Class XI: Physics
Chapter 12: Thermodynamics

Key Learning

1. The nature of heat and its relationship to mechanical work was studied by Joule.

2. Thermal equilibrium implies that systems are at the same temperature.

3. Internal energy of a system is the sum of kinetic energies and potential energies of the molecular constituents of the system. It does not include the over – all kinetic energy of the system.

4. Equilibrium states of a thermodynamics system are described by state variables. The value of a state variable depends only on the particular state, not on the path used to arrive at that state.

5. Examples of state variables are pressure (P), volume (V), temperature (T) and mass (m). Heat and work are not state variables.

6. Zeroth law of thermodynamics states that two systems in thermal equilibrium with a third system, are in thermal equilibrium with each other.

7. The first law if thermodynamics is based on the principle of conservation of energy. It states that $\Delta U = \Delta Q - P\Delta V$

8. The efficiency of a heat engine is defined as the ratio of the work done by the engine to the input heat.

$$\eta = \frac{Work\ \text{done}}{\text{Input heat}} = \frac{W}{Q_H}$$

9. If all the input heat is converted entirely into heat, the engine would have an efficiency of 1.

10. In a reversible process both the system and its environment can be returned to their initial states.

11. Spontaneous processes of nature are irreversible. The idealized reversible process is a quasi – static process with no dissipative factors such as friction viscosity, etc.

12. A quasi – static process is an infinitely slow process such that the system remains in thermal and mechanical equilibrium with the surroundings throughout. In a quasi – static process, the pressure and temperature of the environment can differ from those of the system only infinitesimally.

13. Heat engine is a device in which a system undergoes a cyclic process resulting in conversion of heat into work.

14. Carnot engine is a reversible engine operating between two temperatures T_1 (source) and T_2 (sink). The Carnot cycle consists of two isothermal processes connected by two adiabatic processes.

15. The efficiency of the Carnot engine is independent of the working substance of the engine. It only depends on the temperatures of the hot and cold reservoirs.

16. Efficiency of Carnot engine is $\eta = 1 - T_C / T_H$ = 1 – (Temperature of cold reservoir/Temperature of hot reservoir).

17. No engine can have efficiency more than that of a Carnot engine.

18. Implications of First law of thermodynamics:
    i. Heat lost by hot body = heat gained by the cold body.
    ii. Heat can flow from cooler surroundings into the hotter body like coffee to make it hotter.

19. Kelvin's Statement of second law of thermodynamics:

    No heat engine can convert heat into work with 100 % efficiency.

20. Clausius's Statement: No process is possible whose sole result is the transfer of heat from a colder to a hotter body.

21. Kelvin's Statement: No process is possible whose sole result is the complete conversion of heat into work.

22. The co-efficient of performance of a refrigerator is $\alpha = Q_C/W$.

23. A heat pump, is called so, because it pumps heat from the cold outdoors (cold reservoir) into the warm house (hot reservoir).

24. If Q > 0, heat is added to the system

    If Q < 0, heat is removed to the system

    If W > 0, Work is done by the system

    If W < 0, Work is done on the system

Top Formulae

1. Equation of isothermal changes PV = constant or $P_2 V_2 = P_1 V_1$
2. Equation of adiabatic changes

(i) $P_2V_2^{\gamma} = P_1V_1^{\gamma}$

(ii) $P_2^{1-\gamma}T_2^{\gamma} = P_1^{1-\gamma}T_1^{\gamma}$

(iii) $T_2V_2^{\gamma-1} = T_1V_1^{\gamma-1}$, where $\gamma = C_p / C_v$

3. Work done by the gas in isothermal expansion

$$W = 2.3026\ RT \log_{10} \frac{V_2}{V_1},$$

$$W = 2.3026\ RT \log_{10} \frac{P_1}{P_2}$$

4. Work done in adiabatic expansion

$$W = \frac{R}{(1-\gamma)}(T_2 - T_1)$$

5. $dQ = dU + dW$

   Here $dW = P\,(dV)$, small amount of work done

   $dQ = m\,L$, for change of state and

   $dQ = mc\,\Delta T$ for rise in temperature

   dU = change in internal energy

6. $\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$

   Where T_1 = temperature of source, T_2 = temperature of sink ; Q_1 is amount of heat absorbed/cycle from the source, Q_2 is the amount of heat rejected/cycle to the sink.

7. Useful work done/cycle $W = Q_1 - Q_2$

8. Efficiency of Carnot engine is also given by $\eta = \frac{W}{Q1} = 1 - \frac{T_2}{T_1}$

9. Coefficient of performance of a refrigerator

   $$\beta = \frac{Q_2}{W} = \frac{T_2}{T_1 - T_2}; W = Q_1 - Q_2,$$

   Where Q_2 is amount of heat drawn/cycle from the sink (at T_2) and W is Work done/cycle on the refrigerator. Q_1 is amount of heat rejected/cycle to the source (air at room temp. T_1)

10. $\beta = \frac{1-\eta}{\eta}$