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THERMODYNAMICS

CONCEPT OF HEAT AND TEMPERATURE

Heat

- Heat is the form of energy transferred between two (or more) systems or a system and its surroundings because of temperature difference.

Concept of Temperature

All bodies in thermal equilibrium have a common property, called temperature,

Temperature of a body is the property which determines whether or not it is in thermal equilibrium with other bodies.

Thermodynamic Terms

Thermodynamic system

- A thermodynamic system refers to a definite quantity of matter which is considered unique and separated from everything else, which can influence it

Open System

- It is a system which can exchange mass and energy with the surroundings. A water heater is an open system.

Closed system:

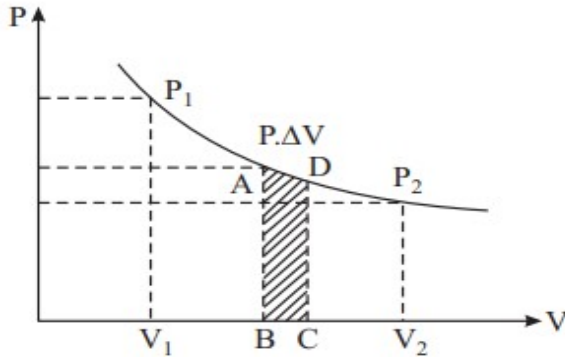
- It is a system which can exchange energy but not mass with the surroundings. A gas enclosed in a cylinder fitted with a piston is a closed system

Isolated system:

- It is a system which can exchange neither mass nor energy with the surrounding. A filled thermos flank is an ideal example of an isolated system.

Indicator diagram :

- How pressure (P) of a system varies with its volume (V) during a thermodynamic process and is known as an indicator diagram
- $\Delta W = P \Delta V$



THERMODYNAMIC EQUILIBRIUM

Thermodynamic Process

Reversible process

- If a process is executed so that all intermediate stages between the initial and final states are equilibrium states and the process can be executed back along the same equilibrium states from its final state to its initial state, it is called reversible process.

Irreversible process:

- A process which cannot be retraced along the same equilibrium state from final to the initial state is called irreversible process.

Isothermal process

- A thermodynamic process that occurs at constant temperature is an isothermal process. The expansion and compression of a perfect gas in a cylinder made of perfectly conducting walls are isothermal processes.

Adiabatic process

- A thermodynamic process in which no exchange of thermal energy occurs is an adiabatic process.

Isobaric process

- A thermodynamic process that occurs at constant pressure is an isobaric process. Heating of water under atmospheric pressure is an isobaric process.

Isochoric process

- A thermodynamic process that occurs at constant volume is an isochoric process.

Cyclic Process

- the system returns back to its initial state. It means that there is no change in the internal energy of the system. $\Delta U = 0$. $\therefore \Delta Q = \Delta W$.

Zeroth Law of Thermodynamics

- If two bodies or systems A and B are separately in thermal equilibrium with a third body C, then A and B are in thermal equilibrium with each other.

Triple Point of Water

- Triple point of a pure substance is a very stable state signified by precisely constant temperature and pressure values.
- Triple point is a point (on the phase diagram) at which solid, liquid and vapour states of matter can co-exist. It is characterised by a particular temperature and pressure.

INTERNAL ENERGY OF A SYSTEM

Internal kinetic energy

- total kinetic energy of the molecules constitutes the internal kinetic energy of the body

Internal potential energy

- The energy arising due to the inter-molecular forces is called the internal potential energy

Internal energy of a system = Kinetic energy of molecules + Potential energy of molecules

FIRST LAW OF THERMODYNAMICS

- The first law of thermodynamics is, in fact, the law of conservation of energy for a thermodynamic system. It states that change in internal energy of a system during a thermodynamic process is equal to the sum of the heat given to it and the work done on it.

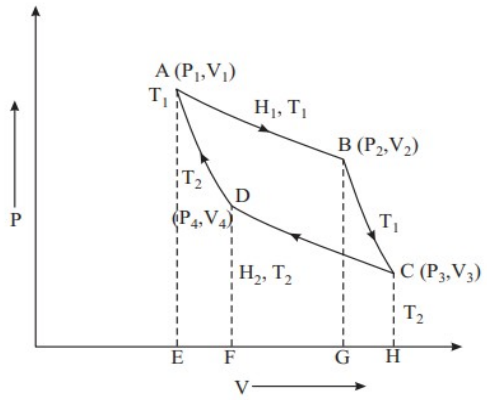
  Suppose that ΔQ amount of heat is given to the system and – ΔW work is done on the system. Then increase in internal energy of the system, ΔU, according to the first law of thermodynamics is given by ΔU = ΔQ – ΔW

SECOND LAW OF THERMODYNAMICS

- It is impossible for any system to absorb heat from a reservoir at a fixed temperature and convert whole of it into work.

Carnot Cycle

- A device which can convert heat into work is called a heat engine



Isothermal expansion

A to B

Adiabatic expansion

B to C

Isothermal compression

C to D

Adiabatic compression

D to A

Efficiency of Carnot Engine

Efficiency is defined as the ratio of heat converted into work in a cycle to heat taken from the source by the working substance.

It is denoted as η: η = Heat converted into work Heat taken from source or η = 12

efficiency of Carnot engine does not depend on the nature of the working substance

It means that efficiency η can be100% only when T2 = 0.

Limitation of Carnot's Engine

the isothermal process will take place only when piston moves very slowly. It means that there should be sufficient time for the heat to transfer from the working substance to the source.

during the adiabatic process, the piston moves extremely fast to avoid heat transfer. it is not possible to fulfill these vital conditions. Due to these very reasons, all practical engines have an efficiency less than that of Carnot's engine.

Check Yourself

1. The temperatures of inside and outside of a refrigerator are 273 K and 303 K respectively. Assuming, that the refrigerator cycle is reversible, for every joule of work done, the heat delivered to the surrounding will be nearly:
   (a) 10 J
   (b) 20 J
   (c) 30 J
   (d) 50 J

2. Which of the following parameters dose not characterize the thermodynamic state of matter?
   (a) work
   (b) volume
   (c) pressure
   (d) Temperature
3. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its absolute temperature. The ratio Cp/Cv for the gas is
   (a) 2
   (b) 3/2
   (c) 4/3
   (d) 5/3

4. The coefficient performance of a refrigerator is 5. If the temperature inside the freezer is -20°C, calculate the heat rejected to the surrounding
   (a) 11°C
   (b) 41°C
   (c) 21°C
   (d) 31°C

5. A black body at a temperature of 227°C radiates heat at the rate of 20 cal m^{-2s-1}. When its temperature rises to 727°C, the heat radiated will be
   (a) 40 units
   (b) 160 units
   (c) 320 units
   (d) 640 units\

Stretch Yourself

1. Define temperature using the Zeroth law of thermodynamics
2. Explain Carnot cycle. Use the indicator diagram to calculate its efficiency.
3. State characteristic of the the triple point.