

2.1: The First Law

The first law of thermodynamics is the conservation of energy, including the equivalence of work and energy, and about assigning an internal energy to the system.

First Law of Thermodynamics

When an amount of heat dQ is supplied to the system and an amount of work dW is done by the system, changes are produced in the thermodynamic coordinates of the system such that

$$dU = dQ - dW \quad (2.1.1)$$

where U is a function of the thermodynamic coordinates of the system. (In other words, dU is an exact differential.)

If the system is in adiabatic isolation, $dQ = 0$ and $dU = -dW$. Since dU is an exact differential, this means that

$$W_{adiab} = U_{initial} - U_{final} \quad (2.1.2)$$

Thus the adiabatic work done by the system is independent of the process involved and depends only on the initial and final states of the system. It is the recognition of this fact through careful experiments (by Joule) which led to the first law.

The quantity U is called the **internal energy** of the system. For a gas, where the work done is given by Equation 2.1.2, we may write the first law as

$$dU = dQ - p dV \quad (2.1.3)$$

If we put $dQ = 0$, we get a relation between p and V which is valid for adiabatic processes. The curve connecting p and V so obtained is called an adiabatic. Starting with different initial states, we can get a family of adiabatics. In general, when we have more thermodynamic coordinates, adiabatics can be similarly defined, but are higher dimensional surfaces.

Specific Heats

When heat is supplied to a body, the temperature increases. The amount of heat dQ needed to raise the temperature by dT is called the specific heat. This depends on the process, on what parameters are kept constant during the supply of heat. Two useful specific heats for a gas are defined for constant volume and constant pressure. If heat is supplied keeping the volume constant, then the internal energy will increase. From the first law, we find, since $dV = 0$,

$$dU = dQ = C_v dT \quad (2.1.4)$$

Thus the specific heat C_v may be defined as the rate of increase of internal energy with respect to temperature. For supply of heat at constant pressure, we have

$$\begin{aligned} d(U + pV) &= dQ + Vdp \\ &= dQ \\ &\equiv C_p dT \end{aligned}$$

Thus the specific heat at constant pressure may be taken as the rate at which the quantity $U + pV$ increases with temperature. The latter quantity is called the enthalpy.

In general, the two specific heats are functions of temperature. The specific heat at constant volume, C_v , can be calculated using statistical mechanics or it can be measured in experiments. C_p can then be evaluated using the equation of state for the material. The ratio $\frac{C_p}{C_v}$ is often denoted by γ .

This page titled 2.1: The First Law is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by V. Parameswaran Nair via source content that was edited to the style and standards of the LibreTexts platform.