

**Reactive**

# Ozone Data & Conversion Tables

**Gas**

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*LIQUOZON® Dissolved  
Ozone Delivery  
Subsystem*



# Ozone Data & Conversion Tables

Ozone is an environmentally friendly alternative to many chemical processes. It has a high redox potential, can be generated at the point of use and is easily converted back to oxygen. Since ozone is an unstable molecule, ozone has to be generated on-site. A common technique is electrical discharge, sometimes also called silent electrical discharge. By applying high-frequency alternating voltage to oxygen gas, the oxygen molecules ( $O_2$ ) will be split into atoms. Ozone ( $O_3$ ) is formed by recombination of atomic and molecular oxygen.

## Typical Applications

### Semiconductor Industry

- Ozone Gas
  - TEOS / Ozone CVD
  - $Ta_2O_5$  CVD
  - ALD
- Dissolved Ozone
  - Photoresist strip
  - Wafer cleaning
  - Contamination removal
  - Surface conditioning
  - Oxide growth



## Physical Properties of Ozone and Oxygen

Property	Ozone (O <sub>3</sub> )	Oxygen (O <sub>2</sub> )
Color	Gas: blue colored Dissolved in water: purple blue in concentration > 20 ppm	Gas: colorless Dissolved in water: light blue
Molecular weight, g/mol	48	32
Boiling Point, °C (K)	-112 (161.3)	-183 (90)
Density, kg/m <sup>3</sup>	2.144	1.429
Solubility in water at 0 °C	0.64	0.049
Electrochemical potential, V	2.08 (Hydroxyl radical OH° 2.80)	1.23

## Typical O<sub>3</sub> Half Life Time as a Function of Temperature

Gaseous		Dissolved In Water (pH 7)	
half life time	at Temp	half life time	at Temp
~ 3 months	-50 °C	~ 30 minutes	15 °C
~ 18 days	-35 °C	~ <b>20 minutes</b>	<b>20 °C</b>
~ 8 days	-25 °C	~ 15 minutes	25 °C
~ <b>3 days</b>	<b>20 °C</b>	~ 12 minutes	30 °C
~1.5 hours	120 °C	~ 8 minutes	35 °C
~1.5 seconds	250 °C		

These values are based on thermal composition, no wall effects or other catalytic effects are considered.

## Solubility of Ozone in Fluids

**Henry's Law:** The maximum achievable balancing concentration of gas in fluids:

$$C_{Liquid} = C_{Gas} \times \beta_{(Temperature)} \times P_{gas}$$

with

$C_{Liquid}$ : dissolved concentration in liquid

$C_{Gas}$ : gas conc.

$\beta$ : Bunsen coefficient (solubility), temperature dependent

$P_{Gas}$ : gas pressure

## Solubility of Ozone in Fluids (cont'd)

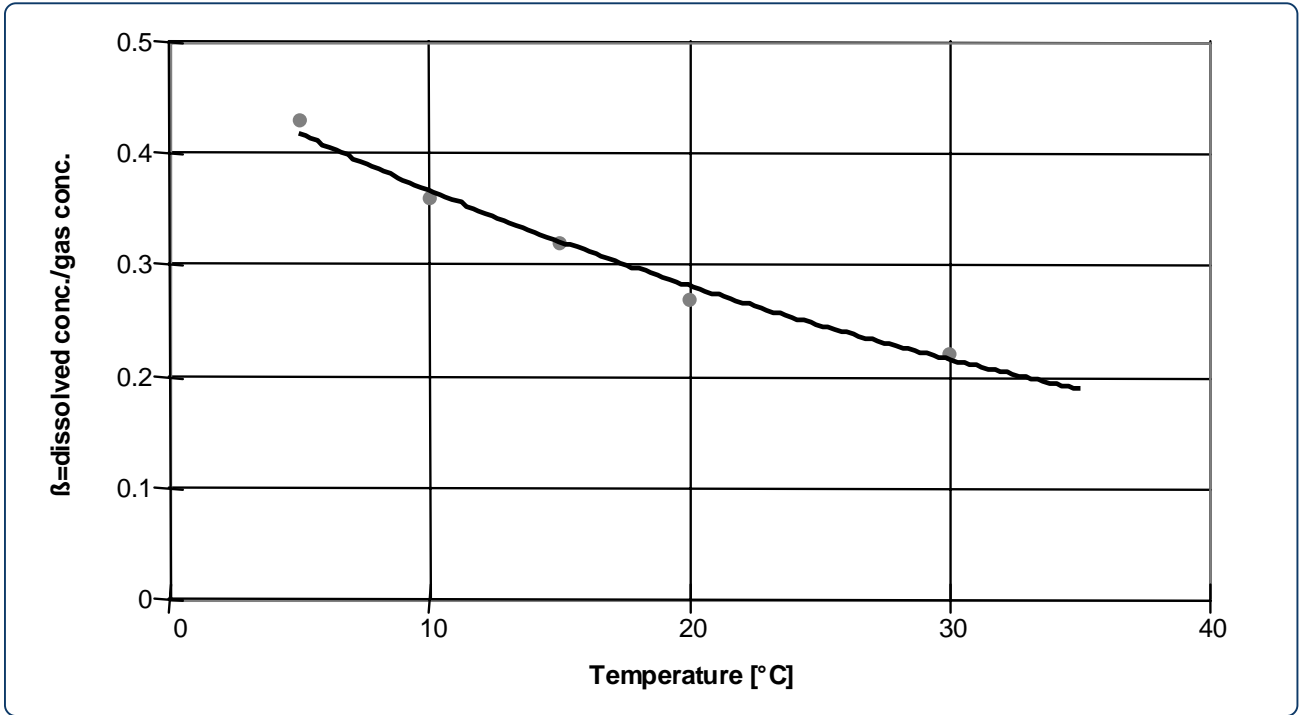


Figure 1 —  
Ozone Solubility in Water as a Function of Temperature

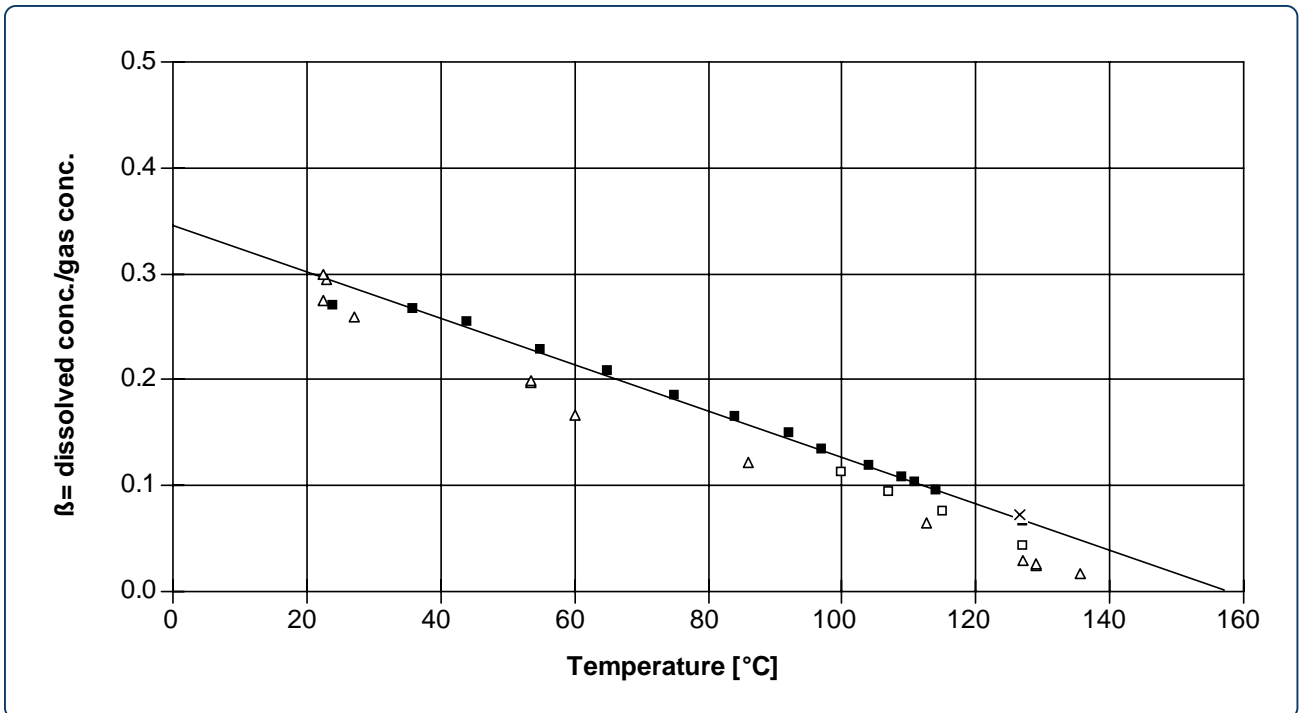


Figure 2 —  
Ozone Solubility in Concentrated Sulfuric Acid as a Function of Temperature (laboratory data)



## Conversion Table For O<sub>3</sub> Gas Phase Concentration in O<sub>2</sub>

Weight - %	Volume - %	Concentration	Productivity at 1 l/min Gas Flow
1.0%	0.7%	14.3 g/m <sup>3</sup>	0.86 g/hr
2.0%	1.3%	28.7 g/m <sup>3</sup>	1.72 g/hr
3.0%	2.0%	43.3 g/m <sup>3</sup>	2.60 g/hr
3.5%	2.3%	50.0 g/m <sup>3</sup>	3.00 g/hr
4.0%	2.7%	57.9 g/m <sup>3</sup>	3.47 g/hr
5.0%	3.4%	72.6 g/m <sup>3</sup>	4.36 g/hr
6.0%	4.1%	87.4 g/m <sup>3</sup>	5.24 g/hr
6.8%	4.7%	100.0 g/m <sup>3</sup>	6.00 g/hr
7.0%	4.8%	102.3 g/m <sup>3</sup>	6.14 g/hr
8.0%	5.5%	117.3 g/m <sup>3</sup>	7.04 g/hr
9.0%	6.2%	132.5 g/m <sup>3</sup>	7.95 g/hr
10.0%	6.9%	147.7 g/m <sup>3</sup>	8.86 g/hr
10.2%	7.0%	150.0 g/m <sup>3</sup>	9.00 g/hr
11.0%	7.6%	163.0 g/m <sup>3</sup>	9.78 g/hr
12.0%	8.3%	178.5 g/m <sup>3</sup>	10.71 g/hr
13.0%	9.1%	194.0 g/m <sup>3</sup>	11.64 g/hr
13.4%	9.3%	200.0 g/m <sup>3</sup>	12.00 g/hr
14.0%	9.8%	209.7 g/m <sup>3</sup>	12.58 g/hr
15.0%	10.5%	225.4 g/m <sup>3</sup>	13.52 g/hr
16.0%	11.3%	241.3 g/m <sup>3</sup>	14.48 g/hr
16.5%	11.7%	250.0 g/m <sup>3</sup>	15.00 g/hr
17.0%	12.0%	257.3 g/m <sup>3</sup>	15.44 g/hr
18.0%	12.8%	273.4 g/m <sup>3</sup>	16.40 g/hr
19.0%	13.5%	289.6 g/m <sup>3</sup>	17.38 g/hr
19.6%	14.0%	300.0 g/m <sup>3</sup>	18.00 g/hr
20.0%	14.3%	305.9 g/m <sup>3</sup>	18.36 g/hr
21.0%	15.1%	322.4 g/m <sup>3</sup>	19.34 g/hr
22.0%	15.8%	338.9 g/m <sup>3</sup>	20.34 g/hr
22.7%	16.3%	350.0 g/m <sup>3</sup>	21.00 g/hr

1 ppm O<sub>3</sub> equals approximately 2 mg/m<sup>3</sup> O<sub>3</sub>

All data in the table related to standard conditions:

T<sub>0</sub>: 0 °C (273.15 K = 32 °F),

P<sub>0</sub>: 101325 Pa (1.013 bar = 14.7 psi = 760 mm Hg), absolute

### Conversion for Other Conditions:

$$\text{conc } O_3 (T_1, P_1) = \text{conc } O_3 (T_0, P_0) \times \frac{273.15}{T_1} \times \frac{P_1}{101325}, \text{ with } T_1 \text{ in [K], } P_1 \text{ in [Pa]}$$

## Safety

Ozone is a highly toxic, oxidizing gas. It can be assimilated via inhalation, skin and eyes. For detailed information, reference the Ozone Material Safety Data Sheet available from Genium Publishing Corporation.

## Material Compatibility of Ozone

Material	O <sub>3</sub> Gas	O <sub>3</sub> Dissolved	Comment
<b>Metals</b>			Metals can suffer severe corrosion
Stainless Steel	+	-	
Silver, Copper- Alloy	-	-	Silver and other metals can destroy ozone catalytically
<b>Inorganic Oxides</b>			
Glass, Quartz	+	+	
Alumina Oxide	+	-	
Fe-, Cu, Mn-Oxide	-	-	Efficient catalyst
<b>Organics</b>			Most organics are severely attacked
PTFE, PFA	+	+	
PVDF, PVC	-	(+)	PVDF/PVC are attacked in gas phase, can be used in drain lines
PP, PE	-	-	
Kalrez <sup>®</sup> , Chemraz <sup>®</sup>	+	+	Seals

Note: Plus sign (+) equals compatible; Minus sign (-) equals incompatible



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