

OC Innovations OC1 & OC2 units – The Science behind the technology

Technical briefing: Reactions of Ozone

Ozone was proposed as a distinct chemical compound by Christian Friedrich Schönbein in 1840, who named it after the Greek verb ozein ("to smell"), from the peculiar odor in lightning storms. The formula for ozone, O₃, was not determined until 1865 by Jacques- Louis Soret and confirmed by Schönbein in 1867.

Physical properties

Ozone is a pale blue gas, slightly soluble in water and much more soluble in inert non-polar Solvents such as carbon tetrachloride or fluorocarbons, where it forms a blue solution. Most people can detect about 0.01 ppm of ozone in air where it has a very specific sharp odour somewhat resembling chlorine bleach.

Structure

According to experimental evidence from microwave spectroscopy, ozone is a bent molecule, with symmetry similar to the water molecule.

OC1 & OC2 units

The OC Innovations OC1 and OC2 units are designed to inject ozone into ductwork at a concentration of 1ppm. This is consumed during the process and we routinely measure 0.06ppm at the egress point. This is further reduced as it enters the atmosphere through a process of degradation to molecular oxygen and dispersion in the air.

The degradation mechanism is:



As such we find that the ozone levels are not measurable beyond 2 meters from the egress point. In sensitive areas we recommend installing a 0.1s dwell time copper oxide impregnated activated carbon which catalyses the destruction of ozone.

This is suitable for the low levels of ozone (0.06ppm which are typically found).

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Reactions

Ozone is a powerful oxidizing agent, far stronger than O₂. It is also unstable at high concentrations, decaying to ordinary diatomic oxygen (in about half an hour in atmospheric conditions): $2 \text{O}_3 \rightarrow 3 \text{O}_2$

This reaction proceeds more rapidly with increasing temperature and increased pressure.

With nitrogen and carbon compounds

Ozone oxidizes nitric oxide to nitrogen dioxide: $\text{NO} + \text{O}_3 \rightarrow \text{NO}_2 + \text{O}_2$ This reaction is accompanied by chemiluminescence. The NO₂ can be further oxidized: $\text{NO}_2 + \text{O}_3 \rightarrow \text{N}_2\text{O}_3 + \text{O}_2$

The N₂O₃ formed can react with NO₂ to form N₂O₅: Solid nitryl perchlorate can be made from NO₂, ClO₂, and O₃ gases: $2 \text{NO}_2 + 2 \text{ClO}_2 + 2 \text{O}_3 \rightarrow 2 \text{NO}_2\text{ClO}_4 + \text{O}_2$

Ozone does not react with ammonium salts but it oxidizes with ammonia to ammonium nitrate: $2 \text{NH}_3 + 4 \text{O}_3 \rightarrow \text{NH}_4\text{NO}_3 + 4 \text{O}_2 + \text{H}_2\text{O}$ Ozone reacts with carbon to form carbon dioxide, even at room temperature:

$\text{C} + 2 \text{O}_3 \rightarrow \text{CO}_2 + 2 \text{O}_2$

With sulfur compounds

Ozone oxidizes sulfides to sulfates. For example, lead(II) sulfide is oxidised to lead(II) sulfate: $\text{PbS} + 4 \text{O}_3 \rightarrow \text{PbSO}_4 + 4 \text{O}_2$ Sulfuric acid can be produced from ozone and either elemental sulfur or sulfur dioxide: $\text{S} + \text{H}_2\text{O} + \text{O}_3 \rightarrow \text{H}_2\text{SO}_4$

$3 \text{SO}_2 + 3 \text{H}_2\text{O} + \text{O}_3 \rightarrow 3 \text{H}_2\text{SO}_4$ In the gas phase, ozone reacts with hydrogen sulfide to form sulfur dioxide: $\text{H}_2\text{S} + \text{O}_3 \rightarrow \text{SO}_2 + \text{H}_2\text{O}$ In an aqueous solution, however, two competing simultaneous reactions occur, one to produce elemental sulfur, and one to produce sulfuric acid: $\text{H}_2\text{S} + \text{O}_3 \rightarrow \text{S} + \text{O}_2 + \text{H}_2\text{O}$ $3 \text{H}_2\text{S} + 4 \text{O}_3 \rightarrow 3 \text{H}_2\text{SO}_4$

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Other substrates

All three atoms of ozone may also react, as in the reaction of tin(II) chloride with hydrochloric acid and ozone: $3 \text{ SnCl}_2 + 6 \text{ HCl} + \text{O}_3 \rightarrow 3$

$\text{SnCl}_4 + 3 \text{ H}_2\text{O}$ Iodine perchlorate can be made by treating iodine dissolved in cold anhydrous perchloric acid with ozone:



Combustion

Ozone can be used for combustion reactions and combusting gases; ozone provides higher temperatures than combusting in dioxygen (O_2). The following is a reaction for the combustion of carbon subnitride which can also cause lower temperatures: $3 \text{ C}_4\text{N}_2 + 4 \text{ O}_3 \rightarrow 12 \text{ CO} + 3 \text{ N}_2$

Ozone can react at cryogenic temperatures. At 77 K (-196°C), atomic hydrogen reacts with liquid ozone to form a hydrogen superoxide radical, which dimerizes:[11] $\text{H} + \text{O}_3 \rightarrow \text{HO}_2 + \text{O}$ $2 \text{ HO}_2 \rightarrow \text{H}_2\text{O}_4$

Reduction to ozonides

Reduction of ozone gives the ozonide anion, O_3^- . Derivatives of this anion are explosive and must be stored at cryogenic temperatures. Ozonides for all the alkali metals are known. KO_3 , RbO_3 , and CsO_3 can be prepared from their respective superoxides: $\text{KO}_2 + \text{O}_3 \rightarrow \text{KO}_3 + \text{O}_2$ Although KO_3 can be formed as above, it can also be formed from potassium hydroxide and ozone:[12] $2 \text{ KOH} + 5 \text{ O}_3 \rightarrow 2 \text{ KO}_3 + 5 \text{ O}_2 + \text{H}_2\text{O}$ NaO_3 and LiO_3 must be prepared by action of CsO_3 in liquid NH_3 on an ion exchange resin containing Na^+ or Li^+ ions:[13] $\text{CsO}_3 + \text{Na}^+ \rightarrow \text{Cs}^+ + \text{NaO}_3$ A solution of calcium in ammonia reacts with ozone to give ammonium ozonide and not calcium ozonide:[11] $3 \text{ Ca} + 10 \text{ NH}_3 + 6 \text{ O}_3 \rightarrow \text{Ca} \cdot 6\text{NH}_3 + \text{Ca(OH)}_2 + \text{Ca(NO}_3)_2 + 2 \text{ NH}_4\text{O}_3 + 2 \text{ O}_2 + \text{H}_2$

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Applications

Ozone can be used to remove manganese from water, forming a precipitate which can be filtered: $2 \text{Mn}^{2+} + 2 \text{O}_3 + 4 \text{H}_2\text{O} \rightarrow 2 \text{MnO}(\text{OH})_2 (\text{s}) + 2 \text{O}_2 + 4 \text{H}^+$ Ozone will also detoxify cyanides by converting it to cyanate, which is a thousand times less toxic.

$\text{CN}^- + \text{O}_3 \rightarrow \text{CNO}^- + \text{O}_2$ Ozone will also completely decompose urea:[14] $(\text{NH}_2)_2\text{CO} + \text{O}_3 \rightarrow \text{N}_2 + \text{CO}_2 + 2 \text{H}_2\text{O}$ Ozone will cleave alkenes to form carbonyl compounds in the ozonolysis process.

