1 Macroscopic Parameters and their measurement

1.1 Work & internal energy

From the first law of thermodynamics we always talk about

$$Q = \Delta \bar{E} + W$$

Given a system, work is *easy* measure i.e. we integrate

$$W = -\int p \mathrm{d}V$$

Measure of internal energy

- Thermal isolation case: $Q = 0$

$$\Delta \bar{E} = \bar{E}_b - \bar{E}_b = -W_{ab} = \int_a^b đW$$

e.g. a thermally isolated piston goes from state a to b.

1.2 Heat

The heat absorbed by a system going from macrostate a to b is simply

$$Q_{ab} = (\bar{E}_b - \bar{E}_a) + W_{ab}$$

Example A superconducting circuit A is connected to the circuit B with a resistor.
Adding 20 µW of heat to the system: we actuallly are doing work on a resistor.

Method of Mixers (Comparison Method)

Bring system A into contact with system B that has a known relation between its internal energy and some parameters (T).

$$Q_A = \Delta \bar{E}_B = -Q_B$$

e.g. system A is submerged in water B and we can measure the change in internal energy of water quite easily.

1.3 Entropy

We define entropy S

$$dS = \frac{đQ}{T}$$

and **Absolute entropy** from the 3rd law

$$T \to 0, \quad S \to S_0$$

Example: Tin
Two structures of a solid:

1. White tin—a metal $\to$ stable > 298 K
2. Grey tin—semiconductor $\to$ stable < 298 K

Thus it requires some amount of heat Q to transform from grey to white tin.

- Case 1: a mole of white tin from $T = 0 \to T_0$ with specific heat $C^{(w)}(T)$

$$S^{(w)}(T_0) = S^{(w)}(T = 0) + \int_0^{T_0} \frac{C^{(w)}(T)}{T} \mathrm{d}T$$

- Case 2: Grey tin from 0 K $\to T_0$ and then it transforms to white tin quasi-statically. It absorbs heat Q and the entropy change is

$$S^{(w)}(T_0) = S^{(g)}(T = 0) + \int_0^{T_0} \frac{C^{(g)}(T)}{T} dT + \frac{Q}{T_0}$$

  where

$$S^{(g)}(T = 0) = S^{(w)}(T = 0) = S_0$$

Figure 1.1: Mole of Tin (DALL-E 3)