CHAPTER TWO

Properties of pure substance

Objectives

- ✓ Introduce the concept of a pure substance.
- ✓ Discuss the physics of phase-change processes.
- ✓ Illustrate the *P-v, T-v, and P-T property diagrams and P-v-T* surfaces of pure substances.
- ✓ Demonstrate the procedures for determining thermodynamic properties of pure substances from tables of property data.
- ✓ Describe the hypothetical substance "ideal gas" and the ideal-gas equation of state.
- ✓ Apply the ideal-gas equation of state in the solution of typical problems.
- ✓ Introduce the compressibility factor, which accounts for the deviation of real gases from ideal-gas behavior.
- ✓ Present some of the best-known equations of state.

Pure substance

In Chemistry you defined a pure substance as an element or a compound.

Something that can not be separated.

In Thermodynamics we'll define it as something that has a fixed chemical composition throughout.

Example

Water ,nitrogen , helium and carbon dioxide

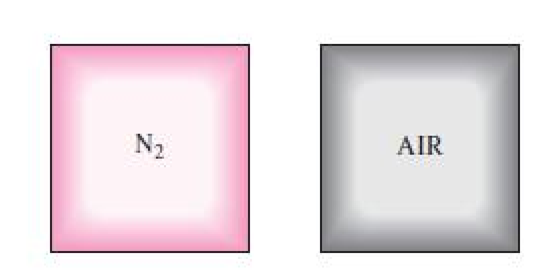

Fig. Nitrogen and gaseous air are pure substances.

A pure substance does not have to be of a single chemical element or compound, however. A mixture of various chemical elements or compounds also qualifies as a pure substance as long as the mixture is homogeneous.

Conti.

Example

Air is a mixture of several gases, but it is often considered to be a pure substance because it has a uniform chemical composition as shown in fig. above.

A mixture of oil and water is not a pure substance. Since oil is not soluble in water, it will collect on top of the water, forming two chemically dissimilar regions.

A mixture of two or more phases of a pure substance is still a pure substance as long as the chemical composition of all phases is the same.

Example

A mixture of ice and liquid water is a pure substance because both phases have the same chemical composition.
A mixture of liquid air and gaseous air, however, is not a pure substance since the composition of liquid air is different from the composition of gaseous air, and thus the mixture is no longer chemically homogeneous. This is due to different components in air condensing at different temperatures at a specified pressure.

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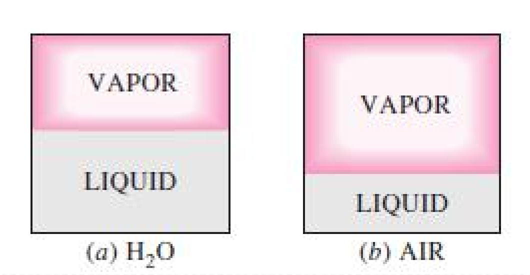

Fig. A mixture of liquid and gaseous water is a pure substance, but a mixture of liquid and gaseous air is not.

Phases of a pure substance

A phase is identified as having a distinct molecular arrangement that is homogeneous throughout and separated from the others by easily identifiable boundary surfaces.

We all know from experience that substances exist in different phases. At room temperature and pressure, copper is a solid, mercury is a liquid, and nitrogen is a gas.
Under different conditions, each may appear in a different phase. Even though there are three principal phases—solid, liquid, and gas—a substance may have several phases within a principal phase, each with a different molecular structure. Carbon, for example, may exist as graphite or diamond in the solid phase.
Helium has two liquid phases; iron has three solid phases. Ice may exist at seven different phases at high pressures.

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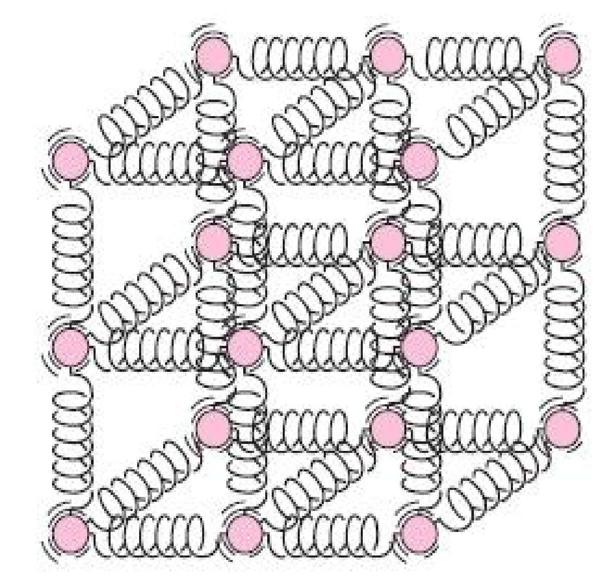

Fig. The molecules in a solid are kept at their positions by the large spring like intermolecular forces.

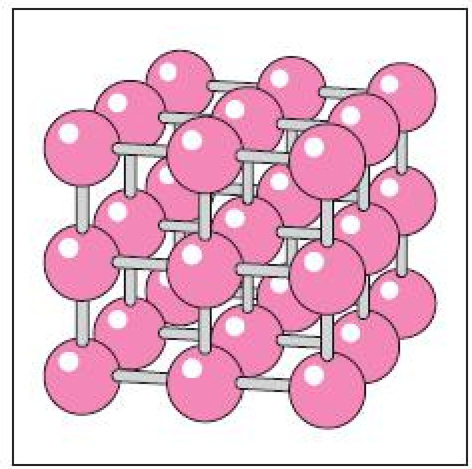

Fig. Molecules are at relatively fixed positions in a solid

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The molecular spacing in the **liquid phase is not much different from that** of the solid phase, except the molecules are no longer at fixed positions relative to each other and they can rotate and translate freely.

In a liquid, the intermolecular forces are weaker relative to solids, but still relatively strong compared with gases. The distances between molecules generally experience a slight increase as a solid turns liquid, with water being a notable exception.

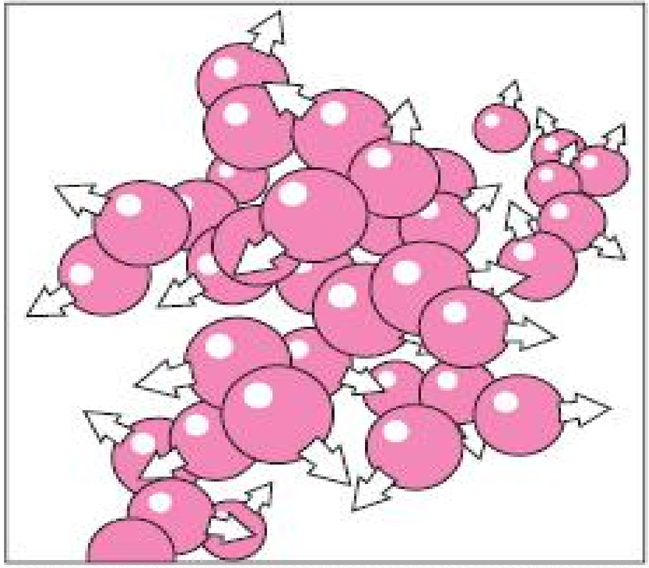

Fig. Groups of molecules move about each other in the liquid phase

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In the gas phase, the molecules are far apart from each other, and a molecular order is nonexistent. Gas molecules move about at random, continually colliding with each other and the walls of the container they are in. Particularly at low densities, the intermolecular forces are very small, and collisions are the only mode of interaction between the molecules. Molecules in the gas phase are at a considerably higher energy level than they are in the liquid or solid phases. Therefore, the gas must release a large amount of its energy before it can condense or freeze.

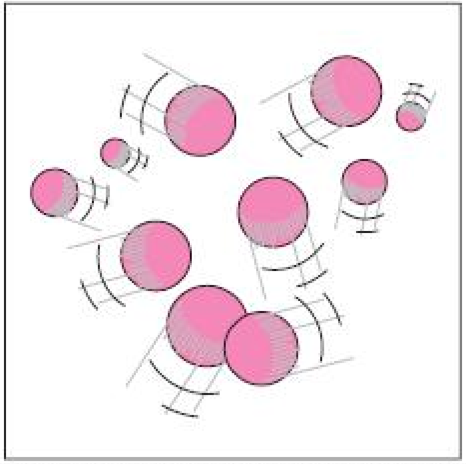

Fig. Molecules move about at random in the gas phase.

PHASE-CHANGE PROCESSES OF PURE SUBSTANCES

Let's study the phase change processes takes place by taking water as example at constant pressure.(all pure substance exhibit the same general behavior)

Consider a piston–cylinder device containing liquid water at 20°C and 1 atm pressure (state 1, Fig. below). Under these conditions, water exists in the liquid phase, and it is called a **compressed liquid, or a subcooled liquid, meaning** that it is not about to vaporize.

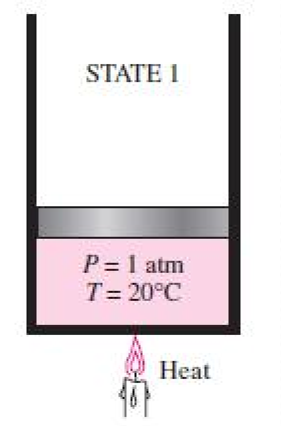

Fig. At 1 atm and 20°C, water exists in the liquid phase (*compressed liquid*).