

2.2: Phases and Physical States of Matter

A **phase** is a region of the system in which each intensive property (such as temperature and pressure) has at each instant either the same value throughout (a *uniform* or *homogeneous* phase), or else a value that varies continuously from one point to another. Whenever this e-book mentions a phase, it is a *uniform* phase unless otherwise stated. Two different phases meet at an **interface surface**, where intensive properties have a discontinuity or change over a small distance.

Some intensive properties (e.g., refractive index and polarizability) can have directional characteristics. A uniform phase may be either *isotropic*, exhibiting the same values of these properties in all directions, or *anisotropic*, as in the case of some solids and liquid crystals. A vacuum is a uniform phase of zero density.

Suppose we have to deal with a *nonuniform* region in which intensive properties vary continuously in space along one or more directions—for example, a tall column of gas in a gravitational field whose density decreases with increasing altitude. There are two ways we may treat such a nonuniform, continuous region: either as a single nonuniform phase, or else as an infinite number of uniform phases, each of infinitesimal size in one or more dimensions.

2.2.1 Physical states of matter

We are used to labeling phases by physical state, or state of aggregation. It is common to say that a phase is a *solid* if it is relatively rigid, a *liquid* if it is easily deformed and relatively incompressible, and a *gas* if it is easily deformed and easily compressed. Since these descriptions of responses to external forces differ only in degree, they are inadequate to classify intermediate cases.

The way in which Z varies with p at different temperatures is shown for the case of carbon dioxide in Fig. 2.3(a).

A temperature at which the initial slope is zero is called the **Boyle temperature**, which for CO_2 is 710 K. Both B and B_p must be zero at the Boyle temperature. At lower temperatures B and B_p are negative, and at higher temperatures they are positive—see Fig. 2.3(b). This kind of temperature dependence is typical for other gases. Experimentally, and also according to statistical mechanical theory, B and B_p for a gas can be zero only at a single Boyle temperature.

The fact that at any temperature other than the Boyle temperature B is nonzero is significant since it means that in the limit as p approaches zero at constant T and the gas approaches ideal-gas behavior, the *difference* between the actual molar volume V_m and the ideal-gas molar volume RT/p does not approach zero. Instead, $V_m - RT/p$ approaches the nonzero value B (see Eq. 2.2.8). However, the *ratio* of the actual and ideal molar volumes, $V_m/(RT/p)$, approaches unity in this limit.

Virial equations of gas *mixtures* will be discussed in Sec. 9.3.4.

2.2.6 Solids

A solid phase responds to a small applied stress by undergoing a small *elastic deformation*. When the stress is removed, the solid returns to its initial shape and the properties return to those of the unstressed solid. Under these conditions of small stress, the solid has an equation of state just as a fluid does, in which p is the pressure of a fluid surrounding the solid (the hydrostatic pressure) as explained in Sec. 2.3.4. The stress is an additional independent variable. For example, the length of a metal spring that is elastically deformed is a unique function of the temperature, the pressure of the surrounding air, and the stretching force.

If, however, the stress applied to the solid exceeds its elastic limit, the response is *plastic deformation*. This deformation persists when the stress is removed, and the unstressed solid no longer has its original properties. Plastic deformation is a kind of hysteresis, and is caused by such microscopic behavior as the slipping of crystal planes past one another in a crystal subjected to shear stress, and conformational rearrangements about single bonds in a stretched macromolecular fiber. Properties of a solid under plastic deformation depend on its past history and are not unique functions of a set of independent variables; an equation of state does not exist.

This page titled [2.2: Phases and Physical States of Matter](#) is shared under a [CC BY 4.0](#) license and was authored, remixed, and/or curated by [Howard DeVoe](#) via [source content](#) that was edited to the style and standards of the LibreTexts platform.