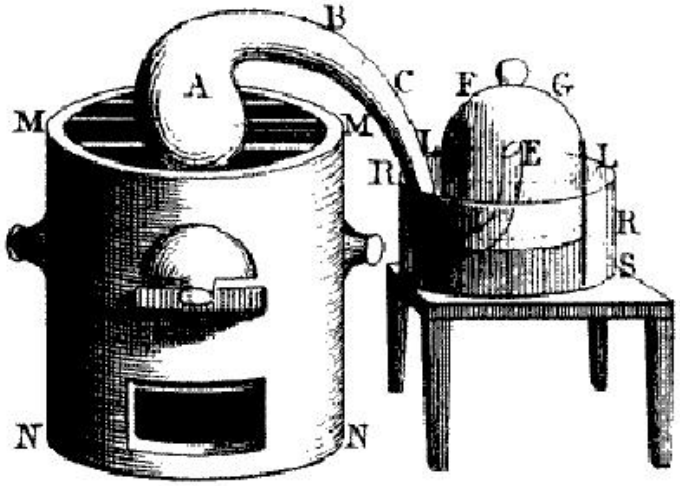
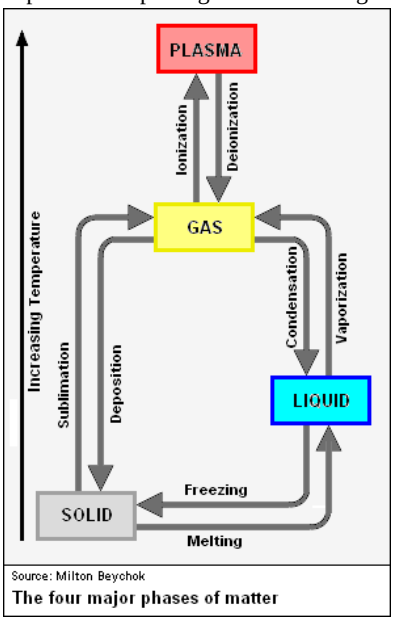
Gas



Engraving of famed Lavoisier experiment exploring the essence of gases. Source: Madame Lavoisier



A **gas**, often also referred to as a **vapor**, is one of the four major states of matter (after solid and liquid, and followed by plasma) that subsequently appear when a solid material is subjected to increasingly higher temperatures.[1]

At temperatures near absolute zero (−273.15 °C or −459.67 °F), substances exist as solids. As energy in the form of heat is added, the temperature of a solid (e.g., ice) increases and it will first melt to become a liquid (e.g., water), which will then boil or evaporate to become a gas (e.g., water vapor).

In some circumstances, a solid (e.g., dry ice)[2] when heated can directly turn into a gas: this is called sublimation.

As shown in the adjacent diagram, if the gas is further heated, its atoms or molecules can become (wholly or partially) ionized, turning the gas into a plasma which provides the upper temperature boundary for gases.

Etymology

The word *gas* was apparently proposed by the 17th century Flemish chemist Jan Baptist Van Helmont,[3]as a phonetic spelling of his Dutch pronunciation of the Greek word *chaos* (the *g* in Dutch being pronounced like the English *ch*). Thus, Van Helmont was simply following the established usage by alchemists for the mythological "air" element,[4] first appearing during the 1530s in the works of Paracelsus.[5]

Physics

In a gas phase, the atoms or molecules constituting a substance basically move independently, with noforces keeping them together or pushing them apart. Their only interactions are rare and random collisions. The particles move in random directions, at high speed. Therefore, the gas phase is a completely disordered state. Following the second law of thermodynamics, gas particles will immediately diffuse to homogeneously fill any shape or volume of space that is made available to them.

The thermodynamic state of a gas is characterized by its volume, its temperature which is determined by the average velocity or kinetic energy of the molecules, and its pressure which measures the average force exerted by the molecules colliding against a surface. These variables are related by the fundamental gas laws, which state that the pressure in an ideal gas is proportional to its temperature and number of molecules, but inversely proportional to its volume.

Like liquids and plasmas, gases are fluids: they have the ability to flow and do not tend to return to their former configuration after deformation, although they do have viscosity. Unlike liquids, however, unconstrained gases do not occupy a fixed volume, but expand to fill whatever space they can occupy. The kinetic energy per molecule in a gas is the second greatest of the states of matter (after plasma). Because of this high kinetic energy, gas atoms and molecules tend to bounce off of any containing surface and off one another, the more powerfully as the kinetic energy is increased.

The words *"gas"* and *"vapor"*

There is no significant physical or chemical difference between a gas and a vapor. However, the words have slightly different connotations and there is often considerable overlap between the connotations, so precise distinctions are not necessary and probably not even possible.[6][7][8]

Almost all physics, chemistry and engineering textbooks refer to the states of matter as solid, liquid, gas and plasma. Rarely, if ever, do the states of matter include *vapor* rather than *gas*. The term *vapor* was used in ancient and medieval times, prior to more widespread use of the term *gas*.

One way in which the word *vapor* sometimes replaces the word *gas* is when the gaseous phase is in equilibrium with the corresponding liquid or solid. We call the pressure of the gas phase in equilibrium with the corresponding liquid phase *vapor pressure*. We connote the equilibrium of the gas and liquid phases of a substance as *vapor-liquid equilibrium*. But note that all of the connotations are defined as the equilibrium between a gas phase and a liquid phase.

The boiling point of a liquid may be defined as the temperature at which it changes its state of matter from a liquid to a gas, but we connote that phase change as *vaporization*. We also connote the heat required to change a liquid into a gas as the *heat of vaporization*.

Then there are definitions like: *a vapor is the gaseous form of a liquid, the word vapor describes the gaseous state of a substance* and *water vapor is the most important greenhouse gas.*

Despite these common connotations of the word *vapor*; there is no physical or chemical difference between a gas and a vapor and the words are often used interchangeably.

Elemental gases

Elemental gases many be monatomic, diatomic, or triatomic. For example:

- Monatomic elemental gases: Helium (He), neon (Ne), argon (Ar), krypton (Kr) and xenon (Xe)
- Diatomic elemental gases: hydrogen (H_2), oxygen (O_2), nitrogen (N_2), fluorine (F_2), chlorine (Cl_2),bromine (Br), and iodine (I_2)
- Triatomic elemental gas: ozone (O_3)

Some special usages of the word *"gases"*

- Ideal gases, in chemistry and physics.
- Various hydrocarbon gases used for heating, lighting, and energy transmission:
- Natural gas, consisting of 80% or more methane.
- Liquefied petroleum gas (LPG), including propane, butane and mixtures of propane and butane.
- Syngas: various synthetic fuel gases with names such as coal gas, water gas, illuminating gas, wood gas, producer gas, manufactured gas, town gas, and SNG (synthetic natural gas).

- Noble gases, all of which have extremely low reactivity. The six naturally occurring noble gases are helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe), and radon (Rn).
- Chemical warfare gases: various poison gases used in warfare.

References

1. A lecture by Professor Michael Mombourquette, Queen's University, Canada.
2. **Note:** Dry ice is solid carbon dioxide (CO_2).
3. Brief biography of Johannes Baptista Van Helmont.
4. Michael A. Seeds and Dana E. Backman (2011), *The Solar System*, 7th Edition, Brooks/Cole, page 77, ISBN 1-4390-5036-6. A discussion of the four classical elements (Earth, Water, Air, Fire) of the ancient alchemists.
5. A biography of Paracelsus, byname of Philippus Aureolus Theophrastus Bombastus Von Hohenheim (1493 - 1541).
6. Robert G. Mortimer (2008), *Physical Chemistry*, 3rd Edition, Academic Press, pp. 27-29, 0-12-370617-3.
7. Phase diagrams of pure substances, Jim Clark, Chemguide website.
8. Heinz P. Bloch (2006), *A Practical Guide to Compressor Technology*, 2nd Edition, page 11, ISBN 0-471-72793-8.

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