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Vaisala SPECTRACAP® Oxygen Transmitters:

What is O_2?

This document describes the general properties of oxygen and lists applications where oxygen is used and thus oxygen measurements are applied. Physical properties of oxygen and safety issues related to low and high oxygen concentrations are discussed. Chemical compatibility and flammability data for common solvents are listed in Tables 2 and 3.

Oxygen in the atmosphere

The diatomic oxygen (O_2) is a colorless and odorless gas. It is the second most abundant gas in the atmosphere after nitrogen (N_2). Oxygen exists in the gas state above -183°C.

Plants produce oxygen in photosynthesis, where carbon dioxide (CO_2) and water react using energy from the sun light to produce sugars and oxygen. Respectively, oxygen is vital to the respiration of all living organisms:

$$6\,CO_2 + 6\,H_2O \underset{\text{respiration}}{\overset{\text{photosynthesis}}{\rightleftarrows}} C_6H_{12}O_6 + 6\,O_2$$

In the ozone layer of the upper stratosphere (10-50 km above Earth's surface) diatomic oxygen is transformed into triatomic ozone:

$$O_2 \xrightarrow{\text{UV light}} 2\,O$$

$$O + O_2 \longrightarrow O_3$$

The stratospheric ozone helps to filter the harmful shorter wavelengths of UV light from the solar radiation.

Industrial applications of oxygen

In addition to its vital role in sustaining life, oxygen has numerous industrial applications. Oxygen is produced in large quantities for industrial needs by cryogenic distillation and various adsorption techniques.

The reactivity of oxygen is utilized in municipal and industrial wastewater treatment and in the pulping and and papermaking processes. Combustion process monitoring is one of the major applications for oxygen measurements. Combustion air can also be enriched with oxygen to increase combustion efficiency. Such optimization is applied in glass and ceramic manufacturing.

Steelmaking and other metal manufacturing processes are significant consumers of oxygen. Chemical, petrochemical and pharmaceutical industries all use oxygen as a reagent. Many bioreactor processes require a controlled oxygen level to drive the reactions to the desired direction. High purity oxygen is important in healthcare applications, where it is used in inhalation therapy, surgery and intensive care treatments.

Due to the high reactivity of oxygen, its concentration is reduced in some applications. Reduced oxygen concentrations are needed for example in reaction vessels and storage tanks of flammable and explosive material. Reduced oxygen concentrations are used also in controlled atmosphere packaging, storage and warehouses.

In all these applications oxygen measurements are employed to ensure a controlled environment for safety, productivity and product quality reasons.

Effects of oxygen on human health

Oxygen is vital to life. Reduced concentrations of oxygen pose a threat to life. The effects of reduced oxygen concentrations are summarized in Table 1.

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Table 1. Effect of low oxygen concentration on people.

O_2 Deficiency: Safety Properties of O_2	
Effect	Volume %
Maximum safe level (OSHA)	23.5
Atmospheric cencentration of O_2	20.95
Minimum safe level (OSHA)	19.5
Impairment of judgement detectable	17
First signs of anoxia	16
Breathing and pulse rate increase	12-16
Abnormal fatigue, disturbed respiration	10-14
Respiration stops	6

In addition to the hazard of oxygen deficiency, high partial pressures of oxygen can also be dangerous. Prolonged periods of breathing 50-100 % oxygen at normal pressure causes lung damage. In scuba diving, oxygen poisoning can occur at even lower oxygen concentration in the gas mixture due to the higher total pressure deep underwater. On the other hand, breathing pure oxygen in space causes no damage due to the low total pressure.

Physical properties of O_2

Oxygen absorbs light in the infrared (IR) region (see Figure 1). The TDL-based SPECTRACAP® transmitters utilize this absorption to measure the volumetric concentration of oxygen.

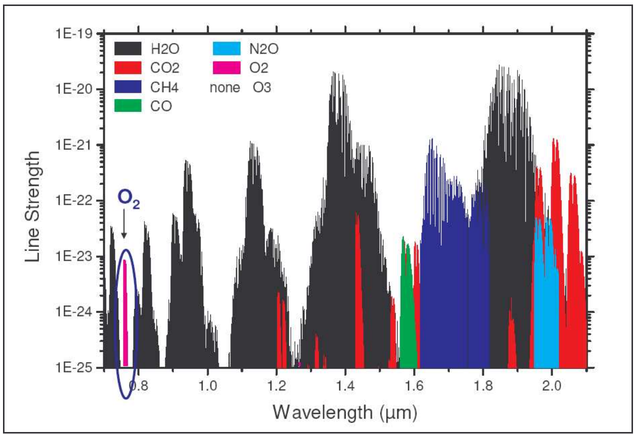

Figure 1. IR absorption of some gases.

Oxygen is paramagnetic, which means that it is attracted by a magnetic field but does not remain magnetic after leaving the magnetic field. This paramagnetic nature of oxygen is caused by two unpaired electrons in the oxygen molecule. This weak phenomenon is utilized in percentage level oxygen measurements.

General properties of oxygen are listed in Table 2.

Table 2.Properties of oxygen.

O_2 Physical Properties	
Molecular weight	32.00 g/mol
Gas density (1013 bar, 15°C)	1.35 kg/m³
Specific gravity (air = 1)	1.105
Boiling point	-183°C
Volume of 1 kg of liquid O2 in gas phase	0.738 m³

Oxygen rich processes

Oxygen rich applications include oxygen enriched combustion, oxygen generation facilities, medical air, chemical processes and a variety of other applications.

There is an increased risk of vigorous fire in applications where oxygen is present in increased concentrations. Even a small increase in oxygen concentration can increase the explosion hazard remarkably. Therefore special attention is required to prevent combustible materials from entering such processes and environments.

All Vaisala SPECTRACAP® Oxygen Transmitters are manufactured and shipped according to such cleaniness criteria that they are compatible with 100 % oxygen. This means that wetted parts are cleaned and the lubrication materials used in the sealings do not react with oxygen.

Compatibility of materials with solvents

Oxygen is often measured in applications where solvents are present. To ensure the durability of the oxygen measurement instrument used in the process, the compatibility of materials should be checked when specifying an instrument. The compatibility of some common solvents with commonly used construction and sealing materials are listed in Table 3.

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Table 3. Compatibility of some common solvents with sealing and construction materials.

	Sealing materials					Construction materials			
Solvent	EPDM	Silicone	Viton	Teflon	Kalrez	Al	AISI316	AISI304	Hastelloy C
Acetone	1	3	4	1	1	1	1	1	1
Benzene	4	4	1	1	1	2	1	1	1
Butanol	2	2	1	1	1	2	1	1	1
Diethyl ether	4	4	4	1	1	2	1	1	1
Ethanol	1	1	1	1	1	2	1	1	1
Ethyl acetate	2	2	4	1	1	2	1	1	1
Isopropanol	1	1	1	1	1	2	1	1	1
Methanol	1	1	1	1	1	2	1	1	1
Toluene	4	4	2	1	1	1	1	1	1
Xylene	4	4	1	1	1	2	1	1	1

Compatibility: 1 = excellent 2 = good 3 = fair 4 = not recommended

The wetted materials coming into contact with the sample gas in Vaisala SPECTRACAP® Oxygen Transmitters are AISI316 stainless steel, MgF2, SiN and O-ring material (EPDM or Kalrez®).

The wetted materials of the calibration gas inlet system are stainless steel and EPDM or Kalrez® sealing material. In addition, there is a Kalrez® seal, AISI302 spring, Krytox 240AC lubricant and a PTFE component in the check valve.

Flammability data of solvents

For an explosion or fire to occur, fuel, an ignition source and an oxidizer are all required. Solvent can be regarded as fuel, an ignition source can be a spark or heat and the atmospheric oxygen usually acts as the oxidizer. This is often presented in the form of an ignition triangle (Figure 2). Explosions can be prevented by elimination of at least one of these components.

Flammability data of some common solvents is listed in Table 3. The explanations for the abbreviations can be found below the table.

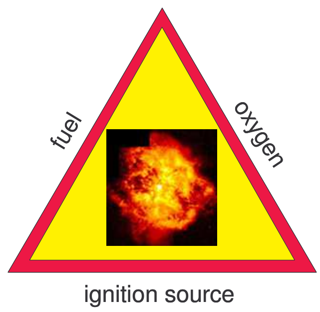

Figure 2. Ignition triangle.

Table 4. Flammability data of solvents.

Substance	LEL Vol %	UEL Vol %	MOC in N2, %	Vapour pressure at 20°C kPa	Flashpoint °C	Autoignition temperature, °C	MIE mJ	Boiling point °C	Explosion group	Temperature glass
Acetone	2.2	13	13.5	24	-18	465	1.15	56	IIA	T1
Benzene	1.2	8	11	10	-11	498	0.2	80		T1
Butanol	1.4	11.3		0.6	29	345	0.14	117	IIA	T2
Diethyl ether	1.7	48	10.5	58.6	-45	160-180	0.2	35		T4
Ethanol	3.3	19	10.5	5.8	13	363	0.14	79	IIA	T2
Ethyl acetate	2.2	11.5	9.8	10	-4	427	0.46	77	IIA	T1
Isopropanol	2	12	8.7	4.4	11.7	456	0.65	83	IIA	T2
Methanol	5.5	44	10	12.3	12	464	0.14	65	IIA	T2
Toluene	1.1	7.1	9.5	3.8	4	480	0.24	111	IIA	T1
Xylene	1.1	7		0.8	27	527	0.2	139		T1

LEL: The lowest concentration of substance in air that will produce a flash of fire with an ignition source present.
UEL: The highest concentration of substance in air that will produce a flash of fire with an ignition source present.
MOC: The maximum concentration of O2 in mixture of combustibles, air and inert gas, in which explosion will not occur.
Vapor pressure: Pressure exerted by a vapor in equilibrium with its solid or liquid phase.
Flashpoint: The lowest temperature at which a substance may ignite in the presence of an ignition source.

Autoignition temperature: The lowest temperature at which a substance spontaneously ignites in air, even without an ignition source
MIE: The minimum energy required to ignite a flammable mixture
Boiling point: The temperature at which a liquid changes to a gas (vapor) at normal atmospheric pressure
Explosion group: Equipment group according to the ATEX directive, required in use with this flammable gas or vapour
Temperature class: Temperature class according to the ATEX directive, required in use with this flammable gas or vapor