C_v \Delta T \quad \dots\dots (2)$

At constant pressure

If one mole of an ideal gas is heated at constant pressure so that its temperature rises by ΔT then the heat transferred Q_p is given by

$$Q_p = C_p \Delta T \quad \dots\dots\dots(3)$$

The internal energy increases by the same amount as at constant volume for the same rise in temperature ΔT

$$\Delta U = C_v \Delta T \quad \dots\dots (4)$$

Since, the gas expands to keep the pressure constant, to the work done by the gas is

$$W = P \Delta V \quad \dots\dots\dots (5)$$

According to first law of thermodynamics

$$Q_p = \Delta U + W$$

Or $C_p \Delta T = C_v \Delta T + P \Delta V$ (6) [Using equation (3), (4) & (5)]

According to general gas equation

$$PV = nRT$$

For one mole of an ideal gas $n = 1$

$$PV = RT$$

At constant pressure P , amount of work done by one mole of a gas due to expansion ΔV caused by the rise in temperature ΔT is given by

$$P \Delta V = R \Delta T$$

Putting value of $P \Delta V$ in equation (6), we get

$$C_p \Delta T = C_v \Delta T + R \Delta T$$

Or $C_p = C_v + R$

Or $C_p - C_v = R$

It is clear that $C_p > C_v$ by an amount equal to universal gas constant R .

Q.9 Write a note on reversible and irreversible processes.

Answer

Reversible Process

A reversible process is one which can be retraced in exactly reverse order, without producing any change in the surroundings.

Explanation

- In the reverse process, the working substance passes through the same stages as in the direct process, but thermal and mechanical effects at each stage are exactly reversed.
- If heat is absorbed in the direct process, it will be given out in the reverse process.
- If work is done by the substance in the direct process, work will be done on the substance in the reverse process.

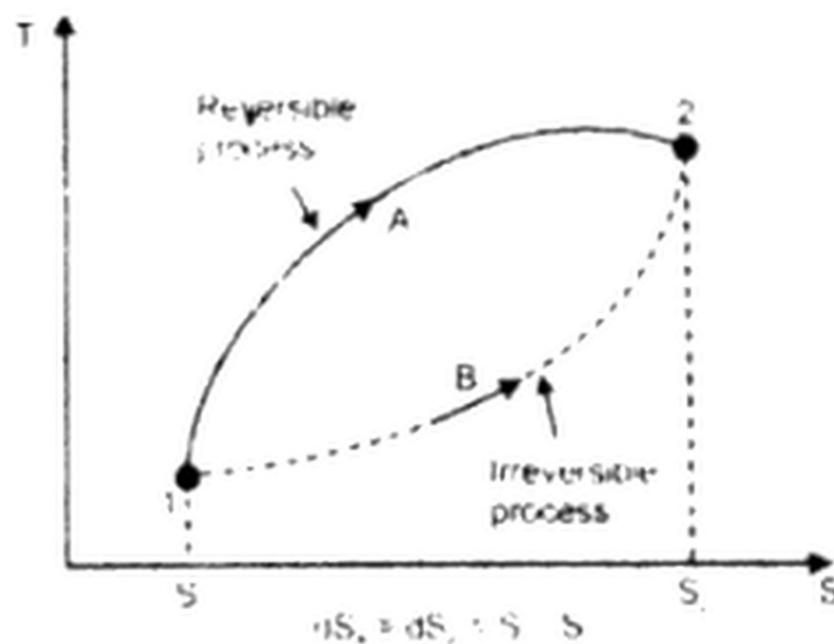
Hence, the working substance is restored to its original conditions.

Cycle

A succession of events which bring the system back to its initial condition is called a cycle.

Examples of Reversible Process

1. The process of liquefaction and the evaporation of a substance performed slowly, are reversible processes.
2. Slow compression of a gas in a cylinder is reversible process as the compression can be changed to expansion by decreasing the pressure on the piston.



Irreversible Process

A reversible process is one which cannot be retraced in exactly reverse order, without producing any change in the surroundings.

Explanation

All changes which occur suddenly or which involve friction or dissipation of energy through conduction, convection and radiation are irreversible.

Examples

- i) Explosion is an example of highly irreversible process.
- ii) Work done against friction.

Q.10 Write a note on Heat Engine.

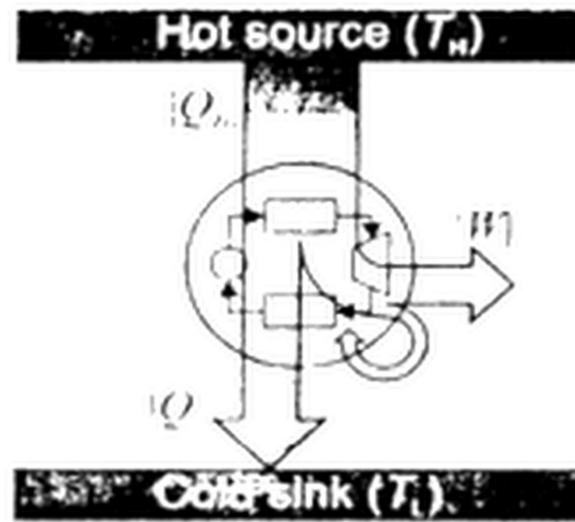
Answer

Heat Engine

Heat engine is a device which converts heat energy into mechanical work.

Introduction

The earliest heat engine was the steam engine. It was developed on the fact that when water is boiled in a vessel covered with a lid, the steam inside tries to push the lid off, showing the ability to do work. This observation helped to develop a steam engine.



Construction

A heat engine consists of:

- Hot reservoir or source which can supply heat at high temperature.
- A cold reservoir or sink into which heat is rejected at a lower temperature.
- A working substance is needed which can absorb heat Q_1 from source, convert some of it into work W by expansion and rejects the rest heat Q_2 to cold reservoir or sink.

Note

A heat engine is made cyclic to provide a continuous supply of work.

Working

Working substance absorbs heat Q_1 from source, converts some of it into work W by expansion and rejects the rest heat Q_2 to cold reservoir of sink.

Efficiency of heat engine

The efficiency of heat engine is defined as the ratio of work done to the heat energy supplied. It is denoted by η .

Where $W = Q_1 - Q_2$

Thus $\text{efficiency} = \frac{W}{Q_1}$

$$\eta = \frac{Q_1 - Q_2}{Q_1} \quad \text{Or} \quad \frac{Q_1}{Q_1} - \frac{Q_2}{Q_1}$$

This is the expression for efficiency of heat engine.

Q.11 State and explain Second Law of Thermodynamics.

Answer

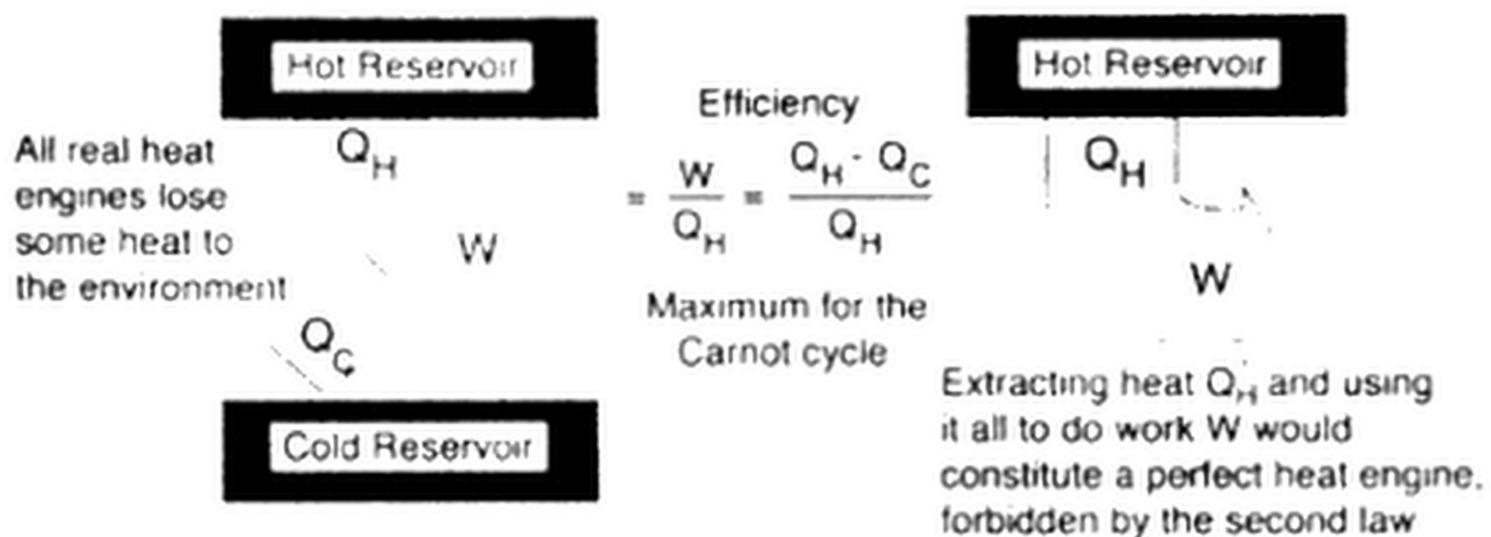
Second Law of Thermodynamics

According to Lord Kelvin's statement for working of heat engine.

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.

OR

There is no perfect heat engine.



Explanation

Let, the engine absorbs a quantity of heat Q_1 from the heat source at temperature T_1 . It does work W and rejects heat Q_2 to low temperature reservoir at temperature T_2 .

As the working substance goes through a cyclic process, in which the substance eventually returns to its initial state, thus the change in internal energy is zero $\Delta U = 0$.

Hence, according to First law of thermodynamics, the net work done is

$$Q = \Delta U + W$$

Therefore $Q_1 - Q_2 = 0 + W$ [$\because W = Q_1 - Q_2$ and $Q = Q_1 - Q_2$]

$$Q_1 - Q_2 = W$$

$$W = Q_1 - Q_2$$

Consequence

As a consequence of second law of thermodynamics two bodies at different temperature are essential for the conversion of heat into work.

A single heat reservoir, no matter how much energy it contains cannot be made to perform any work.

Hence for the working of heat engine there must be source of heat at high temperature and a sink at low temperature to which heat maybe expelled.

Q.12 Why we cannot use the large amount of heat energy in oceans and atmosphere?

Answer

Thus, it is true for oceans and our atmosphere which contains a large amount of heat energy but cannot be converted into useful mechanical work.

Reason

The reason for our inability to utilize the heat contents of oceans & atmosphere is that there is no reservoir at a temperature lower than anyone of the two.

Note

In practice, the petrol engine of a motor car extracts heat from the burning fuel and converts a fraction of this energy to mechanical energy or work & expels the rest to atmosphere.

Q13. What is Carnot's Engine? Explain its working and calculate its efficiency. Also state Carnot's theorem.

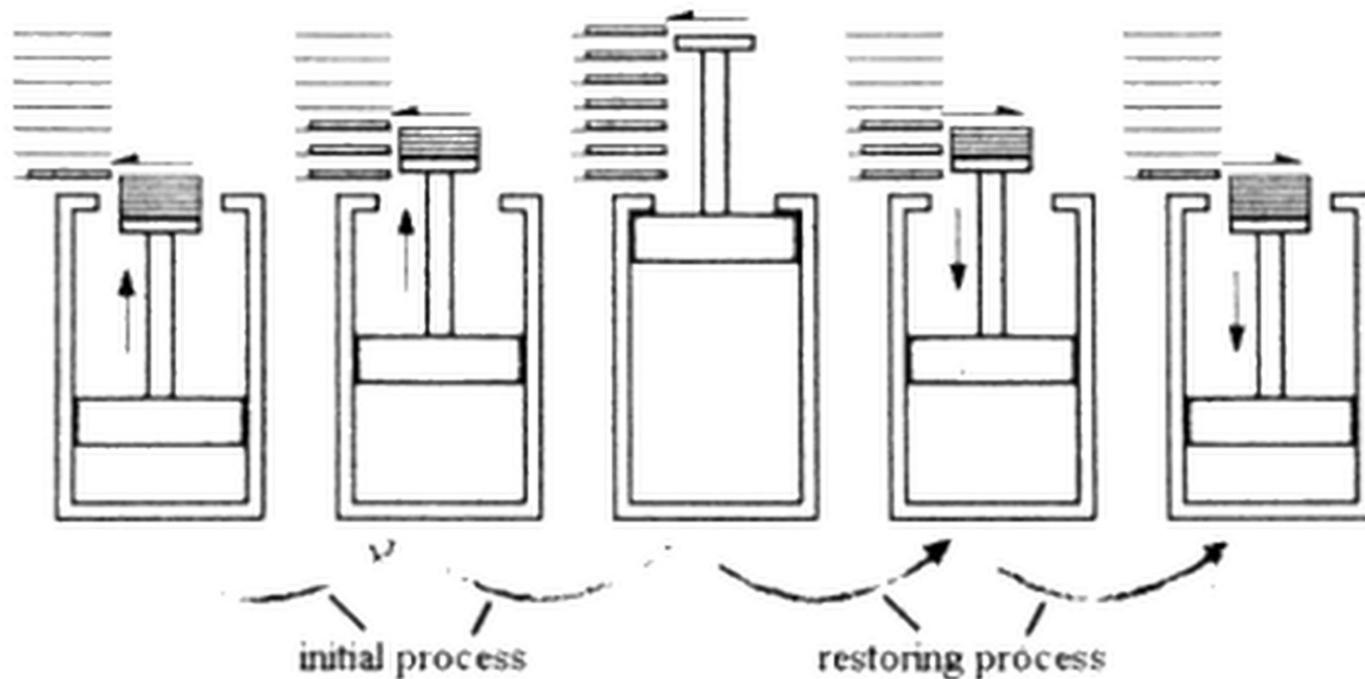
Answer**Carnot's Engine**

A Carnot heat engine is a hypothetical engine that operates on the reversible Carnot cycle. Sadi Carnot in 1824 proposed this ideal engine using only isothermal and adiabatic process.

He showed that a heat engine operating in an ideal reversible cycle between two heat reservoirs at different temperatures would be the most efficient engine.

Principle

Carnot's engine works on the same principle as that of cyclic heat engine. It takes heat from hot body, converts a part of it into work and rejects the remaining part to cold body.



Working

A Carnot cycle using an ideal gas as a working substance is shown in PV-diagram. It consists of following four steps.

1. Isothermal expansion

The gas is allowed to expand isothermally at temperature T_1 , absorbing heat Q_1 from the hot reservoir. The process is represented by curve AB.

2. Adiabatic expansion

The gas is then allowed to expand adiabatically until its temperature drops to T_2 . The process is represented by BC curve.

3. Isothermal compression

The gas at this stage is compressed isothermally at temperature T_2 rejecting heat Q_2 to the cold reservoir. The process is represented by curve CD.

4. Adiabatic compression

Finally, the gas is compressed adiabatically to restore its initial state at temperature T_1 . The process is represented by curve DA.

Thermal and mechanical equilibrium is maintained all the time so that each process is perfectly reversible.

Expression for Efficiency

As the working substance return to the initial state, there is no change in its internal energy i.e. $\Delta U = 0$.

The net work done during one cycle equals to the area enclosed by the path ABCDA of the PV diagram.

It can also be estimated from net heat ΔQ absorbed in one cycle Δ .

$$\Delta Q = Q_1 - Q_2$$

From 1st law of thermodynamics,

$$\Delta Q = \Delta U + W \quad \dots\dots (1)$$

Putting value of ΔQ and ΔU in equation (1), we get

$$Q_1 - Q_2 = 0 + W$$

$$W = Q_1 - Q_2$$

Efficiency η (eta) of heat engine is defined as

$$\begin{aligned} \eta &= \frac{\text{output (work)}}{\text{input (energy)}} \\ \eta &= \frac{W}{Q_1} \\ \eta &= \frac{Q_1 - Q_2}{Q_1} \\ \eta &= 1 - \frac{Q_2}{Q_1} \quad \dots\dots(2) \end{aligned}$$

The energy transfer in an isothermal expansion or compression turns out to be proportional to Kelvin temperature i.e. Q_1 and Q_2 are proportional to Kelvin temperature T_1 and T_2 respectively.

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

Thus equation (2) becomes

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

The efficiency is usually taken in percentage.

$$\text{Percentage efficiency} = \eta\% = \left[1 - \frac{T_2}{T_1} \right] \times 100$$

Dependence of Efficiency

Efficiency of a Carnot Engine depends on the temperature of hot & cold reservoir. It is independent of the nature of the working substance. The larger the temperature difference of the two reservoirs, the greater is the efficiency.

In most practical cases, the cold reservoir is near room temperature. So, the efficiency can be increased by raising the temperature of hot reservoir.

Can efficiency of heat engine be 100%?

It can never be one or 100% unless cold reservoir is at absolute zero temperature. Such reservoirs are not available & hence maximum efficiency is always less than one.

Carnot's Theorem

Statement

No heat engine can be more efficient than a Carnot engine operating between the same two temperatures.

Extended statement

All Carnot's engines operating between the same two temperatures have the same efficiency, irrespective of the nature of working substance.

Note

All real heat engines are less efficient than Carnot's Engine due to friction & heat losses.

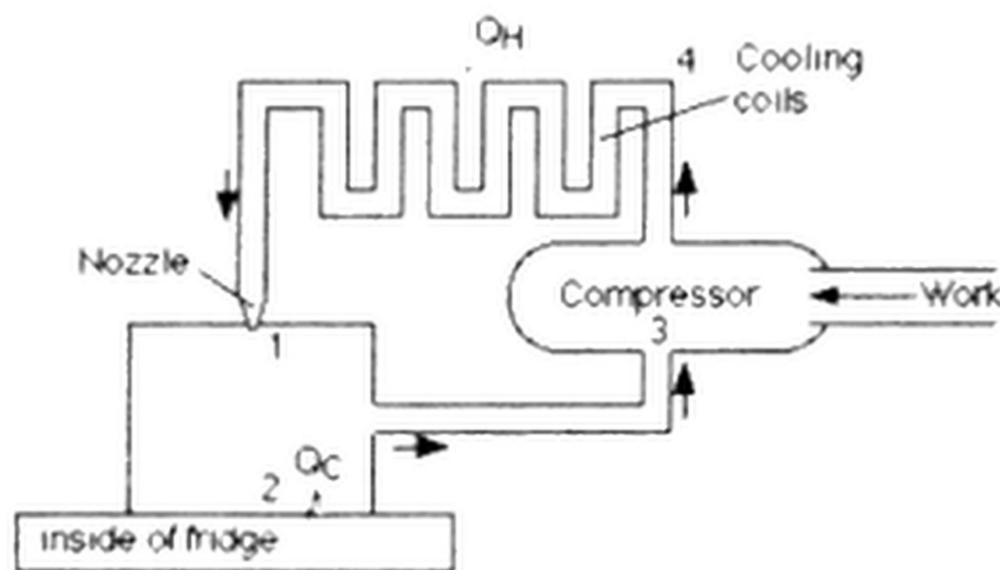
Q.14 Discuss the working principle of refrigerator in terms of second law of thermodynamics.

Answer

Refrigerator

In nature, heat flows from high-temperature regions to low-temperature ones. The reverse process, however, cannot occur by itself.

The transfer of heat from a low-temperature region to a high-temperature one requires special devices called refrigerators. Refrigerators are cyclic devices, and the working fluids used in the cycles are called refrigerant.



Working principle

A refrigerator, consisting of a fluid pumped through a closed system, involves a four-step process.

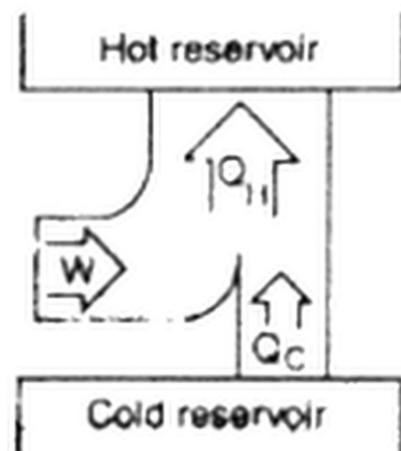
Step 1 - The fluid passes through a nozzle and expands into a low-pressure area. Similar to the way carbon dioxide comes out of a fire extinguisher and cools down, the fluid turns into a gas and cools down. This is essentially an adiabatic expansion.

Step 2 - The cool gas is in thermal contact with the inner compartment of the fridge; it heats up as heat is transferred to it from the fridge. This takes place at constant pressure, so it's an isobaric expansion.

Step 3 - The gas is transferred to a compressor, which does most of the work in this process. The gas is compressed adiabatically, heating it and turning it back to a liquid.

Step 4 - The hot liquid passes through coils on the outside of the fridge, and heat is transferred to the room. This is an isobaric compression process.

All real refrigerators and heat pumps require work to get heat to flow from a cold area to a warmer area



$$\text{Coefficient of Performance} = \frac{Q_H}{W}$$

General definition

$$CP = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_C} \Rightarrow \frac{T_H}{T_H - T_C}$$

Limit for ideal Carnot case

Ideal coefficient of performance

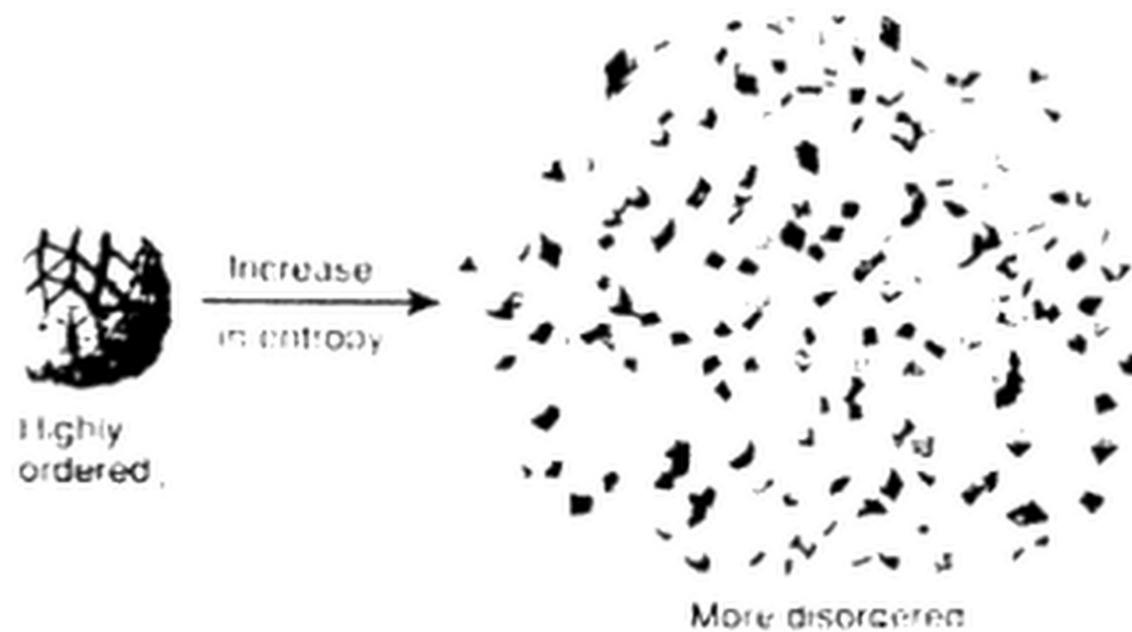
Q.15 Define and explain the term entropy.

Answer

Entropy

Entropy is state variable of thermodynamically system. It was introduced by Rudolph Clausius in 1856. This give quantitative basis or mathematical formula for second law of thermodynamics.

The physical significance of entropy is that it is a measure of disorder of molecules of a system. Change in entropy is denote by ΔS .



If ΔS is the quantity of heat absorbed by the system at temperature T . Then change in entropy (state variable) of the system is,

$$\Delta S = \frac{\Delta Q}{T} \quad (\text{for reversible process})$$

Just like internal energy and potential energy, it is change in entropy which is more important than its absolute value.

Sign Convention

The change in entropy is positive (means that entropy increased) when heat is added to a system. Change of entropy is negative (mean that entropy decreased) when heat is taken out of this system.

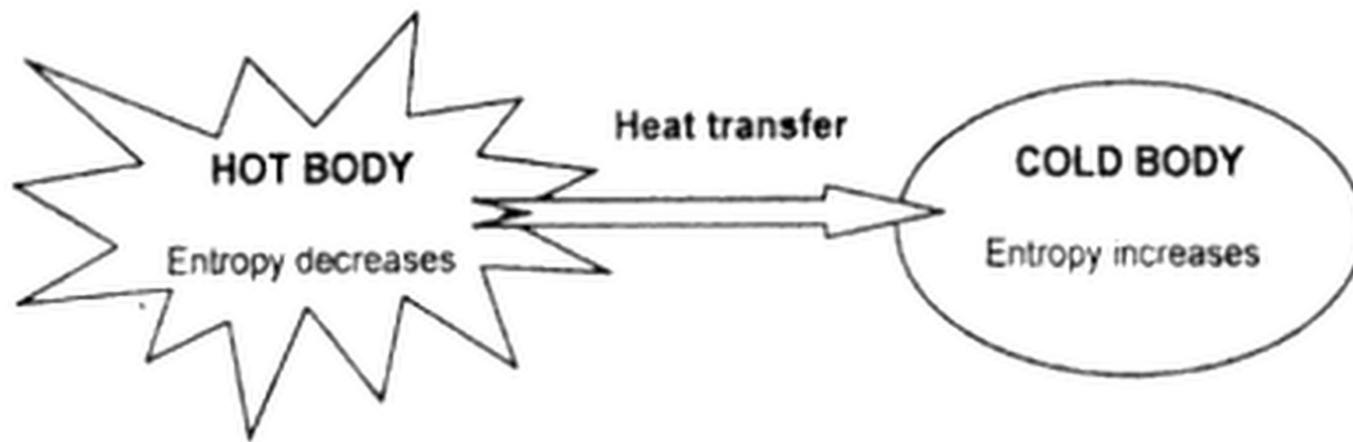
Unit

The SI unit of change of entropy or entropy is joule/Kelvin (JK^{-1})

Principle of Increase of Entropy

This principle states that entropy of a system plus its surroundings increases due to natural process done on or by the thermodynamically system.

Let T_1 and T_2 are the temperature of hot body and cold body respectively (i.e. $T_1 > T_2$) and Q be the amount of heat conducted.



Then

$$\text{Decrease of entropy of HTR} = \frac{Q}{T_1}$$

$$\text{Increase of entropy of LTR} = \frac{Q}{T_2}$$

$$\text{Net change in entropy} = \frac{Q}{T_2} - \frac{Q}{T_1} = \text{positive}$$

As $T_1 > T_2$ so the sign of net change of entropy is +ve or we can say that net entropy of the system is increased.

This proves that there is net increase of entropy due to a natural process (i.e. flow of heat from higher to lower temperature). This is also called another statement of second law of thermodynamics.

Second Law of Thermodynamics in terms of Entropy

If a system undergoes a natural process, it will go in the direction that the entropy of system plus the environment increases. For example, an irreversible heat flows from a hot body to a cold body to increase the disorder. So, we can say that the entropy is increased.

Addition of heat increases the disorder: hence the entropy is also increased.

Unavailability of Mechanical Work (i.e. Degradation of Energy)

Let us consider two water tanks of different temperature, so the average K.E of molecules in higher temperature water is greater than lower temperature. The two water tanks can be used as source and sink of a heat engine, which could be operated between them and mechanical work can be obtained.

But if these two tanks are connected with a conducting rod then heat starts to flow from hot body towards the cold body until thermal equilibrium is reached. So, no mechanical work is done due to the absence of heat engine, which results unavailability of mechanical work. Hence,

Increase in entropy means the degradation of energy.

According to principle of increase of entropy, the entropy of the universe increases after to get mechanical work from heat. It would be called "heat death" or ending up of thermal energy.

Heat death of Universe

When the entropy of the universe will reach at maximum value, everything will be at same temperature and there will be no way to convert heat into useful work and it is called heat death.

Q.16 Describe environmental crisis as entropy crisis.

Answer

Environmental Crisis as Entropy Crisis

According to 2nd law of thermodynamics, every real process causes to increase the disorder or entropy of the universe. Any increase in the disorder of a system procures and even greater increase in the disorder of the environment, which is called "environmental crisis". The disorder producing activities due to all industries may result a great increase of disorder which affect the overall life support system. Our mechanical energy producing processes are not efficient.

For example, petrol engine has its efficiency about 30% and diesel engines about 40%. Hence most of energy is transferred into the environment in form of heat, which causes to increase the entropy of it.

The second law of thermodynamics impose limit on the efficiency of mechanical energy produced by engines, which says that thermal pollution is an inevitable result of second law of thermodynamics. Due to the thermal pollution in environment, temperature change may occur. But a small change in environment may have serious effects on metabolic rate in plants and animals. This may disturb ecological balance.

