Marwari college Darbhanga

Subject---physics (Hons)

Class--- B. Sc. Part 1

Paper – 02 ; Group – A

Topic--- Thermodynamic Potentials (Thermal physics)

Lecture series -- 38

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Thermodynamic potentials

Thermodynamic potential or fundamental function is a quantity used to represent the state of a system.

We have four fundamental functions: internal energy U, enthalpy H, Helmholtz free energy F, and Gibbs free energy G. They are “potential energy” defined as capacity to do work. Starting from the first and second laws of thermodynamics, we derive expressions for the differential form of four thermodynamic potentials. They are called fundamental equations.

Enthalpy

Enthalpy is a thermodynamic property of a system. It is the sum of the internal energy added to the product of the pressure and volume of the system. It reflects the capacity to do non-mechanical work and the capacity to release heat.

Enthalpy is denoted as **H**; specific enthalpy denoted as **h**. Common units used to express enthalpy are the joule, calorie, or BTU (British Thermal Unit.) Enthalpy in a throttling process is constant.

Change in enthalpy is calculated rather than enthalpy, in part because total enthalpy of a system cannot be measured since it is impossible to know the zero point. However, it is possible to measure the difference in enthalpy between one state and another. Enthalpy change may be calculated under conditions of constant pressure.

Enthalpy Formulas

$H = E + PV$

where H is enthalpy, E is internal energy of the system, P is pressure, and V is volume

$dH = T\,dS + P\,dV$

Importance of enthalpy

- Measuring the change in enthalpy allows us to determine whether a reaction was endothermic (absorbed heat, positive change in enthalpy) or exothermic (released heat, a negative change in enthalpy.)

- It is used to calculate the heat of reaction of a chemical process.
- Change in enthalpy is used to measure heat flow in calorimetry.
- It is measured to evaluate a throttling process or Joule-Thomson expansion.
- Enthalpy is used to calculate minimum power for a compressor.
- Enthalpy change occurs during a change in the state of matter.
- There are many other applications of enthalpy in thermal engineering.

Helmholtz free energy

Helmholtz free energy in thermodynamics is a thermodynamic potential which is used to measure the work of a closed system with constant temperature and volume. It can be defined in the form of the following equation:

$$F = U - TS$$

Where,

- F is the Helmholtz free energy in Joules
- U is the internal energy of the system in Joules
- T is the absolute temperature of the surroundings in Kelvin
- S is the entropy of the system in joules per Kelvin

Formula development for laws of thermodynamics:

Formula development for laws of thermodynamics:

$dU = \delta Q + \delta W$. which is from first law of thermodynamics for closed system

$dU = TdS - pdV$ ($\delta Q = TdS$ and $\delta W = pdV$)

$dU = d(TS) - SdT - pdV$. (product rule i.e.; d(TS) = TdS + SdT)

$d(U - TS) = -SdT - pdV$

$dF = -SdT - PdV$ (from $F = U - TS$)

Application of Helmholtz free energy

In equation of state:

Pure fluids with high accuracy (like industrial refrigerants) are represented using Helmholtz function as a sum of ideal gas and residual terms.

In auto-encoder:

Auto-encoder is an artificial neural network which is used to encode efficient data. Here Helmholtz energy is used to find the sum of code cost and reconstructed code.

Helmholtz Function

Helmholtz function is a thermodynamic function which is defined as the decrease in the function and is equal to the maximum amount of work which is available during reversible isothermal process.