THERMODYNAMICS

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Every balanced state of a thermodynamic system is completely explained by certain values of big variables we call state variables. For instance, if you have a gas, the state it's in is fully defined by its pressure, volume, temperature, and how much stuff is there (and what it's made of if it's a mix of gases).

But not every thermodynamic system is in balance all the time. For example, if you let gas expand into a vacuum without any restrictions, it's not in balance. While it's quickly expanding, its pressure might not be the same all over the place. Similarly, if you have a mix of gases that's exploding because of a chemical reaction (like a mix of gasoline vapor and air ignited by a spark), it's not in balance either. In this case, the temperature and pressure aren't even. But over time, the gas will even out, and its temperature and pressure will become the same, making it in balance with everything around it.

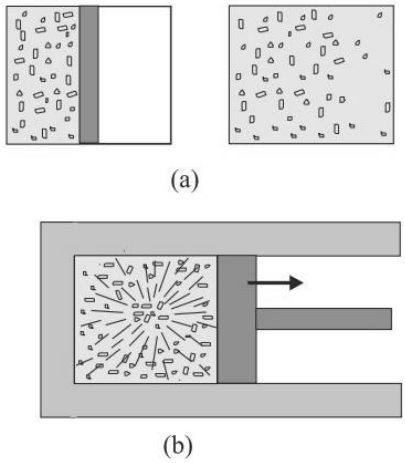

Fig. (a) The partition in the box is taken away, and the gas freely expands.
(b) When gases explode in a chemical reaction, they are not in balance,
and we can't describe those using state variables.

In simple terms, state variables describe balanced states of systems. These variables are connected, and we call this connection the "equation of state." For instance, in the case of an ideal gas, we use the ideal gas relation as the equation of state.

$$P\,V = \mu\,R\,T$$

If we have a set amount of gas (let's call it μ), we only need two independent variables to describe it, like P (pressure) and V (volume), or T (temperature) and V. When you graph pressure against volume at a constant temperature, it's called an "isotherm." Real gases might have more complex equations to describe their behavior.

Thermodynamic state variables come in two types: extensive and intensive. Extensive ones show how big the system is, like its size or total mass. Intensive variables, such as pressure and temperature, don't depend on size.

To figure out if a variable is extensive or intensive, think of a system in balance and split it into two equal parts. The variables that stay the same in each part are intensive, and the ones that get cut in half are extensive.

For example, internal energy U, volume V, and total mass M are extensive. Pressure P, temperature T, and density ρ are intensive. When you're using thermodynamic equations, it's a good idea to make sure you're using the right type of variable. For instance, in the equation

$$\Delta Q = \Delta U + P\,\Delta V,$$

The stuff on both sides is extensive because the product of an intensive variable (P) and an extensive quantity (ΔV) is extensive.