Instruction Manual

Manual No. 012-07688E

PASPort Dissolved Oxygen Sensor

Model No. PS-2108

PASCO ®

10101 Foothills Blvd. • Roseville, CA 95747-7100

Phone (916) 786-3800 • FAX (916) 786-8905 • www.pasco.com

better ways to teach science

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Table of Contents

PASPort Dissolved Oxygen Sensor

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Equipment List

Included Equipment	Replacement Model Number*
1. Dissolved Oxygen Probe (1)	699-06320
2. PASPORT Dissolved Oxygen Sensor box (1)	
3. Membrane Replacement Kit (1)	CI-6541
4. Soaker Bottle (1)	
5. Electrolyte Solution (1)	R001068
6. Syringe for filling cartridge housing (1)	

*Use Replacement Model Numbers to expedite replacement orders.

Introduction

The PASCO PS-2108 Dissolved Oxygen Sensor can be used to monitor and explore factors that affect the concentrations of dissolved oxygen molecules (O_2) in aqueous solutions, particularly in applications related to ecological studies of water environments. The Dissolved Oxygen Sensor is specifically designed for use with a PASPort interface or logger, plus DataStudio® data acquisition software. In the laboratory, students can explore the effects of temperature, water movement, inorganic chemicals, organic matter, and living organisms on levels of dissolved O_2. They can also monitor dissolved O_2 levels in the field as a part of ecological surveys of aqueous habitats, including BOD (Biological Oxygen Demand) studies.

The Dissolved Oxygen Sensor is designed for use in aqueous media at temperatures ranging from 10 °C to 40 °C. For greatest accuracy, the following requirements should be met: although the unit is temperature compensated, it should be calibrated at approximately the same temperature as the test solution; the sensor must equilibrate for a short period when the temperature of the test solution changes-the greater the temperature change, the longer the period of equilibration required; the test solution should constantly flow past the membrane of the probe.

The Dissolved Oxygen Sensor has a polarographic probe composed of a platinum cathode and a silver (Ag) anode surrounded by a potassium chloride ($KCl_{(aq)}$) electrolyte solution.

*PASPORT sensors require a PASPORT computer interface.

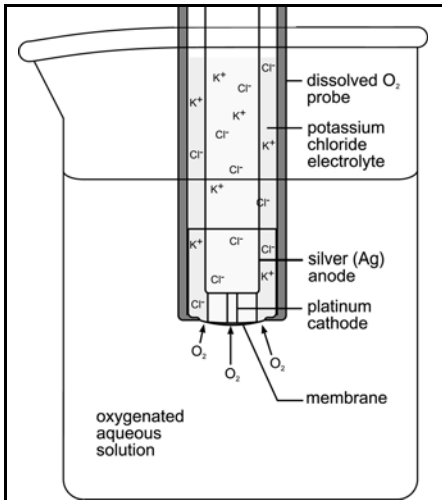


Figure 1
Oxygen molecules pass through the semipermeable membrane into the electrolyte surrounding the electrodes

The sensor functions by measuring the electric current produced by a chemical reaction in the probe. The chemical reaction involves the reduction of oxygen (O_2) molecules and the oxidation of the silver (Ag) atoms of the anode. A voltage of 0.7 volts is applied across the electrodes, causing the desired redox reaction (see below) to be favored. When the dissolved O_2 probe is placed in an aqueous medium, such as deionized water that contains dissolved O_2, the dissolved O_2 molecules diffuse across a thin silicon membrane into the electrolyte that surrounds the electrodes of the probe (Figure 1). The membrane is semipermeable, allowing the dissolved O_2 to pass through it, but preventing passage by most other molecules that might interfere with the chemical reactions at the electrodes. The chemical reactions produce electrons that cause electric current to flow through the sensor's electric circuit. Since the rate of diffusion is dependent on the concentration of the dissolved O_2, the number of diffused O_2 molecules will vary approximately in direct proportion to the concentration of dissolved O_2 in the test solution. Accordingly, the number of electrons produced by the redox chemical reactions of the dissolved O_2 will be almost directly proportional to the concentration of dissolved O_2 in the test solution.

The following is an overview of the chemical and electrical processes at each of the electrodes that are involved in measuring dissolved O_2 with the Dissolved Oxygen Sensor.[1] As soon as the dissolved O_2 molecules pass through the silicon membrane into the electrolyte solution, they come into close proximity to the platinum cathode (Figure 2). The negative charge (excess electrons) of the cathode induces the reduction of the dissolved O_2, forming hydroxide ions (OH^-):

$$\mathbf{O_2 + 2H_2O + 4e^- \rightarrow 4OH^-}$$

(**Reduction potential = 0.40V**)

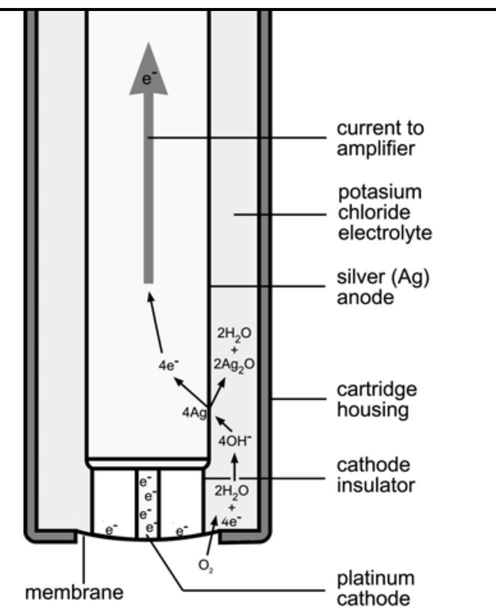


Figure 2
O_2 molecules diffuse across the membrane and react with water molecules in the presence of electrons from the cathode to form hydroxide ions (OH^-). Hydroxide ions diffuse to the anode and react with silver (Ag) atoms, forming silver oxide (Ag_2O), water, and free electrons.

The negatively charged hydroxide ions diffuse to the silver anode. There they combine with silver (Ag) atoms from the silver anode, forming silver oxide and releasing electrons that join the current in the electrode in the following chemical reaction:

$$4Ag + 4OH^- \rightarrow 2Ag_2O + 2H_2O + 4e^-$$

(**Reduction potential = 0.343V**)

The released electrons produce a current that passes from the electrode and is amplified. The current due to the chemical reactions of the O_2 molecules must be corrected for temperature variations, since the rate of reaction varies directly with the temperature.

The correction is accomplished through the use of a temperature-sensing thermistor that is built into the probe. With the temperature sensing thermistor, the temperature of the probe is monitored, and the gain of the amplifier is automatically adjusted to compensate for the temperature dependence of the chemical reactions in the probe. A signal representing the temperature-compensated dissolved O_2 concentration of the solution is fed to the computer interface and displayed by DataStudio in concentration (mg/l) or saturation (%).

DO Sensor Setup and Calibration

Prepare the Sensor for First Use

Prior to the first use of the sensor, you will need to fill the Dissolved Oxygen Sensor electrode membrane cartridge and cartridge housing with an electrolyte solution. See the maintenance section for instructions.

Set up the Dissolved Oxygen Sensor with DataStudio.

1. Attach the probe to the sensor box (Figure 3).

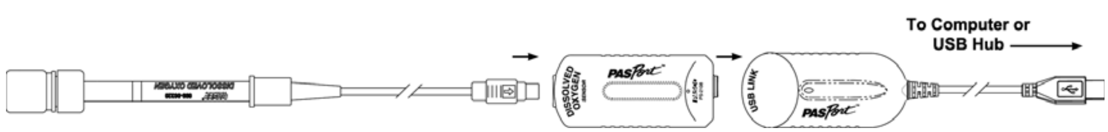


Figure 3
Plug the DO_2 probe into the DO_2 sensor box and connect the sensor box to a PASPort USB interface that is connected to a computer's USB port or to a USB hub that is connected to the computer.

2. Plug the sensor box into a PASPort interface or logger connected to a computer.

3. The PASPortal window should open, allowing a choice between DataStudio or EZScreen. Select DataStudio.

4. The Digits display opens automatically. Open additional or alternate displays as desired.

[1]Find a more detailed discussion in Michael L. Hitchman, Measurement of Dissolved Oxygen, John Wiley and Sons, New York, 1978, pp. 59-123.

Equilibrate the Probe in 100% Humidified Air

1. Place about 5 mL (to a height of about 1 cm) of deionized water into a clean soaker bottle. Slip the cap and O-ring of the soaker bottle over the end of the probe.

2. Insert the probe into the soaker bottle and screw on the lid. Adjust the height of the end of the probe to about 2 cm above the top of the water (Figure 4).

3. Shake the soaker bottle vigorously for about 10 seconds. Shake off any large water drops from the membrane.

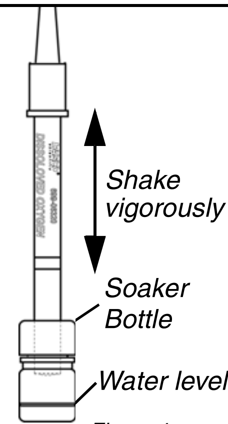


Figure 4
To equilibrate the probe, insert the end of the probe into a clean soaker bottle containing ~5 mL of deionized water. Shake the probe vigorously for about 10 Sec.

Perform a Single-point Calibration (mg/l Dissolved O_2)

1. Obtain current barometric pressure and temperature readings for your location. You can use the PAPSPORT Barometer (PS-2113) and Temperature Sensor (PS-2131), or the PASPORT Weather Sensor (PS-2154) to take the necessary measurements.

2. Refer to the Solubility table 1 in Appendix C and find the appropriate dissolved oxygen value for the temperature and barometric pressure at your location.

   Example: At a temperature of 25ºC and a barometric pressure of 760 MM. Hg, 8.2 mg of oxygen will dissolve in one liter of water at 100% saturation.

3. In DataStudio, click the **Setup** button on the toolbar. Make sure mg/L is selected next to the **Calibrate…** button in the Dissolved Oxygen Sensor dialog.

4. With the DO_2 sensor equilibrated as described above, click the **Calibrate…** button.

5. Refer to the tables for the value of mg/l dissolved O_2 in saturated water at the temperature and uncorrected barometric pressure at which you are measuring. (If you do not know the barometric pressure, assume that it is 760 mm Hg.) Enter the value in the mg/l box. Click OK.

Setup to Calibrate in Percent (%) Saturation

1. (DataStudio only) Click the **Setup** button on the DataStudio toolbar. Click the **mg/L** button next to the **Calibrate…** button and select % from the drop-down menu

Note: Always calibrate the probe before measuring absolute (rather than relative) concentrations. Calibrate at or close to the temperature and barometric pressure at which the test solution is to be measured.-

Note: Percent (%) saturation output is valid only at the temperature and barometric pressure at which the probe is calibrated.

Note: Before taking measurements of dissolved oxygen (DO) concentration (rather than % saturation), change your software settings back to mg/L.

DataStudio: Click the **Setup** button on the DataStudio toolbar. Click the % button next to the Calibrate button and select mg/L from the drop-down menu.

Note: Calibration is not required for measurements of relative DO content, such as before/during/after experiment relative changes.

2. Click the **Calibrate…** button to open the Calibrate dialog.
3. Place the probe in 100% humidified air. When the readings stabilize around a value, click the **Set** button. Then click **OK**. It may take a few minutes for the sensor to equilibrate for calibration. The readings may not completely stabilize at one specific point.

   Calibration in 100% humidified air is equivalent to calibrating in 100% air-saturated water. This is because the oxygen must first pass through the electrolyte solution in the Dissolved Oxygen Sensor to get to the cathode. The concentration of oxygen in both the 100% air-saturated water and the electrolyte solution will be equivalently proportional to the partial pressure of oxygen in air, following Henry's law where

   $$Cg = k \times Pg$$

   Cg = the solubility of the gas (oxygen)
   Pg = the pressure of the gas over the solution

   This relationship holds true whether the end of the sensor is immersed in the water or suspended in air.
4. Before taking measurements of dissolved oxygen concentration, change your unit settings back to mg/L.

General Sampling Procedure

1. Immerse the Dissolved Oxygen probe into the test solution until the silver temperature compensation band is submerged.

2. Click the **Start** button on the DataStudio tool bar or select **Monitor Data** from the Experiment menu.

3. Gently, swirl the probe for a minute or two until the dissolved oxygen readings stabilize around a value. As an alternative, use a magnetic stirrer to slowly stir the test solution (do not stir fast enough to entrain air bubbles or form a large vortex.

Measurements in a Controlled Laboratory Setting

In a laboratory setting, you can make long-term measurements of dissolved oxygen levels by gently and continuously stirring the solution with a magnetic stir plate and stir bar. Minimize the surface area of the atmosphere/liquid interface to retard gas exchange with the atmosphere. A vessel such as an Erlenmeyer flask or a large test tube works well.

Note: DO NOT USE MINERAL OIL, as it is difficult to clean from the membrane.

Using the Dissolved Oxygen Sensor with other PASCO Sensors:

Some PASCO sensors, including the Dissolved Oxygen Sensor, emit electrical signals into the test solution and may interfere with other sensors taking simultaneous measurements. If you want to take simultaneous measurements with the Dissolved Oxygen Sensor and another PASCO sensor (such as the Conductivity Sensor or pH Sensor), conduct controlled experiments and ensure that no intra-sensor interference occurs under your experimental conditions.

Maintenance

Changing the Electrolyte solution

The electrolyte solution (probe filling solution) should be periodically replaced and the silver electrode cleaned to maintain optimal performance of the probe. If the probe is not performing optimally, replace the electrolyte solution as follows:

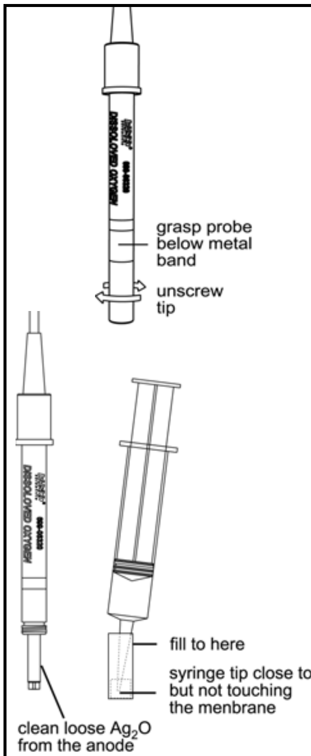


Figure 5
Removing the cartridge housing and filling with electrolyte.

1. Unscrew the end of the probe by turning it to the left, and remove the cartridge housing (Figure 5).

   Always hold the probe below the stainless steel band when unscrewing the cartridge housing or otherwise applying torque to the end of the probe.

2. Rinse the electrode with tap water (or deionized water in areas with hard tap water) and rub it dry with a paper towel, removing loose silver oxide (Ag_2O) from the anode.

3. Rinse and air dry the cartridge housing.

4. Pull about 10 ml of the Polarographic solution into the syringe, being careful not to introduce air bubbles.

5. Place the tip of the syringe very close to, but not touching the membrane, and slowly fill the membrane cartridge and cartridge housing to approximately 5 mm from the top of the housing.

Note: Tap the cartridge housing while filling to avoid introducing air bubbles.

6. Holding the probe in a vertical position, slip the cartridge housing over the electrode and turn to the right to tighten (Figure 6).

7. Dry with a paper towel or tissue.

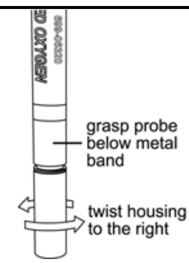


Figure 6
Replacing the cartridge housing.

Replacing the Membrane

If the silicon membrane becomes torn or otherwise damaged, replace it as follows:

1. Follow steps 1 through 3 under "Changing the Electrolyte Solution" above.

2. Use the supplied plunger to push the membrane cartridge out of the cartridge housing (Figure 7A).

3. Examine the O-ring (Figure 8) and replace it if it is damaged (See "Replacing the O-ring" below.).

4. Insert a replacement membrane cartridge and use the plunger to push it down until it is seated at the end of the housing that has the O-ring (Figure 7B).

5. Fill with electrolyte and reassemble the probe as directed in steps 4 through 7 of "Changing the Electrolyte Solution."

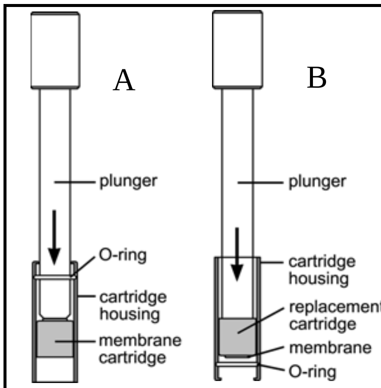


Figure 7
Removing and replacing the membrane cartridge.

Replacing the O-ring

The O-ring should rarely if ever require replacing. However, if it develops nicks or splits and begins to allow leakage of the electrolyte solution from the probe, replace it as follows:

1. Follow steps 1and 2 of the procedure for replacing the membrane cartridge (above).

2. After removing the membrane cartridge, remove the O-ring with a pair of fine-tipped tweezers and insert a new O-ring.

3. Insert the membrane cartridge as directed in step 4 of “Replacing the Membrane”.

4. Fill with electrolyte and reassemble the probe as directed in steps 4 through 7 of "Changing the Electrolyte Solution."

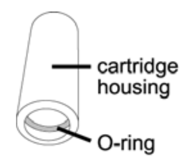


Figure 8
Examine the O-ring for damage.

Storage

Short-Term Storage (two weeks or less)

Store the probe in the plastic storage bag with the tip inserted in the soaker bottle containing about 10 ml of deionized water.

Long-Term Storage (more than two weeks)

1. Unscrew and remove the cartridge housing by turning it to the left.

   Always hold the probe below the stainless steel band when unscrewing the cartridge housing or otherwise applying torque to the end of the probe.

2. Dispose of the electrolyte and rinse the electrode with tap water (or deionized water in areas with hard tap water) and dry it with a paper towel, removing loose silver oxide (Ag_2O) from the anode.

3. Rinse the cartridge housing with tap water and allow it to air dry.

4. Rinse the soaker bottle with tap or deionized water and shake dry.

5. Replace the cartridge housing onto the probe and place the dry probe in its storage bag with the end of the probe in the soaker bottle to protect the membrane from damage.

Troubleshooting

If the Dissolved Oxygen Sensor does not give the expected output, do the following, and check the function of the sensor after each step until the sensor works properly:

1. Replace the filling solution. See "Changing the Electrolyte Solution."

2. Replace the membrane. See "Replacing the Membrane."

3. Check the O-ring and replace if necessary (See "Replacing the O-ring."

If the Dissolved Oxygen Sensor still does not function properly, contact Technical Support (See the Technical Support section in the back of this manual.)

Theory of Dissolved Oxygen:

What is the chemical mechanism by which diatomic oxygen dissolves in water?

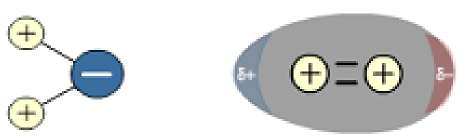
This is a particularly eloquent description of the mechanism of oxygen solubility in water: [from Water on the Web[1]]

> Water, as a polar molecule, induces an accumulation of electron density (dipole moment) at one end of nonpolar gas molecules such as oxygen (O_2) and carbon dioxide (CO_2). In animation, observe a polar water molecule approaching a nonpolar O_2 molecule. The electron cloud of O_2 is normally distributed symmetrically between the bonded O_2 atoms. As the negative end of the H_2O molecule approaches the oxygen molecule, the electron cloud of the O_2 moves away to reduce the negative-to-negative repulsion. As a result, a dipole (a molecule with positive and negative charges separated by a distance) has been induced in the nonpolar O_2 molecule, causing O_2 and H_2O to become weakly attracted to each other. This intermolecular attraction between the oppositely charged poles of nearby molecules is termed a dipole- induced dipole force. The creation of these forces then explains the mechanism by which gases dissolve in water.

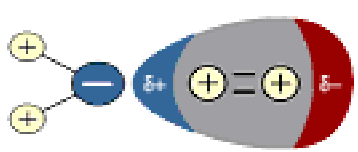
Still images from the Water on the Web animation:

Induced Dipoles

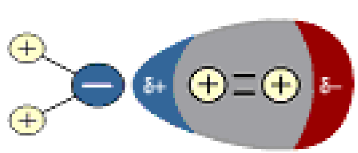
The electron cloud of an isolated Oxygen molecule is distributed symmetrically between the bonded O atoms.



As the negative end of the polar water molecule approaches…



…the O_2 electron cloud is moved away to reduce repulsion between the O_2 cloud and the negative end of the water molecule.



The O_2 molecule itself becomes polar.

A dipole has been induced in the otherwise nonpolar O_2 molecule. The H_2O and the O_2 are now weakly attracted to one another.

II. **What factors influence the amount of dissolved oxygen in water?** There are several factors that can influence the amount of gaseous diatomic oxygen (as well as other gases) that will dissolve in water. When speaking of gases dissolving in water, discussion is limited to gases that do not chemically react with the water.

1. Water Temperature effects

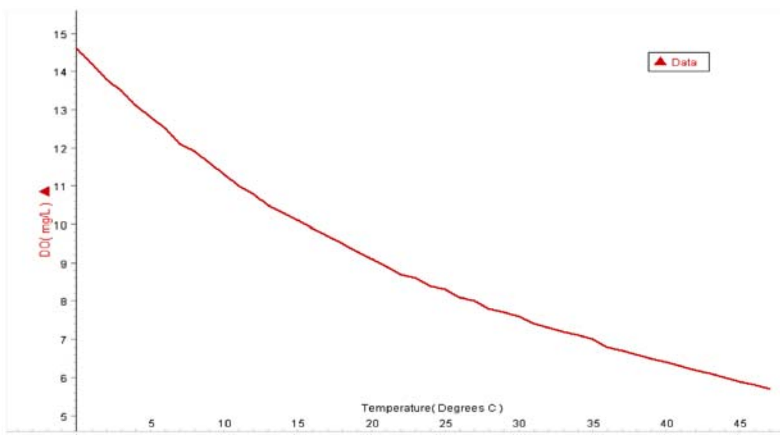
- Gases usually dissolve in liquids in an exothermic process. This expression represents that process:

  gas + solvent liquid ↔ gas saturated solvent + heat (this will reach an equilibrium)

- Le Chatelier's Principle predicts that an added stress to one side of this equilibrium will cause a shift in equilibrium in order to accommodate that stress, thereby driving the equilibrium point to the left in the expression below:

  GAS + solvent liquid ← gas saturated solvent + **heat**

- Experimental results support this theory:



This graph was constructed using DataStudio, drawing on data taken from Table HY-DO-1 in the GLOBE protocol for Dissolved Oxygen.[2]

Table HY-DO-1: Solubility of Oxygen in Fresh Water Exposed to Air at 760 mm Hg Pressure

Temp °C	Solubility mg/L	Temp °C	Solubility mg/L	Temp °C	Solubility mg/L
0	14.6	16	9.9	32	7.3
1	14.2	17	9.7	33	7.2
2	13.8	18	9.5	34	7.1
3	13.5	19	9.3	35	7.0
4	13.1	20	9.1	36	6.8
5	12.8	21	8.9	37	6.7
6	12.5	22	8.7	38	6.6
7	12.1	23	8.6	39	6.5
8	11.9	24	8.4	40	6.4
9	11.6	25	8.3	41	6.3
10	11.3	26	8.1	42	6.2
11	11.0	27	8.0	43	6.1
12	10.8	28	7.8	44	6.0
13	10.5	29	7.7	45	5.9
14	10.3	30	7.6	46	5.8
15	10.1	31	7.4	47	5.7

2. Overlying Gas Pressure Effects

- Henry's Law states that the solubility of a gas in a liquid is affected by the pressure of the gas above the liquid-gas interface.

  $$\mathbf{P=kC}$$

  P=gas pressure (or partial pressure)
  C=concentration of dissolved gas
  k = Henry's Law Constant (differs with temperature, gas, and solvent)

- Changing pressures, while maintaining the same temperature, gas, and solvent allows one to draw a relationship that excludes Henry's Law Constant:

  $$\frac{\mathbf{C1}}{\mathbf{P1}} = \frac{\mathbf{C2}}{\mathbf{P2}}$$

- If a gas-liquid system starts at equilibrium and the partial pressure of a gas is increased (with other factors such as temperature remaining unchanged) the amount of gas that is dissolved in the liquid at the new equilibrium will increase.

  For example:
  P1 = 1012 millibars (approximately sea level)
  C1 = 9 mg / L
  P2 = 790 millibars (approximately 6700 ft or 2050 m above sea level)

  $$\frac{(\mathbf{9mg/L})}{(\mathbf{1012\ milibars})} \times (\mathbf{790\ milibars}) \approx \mathbf{7\ mg/L}$$

- The most significant way in which this effect manifests itself is the reduced maximum possible dissolved oxygen at higher altitudes. This is the reason why barometric pressure at the sample site is important. Higher altitudes lead to a decrease in atmospheric pressure (all atmospheric gases), which leads to a decrease in the partial pressure of oxygen (as well as all of the other atmospheric gases). Please note the weather services often report barometric pressure for a location, which is normalized for the same local conditions as if reported at sea level, that is, the values are corrected for altitude.

- The decrease in atmosphere pressure with increase in altitude is not linear. Please see the altitude correction table in order to compensate for altitude differences.

3. Hydrostatic Pressure

- Water under significant pressure may hold a higher amount of dissolved gas, compared to water under less pressure. Plumbing systems are commonly under significant pressure. The gases dissolved in water that is in a plumbing system may be at equilibrium at that pressure, but when the pressure is released or decreased by an act such as drawing the water from a tap into a container at atmospheric pressure, the solution may be supersaturated. This phenomenon is similar to opening a can of carbonated beverage or soda pop. However, the dissolved gases may take several seconds to several hours to reach equilibrium.

A famous, naturally occurring case of supersaturation and subsequent gas release (in this case it was dissolved carbon dioxide gas) was the Lake Nyos tragedy, which took place in Cameroon (1986).

4. Salinity.

- Salt and other solids dissolved in water will affect the total amount of gas that a liquid solvent can dissolve. Given otherwise identical conditions, fresh water can hold more dissolved oxygen than salt water. When measuring dissolved oxygen in salt water (in excess of 1000 mg/L dissolved salts), calibrate the probe in a sample of the salt water in which the DO measurement is desired. For situations in which the salt content is not constant (such as estuarine environments) one must calibrate the probe using fresh water. For each DO reading, one must also make an accurate determination of dissolved salt content in order to account for the change in oxygen solubility in waters of varying salinity.
- To obtain theoretical maximum DO in saline waters, consult the following table for the theoretical maximum dissolved oxygen at saturation-the low calibration value will remain at 0 mg/L DO (table from Ambient Water Quality Criteria, 1997[3]). For values not found in the table, use the nomogram found on page 28 in Hitchman, 1978.[4]

Solubility of oxygen in water (fresh and saline) exposed to water-saturated air at sea level

760 mm Hg (101.3 kPa)

	Chlorinity (freshwater)					
Temp. (°C)	**0 g/L Cl-**	**5.0 g/L Cl-**	**10.0 g/L Cl-**	**15.0 g/L Cl-**	**20.0 g/L Cl-**	**25.0 g/L Cl-**
0.0	14.621	13.728	12.888	12.097	11.355	10.657
1.0	14.216	13.356	12.545	11.783	11.066	10.392
2.0	13.829	13.000	12.218	11.483	10.790	10.139
3.0	13.460	12.660	11.906	11.195	10.526	9.897
4.0	13.107	12.335	11.607	10.920	10.273	9.664
5.0	12.770	12.024	11.320	10.656	10.031	9.441
6.0	12.447	11.727	11.046	10.404	9.799	9.228
7.0	12.139	11.442	11.783	10.162	9.576	9.023
8.0	11.843	11.169	10.531	9.930	9.362	8.826
9.0	11.559	10.907	10.290	9.707	9.156	8.636
10.0	11.288	10.656	10.058	9.493	8.959	8.454
11.0	11.027	10.415	9.835	9.287	8.769	8.279
12.0	10.777	10.183	9.621	9.089	8.586	8.111
13.0	10.537	9.961	9.416	8.899	8.411	7.949
14.0	10.306	9.747	9.218	8.716	8.242	7.792

	Chlorinity (freshwater)					
Temp. (°C)	**0 g/L Cl-**	**5.0 g/L Cl-**	**10.0 g/L Cl-**	**15.0 g/L Cl-**	**20.0 g/L Cl-**	**25.0 g/L Cl-**
15.0	10.084	9.541	9.027	8.540	8.079	7.642
16.0	9.870	9.344	8.844	8.370	7.922	7.496
17.0	9.665	9.153	8.667	8.207	7.770	7.356

5. Surface Area and Mixing/Turbulence

- The surface area of the water/gas interface may affect the rate at which gas dissolves into the water, but ultimately, it will not affect the total amount of gas dissolved at static (non-turbulent) equilibrium. Situations in which turbulence is constant (such as the outfall from a dam spillway) can host a dynamic equilibrium in which water remains supersaturated at a given point in the stream.
- Stirring a water sample in a laboratory setting has a drastic effect on the behavior of the DO probe. The nature of a Clark-type probe is that it consumes oxygen in its immediate environment (leading to an apparent localized drop in DO level). Stirring the sample, while taking data, is highly recommended in order to obtain faithful DO readings. It is crucial to maintain a sufficient flow rate across the membrane of the sensor. Flow of about 1 cm per second is recommended. Do not stir to the point of causing excessive turbulence in the water.
- Allow the probe to reach equilibrium in experiments that are not conducive to stirring. There will be an initial drop (in most cases up to 60 seconds) on apparent readings until a local equilibrium is established.

Citations:

1. WOW. 2003. Water on the Web - Monitoring Minnesota Lakes on the Internet and Training Water Science Technicians for the Future - A National On-line Curriculum using Advanced Technologies and Real-Time Data. (http://wow.nrri.umn.edu). University of Minnesota-Duluth, Duluth, MN 55812

2. Table HY-DO-1 from Globe Dissolved Oxygen Protocol (http://www.globe.gov/tctg/hydro_prot_do.pdf?sectionId=151)

3. Ambient Water Quality Criteria for Dissolved Oxygen, February, 1997. Water Management Branch Environment and Lands Headquarters Division, Ministry Of Environment, Lands and Parks, Canada

4. Hitchman, Michael L.1978. Measurement of Dissolved Oxygen. John Wiley and Sons, New York. 255 p.

Experiment 1: Introduction to the Operation of the Dissolved O_2 Sensor

Purpose

The purpose of the experiment is to explore the basic operation of the Dissolved Oxygen Sensor: how to set it up, how to calibrate it, and how to obtain the most accurate measurements with it.

Materials and Equipment Needed

- Dissolved Oxygen Sensor (PS-2108)
- 600 ml beaker
- PASCO ScienceWorkshop
- 400 ml deionized water saturated with air
- PASPort Interface and DataStudio software
- Reference tables for dissolved oxygen
- aquarium pump (optional)

Optional Equipment Suggested

To saturate deionized water with air, fill a clean container one-third full with deionized water, seal it, and shake vigorously for 10 seconds. Alternatively, bubble air through the deionized water for 15 minutes using an aquarium pump.

Procedure

1. Set up and calibrate the Dissolved Oxygen Sensor in DataStudio according to the calibration procedure detailed in this manual.

2. Place the probe in the test solution and stir it gently for thirty seconds.

3. Click the **Start** button on the DataStudio toolbar to begin recording data (Data Run #1).

4. Being careful to keep the stainless steel band submerged to at least 1 cm under the surface of the water, gently stir the probe in the test solution until the dissolved O_2 readings stabilize.

5. Click the **Stop** button on the DataStudio toolbar to end data recording.

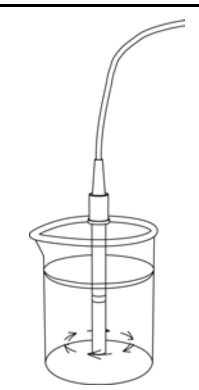


Figure 1
Gently stir the probe in the test solution

6. Click the **Start** button on the DataStudio toolbar to begin recording data (Data Run #2).

7. Allow the probe to rest undisturbed in the test solution and observe the sensor reading.

8. After the sensor reading stabilizes at the new level, gently move the probe back and forth through the test solution and observe the sensor reading.

9. After the sensor reading stabilizes at the new level, repeat steps 6 and 7 several times.

10. . Click the **Stop** button to end data recording. Save the recorded data.

Figure 2
Allow the probe to rest undisturbed in the test solution

Note: The concentration of dissolved O_2 should be about the level of the high value that you entered during calibration. If not, check to be sure that there are no large air bubbles on the bottom of the probe. If the value is still significantly (more than 10%) different than the high value, re-calibrate the sensor.

Data Analysis/Questions

1. Why does the measured dissolved O_2 concentration decline when you leave the probe undisturbed?

2. Why does measured dissolved O_2 concentration stop declining while the probe is undisturbed?

3. Why does the measured dissolved O_2 concentration rise when you move the probe through the test solution?

4. Why does the measured dissolved O_2 concentration stop rising while the probe is moving through the test solution?

5. Which measurement is the most accurate representation of the dissolved O_2 concentration of the test solution?

6. Explain why it is important to move a steady flow of the test solution by the membrane of the Dissolved Oxygen Sensor while taking dissolved O_2 concentration measurements.

Experiment 2: Photosynthesis and Oxygen Generation with Aquatic Plants

Purpose

Explore the change in level of dissolved oxygen in water associated with photosynthesis of aquatic plants.

Materials and Equipment Needed

- 2-PASPort DO sensors PS-2108
- 2-PASPort USB Links PS-2100[1]
- USB equipped computer running DataStudio software
- 100 watt incandescent lamp (or equivalent)
- Lab stand(s)
- Masking Tape
- Paper
- 2-Test Tubes (25mm x 150mm)
- 1-1000 mL beaker
- 1 healthy sprig of Elodea
- Deionized or clean fresh water

Background

Plants carry out the process of photosynthesis when conditions are appropriate. Plants take in reactants including carbon dioxide, water, and energy in the form of light. A waste product from the photosynthetic process is gaseous oxygen, which is released to the environment. For aquatic plants, this gas is released into the water, increasing the amount of dissolved oxygen present in the water.

The dissolved oxygen sensor is well-suited to monitor changing levels of molecular oxygen in the aqueous environment of the Elodea plant.

Tips for success:

- Set up and run the experiment far ahead of time, so that the procedure is familiar.
- Use fresh Elodea (the growing tip will give the best results).
- Allow water to reach equilibrium, in terms of the dissolved gases (this may take up to 24 hours)
- Submerge the DO sensor so that the metallic band is below the surface of the water.
- Use a full beaker of water for the water bath to control thermal fluctuations.
- Set up: (Complete steps 1-4 in advance)

1. or other PASPort interface

Procedure

1. Perform a test run on the DO sensor(s) to ensure that the membrane is intact.

2. Arrange equipment so that the two large test tubes are nearly full of water.

3. Clamp test tubes in place vertically, with the beaker as a water bath (to minimize temperature fluctuations).

4. With no plants in place, allow the entire system to reach equilibrium for about three to four hours (it is not harmful to exceed this time).

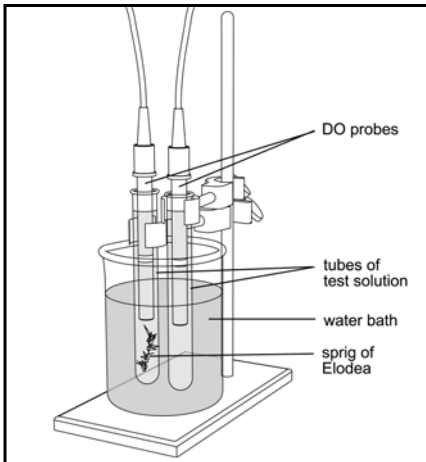


Figure 1
Equipment setup.

During the lab time

1. Insert each DO sensor into its respective test tube. Perform a virtual calibration in DataStudio so that the DO mg/L value is set at the same level for each sensor (7 mg/L is a good starting point). Absolute calibration is less important in this particular situation, since the goal is to measure relative change, instead of absolute dissolved oxygen.

2. Conduct a test run for approximately 30 seconds to ensure that the DO probes are reading values that are reasonably close to each other.

3. Remove the DO sensors. Do not allow the probe tip to contact other surfaces (it helps to clamp the probes to a rack, and then lift the entire rack until the probes are clear of the test tubes).

4. Gently and carefully insert a sprig (about 2-3 cm long) of the healthy green tip of the Elodea plant in one test tube (experiment). Insert a control, such as a plastic Elodea plant, in the other test tube (optional). Take care to avoid stirring or agitating the water in the test tubes more than necessary.

5. Reinsert the DO sensors until the tip of the sensor is close to, but not touching the plant.

6. Use tape and a folded piece of paper to form a light mask around the upper part of the beaker, such that it's lower edge is even with the bottom of the DO sensor probe tip.

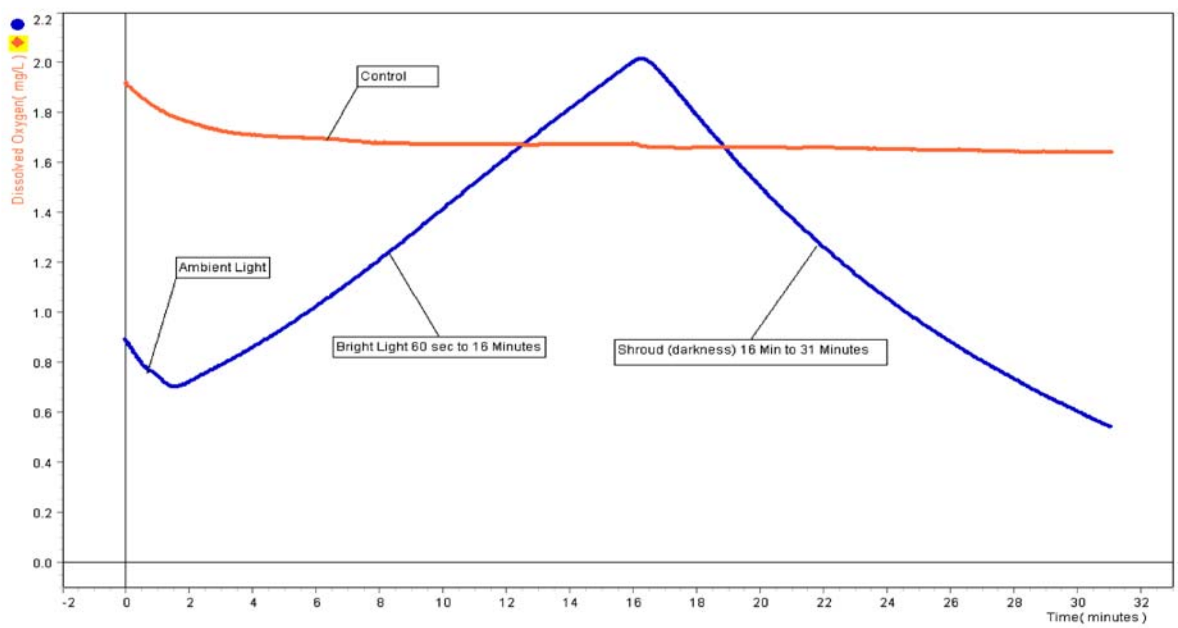
7. Position the light about one meter away from the beaker, so that it can illuminate the plants through the side of the beaker (horizontally). Turn the light on for a momentary check of positioning then turn it off.

Collecting Data

8. Begin collecting data. Allow the system to take in ambient light for 60 seconds, and then cover the entire set up with an opaque cloth, such as a rubberized lab apron. After fifteen minutes, remove the cover and turn on the light. Continue to collect data for another fifteen minutes. Stop data collection.

9. If desired, conduct additional data runs in a similar manner.

Sample Data



Analysis

1. Discuss the reasons for use of a control in this experiment.

2. Why was it not necessary to calibrate the sensors to an absolute standard?

Experiment 3: Effect of Sodium Sulfite on Dissolved O_2 Concentrations

Materials and Equipment Needed

- Dissolved Oxygen Sensor
- PASPort interface or logger
- 2 M sodium sulfite (25.2 g Na_2SO_3/100 ml)
- aquarium pump or large bottle
- PASPort USB Interface and DataStudio software
- 600 ml beaker
- 400 ml deionized water
- pipet

Optional Materials

- hot plate/stir plate and magnetic stir bar

CAUTION: Sodium sulfite is a potential skin irritant. Use safety glasses and avoid skin contact. Skin that contacts the solution should be rinsed liberally with water.

Purpose

The purpose of the experiment is to explore the effect of the inorganic chemical, sodium sulfite on dissolved O_2 concentrations. Sodium sulfite (Na_2SO_3) is a commonly used chemical in photographic developers, paper making, dyeing, bleaching, and engraving.

Procedure

1. Set up and calibrate the Dissolved Oxygen Sensor.

2. Saturate the deionized water with air by vigorously shaking the water in a bottle or by bubbling with the aquarium pump.

3. Monitor the dissolved O_2 concentrations of the deionized water while stirring gently with the dissolved O_2 probe.

4. When the meter reading stabilizes, record for 30 seconds.

5. After 30 seconds, add 1 ml of the 2 M Na_2SO_3 solution into the water.

6. Continue stirring the solution and recording until the reaction stops.

7. Stop recording and save your data.

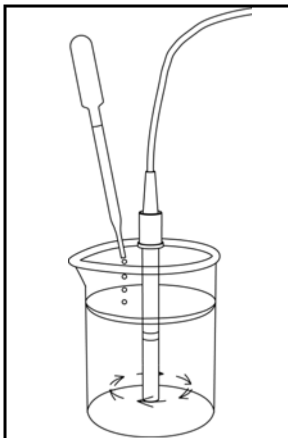


Figure 3
Stir test solution with probe while adding sodium sulfite.

Questions

1. Describe the effect of sodium sulfite on dissolved O_2 concentrations.

2. Discuss some potential environmental effects of untreated effluent from industries or businesses such as paper mills and photo labs that may use sodium sulfite.

Experiment 4: Biochemical Oxygen Demand [1]

Background

Biochemical oxygen demand (BOD) is an important measure of water quality. BOD is a measurement of the quantity of oxygen used by microorganisms in the aerobic oxidation of organic matter. In rivers and streams with high BOD levels, much of the available dissolved oxygen is consumed by aerobic bacteria, robbing other aquatic organisms of the oxygen they need to live. This is a condition that may be exacerbated by excessive nitrogenous wastes in runoff water.

Procedure

1. Measure the dissolved O_2 concentration and water temperature in a waterway, preferably on site using the PASPort logger of choice, with the dissolved oxygen sensor.

2. Collect a sample of the water in an airtight, black bottle, and incubate the water sample at room temperature for 5 days.

3. Bring the water sample to approximately the same temperature as the first sample and measure the dissolved O_2 concentration.

4. Calculate the BOD level: mg/l dissolved O_2 (original sample) - mg/l dissolved O_2 (5-day old sample).

5. Score the BOD as follows:

    4 (excellent): less than 2 mg/l
    3 (good): 2- 4mg/l
    2 (fair): 4.1-10 mg/l
    1 (poor): greater than 10 mg/l

1.Adapted from a 1996 publication by Stevens Institute of Technology

Experiment 5: The Effect Of Respiration On Dissolved O_2 Concentration

Purpose

The purpose of the experiment is to explore the effect of respiration on dissolved O_2 concentrations.

Materials required

- Dissolved Oxygen Sensor (PS-2108)
- 400 ml deionized water
- PASPort interface hardware and DataStudio software
- aquarium pump or large bottle
- 1 package rapid active yeast
- 600 ml beaker (2)
- table sugar

Optional materials

- hot plate/stir plate and magnetic stir bar

Procedure

1. Follow the directions on the yeast package to activate the yeast in a beaker using tap water and sugar.
2. Set up and calibrate the Dissolved Oxygen Sensor.
3. Stir 1 teaspoon sugar into the deionized water and saturate it with air.
4. Monitor the dissolved O_2 concentrations of the deionized sugar water while stirring gently with the dissolved O_2 probe.
5. When the reading stabilizes, click the Start button in DataStudio and record data for 30 seconds.

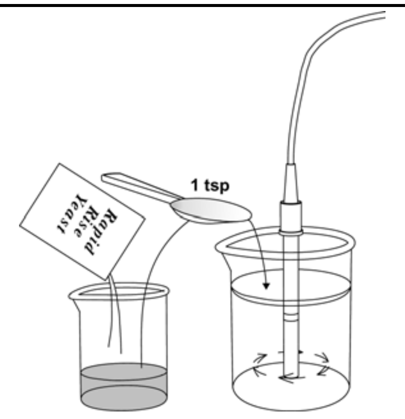


Figure 1
Transfer activated yeast solution to the test beaker.

6. After 30 seconds, transfer about 1 teaspoon of the activated yeast solution into the water.
7. Continue stirring with the probe and recording data for about 10 minutes or until the oxygen level stabilizes.

8. Stop recording and save the data.

Questions

1. What is the evidence that the yeast cells are alive and respiring during the experiment?
2. What happens to the yeast cells when the dissolved O2 concentration reaches zero? (Hint: Look carefully at the beaker that contains the concentrated yeast solution and think about how yeast is used in industry.)

Appendix A: Copyright and Warranty Information

Copyright Notice

Limited Warranty

PASCO scientific warrants the product to be free from defects in materials and workmanship for a period of one year from the date of shipment to the customer. PASCO will repair or replace at its option any part of the product which is deemed to be defective in material or workmanship. The warranty does not cover damage to the product caused by abuse or improper use. Determination of whether a product failure is the result of a manufacturing defect or improper use by the customer shall be made solely by PASCO scientific. Responsibility for the return of equipment for warranty repair belongs to the customer. Equipment must be properly packed to prevent damage and shipped postage or freight prepaid. (Damage caused by improper packing of the equipment for return shipment will not be covered by the warranty.) Shipping costs for returning the equipment after repair will be paid by PASCO scientific.

Equipment Return

Should the product have to be returned to PASCO scientific for any reason, notify PASCO scientific by email, letter, phone, or fax BEFORE returning the product. Upon notification, the return authorization and shipping instructions will be promptly issued.

NOTE: NO EQUIPMENT WILL BE ACCEPTED FOR RETURN WITHOUT AN AUTHORIZATION FROM PASCO.

When returning equipment for repair, the units must be packed properly. Carriers will not accept responsibility for damage caused by improper packing. To be certain the unit will not be damaged in shipment, observe the following rules:

1. The packing carton must be strong enough for the item shipped.
2. Make certain there are at least two inches of packing material between any point on the apparatus and the inside walls of the carton.
3. Make certain that the packing material cannot shift in the box or become compressed, allowing the instrument come in contact with the packing carton.

Appendix B: Specifications, Replacement Parts, Technical Support

Specifications

- Cathode: platinum
- Anode: silver/silver chloride
- Response: 98% in 60 seconds
- Stability: Better than 2%
- Fully temperature compensated: 10 °C - 40 °C
- Temperature range: 0 °C - 60 °C
- Output (medium saturated with air): 240 -320 nA
- Membrane: 1 ml silicon
- Probe body: PVC

Replacement Parts

Order from PASCO (1-800-772-8700)
Replacement kit (part number CI-6541) includes:

- Three dissolved O_2 probe membrane cartridge
- three O-rings
- bottle of dissolved O_2 probe filling solution (contains enough solution to refill the probe about ten times)
- 10 ml syringe
- Plunger tool

Technical Support

For assistance with the PS-2108 Dissolved Oxygen Sensor or any other PASCO products, contact PASCO as follows:

Address: PASCO scientific
10101 Foothills Blvd.
Roseville, CA 95747-7100

Phone: (800) 772-8700 (toll-free within U.S.)
Phone: (916) 786-3800
FAX: (916) 786-3292
Web: www.pasco.com
Email: support@pasco.com

Appendix C: Tables

Table 1: Concentration of dissolved oxygen (mg/L) in water at various temperatures and pressures

From R. F. Weiss (1970). Temp ° C, temperature in degrees Celsius;
atmospheric pressures from 695-600 millimeters mercury (27.36-23.62 “Hg) begin after 40° C

Conversion Factors: 1.0 “Hg = 25.4 mmHg = 33.86 mb or hPa

Temp.	Atmospheric pressure, in millimeters of mercury and (inches of mercury)																			
°C	795 (31.30)	790 (31.10)	785 (30.91)	780 (30.71)	775 (30.51)	770 (30.31)	765 (30.12)	760 (29.92)	755 (29.72)	750 (29.53)	745 (29.33)	740 (29.13)	735 (28.94)	730 (28.74)	725 (28.54)	720 (28.35)	715 (28.15)	710 (27.95)	705 (27.76)	700 (27.56)
0.0	15.3	15.2	15.1	15.0	14.9	14.8	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4
0.5	15.1	15.0	14.9	14.8	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2
1.0	14.8	14.7	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2	13.2	13.1
1.5	14.6	14.5	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2	13.2	13.1	13.0	12.9
2.0	14.4	14.3	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7
2.5	14.2	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5
3.0	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.5	12.4
3.5	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.6	12.5	12.4	12.3	12.2
4.0	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.6	12.5	12.4	12.3	12.2	12.1	12.0
4.5	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.1	12.0	11.9
5.0	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.7	12.6	12.5	12.4	12.3	12.2	12.2	12.1	12.0	11.9	11.8	11.7
5.5	13.2	13.1	13.0	12.9	12.8	12.7	12.7	12.6	12.5	12.4	12.3	12.2	12.2	12.1	12.0	11.9	11.8	11.7	11.7	11.6
6.0	13.0	12.9	12.8	12.8	12.7	12.6	12.5	12.4	12.3	12.3	12.2	12.1	12.0	11.9	11.8	11.8	11.7	11.6	11.5	11.4
6.5	12.8	12.8	12.7	12.6	12.5	12.4	12.3	12.3	12.2	12.1	12.0	11.9	11.9	11.8	11.7	11.6	11.5	11.5	11.4	11.3
7.0	12.7	12.6	12.5	12.4	12.4	12.3	12.2	12.1	12.0	12.0	11.9	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.2	11.1
7.5	12.5	12.4	12.4	12.3	12.2	12.1	12.0	12.0	11.9	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.3	11.2	11.1	11.0
8.0	12.4	12.3	12.2	12.1	12.1	12.0	11.9	11.8	11.7	11.7	11.6	11.5	11.4	11.3	11.3	11.2	11.1	11.0	11.0	10.9
8.5	12.2	12.1	12.1	12.0	11.9	11.8	11.8	11.7	11.6	11.5	11.4	11.4	11.3	11.2	11.1	11.1	11.0	10.9	10.8	10.7
9.0	12.1	12.0	11.9	11.8	11.8	11.7	11.6	11.5	11.5	11.4	11.3	11.2	11.2	11.1	11.0	10.9	10.8	10.8	10.7	10.6
9.5	11.9	11.9	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.2	11.2	11.1	11.0	10.9	10.9	10.8	10.7	10.6	10.6	10.5
10.0	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.3	11.2	11.1	11.0	11.0	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.4
10.5	11.7	11.6	11.5	11.4	11.4	11.3	11.2	11.1	11.1	11.0	10.9	10.8	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.2
11.0	11.5	11.4	11.4	11.3	11.2	11.2	11.1	11.0	10.9	10.9	10.8	10.7	10.6	10.6	10.5	10.4	10.3	10.3	10.2	10.1
11.5	11.4	11.3	11.2	11.2	11.1	11.0	11.0	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.2	10.1	10.0
12.0	11.3	11.2	11.1	11.0	11.0	10.9	10.8	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.3	10.2	10.1	10.0	10.0	9.9
12.5	11.1	11.1	11.0	10.9	10.8	10.8	10.7	10.6	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.1	10.0	9.9	9.9	9.8
13.0	11.0	10.9	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.2	10.1	10.0	10.0	9.9	9.8	9.7	9.7
13.5	10.9	10.8	10.7	10.7	10.6	10.5	10.5	10.4	10.3	10.3	10.2	10.1	10.1	10.0	9.9	9.8	9.8	9.7	9.6	9.6
14.0	10.8	10.7	10.6	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.1	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5	9.5

Temp.	Atmospheric pressure, in millimeters of mercury and (inches of mercury)																			
°C	795 (31.30)	790 (31.10)	785 (30.91)	780 (30.71)	775 (30.51)	770 (30.31)	765 (30.12)	760 (29.92)	755 (29.72)	750 (29.53)	745 (29.33)	740 (29.13)	735 (28.94)	730 (28.74)	725 (28.54)	720 (28.35)	715 (28.15)	710 (27.95)	705 (27.76)	700 (27.56)
14.5	10.6	10.6	10.5	10.4	10.4	10.3	10.2	10.2	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4
15.0	10.5	10.5	10.4	10.3	10.3	10.2	10.1	10.1	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3
15.5	10.4	10.4	10.3	10.2	10.2	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.2	9.2
16.0	10.3	10.2	10.2	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.1	9.1
16.5	10.2	10.1	10.1	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.4	9.3	9.2	9.2	9.1	9.0	9.0
17.0	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.9
17.5	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.8	8.8
18.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.7	8.7
18.5	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.7	8.6
19.0	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.8	8.7	8.6	8.6	8.5
19.5	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.5	8.5	8.4
20.0	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.3
20.5	9.4	9.3	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3
21.0	9.3	9.2	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3	8.2	8.2
21.5	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3	8.2	8.1	8.1
22.0	9.1	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.1	8.0
22.5	9.0	9.0	8.9	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9
23.0	9.0	8.9	8.8	8.8	8.7	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.9
23.5	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.8	7.8
24.0	8.8	8.7	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7
24.5	8.7	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6
25.0	8.6	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.6
25.5	8.5	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5
26.0	8.5	8.4	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.5	7.4
26.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4
27.0	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.3	7.3
27.5	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2
28.0	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2
28.5	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.1	7.1
29.0	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0
29.5	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0
30.0	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9
30.5	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9
31.0	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8
31.5	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7
32.0	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7
32.5	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6
33.0	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6

Temp.	Atmospheric pressure, in millimeters of mercury and (inches of mercury)																			
°C	795 (31.30)	790 (31.10)	785 (30.91)	780 (30.71)	775 (30.51)	770 (30.31)	765 (30.12)	760 (29.92)	755 (29.72)	750 (29.53)	745 (29.33)	740 (29.13)	735 (28.94)	730 (28.74)	725 (28.54)	720 (28.35)	715 (28.15)	710 (27.95)	705 (27.76)	700 (27.56)
33.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5
34.0	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.5	6.5
34.5	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.5	6.4
35.0	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3
35.5	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3
36.0	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2
36.5	7.1	7.0	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2
37.0	7.0	7.0	6.9	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1
37.5	7.0	6.9	6.9	6.8	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1
38.0	6.9	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0
38.5	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0
39.0	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	6.0
39.5	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	6.0	5.9
40.0	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.9

Temp.	Atmospheric pressure, in millimeters of mercury and (inches of mercury)																			
°C	695 (27.36)	690 (27.17)	685 (26.97)	680 (26.77)	675 (26.57)	670 (26.38)	665 (26.18)	660 (25.98)	655 (25.79)	650 (25.59)	645 (25.39)	640 (25.20)	635 (25.00)	630 (24.80)	625 (24.61)	620 (24.41)	615 (24.21)	610 (24.02)	605 (23.82)	600 (23.62)
0.0	13.3	13.2	13.1	13.0	12.9	12.8	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5
0.5	13.1	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3
1.0	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.2
1.5	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0
2.0	12.6	12.5	12.4	12.3	12.2	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.1	11.0	10.9
2.5	12.4	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7
3.0	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.9	10.8	10.7	10.6
3.5	12.1	12.0	11.9	11.8	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4
4.0	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.3
4.5	11.8	11.7	11.6	11.5	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.3	10.2
5.0	11.6	11.6	11.5	11.4	11.3	11.2	11.1	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.2	10.1	10.0
5.5	11.5	11.4	11.3	11.2	11.2	11.1	11.0	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.3	10.2	10.2	10.1	10.0	9.9
6.0	11.4	11.3	11.2	11.1	11.0	10.9	10.9	10.8	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.0	9.9	9.9	9.8
6.5	11.2	11.1	11.0	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.4	10.3	10.2	10.1	10.1	10.0	9.9	9.8	9.7	9.7
7.0	11.1	11.0	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.3	10.3	10.2	10.1	10.0	9.9	9.9	9.8	9.7	9.6	9.5
7.5	10.9	10.9	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.2	10.1	10.1	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.4
8.0	10.8	10.7	10.6	10.6	10.5	10.4	10.3	10.2	10.2	10.1	10.0	9.9	9.9	9.8	9.7	9.6	9.5	9.5	9.4	9.3

Temp.	Atmospheric pressure, in millimeters of mercury and (inches of mercury)																			
°C	695 (27.36)	690 (27.17)	685 (26.97)	680 (26.77)	675 (26.57)	670 (26.38)	665 (26.18)	660 (25.98)	655 (25.79)	650 (25.59)	645 (25.39)	640 (25.20)	635 (25.00)	630 (24.80)	625 (24.61)	620 (24.41)	615 (24.21)	610 (24.02)	605 (23.82)	600 (23.62)
8.5	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.0	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.4	9.3	9.3	9.2
9.0	10.5	10.5	10.4	10.3	10.2	10.2	10.1	10.0	9.9	9.8	9.8	9.7	9.6	9.5	9.5	9.4	9.3	9.2	9.2	9.1
9.5	10.4	10.3	10.3	10.2	10.1	10.0	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.4	9.4	9.3	9.2	9.1	9.0	9.0
10.0	10.3	10.2	10.1	10.1	10.0	9.9	9.8	9.8	9.7	9.6	9.5	9.5	9.4	9.3	9.2	9.2	9.1	9.0	8.9	8.9
10.5	10.2	10.1	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5	9.4	9.4	9.3	9.2	9.1	9.1	9.0	8.9	8.8	8.8
11.0	10.1	10.0	9.9	9.8	9.8	9.7	9.6	9.5	9.5	9.4	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.8	8.7	8.7
11.5	9.9	9.9	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.2	9.1	9.1	9.0	8.9	8.8	8.8	8.7	8.6	8.6
12.0	9.8	9.8	9.7	9.6	9.5	9.5	9.4	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.8	8.7	8.7	8.6	8.5	8.5
12.5	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.7	8.6	8.6	8.5	8.4	8.4
13.0	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.6	8.5	8.5	8.4	8.3	8.3
13.5	9.5	9.4	9.4	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.3	8.2	8.2
14.0	9.4	9.3	9.3	9.2	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.2	8.2	8.1
14.5	9.3	9.2	9.2	9.1	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.1	8.1	8.0
15.0	9.2	9.1	9.1	9.0	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.0	8.0	7.9
15.5	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.8
16.0	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.1	8.1	8.0	7.9	7.9	7.8	7.7
16.5	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7
17.0	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.6	7.6
17.5	8.7	8.6	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.1	8.1	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.5
18.0	8.6	8.6	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.5	7.5	7.4
18.5	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.5	7.5	7.4	7.3
19.0	8.4	8.4	8.3	8.3	8.2	8.1	8.1	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.3
19.5	8.4	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.2	7.2
20.0	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.5	7.5	7.4	7.4	7.3	7.2	7.2	7.1
20.5	8.2	8.1	8.1	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.0
21.0	8.1	8.1	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.0	7.0
21.5	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.3	7.2	7.1	7.1	7.0	7.0	6.9
22.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.5	7.5	7.4	7.4	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.8
22.5	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	6.9	6.9	6.8	6.8
23.0	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7
23.5	7.7	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.0	7.0	6.9	6.9	6.8	6.7	6.7	6.6
24.0	7.7	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.7	6.7	6.6	6.6
24.5	7.6	7.5	7.5	7.4	7.4	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5
25.0	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.4
25.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.4	6.4
26.0	7.4	7.3	7.3	7.2	7.2	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.5	6.5	6.4	6.4	6.3
26.5	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3

Temp.	Atmospheric pressure, in millimeters of mercury and (inches of mercury)																			
°C	695 (27.36)	690 (27.17)	685 (26.97)	680 (26.77)	675 (26.57)	670 (26.38)	665 (26.18)	660 (25.98)	655 (25.79)	650 (25.59)	645 (25.39)	640 (25.20)	635 (25.00)	630 (24.80)	625 (24.61)	620 (24.41)	615 (24.21)	610 (24.02)	605 (23.82)	600 (23.62)
27.0	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2
27.5	7.2	7.1	7.1	7.0	7.0	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2
28.0	7.1	7.1	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.1	6.1
28.5	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.2	6.2	6.1	6.1	6.0
29.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.2	6.2	6.1	6.1	6.0	6.0
29.5	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9
30.0	6.9	6.8	6.8	6.7	6.7	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9
30.5	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8
31.0	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8
31.5	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7
32.0	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7
32.5	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6
33.0	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6
33.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5
34.0	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5
34.5	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4
35.0	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4
35.5	6.2	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3
36.0	6.2	6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3
36.5	6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.2
37.0	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.3	5.2
37.5	6.0	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.3	5.2	5.2
38.0	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.1
38.5	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.2	5.2	5.1	5.1
39.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.2	5.2	5.1	5.1	5.0
39.5	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.2	5.2	5.1	5.1	5.0	5.0
40.0	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.2	5.2	5.1	5.1	5.0	5.0	5.0

Table 2: Salinity correction factors for dissolved oxygen in water (based on conductivity)

From R. F. Weiss (1970). Temp ° C, temperature in degrees Celsius;

Temp.	Conductivity, in microsiemens per centimeter at 25 degrees Celsius																
°C	0	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000
0.0	1.000	0.996	0.992	0.989	0.985	0.981	0.977	0.973	0.969	0.965	0.961	0.957	0.953	0.950	0.946	0.942	0.938
1.0	1.000	0.996	0.992	0.989	0.985	0.981	0.977	0.973	0.969	0.965	0.962	0.958	0.954	0.950	0.946	0.942	0.938
2.0	1.000	0.996	0.992	0.989	0.985	0.981	0.977	0.973	0.970	0.966	0.962	0.958	0.954	0.950	0.946	0.942	0.938
3.0	1.000	0.996	0.993	0.989	0.985	0.981	0.977	0.974	0.970	0.966	0.962	0.958	0.954	0.951	0.947	0.943	0.939
4.0	1.000	0.996	0.993	0.989	0.985	0.981	0.978	0.974	0.970	0.966	0.962	0.959	0.955	0.951	0.947	0.943	0.939
5.0	1.000	0.996	0.993	0.989	0.985	0.981	0.978	0.974	0.970	0.966	0.963	0.959	0.955	0.951	0.947	0.944	0.940
6.0	1.000	0.996	0.993	0.989	0.985	0.982	0.978	0.974	0.970	0.967	0.963	0.959	0.955	0.952	0.948	0.944	0.940
7.0	1.000	0.996	0.993	0.989	0.985	0.982	0.978	0.974	0.971	0.967	0.963	0.959	0.956	0.952	0.948	0.944	0.941
8.0	1.000	0.996	0.993	0.989	0.986	0.982	0.978	0.975	0.971	0.967	0.963	0.960	0.956	0.952	0.949	0.945	0.941
9.0	1.000	0.996	0.993	0.989	0.986	0.982	0.978	0.975	0.971	0.967	0.964	0.960	0.956	0.953	0.949	0.945	0.941
10.0	1.000	0.996	0.993	0.989	0.986	0.982	0.979	0.975	0.971	0.968	0.964	0.960	0.957	0.953	0.949	0.946	0.942
11.0	1.000	0.996	0.993	0.989	0.986	0.982	0.979	0.975	0.971	0.968	0.964	0.961	0.957	0.953	0.950	0.946	0.942
12.0	1.000	0.997	0.993	0.989	0.986	0.982	0.979	0.975	0.972	0.968	0.965	0.961	0.957	0.954	0.950	0.946	0.943
13.0	1.000	0.997	0.993	0.990	0.986	0.983	0.979	0.975	0.972	0.968	0.965	0.961	0.958	0.954	0.950	0.947	0.943
14.0	1.000	0.997	0.993	0.990	0.986	0.983	0.979	0.976	0.972	0.969	0.965	0.961	0.958	0.954	0.951	0.947	0.943
15.0	1.000	0.997	0.993	0.990	0.986	0.983	0.979	0.976	0.972	0.969	0.965	0.962	0.958	0.955	0.951	0.947	0.944
16.0	1.000	0.997	0.993	0.990	0.986	0.983	0.979	0.976	0.972	0.969	0.966	0.962	0.958	0.955	0.951	0.948	0.944
17.0	1.000	0.997	0.993	0.990	0.986	0.983	0.980	0.976	0.973	0.969	0.966	0.962	0.959	0.955	0.952	0.948	0.945
18.0	1.000	0.997	0.993	0.990	0.987	0.983	0.980	0.976	0.973	0.969	0.966	0.963	0.959	0.956	0.952	0.949	0.945
19.0	1.000	0.997	0.993	0.990	0.987	0.983	0.980	0.976	0.973	0.970	0.966	0.963	0.959	0.956	0.952	0.949	0.945
20.0	1.000	0.997	0.993	0.990	0.987	0.983	0.980	0.977	0.973	0.970	0.966	0.963	0.960	0.956	0.953	0.949	0.946
21.0	1.000	0.997	0.993	0.990	0.987	0.984	0.980	0.977	0.973	0.970	0.967	0.963	0.960	0.957	0.953	0.950	0.946
22.0	1.000	0.997	0.993	0.990	0.987	0.984	0.980	0.977	0.974	0.970	0.967	0.964	0.960	0.957	0.953	0.950	0.947
23.0	1.000	0.997	0.994	0.990	0.987	0.984	0.980	0.977	0.974	0.971	0.967	0.964	0.960	0.957	0.954	0.950	0.947
24.0	1.000	0.997	0.994	0.990	0.987	0.984	0.981	0.977	0.974	0.971	0.967	0.964	0.961	0.957	0.954	0.951	0.947
25.0	1.000	0.997	0.994	0.990	0.987	0.984	0.981	0.977	0.974	0.971	0.968	0.964	0.961	0.958	0.954	0.951	0.948
26.0	1.000	0.997	0.994	0.990	0.987	0.984	0.981	0.978	0.974	0.971	0.968	0.965	0.961	0.958	0.955	0.951	0.948
27.0	1.000	0.997	0.994	0.991	0.987	0.984	0.981	0.978	0.975	0.971	0.968	0.965	0.962	0.958	0.955	0.952	0.948
28.0	1.000	0.997	0.994	0.991	0.987	0.984	0.981	0.978	0.975	0.972	0.968	0.965	0.962	0.959	0.955	0.952	0.949
29.0	1.000	0.997	0.994	0.991	0.988	0.984	0.981	0.978	0.975	0.972	0.969	0.965	0.962	0.959	0.956	0.952	0.949

Temp.	Conductivity, in microsiemens per centimeter at 25 degrees Celsius																
°C	0	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000
30.0	1.000	0.997	0.994	0.991	0.988	0.985	0.981	0.978	0.975	0.972	0.969	0.966	0.962	0.959	0.956	0.953	0.950
31.0	1.000	0.997	0.994	0.991	0.988	0.985	0.982	0.978	0.975	0.972	0.969	0.966	0.963	0.959	0.956	0.953	0.950
32.0	1.000	0.997	0.994	0.991	0.988	0.985	0.982	0.979	0.975	0.972	0.969	0.966	0.963	0.960	0.957	0.953	0.950
33.0	1.000	0.997	0.994	0.991	0.988	0.985	0.982	0.979	0.976	0.973	0.969	0.966	0.963	0.960	0.957	0.954	0.951
34.0	1.000	0.997	0.994	0.991	0.988	0.985	0.982	0.979	0.976	0.973	0.970	0.967	0.963	0.960	0.957	0.954	0.951
35.0	1.000	0.997	0.994	0.991	0.988	0.985	0.982	0.979	0.976	0.973	0.970	0.967	0.964	0.961	0.957	0.954	0.951

Temp.	Conductivity, in microsiemens per centimeter at 25 degrees Celsius																
°C	17000	18000	19000	20000	21000	22000	23000	24000	25000	26000	27000	28000	29000	30000	31000	32000	33000
0.0	0.934	0.930	0.926	0.922	0.918	0.914	0.910	0.905	0.901	0.897	0.893	0.889	0.885	0.881	0.877	0.873	0.869
1.0	0.934	0.930	0.926	0.922	0.918	0.914	0.910	0.906	0.902	0.898	0.894	0.890	0.886	0.882	0.878	0.874	0.870
2.0	0.935	0.931	0.927	0.923	0.919	0.915	0.911	0.907	0.903	0.899	0.895	0.891	0.887	0.883	0.879	0.875	0.871
3.0	0.935	0.931	0.927	0.923	0.919	0.915	0.911	0.907	0.903	0.899	0.895	0.891	0.887	0.883	0.879	0.875	0.871
4.0	0.935	0.932	0.928	0.924	0.920	0.916	0.912	0.908	0.904	0.900	0.896	0.892	0.888	0.884	0.880	0.876	0.872
5.0	0.936	0.932	0.928	0.924	0.920	0.917	0.913	0.909	0.905	0.901	0.897	0.893	0.889	0.885	0.881	0.877	0.873
6.0	0.936	0.933	0.929	0.925	0.921	0.917	0.913	0.909	0.905	0.902	0.898	0.894	0.890	0.886	0.882	0.878	0.874
7.0	0.937	0.933	0.929	0.925	0.922	0.918	0.914	0.910	0.906	0.902	0.898	0.894	0.891	0.887	0.883	0.879	0.875
8.0	0.937	0.933	0.930	0.926	0.922	0.918	0.914	0.911	0.907	0.903	0.899	0.895	0.891	0.887	0.884	0.880	0.876
9.0	0.938	0.934	0.930	0.926	0.923	0.919	0.915	0.911	0.907	0.904	0.900	0.896	0.892	0.888	0.884	0.880	0.877
10.0	0.938	0.934	0.931	0.927	0.923	0.919	0.916	0.912	0.908	0.904	0.900	0.897	0.893	0.889	0.885	0.881	0.877
11.0	0.939	0.935	0.931	0.927	0.924	0.920	0.916	0.912	0.909	0.905	0.901	0.897	0.894	0.890	0.886	0.882	0.878
12.0	0.939	0.935	0.932	0.928	0.924	0.920	0.917	0.913	0.909	0.906	0.902	0.898	0.894	0.890	0.887	0.883	0.879
13.0	0.939	0.936	0.932	0.928	0.925	0.921	0.917	0.914	0.910	0.906	0.902	0.899	0.895	0.891	0.887	0.884	0.880
14.0	0.940	0.936	0.933	0.929	0.925	0.922	0.918	0.914	0.911	0.907	0.903	0.899	0.896	0.892	0.888	0.884	0.881
15.0	0.940	0.937	0.933	0.929	0.926	0.922	0.918	0.915	0.911	0.907	0.904	0.900	0.896	0.893	0.889	0.885	0.882
16.0	0.941	0.937	0.934	0.930	0.926	0.923	0.919	0.915	0.912	0.908	0.904	0.901	0.897	0.893	0.890	0.886	0.882
17.0	0.941	0.938	0.934	0.930	0.927	0.923	0.920	0.916	0.912	0.909	0.905	0.901	0.898	0.894	0.891	0.887	0.883
18.0	0.942	0.938	0.934	0.931	0.927	0.924	0.920	0.917	0.913	0.909	0.906	0.902	0.899	0.895	0.891	0.888	0.884
19.0	0.942	0.938	0.935	0.931	0.928	0.924	0.921	0.917	0.914	0.910	0.906	0.903	0.899	0.896	0.892	0.888	0.885
20.0	0.942	0.939	0.935	0.932	0.928	0.925	0.921	0.918	0.914	0.911	0.907	0.903	0.900	0.896	0.893	0.889	0.886
21.0	0.943	0.939	0.936	0.932	0.929	0.925	0.922	0.918	0.915	0.911	0.908	0.904	0.901	0.897	0.893	0.890	0.886
22.0	0.943	0.940	0.936	0.933	0.929	0.926	0.922	0.919	0.915	0.912	0.908	0.905	0.901	0.898	0.894	0.891	0.887
23.0	0.944	0.940	0.937	0.933	0.930	0.926	0.923	0.919	0.916	0.912	0.909	0.905	0.902	0.898	0.895	0.891	0.888

Temp.	Conductivity, in microsiemens per centimeter at 25 degrees Celsius															
°C	17000	18000	19000	20000	21000	22000	23000	24000	25000	26000	27000	28000	29000	30000	31000	32000	33000
24.0	0.944	0.941	0.937	0.934	0.930	0.927	0.923	0.920	0.917	0.913	0.910	0.906	0.903	0.899	0.896	0.892	0.889
25.0	0.944	0.941	0.938	0.934	0.931	0.927	0.924	0.921	0.917	0.914	0.910	0.907	0.903	0.900	0.896	0.893	0.889
26.0	0.945	0.941	0.938	0.935	0.931	0.928	0.925	0.921	0.918	0.914	0.911	0.907	0.904	0.901	0.897	0.894	0.890
27.0	0.945	0.942	0.938	0.935	0.932	0.928	0.925	0.922	0.918	0.915	0.911	0.908	0.905	0.901	0.898	0.894	0.891
28.0	0.946	0.942	0.939	0.936	0.932	0.929	0.926	0.922	0.919	0.915	0.912	0.909	0.905	0.902	0.898	0.895	0.892
29.0	0.946	0.943	0.939	0.936	0.933	0.929	0.926	0.923	0.919	0.916	0.913	0.909	0.906	0.903	0.899	0.896	0.892
30.0	0.946	0.943	0.940	0.936	0.933	0.930	0.927	0.923	0.920	0.917	0.913	0.910	0.907	0.903	0.900	0.896	0.893
31.0	0.947	0.943	0.940	0.937	0.934	0.930	0.927	0.924	0.920	0.917	0.914	0.911	0.907	0.904	0.901	0.897	0.894
32.0	0.947	0.944	0.941	0.937	0.934	0.931	0.928	0.924	0.921	0.918	0.914	0.911	0.908	0.905	0.901	0.898	0.895
33.0	0.947	0.944	0.941	0.938	0.935	0.931	0.928	0.925	0.922	0.918	0.915	0.912	0.908	0.905	0.902	0.899	0.895
34.0	0.948	0.945	0.941	0.938	0.935	0.932	0.929	0.925	0.922	0.919	0.916	0.912	0.909	0.906	0.903	0.899	0.896
35.0	0.948	0.945	0.942	0.939	0.935	0.932	0.929	0.926	0.923	0.919	0.916	0.913	0.910	0.906	0.903	0.900	0.897

Temp.	Conductivity, in microsiemens per centimeter at 25 degrees Celsius															
°C	34000	35000	36000	37000	38000	39000	40000	41000	42000	43000	44000	45000	46000	47000	48000	49000	50000
0.0	0.865	0.861	0.856	0.852	0.848	0.844	0.840	0.836	0.832	0.828	0.823	0.819	0.815	0.811	0.807	0.803	0.799
1.0	0.866	0.862	0.857	0.853	0.849	0.845	0.841	0.837	0.833	0.829	0.825	0.821	0.816	0.812	0.808	0.804	0.800
2.0	0.867	0.862	0.858	0.854	0.850	0.846	0.842	0.838	0.834	0.830	0.826	0.822	0.818	0.814	0.809	0.805	0.801
3.0	0.867	0.863	0.859	0.855	0.851	0.847	0.843	0.839	0.835	0.831	0.827	0.823	0.819	0.815	0.811	0.807	0.803
4.0	0.868	0.864	0.860	0.856	0.852	0.848	0.844	0.840	0.836	0.832	0.828	0.824	0.820	0.816	0.812	0.808	0.804
5.0	0.869	0.865	0.861	0.857	0.853	0.849	0.845	0.841	0.837	0.833	0.829	0.825	0.821	0.817	0.813	0.809	0.805
6.0	0.870	0.866	0.862	0.858	0.854	0.850	0.846	0.842	0.838	0.834	0.830	0.826	0.822	0.818	0.814	0.810	0.806
7.0	0.871	0.867	0.863	0.859	0.855	0.851	0.847	0.843	0.839	0.835	0.831	0.828	0.824	0.820	0.816	0.812	0.808
8.0	0.872	0.868	0.864	0.860	0.856	0.852	0.848	0.844	0.840	0.837	0.833	0.829	0.825	0.821	0.817	0.813	0.809
9.0	0.873	0.869	0.865	0.861	0.857	0.853	0.849	0.845	0.842	0.838	0.834	0.830	0.826	0.822	0.818	0.814	0.810
10.0	0.874	0.870	0.866	0.862	0.858	0.854	0.850	0.846	0.843	0.839	0.835	0.831	0.827	0.823	0.819	0.815	0.811
11.0	0.874	0.871	0.867	0.863	0.859	0.855	0.851	0.848	0.844	0.840	0.836	0.832	0.828	0.824	0.820	0.817	0.813
12.0	0.875	0.871	0.868	0.864	0.860	0.856	0.852	0.849	0.845	0.841	0.837	0.833	0.829	0.825	0.822	0.818	0.814
13.0	0.876	0.872	0.869	0.865	0.861	0.857	0.853	0.850	0.846	0.842	0.838	0.834	0.830	0.827	0.823	0.819	0.815
14.0	0.877	0.873	0.869	0.866	0.862	0.858	0.854	0.851	0.847	0.843	0.839	0.835	0.832	0.828	0.824	0.820	0.816
15.0	0.878	0.874	0.870	0.867	0.863	0.859	0.855	0.852	0.848	0.844	0.840	0.836	0.833	0.829	0.825	0.821	0.817
16.0	0.879	0.875	0.871	0.867	0.864	0.860	0.856	0.853	0.849	0.845	0.841	0.838	0.834	0.830	0.826	0.822	0.819
17.0	0.879	0.876	0.872	0.868	0.865	0.861	0.857	0.854	0.850	0.846	0.842	0.839	0.835	0.831	0.827	0.824	0.820

Temp.	Conductivity, in microsiemens per centimeter at 25 degrees Celsius																
°C	34000	35000	36000	37000	38000	39000	40000	41000	42000	43000	44000	45000	46000	47000	48000	49000	50000
18.0	0.880	0.877	0.873	0.869	0.866	0.862	0.858	0.855	0.851	0.847	0.843	0.840	0.836	0.832	0.829	0.825	0.821
19.0	0.881	0.877	0.874	0.870	0.867	0.863	0.859	0.855	0.852	0.848	0.844	0.841	0.837	0.833	0.830	0.826	0.822
20.0	0.882	0.878	0.875	0.871	0.867	0.864	0.860	0.856	0.853	0.849	0.845	0.842	0.838	0.834	0.831	0.827	0.823
21.0	0.883	0.879	0.876	0.872	0.868	0.865	0.861	0.857	0.854	0.850	0.846	0.843	0.839	0.836	0.832	0.828	0.825
22.0	0.884	0.880	0.876	0.873	0.869	0.866	0.862	0.858	0.855	0.851	0.848	0.844	0.840	0.837	0.833	0.829	0.826
23.0	0.884	0.881	0.877	0.874	0.870	0.866	0.863	0.859	0.856	0.852	0.849	0.845	0.841	0.838	0.834	0.830	0.827
24.0	0.885	0.882	0.878	0.874	0.871	0.867	0.864	0.860	0.857	0.853	0.850	0.846	0.842	0.839	0.835	0.832	0.828
25.0	0.886	0.882	0.879	0.875	0.872	0.868	0.865	0.861	0.858	0.854	0.851	0.847	0.843	0.840	0.836	0.833	0.829
26.0	0.887	0.883	0.880	0.876	0.873	0.869	0.866	0.862	0.859	0.855	0.852	0.848	0.844	0.841	0.837	0.834	0.830
27.0	0.887	0.884	0.880	0.877	0.874	0.870	0.867	0.863	0.860	0.856	0.853	0.849	0.845	0.842	0.838	0.835	0.831
28.0	0.888	0.885	0.881	0.878	0.874	0.871	0.867	0.864	0.860	0.857	0.853	0.850	0.846	0.843	0.839	0.836	0.832
29.0	0.889	0.886	0.882	0.879	0.875	0.872	0.868	0.865	0.861	0.858	0.854	0.851	0.848	0.844	0.841	0.837	0.834
30.0	0.890	0.886	0.883	0.879	0.876	0.873	0.869	0.866	0.862	0.859	0.855	0.852	0.849	0.845	0.842	0.838	0.835
31.0	0.890	0.887	0.884	0.880	0.877	0.873	0.870	0.867	0.863	0.860	0.856	0.853	0.850	0.846	0.843	0.839	0.836
32.0	0.891	0.888	0.884	0.881	0.878	0.874	0.871	0.868	0.864	0.861	0.857	0.854	0.851	0.847	0.844	0.840	0.837
33.0	0.892	0.889	0.885	0.882	0.879	0.875	0.872	0.868	0.865	0.862	0.858	0.855	0.851	0.848	0.845	0.841	0.838
34.0	0.893	0.889	0.886	0.883	0.879	0.876	0.873	0.869	0.866	0.863	0.859	0.856	0.852	0.849	0.846	0.842	0.839
35.0	0.893	0.890	0.887	0.883	0.880	0.877	0.874	0.870	0.867	0.863	0.860	0.857	0.853	0.850	0.847	0.843	0.840

Temp.	Conductivity, in microsiemens per centimeter at 25 degrees Celsius																
°C	51000	52000	53000	54000	55000	56000	57000	58000	59000	60000	61000	62000	63000	64000	65000	66000	67000
0.0	0.795	0.790	0.786	0.782	0.778	0.774	0.770	0.766	0.761	0.757	0.753	0.749	0.745	0.741	0.737	0.732	0.728
1.0	0.796	0.792	0.788	0.783	0.779	0.775	0.771	0.767	0.763	0.759	0.755	0.751	0.746	0.742	0.738	0.734	0.730
2.0	0.797	0.793	0.789	0.785	0.781	0.777	0.773	0.768	0.764	0.760	0.756	0.752	0.748	0.744	0.740	0.736	0.732
3.0	0.798	0.794	0.790	0.786	0.782	0.778	0.774	0.770	0.766	0.762	0.758	0.754	0.750	0.746	0.741	0.737	0.733
4.0	0.800	0.796	0.792	0.788	0.784	0.780	0.775	0.771	0.767	0.763	0.759	0.755	0.751	0.747	0.743	0.739	0.735
5.0	0.801	0.797	0.793	0.789	0.785	0.781	0.777	0.773	0.769	0.765	0.761	0.757	0.753	0.749	0.745	0.741	0.737
6.0	0.802	0.798	0.794	0.790	0.786	0.782	0.778	0.774	0.770	0.766	0.762	0.758	0.754	0.750	0.746	0.742	0.738
7.0	0.804	0.800	0.796	0.792	0.788	0.784	0.780	0.776	0.772	0.768	0.764	0.760	0.756	0.752	0.748	0.744	0.740
8.0	0.805	0.801	0.797	0.793	0.789	0.785	0.781	0.777	0.773	0.769	0.765	0.761	0.757	0.753	0.749	0.745	0.742
9.0	0.806	0.802	0.798	0.794	0.790	0.787	0.783	0.779	0.775	0.771	0.767	0.763	0.759	0.755	0.751	0.747	0.743
10.0	0.807	0.804	0.800	0.796	0.792	0.788	0.784	0.780	0.776	0.772	0.768	0.764	0.760	0.757	0.753	0.749	0.745
11.0	0.809	0.805	0.801	0.797	0.793	0.789	0.785	0.781	0.778	0.774	0.770	0.766	0.762	0.758	0.754	0.750	0.746

Temp.	Conductivity, in microsiemens per centimeter at 25 degrees Celsius															
°C	51000	52000	53000	54000	55000	56000	57000	58000	59000	60000	61000	62000	63000	64000	65000	66000	67000
12.0	0.810	0.806	0.802	0.798	0.794	0.791	0.787	0.783	0.779	0.775	0.771	0.767	0.763	0.760	0.756	0.752	0.748
13.0	0.811	0.807	0.804	0.800	0.796	0.792	0.788	0.784	0.780	0.777	0.773	0.769	0.765	0.761	0.757	0.753	0.750
14.0	0.812	0.809	0.805	0.801	0.797	0.793	0.789	0.786	0.782	0.778	0.774	0.770	0.766	0.763	0.759	0.755	0.751
15.0	0.814	0.810	0.806	0.802	0.798	0.795	0.791	0.787	0.783	0.779	0.776	0.772	0.768	0.764	0.760	0.756	0.753
16.0	0.815	0.811	0.807	0.804	0.800	0.796	0.792	0.788	0.785	0.781	0.777	0.773	0.769	0.766	0.762	0.758	0.754
17.0	0.816	0.812	0.809	0.805	0.801	0.797	0.794	0.790	0.786	0.782	0.778	0.775	0.771	0.767	0.763	0.760	0.756
18.0	0.817	0.814	0.810	0.806	0.802	0.799	0.795	0.791	0.787	0.784	0.780	0.776	0.772	0.769	0.765	0.761	0.757
19.0	0.819	0.815	0.811	0.807	0.804	0.800	0.796	0.792	0.789	0.785	0.781	0.777	0.774	0.770	0.766	0.763	0.759
20.0	0.820	0.816	0.812	0.809	0.805	0.801	0.797	0.794	0.790	0.786	0.783	0.779	0.775	0.771	0.768	0.764	0.760
21.0	0.821	0.817	0.814	0.810	0.806	0.802	0.799	0.795	0.791	0.788	0.784	0.780	0.777	0.773	0.769	0.766	0.762
22.0	0.822	0.818	0.815	0.811	0.807	0.804	0.800	0.796	0.793	0.789	0.785	0.782	0.778	0.774	0.771	0.767	0.763
23.0	0.823	0.820	0.816	0.812	0.809	0.805	0.801	0.798	0.794	0.790	0.787	0.783	0.779	0.776	0.772	0.768	0.765
24.0	0.824	0.821	0.817	0.814	0.810	0.806	0.803	0.799	0.795	0.792	0.788	0.785	0.781	0.777	0.774	0.770	0.766
25.0	0.826	0.822	0.818	0.815	0.811	0.808	0.804	0.800	0.797	0.793	0.789	0.786	0.782	0.779	0.775	0.771	0.768
26.0	0.827	0.823	0.820	0.816	0.812	0.809	0.805	0.802	0.798	0.794	0.791	0.787	0.784	0.780	0.776	0.773	0.769
27.0	0.828	0.824	0.821	0.817	0.814	0.810	0.806	0.803	0.799	0.796	0.792	0.789	0.785	0.781	0.778	0.774	0.771
28.0	0.829	0.825	0.822	0.818	0.815	0.811	0.808	0.804	0.801	0.797	0.794	0.790	0.786	0.783	0.779	0.776	0.772
29.0	0.830	0.827	0.823	0.820	0.816	0.812	0.809	0.805	0.802	0.798	0.795	0.791	0.788	0.784	0.781	0.777	0.774
30.0	0.831	0.828	0.824	0.821	0.817	0.814	0.810	0.807	0.803	0.800	0.796	0.793	0.789	0.786	0.782	0.779	0.775
31.0	0.832	0.829	0.825	0.822	0.818	0.815	0.811	0.808	0.804	0.801	0.797	0.794	0.790	0.787	0.783	0.780	0.776
32.0	0.833	0.830	0.826	0.823	0.820	0.816	0.813	0.809	0.806	0.802	0.799	0.795	0.792	0.788	0.785	0.781	0.778
33.0	0.834	0.831	0.828	0.824	0.821	0.817	0.814	0.810	0.807	0.803	0.800	0.797	0.793	0.790	0.786	0.783	0.779
34.0	0.836	0.832	0.829	0.825	0.822	0.818	0.815	0.812	0.808	0.805	0.801	0.798	0.794	0.791	0.788	0.784	0.781
35.0	0.837	0.833	0.830	0.826	0.823	0.820	0.816	0.813	0.809	0.806	0.803	0.799	0.796	0.792	0.789	0.785	0.782