mks

Plasma & Reactive Gas Solutions

WWW.MKSINST.COM

Ozone Data & Conversion Tables

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_3)	Oxygen (O_2)
Color	Gas: blue colored	Gas: colorless
	Dissolved in water: purple blue in concentration > 20 ppm	Dissolved in water: light blue
Molecular weight, g/mol	48	32
Boiling Point, °C (K)	-112 (161.3)	-183 (90)
Density, kg/m³	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_3 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 ºC	~ 30 minutes	15 ºC
~ 18 days	-35 ºC	**~ 20 minutes**	**20 ºC**
~ 8 days	-25 ºC	~ 15 minutes	25 ºC
~ 3 days	**20 ºC**	~ 12 minutes	30 ºC
~1.5 hours	120 ºC	~ 8 minutes	35 ºC
~1.5 seconds	250 ºC		

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:

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

with

C_{Liquid}: dissolved concentration in liquid

C_{Gas}: gas conc.

ß: Bunsen coefficient (solubility), temperature dependent

P_{Gas}: gas pressure

Conversion Table For O_3 Gas Phase Concentration in O_2

Weight - %	Volume - %	Concentration	Productivity at 1 l/min Gas Flow
1.0%	0.7%	14.3 g/m³	0.86 g/hr
2.0%	1.3%	28.7 g/m³	1.72 g/hr
3.0%	2.0%	43.3 g/m³	2.60 g/hr
3.5%	2.3%	50.0 g/m³	3.00 g/hr
4.0%	2.7%	57.9 g/m³	3.47 g/hr
5.0%	3.4%	72.6 g/m³	4.36 g/hr
6.0%	4.1%	87.4 g/m³	5.24 g/hr
6.8%	4.7%	100.0 g/m³	6.00 g/hr
7.0%	4.8%	102.3 g/m³	6.14 g/hr
8.0%	5.5%	117.3 g/m³	7.04 g/hr
9.0%	6.2%	132.5 g/m³	7.95 g/hr
10.0%	6.9%	147.7 g/m³	8.86 g/hr
10.2%	7.0%	150.0 g/m³	9.00 g/hr
11.0%	7.6%	163.0 g/m³	9.78 g/hr
12.0%	8.3%	178.5 g/m³	10.71 g/hr
13.0%	9.1%	194.0 g/m³	11.64 g/hr
13.4%	9.3%	200.0 g/m³	12.00 g/hr
14.0%	9.8%	209.7 g/m³	12.58 g/hr
15.0%	10.5%	225.4 g/m³	13.52 g/hr
16.0%	11.3%	241.3 g/m³	14.48 g/hr
16.5%	11.7%	250.0 g/m³	15.00 g/hr
17.0%	12.0%	257.3 g/m³	15.44 g/hr
18.0%	12.8%	273.4 g/m³	16.40 g/hr
19.0%	13.5%	289.6 g/m³	17.38 g/hr
19.6%	14.0%	300.0 g/m³	18.00 g/hr
20.0%	14.3%	305.9 g/m³	18.36 g/hr
21.0%	15.1%	322.4 g/m³	19.34 g/hr
22.0%	15.8%	338.9 g/m³	20.34 g/hr
22.7%	16.3%	350.0 g/m³	21.00 g/hr

1 ppm O_3 equals approximately 2 mg/m³ O_3

All data in the table related to standard conditions:

T_0: 0 °C (273.15 K = 32 °F),
P_0:101325 Pa (1.013 bar = 14.7 psi = 760 mm Hg), absolute

Conversion for Other Conditions:

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

Solubility of Ozone in Fluids (cont'd)

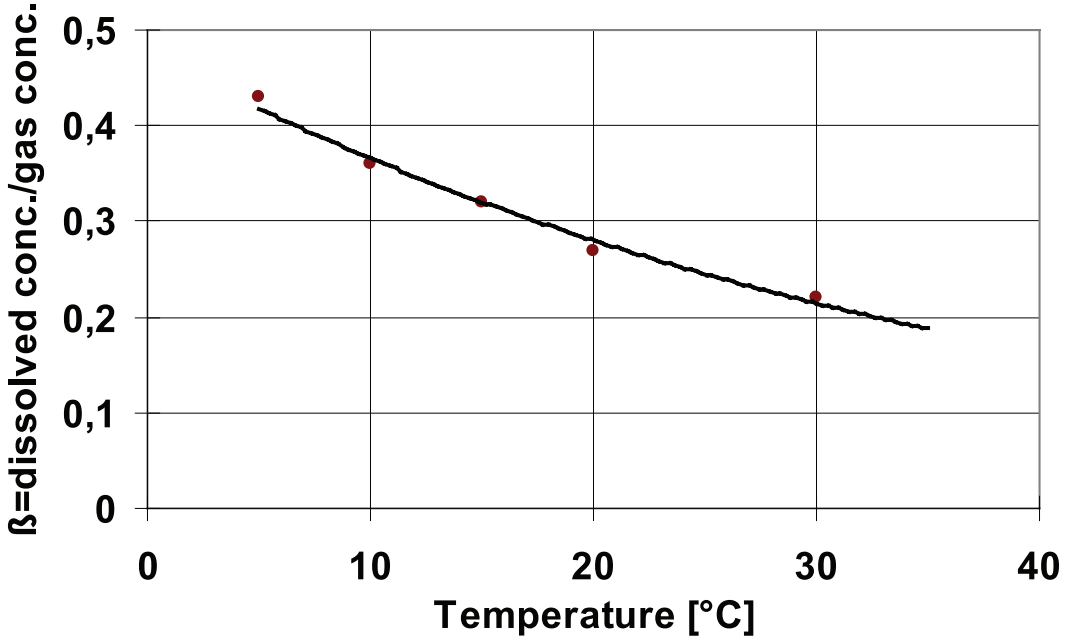

Figure 1 —
Ozone Solubility in Water as a Function of Temperature

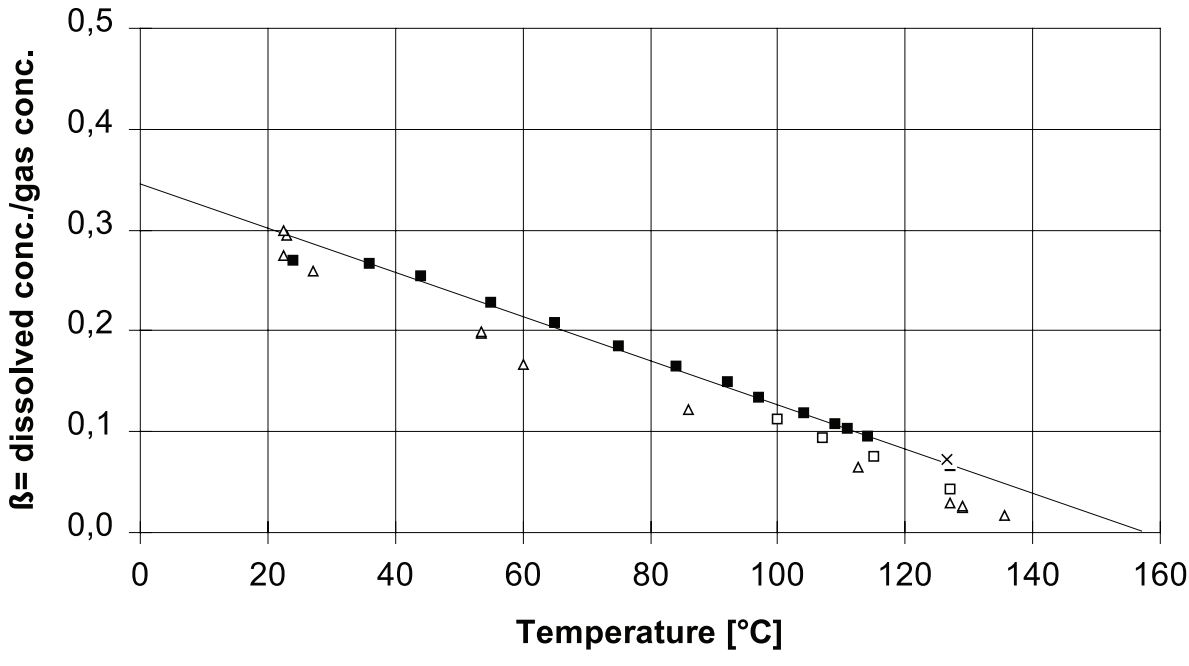

Figure 2 —
Ozone Solubility in Concentrated Sulfuric Acid as a Function of Temperature (laboratory data)

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_3 Gas	O_3 Dissolved	Comment
Metals			Metals can suffer severe corrosion
Stainless Steel	+	-	
Silver, Copper- Alloy	-	-	Silver and other metals can destroy ozone catalytically
Inorganic Oxides			
Glass, Quartz	+	+	
Alumina Oxide	+	-	
Fe-, Cu, Mn-Oxide	-	-	Efficient catalyst
Organics			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®, Chemraz®	+	+	Seals

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

MKS Instruments, Inc. Global Headquarters
2 Tech Drive, Suite 201
Andover, MA 01810
Tel: 978.645.5500
Tel: 800.227.8766 (in USA)
Web: www.mksinst.com

MKS Instruments, Inc. Plasma & Reactive Gas Solutions
90 Industrial Way
Wilmington, MA 01887
Tel: 978.284.4000

MKS Instruments Deutschland GmbH Plasma & Reactive Gas Solutions
Wattstr. 11-13
13355 Berlin, Germany
Tel: +49.30.464.0030

OzoneConversion - 11/15