

# Gaseous oxygen

Oxygen is the second largest component of the atmosphere, comprising 20.8% by volume. Gaseous oxygen is colorless, odorless, tasteless, and nonflammable. Oxygen is necessary to support life. It is a strong oxidizer that combines readily with many elements to form an oxide and is necessary to support combustion.

Oxygen will react with nearly all organic materials and metals. Materials that burn easily in air will burn more vigorously in oxygen. Equipment used in oxygen service must meet stringent cleaning requirements; any system must be constructed of materials that have high ignition temperatures and which are nonreactive with oxygen under the service conditions. Vessels must be designed to withstand the pressure and temperatures involved and comply with applicable codes and regulations.

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## Uses

Oxygen is generally liquefied so it can be more effectively transported and stored in large volumes. However, most applications use oxygen in the gaseous form. The primary uses of oxygen relate to its strong oxidizing and life-sustaining properties. Oxygen is commonly relied upon in health and medical applications. Liquid oxygen is used as an oxidant for liquid fuels in the propellant systems of missiles and rockets.

Oxygen is widely utilized in the metal industries in conjunction with acetylene and other fuel gases for metal cutting, welding, scarfing, hardening, cleaning, and melting. Steel and iron manufacturers also extensively use oxygen or oxygen-enriched air to affect chemical refining and heating associated with carbon removal and other oxidation reactions. Benefits such as fuel and energy savings plus lower total emission volumes are realized when air is enriched or replaced with higher-purity oxygen.

In the chemical and petroleum industries, oxygen is used as a feed component to react with hydrocarbon building blocks to produce chemicals such as alcohols and aldehydes that contain oxygen in their structure. In many processes, the oxygen for reaction can be obtained from the use of air. However, direct use of oxygen, or enrichment of the air with oxygen, is necessary for some processes. There are several major petrochemical intermediates that are presently manufactured with high-purity oxygen including ethylene and propylene oxide (antifreeze), vinyl chloride (for PVC), and caprolactam (for nylon).

The pulp and paper industry uses oxygen as a bleaching and oxidizing agent. A variety of process (liquor) streams show enhanced physical properties after treatment with oxygen; plant operating costs also improve.

Similarly, oxygen enhances the combustion process in industries that manufacture glass, aluminum, copper, gold, lead, and cement or that are involved in waste incineration or remediation.

Wastewater treatment plants successfully employ oxygen to enhance their chemical process efficiency. Aquaculturists such as fish-farmers also see benefits in the health or size of their livestock when the host environment is oxygenated.

## Health effects

Normally air contains 21% oxygen, and oxygen is essentially nontoxic. No health effects have been observed in people exposed to concentrations up to 50% at 1 atmosphere for 24 hours or longer.

The inhalation at 1 atmosphere of 80% oxygen for more than 12 hours can cause irritation of the respiratory tract, progressive decrease in vital capacity, coughing, nasal stuffiness, sore throat, and chest pain, followed by tracheobronchitis and later by pulmonary congestion/edema.

Inhalation of pure oxygen at atmospheric pressure or less can cause pulmonary irritation and edema after 24 hours.

Respiratory symptoms can occur in two to six hours at pressures above 1 atmosphere. One of the earliest responses of the lung is accumulation of water in the interstitial spaces and within the pulmonary cells. This can cause reduced lung function, which is the earliest measurable sign of toxicity. Other symptoms include fever and sinus and eye irritation.

**Table 1: Gaseous Oxygen Physical and Chemical Properties**

Chemical Formula	O <sub>2</sub>
Molecular Weight	31.999
Boiling Point @ 1 atm	-297.4°F (-183.0°C)
Freezing Point @ 1 atm	-361.9°F (-218.8°C)
Critical Temperature	-181.8°F (-118.4°C)
Critical Pressure	729.1 psia (49.6 atm)
Density, Liquid, @ BP, 1 atm	71.23 lb/ft <sup>3</sup> (1141 kg/m <sup>3</sup> )
Density, Gas @ 68°F (20°C), 1 atm	0.0831 lb/ft <sup>3</sup> (1.33 kg/m <sup>3</sup> )
Specific Gravity, Gas (air=1) @ 68°F (20°C), 1 atm	1.11
Specific Volume @ 68°F (20°C), 1 atm	12.08 ft <sup>3</sup> /lb (0.754 m <sup>3</sup> /kg)
Latent Heat of Vaporization	91.7 Btu/lb (213 kJ/kg)
Expansion Ratio, Liquid to Gas, BP to 68°F (20°C)	1 to 860
Solubility in Water @ 77°F (25°C), 1 atm	3.16% by volume

When pure oxygen is inhaled at pressures greater than 2 or 3 atmospheres, a characteristic neurological syndrome can be observed. Signs and symptoms include nausea, dizziness, vomiting, tiredness, light-headedness, mood changes, euphoria, confusion, incoordination, muscular twitching, burning/tingling sensations (particularly of the fingers and toes), and loss of consciousness. Characteristic epileptic-like convulsions, which may be preceded by visual disturbances, such as loss of peripheral vision, also occur. Continued exposure can cause severe convulsions that can lead to death. The effects are reversible after reduction of oxygen pressure.

Premature infants placed in incubators to breathe oxygen in concentrations greater than in air can develop irreversible eye damage. Within six hours after an infant is placed in a high-oxygen atmosphere, vasoconstriction of the immature vessels of the retina occurs, which is reversible if the child is immediately returned to air but irreversible if oxygen-rich therapy is continued. Fully developed blood vessels are not sensitive to oxygen toxicity.

## Containers

Gaseous oxygen is shipped and stored in high-pressure cylinders, tubes, or tube trailers, depending on the quantity required by the user. Cylinders are designed and manufactured according to applicable codes and specifications for the pressures and temperatures involved. Cylinders are manufactured according to Transportation regulations, which specify the material of construction, method of manufacture, testing, and with what products they are permitted to be filled, as well as other details. The quantity of product a container can hold is determined by its pressure rating and internal volume.

## Cylinders

A cylinder is a hollow tube with a closed concave base that permits it to stand upright. The opposite end is tapered to a small opening that is threaded to accommodate the installation of a valve. A threaded neck ring is attached to the tapered end so that a protective cylinder cap can be installed.

Cylinders may be used individually or in groups. When used in groups, the cylinders should be piped together for either stationary storage or to form portable banks.

## Tubes

A tube is a pipe tapered at both ends. Each end is threaded to allow the installation of valves, connections, or relief devices.

Tubes are manufactured according to varying regional standards and regulations, depending on whether they are used for transportation or mounted permanently at a site. Tubes are generally mounted on a truck-trailer chassis or railcar bed, or placed at stationary locations when large amounts of oxygen are needed.

## Valve connections

Different valve outlet connections are used based on national or regional standards. In North America, the Compressed Gas Association (CGA) recommends three different connections for oxygen depending on the pressure rating of the container.

In addition, a high-integrity connection also known as a Diameter Index Safety System (DISS) connection has been assigned to oxygen service; medical post-type valves are assigned a yoke connection. See Table 2 for details. For detailed drawings of these connections, consult CGA Pamphlet V-1.

**WARNING: NEVER use adapters to make cylinder connections!**

## Pressure-relief devices

In North America and Asia, oxygen containers are equipped with pressure-relief devices to protect from overpressurization and possible rupture. Cylinders less than 65" long use a rupture disk device. Cylinders over 65" use a combination device consisting of a rupture disk backed by a fusible alloy. Combination devices require that both the temperature and pressure requirements be reached before the device will relieve. For more information on pressure-relief devices, consult Air Products' Safetygram #15, "Cylinder Pressure-Relief Devices." In Europe, pressure relief devices are not commonly used on cylinders.

**Table 2: Oxygen Service Connections**

Cylinder Service	CGA Connection
Oxygen < 3,000 psig	540
Oxygen at 3,001 to 4,000 psig	577
Oxygen at 4,001 to 5,500 psig	701
Medical oxygen with post valve	870
Semiconductor	714

## Shipment of gaseous oxygen

Compliance with applicable Dangerous Goods regulations is required for all shipments by motor freight, rail, air and water. These regulations describe the marking, labeling, placarding, and shipping papers required. International shipments by air must comply with International Air Transport Association/International Civil Air Organization (IATA/CAO) Dangerous Goods regulations. Final acceptance for air transport is at the discretion of the airline. International shipments by water must comply with International Maritime Organization (IMO) regulations.

## Safety considerations

Fire is the primary hazard associated with gaseous oxygen. Although non-flammable, oxygen readily supports combustion. Explosions may occur in locations where a mixture of fuel gas and oxygen can accumulate.

It is important to note that fire chemistry starts to change in oxygen-enriched environments. The International Organization for Standardization (ISO) has established the definition of an oxygen enriched atmosphere as being any atmosphere containing more than 23.5% oxygen.. Materials easily ignited in air not only become more susceptible to ignition but also burn with added violence. These materials include clothing and hair, which have air spaces that readily trap oxygen. Elevated oxygen levels can be reached very quickly, and all personnel must be aware of the hazard.

Systems used in oxygen service must meet stringent cleaning requirements to eliminate any incompatible contaminants. CGA Pamphlet G-4.1, "Cleaning Equipment for Oxygen Service," describes cleaning methods for equipment used in oxygen service and CGA Pamphlet O2-DIR, "Directory of Cleaning Agents for Oxygen Service," provides comparative information on cleaning agents used to clean oxygen equipment. Also, review the appropriate Safety Data Sheet (SDS).

## Buildings

Adequate ventilation must be provided in areas where oxygen is in use. Keep them clear of combustible materials and post signs indicating the hazard. Also post "No Smoking" signs. Test the atmospheres in confined work areas for oxygen content. Oxygen-enriched atmospheres can cause materials that burn in air to burn more violently or even explosively, and the potential hazard exposure to personnel and material is increased.

**Remember, oxygen has no warning properties!**

## Storage

- Cylinders should be stored upright in a well ventilated, dry, cool, secure area that is protected from the weather and preferable fire-resistant.
- No part of a cylinder should ever be allowed to exceed 125° F (52° C), and areas should be free of combustible materials. Never deliberately overheat a cylinder to increase the pressure or discharge rate.
- Cylinders should be stored away from heavily traveled areas and emergency exits.
- Avoid areas where salt and other corrosive materials are present.
- The valve outlet seal and valve protective cap should be left in place until the cylinder has been secured against a wall or bench, or placed in a cylinder stand, and is ready for use.
- When returning empty cylinders, ensure the valve is closed and that some positive pressure remains in the cylinder. Replace any valve outlet and protective caps originally shipped with the container and label the cylinder as “Empty.” Do not store full and empty containers together.
- Post “No Smoking” and “No Open Flames” signs in storage and use areas.
- Oxygen must be separated from flammables and combustibles by distances stipulated by regional standards and regulations.

## Handling

- Never drop, drag, roll or slide cylinders. Use a specifically designed hand-truck for cylinder movement.
- Never attempt to lift a cylinder by its cap.
- Wrenches should never be used to open or close a valve equipped with a handwheel. If the valve is faulty, contact the gas supplier.
- If difficulty is experienced operating the container valve or using the container connections, discontinue use and contact the gas supplier. Use only the proper connections on the container.
- **DO NOT USE ADAPTERS!**
- Never permit oil, grease or readily combustible substances to come in contact with cylinders or valves.
- Use only oxygen-compatible lubricants.
- Always open a compressed gas cylinder valve slowly to avoid rapid system pressurization.

- **NEVER** insert an object (e.g., wrench, screwdriver, pry bar, etc.) into the opening of the cylinder cap. Doing so may damage or inadvertently open the valve. Use only a specially designed strap-wrench to remove over-tightened or rusted caps.
- Never tamper with the safety devices on valves or cylinders.
- Use piping and equipment designed to withstand the maximum pressures encountered.
- Use a pressure reducing regulator or separate control valve along with properly designed pressure relief devices to safely discharge gas to working systems.
- Use a check valve to prevent reverse gas flow into the containers.
- It is recommended that all vents be piped to the exterior of the building and are in accordance with local regulations.
- Refilling or shipping a compressed gas cylinder without the consent of the owner is forbidden.

## Personal protective equipment (PPE)

Personnel must be thoroughly familiar with properties and safety considerations before being allowed to handle oxygen and its associated equipment. Safety glasses, safety shoes, and leather work gloves are recommended when handling cylinders.

Only trained and certified emergency responders should respond to emergency situations. In emergency situations, self-contained breathing apparatus (SCBA) must be used. Clothing that is fire-resistant in air may be readily ignitable in oxygen-enriched atmospheres.

## First aid

When breathing oxygen mixtures are used at pressures above 1 atmosphere, seek medical advice for proper health instructions.

## Fighting fires

Since oxygen is nonflammable but supports combustion, fire-fighting actions require shutting off the source of oxygen, if possible, then fighting the fire according to the material involved. Most cylinders are designed to vent contents when exposed to elevated temperatures. However, upon exposure to intense heat or flame, a cylinder may vent rapidly and/or rupture violently.



### Emergency Response System

T 800-523-9374 (Continental U.S. and Puerto Rico)

T +1-610-481-7711 (other locations)

For regional ER telephone numbers, please refer to the local SDS 24 hours a day, 7 days a week for assistance involving Air Products and Chemicals, Inc. products

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### Technical Information Center

T 800-752-1597 (U.S.)

T +1-610-481-8565 (other locations)

Monday–Friday, 8:00 a.m.–5:00 p.m. EST

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