Thermodynamics

Heat Engines

1. Second law of thermo dynamics

a. **Kelvin:** It is impossible to derive a continuous supply of work by cooling a body to the temperature lower than the coldest of the surroundings.

b. **Claussius**: It is impossible for a self acting machine unaided by any external agency to transfer heat from a body at a lower temperature to another at a higher temp.

c. **Planck:** It is impossible to construct a heat engine which can completely convert heat energy into mechanical energy with out rejecting heat to the surroundings.

2. Reversible process

a. A process which can be retraced back in the opposite direction in such a way that the system passes through the same state as that in the direct process and finally the system acquire the initial conditions is called a reversible process.

b. The system must always be in thermal and chemical equilibrium with the surroundings.

c. There should not be any loss of energy.

d. Ex: fusion of ice, vaporization of water, seebeck effect etc.

3. Irreversible process

a. A process which cannot be retraced back in opposite direction is called as an irreversible process.

b. The system does not pass through the same intermediate states as that in the direct process.

c. Ex: Work done against friction, joules heating effect, diffusion of gases into one another, the magnetic hysteresis.

d. All most all natural process all irreversible.

4. Free expansion

a. When a gas expands into vacuum absorbing no heat energy from the surroundings and performing no external work, then it is called free expansion (or) Joule expansion.

b. In free expansion, $\Delta Q = 0,\ \Delta W = 0$ from the first law of thermodynamics,

$\Delta Q = \Delta U + \Delta W$ OR $\Delta U = 0$

$\therefore$ U = constant and T = constant.

c. Boyle's law is applicable in free expansion.

5. Cyclic process

a. If a system undergoes a series of processes such that it finally returns to the original state, then the system is said to undergo a cyclic process.

b. The change in the internal energy is zero.

c. $(\Delta Q = \Delta U + \Delta W)_{\max} = 0 + W_{\max}$ and $\Delta Q_{net} = W_{heat}$

d. The net amount of heat energy absorbed by the ideal gas is equal to the net work done by the gas.

e. If a cyclic process is represented by a PV graph the area bounded with in the closed curve gives the net work done by the gas.

6. When the door of a refrigerator is opened, the temperature of the room increases, because the motor of the refrigerator extract the heat from the freezing chamber and releases it to outer atmosphere.

7. When a thermos flask containing coffee is vigorously shaken, its temperature increases slightly due to work done against the viscous forces of the liquid.

8. A cyclic device by which heat energy can be continuously transformed into mechanical work by repeating the same thermodynamic process a number of times is said to be a heat engine.

9. The material used in the operation of an engine is called the working substance which is different for different heat engines.

10. There are three parts in a heat engine.

a) Source (hot body) b) Working substance c) Sink (cold body)

11. Efficiency $\eta = \frac{\text{Heat converted as work}}{\text{heat drawn from the source}} = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$

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

12. Efficiency depends on the temperature of the source and sink but not on the working substance.

13. For 100% efficiency $T_1 = \infty$ (or) T_2 = 0 k. As absolute zero and infinite temperature cannot be realized in practice, the efficiency of a heat engine can not have 100%. The efficiency of a heat engine is always less than unity.

14. If T_2= 0 then Q_2 is also zero. Since T_2 = 0 is not positive Q_2 = 0 is also not possible (i.e.) it is not possible to convert whole heat energy into work without rejecting a part to the sink.

Refrigerator

a. Any device capable of transferring heat from a cold body to a relatively hotter body is called refrigerator. An ideal heat engine operating in the reverse processes is called refrigerator.

b. The working substance absorbs heat energy from the sink at lower temperature, a net amount of work is done on it by an external agent and a large amount of heat is refused to the source.

c. The working substance is called refrigerant.

d. If Q_2 is the heat energy absorbed from the sink at T_2k and Q_1 is the heat given to the source at T_1k. Then

The ratio of heat extracted from the sink and to the work required to be done on the refrigerator is called the coefficient of performance $K = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2} = \frac{1}{\left(\frac{T_1}{T_2} - 1\right)}$

e. The coefficient of performance of a refrigerator is more than 100%.