THE LINDE GROUP

Safety advice.

Ozone.

Properties

Ozone is an unstable triatomic molecule and an allotropic form of oxygen. It is formed in the atmosphere by short-wave ultraviolet radiation, which reacts with diatomic oxygen molecules (O_2) to form ozone (O_3). Ozone absorbs radiation in the ultraviolet and infrared wavelength. The ultraviolet absorption is vital for the maintenance of life on Earth preventing decomposition of organic molecules in living organisms.

Physical properties

At ambient temperatures, concentrated ozone is a blue gas heavier than air (relative density 1.66). At the concentrations and temperatures prevailing in the manufacturing process, the gas is nearly colourless. Ozone in higher concentrations has a disagreeable pungent odour, like chlorine. The recognised odour detection threshold is 0.01 ppm to 0.04 ppm; however the nose rapidly loses its ability to detect ozone. Do not rely on odour as a warning of high ozone concentrations.

Physical properties

Symbol	O_3
Molecular weight at 0 °C and atmospheric pressure	48
Density of gas (0 °C, 101.3 kPa)	2.146 kg/m^3
Specific gravity of the gas (0 °C, 101.3 kPa)	1.66
Boiling point at atmospheric pressure	–111.9 °C
Melting point at atmospheric pressure	–192.5 °C
Critical temperature	–12.1 °C
Critical pressure	5460 kPa (abs)
Solubility in water, vol/vol at 0 °C	0.64
Weight of liquid at boiling point	1,352 kg/m^3

Chemical properties

Ozone is an oxidising gas. The substance itself does not burn, but in contact with combustible substances it increases the risk of fire and can fuel any existing fire substantially. Ozone is not stable in water and rapidly decomposes to oxygen. Its half-life is 20 to 100 hours at room temperature and just seconds at 300 °C.

Ozone is locally produced in an ozone generator at the point of application and is not stored in containers.

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Hazards

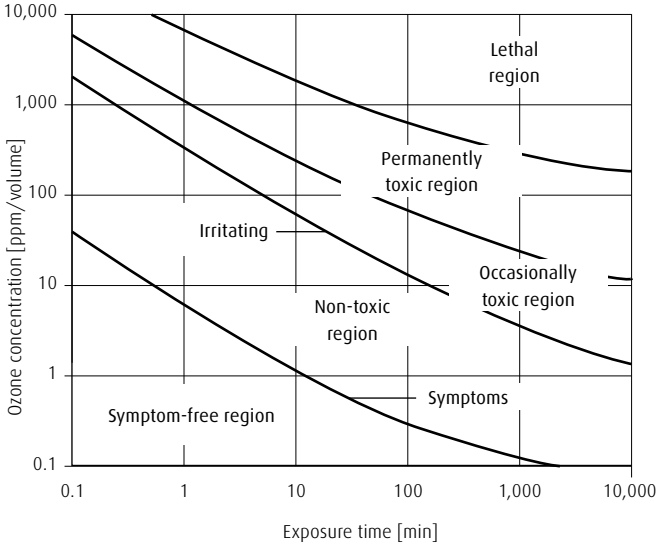
Health hazard

Ozone is a sharp irritant and prolonged breathing of air containing an ozone concentration in excess of the permissible exposure limit must be avoided. The 8 hour exposure limit varies by country: 0.1 ppm (US) or 0.2 ppm (EU). At higher exposure levels – and as a function of the exposure time (see the graphic) – there will be more severe effects:

[ppm]	
0.1–0.5	Minor eye, nose and throat irritation, headache, shortness of breath
0.5–1	Breathing disorders, reduced oxygen consumption, lung irritation, severe fatigue, chest pain, dry cough
1–10	Headache, respiratory irritation, and possible coma. Possibility of severe pneumonia at higher levels of exposure
15–20	Lethal to small animals within two hours
>1700	Lethal in a few minutes

Severe work strain and a high and room temperature will increase the toxicity of ozone, e.g. increasing the room temperature by 8 °C will double the toxicity of ozone. The symptoms of lung oedema may often not appear until a few hours after exposure. Ozone is a category 2 mutagenic substance and it is suspected of causing genetic defects.

Ozone toxicity



Reactivity

Ozone is highly reactive and it reacts with any oxidisable compound. There is a risk of aggressive reaction on contact with: ammonia, combustible substances, bromine, fluorine, substances which can be oxidised, and reducing agents. The decomposition to oxygen is accelerated by metal oxides, light and heat, so diluted ozone may also pose an explosion hazard.

See the safety advice on oxygen-enriched atmospheres for more details.

Environment hazard

Ozone is very toxic to aquatic life.

Precautions

PPE
Wear eye protection when using gases. Wear flame resistant/ retardant clothing. Gas detectors should be used when quantities of gas may be released. Appropriate respiratory protection (either self-contained breathing apparatus or supplied air mask) is required for entering a work space where an ozone leak of unknown magnitude has occurred.

Generator
Be aware of all normal and maximum operating conditions of the equipment. Be familiar with all control and safety devices, especially all emergency shut-down devices. Operation of the ozone generator must be carried out in strict compliance with the operation and maintenance manual supplied by the manufacturer and in compliance with all applicable safety and environmental regulations. Waste ozone should only be disposed of via an appropriate scrubber/ disposal system.

Equipment
Ozone should only be manufactured and handled in a closed system. Suitable safety measures and equipment should be provided to prevent overpressure. If a release of the substance cannot be prevented, it then should be directed to an appropriate scrubber/ disposal system. Label containers and pipelines clearly. There should be a remotely operated shut-off system for the installation.

Ventilation
Rooms containing ozone units and equipment should be gas-tight and separated from adjacent rooms. The ozone generator room must be mechanically ventilated during normal operation with a minimum of 10 air changes per hour. In the event of an ozone gas leak being detected, emergency ventilation should be increased to a higher rate of air changes to ensure rapid evacuation of the toxic gas from the workplace (20 to 30 air changes per hour are often sufficient for this purpose).

Gas detection system
An ozone gas detection system should be installed with sampling points located in the generator room and any other locations where an ozone leak might occur in a confined area. The monitoring system should issue an alarm when 0.1 ppm ozone is detected, and it should shut off power to the ozone generator and start the emergency ventilation whenever the ozone concentration exceeds 0.3 ppm.

Confined spaces
A risk assessment must be carried out before entering or working in a confined space and a permit to work must be obtained to ensure safe working conditions.

Materials
Compatibility studies of materials in ozone environments are scarce. One should not assume that materials that are compatible with oxygen are compatible with ozone. As a general guideline:

- Suitable materials are glass, ceramic, stainless steel, very high purity aluminium, Teflon® (PTFE), fluorine compounds.
- Unsuitable materials are copper and copper alloys, titanium, zirconium (and their alloys), iron, plastics, rubber.

Extreme precautions should be taken to avoid contact with oil, grease or other readily combustible materials. Equipment might require passivation of materials before the introduction of pure ozone. Refer to the ozone generation system manufacturer for more detailed instructions.

Regular check and maintenance
Systems should be regularly checked for leaks. Leak detection solutions must be compatible with oxygen. Only conduct maintenance and other work on the ozone generator or associated equipment after obtaining a written permit to work.

Proper clothes and personal protection equipment, e.g. gloves and safety shoes, must be worn.

Permission to enter a confined space shall be given only after the issue of an entry permit.

Emergency

Ozone is an oxidiser and supports combustion. Ozone is toxic if inhaled. In case of emergency, activate emergency shut-down system. Leaks should only be approached if appropriate personal protective equipment and self-contained breathing apparatus are worn.

Spill or leak

1. Keep combustibles (wood, paper, oil, etc.) away from spilled material
2. Stop leak, if possible. Turn off ozone generators and compressors
3. Shut off sources of ignition
4. Provide adequate ventilation
5. Evacuate area
6. Wear respiratory protection, eye protection, hand protection and body protection
7. Do not direct water at spill or source of leak
8. Use water spray to reduce vapours or divert vapour cloud drift
9. Prevent entry into waterways, sewers, basements or confined areas
10. Isolate area until gas has dispersed.

First aid

1. Inhalation: Remove victim to uncontaminated area and fresh air. Keep victim warm and rested. Call a doctor. Apply artificial respiration if breathing has stopped.
2. Eye contact: Start immediate irrigation with water or normal saline and seek immediate medical attention.

Fire

1. Use extinguishing medium for the type of surrounding fire; ozone supports combustion
2. Shut off sources of ignition
3. If possible, turn off ozone-producing units immediately
4. Advise fire service of equipment location and contents.

Refer to the Compressed Gas Association (CGA) P-34 standard for further information/contact your local Linde supplier for specific questions.