TC 147

International Standard ISO 5814

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Water quality — Determination of dissolved oxygen — Electrochemical probe method

Qualité de l'eau — Dosage de l'oxygène dissous — Méthode électrochimique à la sonde

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been authorized has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 5814 was developed by Technical Committee ISO/TC 147, *Water quality*, and was circulated to the member bodies in October 1982.

It has been approved by the member bodies of the following countries:

Australia	Hungary	Norway
Austria	India	Poland
Belgium	Iran	Romania
Canada	Iraq	South Africa, Rep. of
China	Ireland	Spain
Czechoslovakia	Italy	Sweden
Denmark	Japan	Switzerland
Egypt, Arab Rep. of	Korea, Dem. P. Rep. of	Thailand
Finland	Mexico	United Kingdom
France	Netherlands	USSR
Germany, F.R.	New Zealand	

No member body expressed disapproval of the document.

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Water quality — Determination of dissolved oxygen — Electrochemical probe method

1 Scope and field of application

This International Standard specifies an electrochemical method for the determination of dissolved oxygen in water by means of an electrochemical cell which is isolated from the sample by a gas permeable membrane.

Depending on the type of probe employed, measurement can be made either as concentration of oxygen (mg/l), percentage saturation (% dissolved oxygen) or both. The method measures oxygen in water corresponding to 0 % to 100 % saturation. However, most instruments permit measurement of values higher than 100 % i.e. supersaturation.

The method is suitable for measurements made in the field and for continuous monitoring of dissolved oxygen as well as measurements made in the laboratory. It is the preferred method for highly coloured and turbid waters, and also for waters containing iron and iodine fixing substances, all of which may interfere in the iodometric method specified in ISO 5813. Gases and vapours such as chlorine, sulfur dioxide, hydrogen sulfide, amines, ammonia, carbon dioxide, bromine and iodine which diffuse through the membrane, may interfere, if present, by affecting the measured current. Other substances present in the sample may interfere with the measured current by causing obstruction, or deterioration of the membrane or corrosion of the electrodes. These include solvents, oils, sulfides, carbonates and algae.

The method is suitable for natural, waste and saline waters. If used for saline waters such as sea waters, or estuarine waters, a correction for salinity is essential.

2 Reference

ISO 5813, *Water quality — Determination of dissolved oxygen — Iodometric method.*

3 Principle

Immersion of a probe, consisting of a cell enclosed by a selective membrane and containing the electrolyte and two metallic electrodes, in the water to be analysed. (The membrane is practically impermeable to water and ionic dissolved matter, but is permeable to oxygen and a certain number of the other gases and lyophylic substances.)

Because of the potential difference between the electrodes, caused by galvanic action or an external voltage, oxygen passing through the membrane is reduced at the cathode, while metal ions pass into solution at the anode.

The current so produced is directly proportional to the rate of transport of oxygen through the membrane and the layer of electrolyte and hence to the partial pressure of the oxygen in the sample at a given temperature.

Since the permeability of the membrane varies greatly with temperature, compensation has to be made, either mathematically (by using a nomogram or a computer program), or by regulating the apparatus, or by the inclusion of heat-sensitive elements in the electrode circuit. Some instruments also compensate for variation in the solubility of oxygen at different temperatures.

4 Reagents

During the analysis, use only reagents of recognized analytical grade and only distilled water or water of equivalent purity.

4.1 Sodium sulfite, anhydrous (Na_2SO_3) or heptahydrate, ($Na_2SO_3 \cdot 7H_2O$).

4.2 Cobalt(II) salt, for example cobalt(II) chloride hexahydrate ($CoCl_2 \cdot 6H_2O$).

5 Apparatus

5.1 Measuring instrument, comprising the following components:

5.1.1 Measuring probe, either of the galvanic type (for example lead/silver) or the polarographic type (for example silver, gold), with, if required, a temperature sensitive compensating device.

5.1.2 Meter, graduated to show the concentration of dissolved oxygen directly, and/or the percentage saturation with oxygen, or the current in microamperes.

5.2 Thermometer, graduated in divisions of 0,5 °C.

5.3 Barometer, graduated in divisions of 10 Pa.

6 Procedure

When using the measuring instrument, the manufacturer's instructions should be followed.

6.1 Measuring technique and precautions to be taken

6.1.1 Never touch the active surface of the membrane with the fingers.

6.1.2 After changing the electrolyte and the membrane, or if the membrane has been allowed to dry out, wet the membrane and allow the reading to become stable before carrying out the calibration (see 6.2). The time required depends on that necessary for consumption of the oxygen dissolved in the electrolyte.

6.1.3 Ensure that air bubbles are not trapped in the probe when immersing it in the sample.

6.1.4 It is essential that the sample should flow past the membrane of the probe to prevent the occurrence of false readings due to depletion of the oxygen in the sample in immediate contact with the membrane. Ensure that the flow rate is such that variations in readings are not produced, and consult the instrument manufacturer's instructions on this matter.

6.1.5 In the case of a discrete sample, carry out the determination in a vessel filled to overflowing, sealed to exclude air and containing a stirrer, for example a magnetic bar. Adjust the stirring rate such that the reading remains stable after reaching equilibrium, and there is no entrapment of air.

In the case of a flowing sample, such as a water course, check the flow rate to ensure that it is sufficient. If not, then either move the probe about in the sample or take a discrete sample and treat it as described in the previous paragraph.

6.2 Calibration

The procedure is described in 6.2.1 to 6.2.3, but it is necessary to consult the instrument manufacturer's instructions.

6.2.1 Regulation

Adjust the electrical zero of the instrument. Some instruments are zero compensated and need no adjustment.

6.2.2 *Checking the zero*

Check, and if possible, adjust the zero setting of the instrument by immersing the probe in 1 litre of water to which about 1 g of sodium sulfite (4.1) and about 1 mg of the cobalt(II) salt (4.2) have been added.

A stable response should be obtained in 10 min.

NOTE — Modern instruments only require 2 to 3 min.

6.2.3 Calibration at a value near saturation

Bubble air through water at a constant temperature so that its oxygen content is brought to saturation or near saturation. Leave for about 15 min at this temperature and determine the dissolved oxygen concentration, for example by the iodometric method specified in ISO 5813.

Regulate the instrument.

Immerse the probe in a bottle completely filled with the sample, prepared and standardized as described. After allowing the probe to stabilize in the stirred solution for 10 min (see the note to 6.2.2), adjust the instrument reading to the known oxygen concentration of the sample, if necessary.

Replace the electrolyte and the membrane when the instrument can no longer be calibrated or when the response becomes unstable or slow (see the manufacturer's instructions).

NOTES

1 If previous experience has shown that the bubbling time and the air flow rate used provide a sample saturated with air, the iodometric determination may be replaced by consultation of the tables 1 and 2.

2 Many instruments allow calibration in air.

6.3 Determination

Carry out the determination on the water to be analysed following the instrument manufacturer's instructions.

After immersion of the probe in the sample, allow sufficient time for the probe to attain the water temperature and reach a stable reading. If necessary, because of the type of instrument used and the result required, check the water temperature and/or the atmospheric pressure.

7 Calculation and expression of results

7.1 Dissolved oxygen concentration, (mg/l)

Express the dissolved oxygen concentration in milligrams of oxygen per litre and report the result to the first decimal place.

If the reading on the sample was made at a temperature different from that at which the instrument was calibrated, correct the value given by the instrument to allow for this. Some instruments make this correction automatically. This correction makes allowance for the difference in the solubility of oxygen at the two temperatures. Calculate the real value by multiplying the value read at the temperature at which the measurement was made by the ratio

$$\frac{C_m}{C_c}$$

where

C_m is the solubility at the temperature of measurement;

C_c is the solubility at the temperature of calibration.

Example:

Temperature of calibration .... 25 °C

Solubility at 25 °C .... 8,3 mg/l

Temperature at the time of the measurement ..... 10 °C

Reading of the instrument .... 7 mg/l

Solubility at 10 °C .... 11,3 mg/l

Real value at 10 °C .... $\frac{11,3}{8,3} \times 7,0 = 9,5$ mg/l

NOTE — The values for C_m and C_c, expressed in milligrams per litre, in the given example are obtainable from the "C_s" column in table 1, against the required temperature.

7.2 Dissolved oxygen concentration (mg/l) as a function of temperature and pressure

Tables 1 and 2 give the theoretical values for the dissolved oxygen concentration both as a function of temperature at atmospheric pressure (table 1) and as a function of both temperature and pressure (table 2).

7.3 Dissolved oxygen concentration (mg/l), corrected for saline samples

The solubility of oxygen in water decreases with increasing salinity. The relationship is reasonably linear for practical purposes up to a concentration of 35 g/l salinity, expressed in grams of total salts per litre of water. Table 1 gives the correction to be subtracted, ΔC_s, for each gram per litre of salinity. Therefore the solubility of oxygen in water having a salinity of n g/l of water is given by subtracting $n\,\Delta C_s$ from the corresponding solubility in pure water.

7.4 Dissolved oxygen concentration expressed as a percentage saturation

This is the actual concentration, expressed in milligrams per litre, of dissolved oxygen, corrected if necessary for temperature, as a percentage of the theoretical value as given in table 1 or table 2.

$$\frac{C_s \text{ (found)}}{C_s \text{ (theoretical)}} \times 100$$

8 Test report

The test report shall include the following information:

a) a reference to this International Standard;

b) the result and the method of expression used;

c) the temperature of the water when the sample was taken and when the measurement was carried out;

d) the atmospheric pressure when the sample was taken and when the measurement was carried out;

e) the salinity of the water;

f) the model of instrument used;

g) any special details which may have been noted during the determination;

h) details of any operations not specified in this International Standard, or regarded as optional.

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Annex

Solubility of oxygen in water in relation to temperature, pressure and salinity

A.1 General

This annex indicates values for the solubility of oxygen in water in relation to temperature and pressure. It is based on Mortimer.[2].

Revised values were published in 1981[4]; if these values are used instead of those given in table 1, the values in table 2 must be corrected accordingly.

A.2 Solubility of oxygen as a function of temperature and salinity

See table 1.

NOTES

1 Column 2 of the table gives the solubility (C_s) of oxygen, expressed in milligrams of oxygen per litre, in pure water in the presence of air saturated with water vapour, containing 20,94 % (V/V) of oxygen, at a pressure of 101,3 kPa.[2]

2 Column 3 of the table gives the variation of solubility (ΔC_s) for a total salinity of 1 g/l.[1]

Table 1 — Solubility of oxygen in water as a function of temperature and salinity

Temperature	C_s	ΔC_s	Temperature	C_s	ΔC_s
°C	mg/l	mg/l	°C	mg/l	mg/l
0	14,64	0,092 5	20	9,08	0,048 1
1	14,22	0,089 0	21	8,90	0,046 7
2	13,82	0,085 7	22	8,73	0,045 3
3	13,44	0,082 7	23	8,57	0,044 0
4	13,09	0,079 8	24	8,41	0,042 7
5	12,74	0,077 1	25	8,25	0,041 5
6	12,42	0,074 5	26	8,11	0,040 4
7	12,11	0,072 0	27	7,96	0,039 3
8	11,81	0,069 7	28	7,82	0,038 2
9	11,53	0,067 5	29	7,69	0,037 2
10	11,26	0,065 3	30	7,56	0,036 2
11	11,01	0,063 3	31	7,43	
12	10,77	0,061 4	32	7,30	
13	10,53	0,059 5	33	7,18	
14	10,30	0,057 7	34	7,07	
15	10,08	0,055 9	35	6,95	
16	9,86	0,054 3	36	6,84	
17	9,66	0,052 7	37	6,73*	
18	9,46	0,051 1	38	6,63	
19	9,27	0,049 6	39	6,53*	

* Values not given by Mortimer[2] and calculated by the regression equation

$$C_s = 14,603\,07 - 0,402\,146\,9\,T + 0,007\,687\,03\,T^2 - 0,000\,069\,257\,5\,T^3$$

The solubility of oxygen in water decreases with increasing salinity. The relation is reasonably linear for practical purposes up to 35 g/l, expressed in grams of total salts per litre of water. The solubility of oxygen in water with a salinity of n g/l is found by subtracting the value $n\,\Delta C_s$ from the corresponding solubility in pure water.

A.3 Correction for atmospheric pressure or altitude

If the atmospheric pressure, p, is other than 101,3 kPa, the solubility C'_s is derived from the value of C_s at 101,3 kPa, by the equation

$$C'_s = C_s \times \frac{p - p_w}{101,3 - p_w}$$

where p_w is the pressure, in kilopascals, of water vapour in contact with air, at the temperature considered.

Values for C'_s, in milligrams of oxygen per litre, for pressures at intervals of 0,5 kPa between 77,5 and 110 kPa, are given in table 2.

NOTE — The mean atmospheric pressure as a function of altitude can be calculated by Schassmann's equation

$$\log_{10} p_h = \log_{10} 101,3 - \frac{h}{18\,400}$$

where p_h is the mean atmospheric pressure, in kilopascals, at altitude h, in metres.

The following table gives some of the corresponding values.

Altitude, h	p_h	Altitude, h	p_h
m	kPa	m	kPa
0	1 01,3	1 100	88,3
100	1 00,1	1 200	87,2
200	98,8	1 300	86,1
300	97,6	1 400	85,0
400	96,4	1 500	84,0
500	95,2	1 600	82,9
600	94,0	1 700	81,9
700	92,8	1 800	80,9
800	91,7	1 900	79,9
900	90,5	2 000	78,9
1 000	89,4	2 100	77,9

Table 2 — Solubility, C'_s, in milligrams per litre, of oxygen in water as a function of temperature and pressure

Temperature °C	Pressure (kPa)																
	77,5	78,0	78,5	79,0	79,5	80,0	80,5	81,0	81,5	82,0	82,5	83,0	83,5	84,0	84,5	85,0	85,5
0	11,17	11,24	11,32	11,39	11,46	11,53	11,61	11,68	11,75	11,82	11,90	11,97	12,04	12,11	12,19	12,26	12,33
1	10,85	10,92	11,00	11,07	11,14	11,21	11,28	11,35	11,42	11,49	11,56	11,63	11,70	11,77	11,84	11,91	11,98
2	10,55	10,62	10,69	10,76	10,83	10,90	10,96	11,03	11,10	11,17	11,24	11,31	11,38	11,45	11,51	11,58	11,65
3	10,27	10,33	10,40	10,47	10,53	10,60	10,67	10,73	10,80	10,87	10,93	11,00	11,07	11,13	11,20	11,27	11,34
4	9,99	10,06	10,12	10,19	10,25	10,32	10,38	10,45	10,51	10,58	10,64	10,71	10,77	10,84	10,90	10,97	11,03
5	9,73	9,79	9,86	9,92	9,98	10,05	10,11	10,17	10,24	10,30	10,36	10,43	10,49	10,55	10,62	10,68	10,75
6	9,48	9,54	9,60	9,67	9,73	9,79	9,85	9,91	9,98	10,04	10,10	10,16	10,22	10,28	10,35	10,41	10,47
7	9,24	9,30	9,36	9,42	9,48	9,54	9,60	9,66	9,72	9,78	9,85	9,91	9,97	10,03	10,09	10,15	10,21
8	9,01	9,07	9,13	9,19	9,25	9,31	9,37	9,43	9,49	9,54	9,60	9,66	9,72	9,78	9,84	9,90	9,96
9	8,80	8,85	8,91	8,97	9,03	9,08	9,14	9,20	9,26	9,31	9,37	9,43	9,49	9,54	9,60	9,66	9,72
10	8,59	8,64	8,70	8,76	8,81	8,87	8,92	8,98	9,04	9,09	9,15	9,21	9,26	9,32	9,37	9,43	9,49
11	8,39	8,44	8,50	8,55	8,61	8,66	8,72	8,77	8,83	8,88	8,94	8,99	9,05	9,10	9,16	9,21	9,27
12	8,20	8,25	8,30	8,36	8,41	8,46	8,52	8,57	8,63	8,68	8,73	8,79	8,84	8,90	8,95	9,00	9,06
13	8,01	8,07	8,12	8,17	8,22	8,28	8,33	8,38	8,43	8,49	8,54	8,59	8,64	8,70	8,75	8,80	8,85
14	7,84	7,89	7,94	7,99	8,04	8,09	8,15	8,20	8,25	8,30	8,35	8,40	8,45	8,51	8,56	8,61	8,66
15	7,67	7,72	7,77	7,82	7,87	7,92	7,97	8,02	8,07	8,12	8,17	8,22	8,27	8,32	8,37	8,42	8,47
16	7,50	7,55	7,60	7,65	7,70	7,75	7,80	7,85	7,90	7,95	8,00	8,05	8,10	8,15	8,20	8,25	8,29
17	7,35	7,40	7,44	7,49	7,54	7,59	7,64	7,69	7,73	7,78	7,83	7,88	7,93	7,98	8,03	8,07	8,12
18	7,20	7,24	7,29	7,34	7,39	7,43	7,48	7,53	7,58	7,62	7,67	7,72	7,77	7,81	7,86	7,91	7,96
19	7,05	7,10	7,14	7,19	7,24	7,28	7,33	7,38	7,42	7,47	7,52	7,56	7,61	7,66	7,70	7,75	7,80
20	6,91	6,96	7,00	7,05	7,09	7,14	7,18	7,23	7,28	7,32	7,37	7,41	7,46	7,50	7,55	7,60	7,64
21	6,77	6,82	6,86	6,91	6,95	7,00	7,04	7,09	7,13	7,18	7,22	7,27	7,31	7,36	7,40	7,45	7,49
22	6,64	6,69	6,73	6,77	6,82	6,86	6,91	6,95	6,99	7,04	7,08	7,13	7,17	7,21	7,26	7,30	7,35
23	6,51	6,56	6,60	6,64	6,69	6,73	6,77	6,82	6,86	6,90	6,95	6,99	7,03	7,08	7,12	7,16	7,21
24	6,39	6,43	6,47	6,52	6,56	6,60	6,64	6,69	6,73	6,77	6,82	6,86	6,90	6,94	6,99	7,03	7,07
25	6,27	6,31	6,35	6,39	6,44	6,48	6,52	6,56	6,60	6,65	6,69	6,73	6,77	6,81	6,86	6,90	6,94
26	6,15	6,19	6,23	6,28	6,32	6,36	6,40	6,44	6,48	6,52	6,56	6,61	6,65	6,69	6,73	6,77	6,81
27	6,04	6,08	6,12	6,16	6,20	6,24	6,28	6,32	6,36	6,40	6,44	6,48	6,52	6,57	6,61	6,65	6,69
28	5,93	5,97	6,01	6,05	6,09	6,13	6,17	6,21	6,25	6,29	6,33	6,37	6,41	6,45	6,49	6,53	6,57
29	5,82	5,86	5,90	5,94	5,98	6,02	6,06	6,10	6,13	6,17	6,21	6,25	6,29	6,33	6,37	6,41	6,45
30	5,72	5,76	5,79	5,83	5,87	5,91	5,95	5,99	6,03	6,06	6,10	6,14	6,18	6,22	6,26	6,30	6,33
31	5,62	5,65	5,69	5,73	5,77	5,81	5,84	5,88	5,92	5,96	6,00	6,03	6,07	6,11	6,15	6,19	6,22
32	5,52	5,55	5,59	5,63	5,67	5,70	5,74	5,78	5,82	5,85	5,89	5,93	5,97	6,00	6,04	6,08	6,12
33	5,42	5,46	5,50	5,53	5,57	5,61	5,64	5,68	5,72	5,75	5,79	5,83	5,86	5,90	5,94	5,97	6,01
34	5,33	5,36	5,40	5,44	5,47	5,51	5,55	5,58	5,62	5,66	5,69	5,73	5,76	5,80	5,84	5,87	5,91
35	5,24	5,27	5,31	5,35	5,38	5,42	5,45	5,49	5,53	5,56	5,60	5,63	5,67	5,70	5,74	5,78	5,81
36	5,15	5,19	5,22	5,26	5,29	5,33	5,36	5,40	5,43	5,47	5,51	5,54	5,58	5,61	5,65	5,68	5,72
37	5,07	5,10	5,14	5,17	5,21	5,24	5,28	5,31	5,35	5,38	5,42	5,45	5,49	5,52	5,56	5,59	5,63
38	4,99	5,02	5,05	5,09	5,12	5,16	5,19	5,23	5,26	5,30	5,33	5,37	5,40	5,43	5,47	5,50	5,54
39	4,91	4,94	4,98	5,01	5,04	5,08	5,11	5,15	5,18	5,21	5,25	5,28	5,32	5,35	5,39	5,42	5,45
40	4,83	4,87	4,90	4,93	4,97	5,00	5,04	5,07	5,10	5,14	5,17	5,20	5,24	5,27	5,31	5,34	5,37

Table 2 (*continued*)

Temperature °C	Pressure (kPa)																
	86,0	86,5	87,0	87,5	88,0	88,5	89,0	89,5	90,0	90,5	91,0	91,5	92,0	92,5	93,0	93,5	94,0
0	12,40	12,48	12,55	12,62	12,70	12,77	12,84	12,91	12,99	13,06	13,13	13,20	13,28	13,35	13,42	13,49	13,57
1	12,05	12,13	12,20	12,27	12,34	12,41	12,48	12,55	12,62	12,69	12,76	12,83	12,90	12,97	13,04	13,11	13,18
2	11,72	11,79	11,86	11,93	12,00	12,06	12,13	12,20	12,27	12,34	12,41	12,48	12,55	12,61	12,68	12,75	12,82
3	11,40	11,47	11,54	11,60	11,67	11,74	11,80	11,87	11,94	12,00	12,07	12,14	12,20	12,27	12,34	12,41	12,47
4	11,10	11,16	11,23	11,29	11,36	11,42	11,49	11,55	11,62	11,68	11,75	11,82	11,88	11,95	12,01	12,08	12,14
5	10,81	10,87	10,94	11,00	11,06	11,13	11,19	11,25	11,32	11,38	11,44	11,51	11,57	11,63	11,70	11,76	11,82
6	10,53	10,59	10,66	10,72	10,78	10,84	10,90	10,97	11,03	11,09	11,15	11,21	11,27	11,34	11,40	11,46	11,52
7	10,27	10,33	10,39	10,45	10,51	10,57	10,63	10,69	10,75	10,81	10,87	10,93	10,99	11,05	11,11	11,17	11,23
8	10,02	10,07	10,13	10,19	10,25	10,31	10,37	10,43	10,49	10,55	10,60	10,66	10,72	10,78	10,84	10,90	10,96
9	9,77	9,83	9,89	9,95	10,00	10,06	10,12	10,18	10,23	10,29	10,35	10,41	10,46	10,52	10,58	10,64	10,69
10	9,54	9,60	9,66	9,71	9,77	9,82	9,88	9,94	9,99	10,05	10,11	10,16	10,22	10,27	10,33	10,39	10,44
11	9,32	9,38	9,43	9,49	9,54	9,60	9,65	9,71	9,76	9,82	9,87	9,93	9,98	10,04	10,09	10,15	10,20
12	9,11	9,16	9,22	9,27	9,33	9,38	9,43	9,49	9,54	9,59	9,65	9,70	9,76	9,81	9,86	9,92	9,97
13	8,91	8,96	9,01	9,06	9,12	9,17	9,22	9,28	9,33	9,38	9,43	9,49	9,54	9,59	9,64	9,70	9,75
14	8,71	8,76	8,81	8,87	8,92	8,97	9,02	9,07	9,12	9,18	9,23	9,28	9,33	9,38	9,43	9,48	9,54
15	8,52	8,58	8,63	8,68	8,73	8,78	8,83	8,88	8,93	8,98	9,03	9,08	9,13	9,18	9,23	9,28	9,33
16	8,34	8,39	8,44	8,49	8,54	8,59	8,64	8,69	8,74	8,79	8,84	8,89	8,94	8,99	9,04	9,09	9,14
17	8,17	8,22	8,27	8,32	8,36	8,41	8,46	8,51	8,56	8,61	8,66	8,70	8,75	8,80	8,85	8,90	8,95
18	8,00	8,05	8,10	8,15	8,19	8,24	8,29	8,34	8,38	8,43	8,48	8,53	8,57	8,62	8,67	8,72	8,76
19	7,84	7,89	7,94	7,98	8,03	8,08	8,12	8,17	8,22	8,26	8,31	8,36	8,40	8,45	8,50	8,54	8,59
20	7,69	7,73	7,78	7,82	7,87	7,92	7,96	8,01	8,05	8,10	8,14	8,19	8,24	8,28	8,33	8,37	8,42
21	7,54	7,58	7,63	7,67	7,72	7,76	7,81	7,85	7,90	7,94	7,99	8,03	8,08	8,12	8,17	8,21	8,25
22	7,39	7,43	7,48	7,52	7,57	7,61	7,66	7,70	7,74	7,79	7,83	7,88	7,92	7,96	8,01	8,05	8,10
23	7,25	7,29	7,34	7,38	7,42	7,47	7,51	7,55	7,60	7,64	7,68	7,73	7,77	7,81	7,86	7,90	7,94
24	7,11	7,16	7,20	7,24	7,28	7,33	7,37	7,41	7,45	7,50	7,54	7,58	7,62	7,67	7,71	7,75	7,79
25	6,98	7,02	7,06	7,11	7,15	7,19	7,23	7,27	7,32	7,36	7,40	7,44	7,48	7,52	7,57	7,61	7,65
26	6,85	6,89	6,93	6,98	7,02	7,06	7,10	7,14	7,18	7,22	7,26	7,30	7,35	7,39	7,43	7,47	7,51
27	6,73	6,77	6,81	6,85	6,89	6,93	6,97	7,01	7,05	7,09	7,13	7,17	7,21	7,25	7,29	7,33	7,37
28	6,61	6,65	6,69	6,73	6,77	6,80	6,84	6,88	6,92	6,96	7,00	7,04	7,08	7,12	7,16	7,20	7,24
29	6,49	6,53	6,57	6,61	6,64	6,68	6,72	6,76	6,80	6,84	6,88	6,92	6,96	7,00	7,04	7,08	7,11
30	6,37	6,41	6,45	6,49	6,53	6,57	6,60	6,64	6,68	6,72	6,76	6,80	6,84	6,87	6,91	6,95	6,99
31	6,26	6,30	6,34	6,38	6,41	6,45	6,49	6,53	6,57	6,60	6,64	6,68	6,72	6,76	6,79	6,83	6,87
32	6,15	6,19	6,23	6,27	6,30	6,34	6,38	6,42	6,45	6,49	6,53	6,57	6,60	6,64	6,68	6,72	6,75
33	6,05	6,09	6,12	6,16	6,20	6,23	6,27	6,31	6,34	6,38	6,42	6,45	6,49	6,53	6,57	6,60	6,64
34	5,95	5,98	6,02	6,06	6,09	6,13	6,17	6,20	6,24	6,27	6,31	6,35	6,38	6,42	6,46	6,49	6,53
35	5,85	5,88	5,92	5,96	5,99	6,03	6,06	6,10	6,14	6,17	6,21	6,24	6,28	6,31	6,35	6,39	6,42
36	5,75	5,79	5,82	5,86	5,89	5,93	5,97	6,00	6,04	6,07	6,11	6,14	6,18	6,21	6,25	6,28	6,32
37	5,66	5,70	5,73	5,77	5,80	5,84	5,87	5,91	5,94	5,98	6,01	6,05	6,08	6,12	6,15	6,19	6,22
38	5,57	5,61	5,64	5,68	5,71	5,75	5,78	5,81	5,85	5,88	5,92	5,95	5,99	6,02	6,06	6,09	6,13
39	5,49	5,52	5,56	5,59	5,62	5,66	5,69	5,73	5,76	5,79	5,83	5,86	5,90	5,93	5,97	6,00	6,03
40	5,41	5,44	5,47	5,51	5,54	5,58	5,61	5,64	5,68	5,71	5,74	5,78	5,81	5,85	5,88	5,91	5,95

Table 2 *(continued)*

Temperature °C	Pressure (kPa)															
	94,5	95,0	95,5	96,0	96,5	97,0	97,5	98,0	98,5	99,0	99,5	100,0	100,5	101,0	101,5	102,0
0	13,64	13,71	13,78	13,86	13,93	14,00	14,08	14,15	14,22	14,29	14,37	14,44	14,51	14,58	14,66	14,73
1	13,26	13,33	13,40	13,47	13,54	13,61	13,68	13,75	13,82	13,89	13,96	14,03	14,10	14,17	14,24	14,31
2	12,89	12,96	13,03	13,09	13,16	13,23	13,30	13,37	13,44	13,51	13,58	13,64	13,71	13,78	13,85	13,92
3	12,54	12,61	12,67	12,74	12,81	12,87	12,94	13,01	13,07	13,14	13,21	13,27	13,34	13,41	13,48	13,54
4	12,21	12,27	12,34	12,40	12,47	12,53	12,60	12,66	12,73	12,79	12,86	12,92	12,99	13,05	13,12	13,18
5	11,89	11,95	12,01	12,08	12,14	12,21	12,27	12,33	12,40	12,46	12,52	12,59	12,65	12,71	12,78	12,84
6	11,58	11,65	11,71	11,77	11,83	11,89	11,96	12,02	12,08	12,14	12,20	12,26	12,33	12,39	12,45	12,51
7	11,29	11,35	11,41	11,48	11,54	11,60	11,66	11,72	11,78	11,84	11,90	11,96	12,02	12,08	12,14	12,20
8	11,02	11,08	11,14	11,19	11,25	11,31	11,37	11,43	11,49	11,55	11,61	11,67	11,72	11,78	11,84	11,90
9	10,75	10,81	10,87	10,92	10,98	11,04	11,10	11,16	11,21	11,27	11,33	11,39	11,44	11,50	11,56	11,62
10	10,50	10,56	10,61	10,67	10,72	10,78	10,84	10,89	10,95	11,01	11,06	11,12	11,17	11,23	11,29	11,34
11	10,26	10,31	10,37	10,42	10,48	10,53	10,59	10,64	10,70	10,75	10,81	10,86	10,92	10,97	11,03	11,08
12	10,02	10,08	10,13	10,19	10,24	10,29	10,35	10,40	10,45	10,51	10,56	10,62	10,67	10,72	10,78	10,83
13	9,80	9,85	9,91	9,96	10,01	10,06	10,12	10,17	10,22	10,27	10,33	10,38	10,43	10,49	10,54	10,59
14	9,59	9,64	9,69	9,74	9,79	9,84	9,90	9,95	10,00	10,05	10,10	10,15	10,21	10,26	10,31	10,36
15	9,38	9,43	9,48	9,53	9,58	9,63	9,68	9,74	9,79	9,84	9,89	9,94	9,99	10,04	10,09	10,14
16	9,18	9,23	9,28	9,33	9,38	9,43	9,48	9,53	9,58	9,63	9,68	9,73	9,78	9,83	9,88	9,93
17	8,99	9,04	9,09	9,14	9,19	9,24	9,29	9,33	9,38	9,43	9,48	9,53	9,58	9,62	9,67	9,72
18	8,81	8,86	8,91	8,95	9,00	9,05	9,10	9,14	9,19	9,24	9,29	9,33	9,38	9,43	9,48	9,52
19	8,63	8,68	8,73	8,77	8,82	8,87	8,91	8,96	9,01	9,05	9,10	9,15	9,19	9,24	9,29	9,33
20	8,46	8,51	8,56	8,60	8,65	8,69	8,74	8,78	8,83	8,88	8,92	8,97	9,01	9,06	9,10	9,15
21	8,30	8,34	8,39	8,43	8,48	8,52	8,57	8,61	8,66	8,70	8,75	8,79	8,84	8,88	8,93	8,97
22	8,14	8,18	8,23	8,27	8,32	8,36	8,41	8,45	8,49	8,54	8,58	8,63	8,67	8,71	8,76	8,80
23	7,99	8,03	8,07	8,12	8,16	8,20	8,25	8,29	8,33	8,38	8,42	8,46	8,51	8,55	8,59	8,64
24	7,84	7,88	7,92	7,96	8,01	8,05	8,09	8,13	8,18	8,22	8,26	8,31	8,35	8,39	8,43	8,48
25	7,69	7,73	7,78	7,82	7,86	7,90	7,94	7,99	8,03	8,07	8,11	8,15	8,19	8,24	8,28	8,32
26	7,55	7,59	7,63	7,68	7,72	7,76	7,80	7,84	7,88	7,92	7,96	8,00	8,05	8,09	8,13	8,17
27	7,42	7,46	7,50	7,54	7,58	7,62	7,66	7,70	7,74	7,78	7,82	7,86	7,90	7,94	7,98	8,02
28	7,28	7,32	7,36	7,40	7,44	7,48	7,52	7,56	7,60	7,64	7,68	7,72	7,76	7,80	7,84	7,88
29	7,15	7,19	7,23	7,27	7,31	7,35	7,39	7,43	7,47	7,51	7,55	7,59	7,62	7,66	7,70	7,74
30	7,03	7,07	7,11	7,15	7,18	7,22	7,26	7,30	7,34	7,38	7,42	7,45	7,49	7,53	7,57	7,61
31	6,91	6,95	6,98	7,02	7,06	7,10	7,14	7,17	7,21	7,25	7,29	7,33	7,36	7,40	7,44	7,48
32	6,79	6,83	6,87	6,90	6,94	6,98	7,01	7,05	7,09	7,13	7,16	7,20	7,24	7,28	7,31	7,35
33	6,68	6,71	6,75	6,79	6,82	6,86	6,90	6,93	6,97	7,01	7,05	7,08	7,12	7,16	7,19	7,23
34	6,57	6,60	6,64	6,67	6,71	6,75	6,78	6,82	6,86	6,89	6,93	6,97	7,00	7,04	7,07	7,11
35	6,46	6,49	6,53	6,57	6,60	6,64	6,67	6,71	6,75	6,78	6,82	6,85	6,89	6,92	6,96	7,00
36	6,35	6,39	6,43	6,46	6,50	6,53	6,57	6,60	6,64	6,67	6,71	6,74	6,78	6,82	6,85	6,89
37	6,26	6,29	6,33	6,36	6,40	6,43	6,47	6,50	6,53	6,57	6,60	6,64	6,67	6,71	6,74	6,78
38	6,16	6,19	6,23	6,26	6,30	6,33	6,37	6,40	6,44	6,47	6,50	6,54	6,57	6,61	6,64	6,68
39	6,07	6,10	6,14	6,17	6,20	6,24	6,27	6,31	6,34	6,37	6,41	6,44	6,48	6,51	6,55	6,58
40	5,98	6,01	6,05	6,08	6,12	6,15	6,18	6,22	6,25	6,28	6,32	6,35	6,39	6,42	6,45	6,49