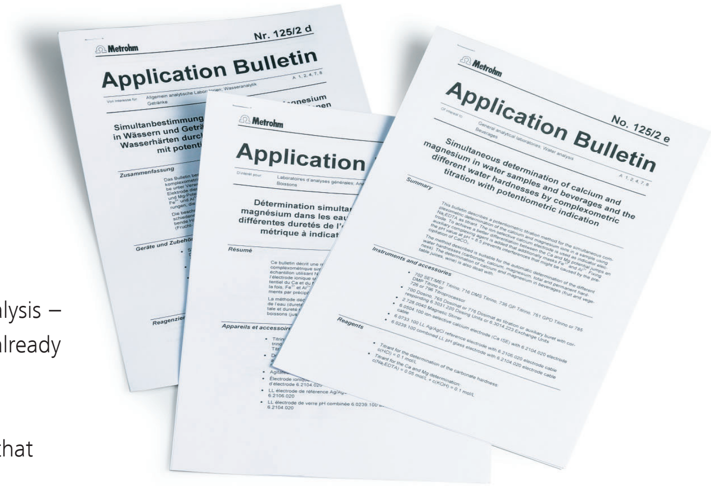
Metrosensor electrodes

Precision is not accidental, but brought about by design!

Metrohm

Table of contents



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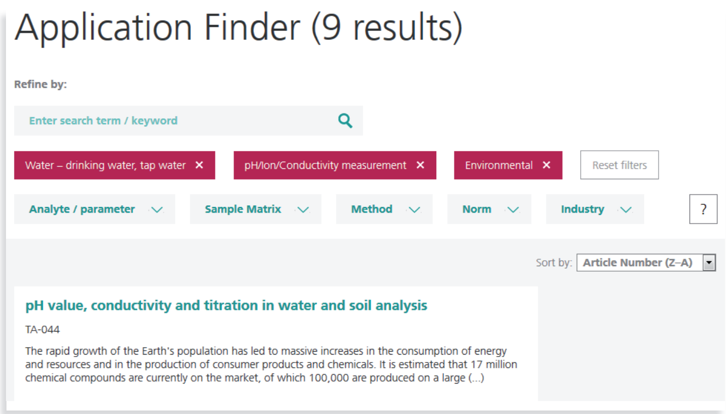

You can find the applications listed here as well as others in the Application Finder at:
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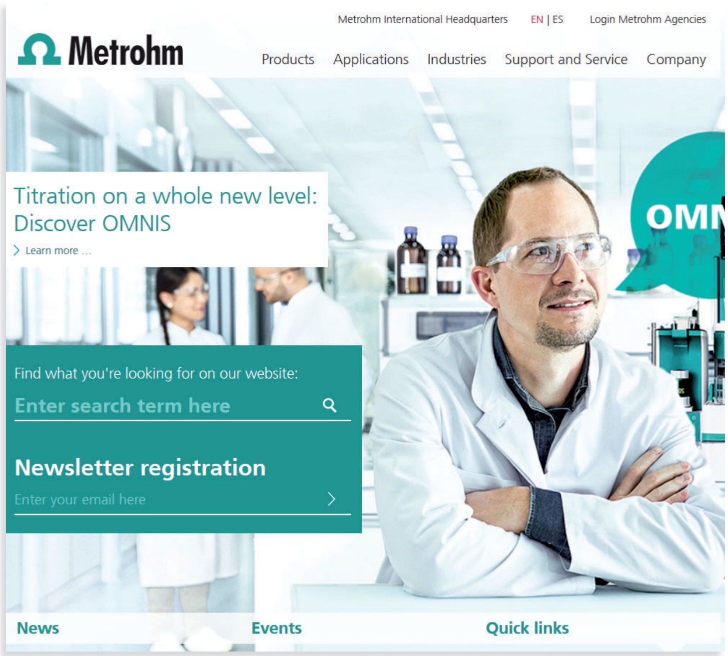

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Electrode catalog

The illustrations of the articles are, unless specified otherwise, approximately in original size.

Unless otherwise specified, all combined pH electrodes are filled with the referenced electrolytes c(KCl) = 3 mol/L (Order number 6.2308.020).

The abbreviation «LL reference system» stands for the Metrosensor «Long Life» reference system. More detailed information on this can be found in the theoretical section, Chapter 1.4.2.

«DJ» stands for «double junction». These electrodes are equipped with a bridge electrolyte chamber; the bridge electrolyte is replaceable, which means that it can be adapted to suit the sample.

Detailed information concerning technical specifications can be found in the appendix «Technical Specifications.» The electrochemical parameters are specified for 25 °C, the outflow rates with a hydrostatic pressure of a 10 cm high water column. «Shaft length» refers to the length of the electrode tip up to the lower edge of the electrode plug-in head. The installation length is the length from the electrode tip to the upper edge of the standard ground-joint. In the case of flexible SGJ sleeves, this corresponds to the length down to the electrolyte refill opening below. All flexible SGJ sleeves have like their size the standard ground-joint 14/15.

Materials abbreviations:

EP	Epoxide
EVA	Ethylenvinylacetate
PBT	Polybutylenterephthalate
PCTFE	Polychlortrifluoroethylene
PE	Polyethylene
PEEK	Polyetheretherketone
PMMA	Polymethyl metacrylate
POM	Polyoxymethylene
PP	Polypropylene
PPO	Polyphenylenoxide
PTFE	Polytetrafluoroethylene
PVC	Polyvinyl chloride

Electrodes for pH measurement

Application	Details	Electrode	Order number	Page
Universal	Clear, aqueous solutions, pH 0...14	Primatrode with NTC	6.0228.010	16
	Universal laboratory use, pH 0...14	Unitrode easyClean with Pt1000	6.0260.010	18
	Routine measurement in similar samples pH 1...11	Ecotrode Gel with NTC	6.0221.600	16
Water	General (demineralized water, drinking water, process water, sea water, environmental sector)	Aquatrode Plus with Pt1000	6.0257.600	18
Waste water	General	Unitrode easyClean with Pt1000	6.0260.010	18
	Sewage containing sulfides	Profitrode[x]	6.0255.100	20
Soil samples	General (aqueous suspensions)	Flat-membrane electrode[x]	6.0256.100	24
Agriculture Horticulture Plant cultivation	Fertilizers	Unitrode with Pt1000	6.0258.600	18
	solutions containing proteins	Porotrode[x]	6.0235.200	24
	Liquid manure	Profitrode[x]	6.0255.100	20
	Small sample volumes, culture media	Biotrode[x]	6.0224.100	24
	Nutrient solutions	Viscotrode[x]	6.0239.100	26
Food Beverages Semi-luxury articles	General	Unitrode with Pt1000	6.0258.600	18
	Food containing proteins, beer	Porotrode[x]	6.0235.200	24
	Bread, meat, cheese, dough (measurements semi-solid samples)	Spearhead electrode with Pt1000	6.00226.600	24
	Fruit and vegetable juices, wine, spirits	Unitrode easyClean with Pt1000	6.0260.010	18
	Drinking water	Aquatrode Plus with Pt1000	6.0257.600	18
Pharmaceuticals Biological samples	Creams, liquid formulations, medicinal syrup, mouthwash solutions, raw materials monitoring in accordance with pharmacopoeias	Viscotrode[x]	6.0239.100	26
	Dialysis solutions, urine	Unitrode easyClean with Pt1000	6.0260.010	18
	Solutions containing proteins	Porotrode[x]	6.0235.200	24
	Infusion solutions	Aquatrode Plus with Pt1000	6.0257.600	18
	Small sample volumes, gastric juice, serum	Biotrode[x]	6.0224.100	24
	Pilot plant measurements	Syntrode with Pt1000	6.0248.600	26
Cosmetics	General (emulsions, shampoos, shower baths, liquid soaps, lotions, mouthwashes, perfumes)	Viscotrode[x]	6.0239.100	26
	Skin (surfaces)	Flat-membrane electrode[x]	6.0256.100	24
	Make-up	Microelectrode[x]	6.0234.100	26
Cleaning agents Detergents	General (detergents, dishwashing liquids, cleaning agents, surfactant solutions)	Viscotrode[x]	6.0239.100	26
	Samples with pH values > 10	Profitrode[x]	6.0255.100	20
	High-viscosity samples	Unitrode with Pt1000	6.0258.600	18
Leather Paper Textiles	Bleaching and dyeing baths, tanning liquors	Profitrode[x]	6.0255.100	20
	Fountain solution for offset printing, glue	Unitrode easyClean with Pt1000	6.0260.010	18
	Leather, paper, textiles (surface)	Flat-membrane electrode[x]	6.0256.100	24
	Washing liquors	Viscotrode[x]	6.0239.100	26
Paints Lacquers Solvents	Stains (wood), dye baths, inks	Profitrode[x]	6.0255.100	20
	Dispersions, emulsions, resins, lacquers, suspensions	Unitrode easyClean with Pt1000	6.0260.010	18
	Paint coatings (surfaces)	Flat-membrane electrode[x]	6.0256.100	24
	Non-aqueous, polar solvents	EtOH-Trode[x]	6.0269.100	18
Electroplating Metal processing	General (etching, pickling and degreasing baths, alkaline electroplating and phosphatizing baths)	Profitrode[x]	6.0255.100	20
	Acidic electroplating baths	Unitrode with Pt1000	6.0258.600	18
	Drilling oil emulsions	Viscotrode[x]	6.0239.100	26
Special applications	Measurements in semi-solid samples	Spearhead electrode with Pt1000	6.00226.600	24
	Solutions containing proteins	Porotrode[x]	6.0235.200	24
	Samples with pH values > 12 and temperatures 50...80 °C	Unitrode with Pt1000	6.0258.600	18
	Temperature 80...100 °C	Unitrode with Pt1000 reference electrolyte: Idrolyte	6.0258.600	18
	Ion-deficient, weakly buffered solutions	Aquatrode Plus with Pt1000	6.0257.600	18
	Small sample volumes	Biotrode[x]	6.0224.100	24
		Flat-membrane electrode[x]	6.0256.100	24
	Surface measurements	Flat-membrane electrode[x]	6.0256.100	24
	Developer baths, concentrated acids	Profitrode[x]	6.0255.100	20
	Emulsions/suspensions	Unitrode easyClean with Pt1000	6.0260.010	18
	Fuels containing ethanol/E85	EtOH-Trode[x]	6.0269.100	18

[x] It is recommended to use an external temperature sensor (e.g. 6.1114.010 or 6.1110.100)

Electrodes for titration

Application	Details	Electrode	Order number	Page
Aqueous acid/base titrations	General	Ecotrode Plus	6.0262.100	20
	Routine measurement in similar samples	Ecotrode Gel	6.0221.100	20
	Alkaline samples, Bayer liquors	Unitrode	6.0259.100	20
	Titrations at high temperatures	Unitrode with reference electrolyte: Idrolyte	6.0259.100	20
	Acid content of alcoholic beverages	Unitrode easyClean with Pt1000	6.0260.010	18
	Titrations with small sample volumes	Microelectrode Flat-membrane electrode	6.0234.100 6.0256.100	26 24
	Titrations in ion-deficient aqueous media	Aquatrode Plus	6.0253.100	22
	Carbonate hardness and acid capacity of water, p & m values	Aquatrode Plus with Pt1000	6.0257.600	18
	Electroplating, etching and phosphatizing baths	Profitrode	6.0255.100	20
	Etching baths containing fluoride or hydrofluoric acid	Solitrode HF Combined antimony electrode	6.0223.100 6.0421.100	28 28
	Samples containing protein	Porotrode	6.0235.200	24
Nonaqueous acid/base titrations	Titrations with perchloric acid, cyclohexylamine, alcoholic HCl, determination of base number (TBN) of crude oil products	Solvotrode easyClean with c(LiCl) = 2 mol/L in ethanol	6.0229.010	22
	Titrations with alcoholic KOH, NaOH and TBAOH, potassium methylate, determination of the total acid number (TAN) of petroleum products, free fatty acid/hydroxyl number in oils and fats	Solvotrode easyClean with c(TEABr) = 0.4 mol/L in ethylene glycol	6.0229.010	22
Redox titrations Titrants: arsenite, cersulfate iron(III), iodine, potassium bromate sodium nitrite oxalic acid, permanganate, thiosulfate, titanium(III), $Hg(NO_3)_2$	Titrations without change of the pH value	Pt-Titrode	6.0431.100	34
	Titrations with change of the pH value	Combined Pt-ring electrode	6.0451.100	36
	Chemical oxygen demand (COD) in waters	Combined Au-ring electrode	6.0452.100	36
	Penicillin, ampicillin	Combined Au-ring electrode	6.0452.100	36
	Bromatometry, iodometry and cerimetry in accordance with Pharm. Europe & USP	Pt-Titrode	6.0431.100	34
	Titrations in I_{pol} mode	Double Pt-sheet electrode Double Au-ring electrode	6.0309.100 6.00353.100	32 32
Karl Fischer titrations	Water determination according to Karl Fischer	Double Pt-wire electrode	6.0338.100	38
Precipitation titrations Titrants: Silver nitrate	Chloride in general, sodium chloride content in foods	Ag-Titrode	6.00430.100	34
	Chloride in dialysis and infusion solutions	Ag-Titrode with Ag_2S coating	6.00430.100S	34
	Titrations in accordance with Pharm. Europe & USP	Ag-Titrode with Ag_2S coating	6.00430.100S	34
	Determination of hydrogen sulfide, mercaptans, carbonyl sulfides, sulfides	Ag-Titrode with Ag_2S coating	6.00430.100S	34
	Chloride, bromide, iodide and cyanide in electroplating baths	Ag-Titrode with Ag_2S coating	6.00430.100S	34
	Fluoride/hydrofluoric acid in etching baths	F^--ISE – crystal membrane	6.0502.150	42
Complexometry Titrants: EDTA, Complexon© III and IV	Back titration of excess Ba^{2+} with EDTA	Combined Ca^{2+}-ISE polymer membrane	6.0510.100	42
	Determination of Ca^{2+}, Mg^{2+} in aqueous solutions (in accordance with AB 125)	Combined Ca^{2+}-ISE polymer membrane	6.0510.100	42 42
	Determination of Al, Ba, Bi, Ca, Cd, Co, Fe, Mg, Ni, Pb, Zn	Cu^{2+}-ISE crystal membrane	6.0502.140	42
Photometric titrations	Titrations in aqueous and nonaqueous solutions	Optrode	6.1115.000	86
Surfactants in nonaqueous media Aromatic and aliphatic hydrocarbons, ketones, gasoline, kerosene, dichloroethane and trichloroethane	Titration of anionic and cationic surfactants, titrations in chloroform, formulations containing oil such as cooling lubricants, drilling and cutting oils, oil-containing shower baths, pH < 10	Surfactrode Resistant	6.0507.130	46
	Titration of anionic and cationic surfactants, titration of surfactant formulations, washing powders, soaps, pH > 10	Surfactrode Refill	6.0507.140	46
Surfactants in aqueous media	Titration of cationic surfactants	«Cationic Surfactant» electrode	6.0507.150	46
	Titration of anionic surfactants	«Ionic Surfactant» electrode	6.0507.120	46
	Titration of non-ionic surfactants Titration of pharmaceutical ingredients with sodium tetraphenylborate	NIO electrode	6.0507.010	46

dTrodes – Digital electrodes for OMNIS

dTrodes – simply easier

The latest generation of intelligent, digital electrodes – the dTrodes – were specifically developed for the OMNIS platform. The dTrodes combine the measuring electrode and the measuring amplifier in one slim and robust sensor.

The electrode head contains an analog-to-digital converter, which converts the measured analog signal into a binary code. The digital data is then optically transmitted to the titrator. This means, the sensor is electrostatically decoupled from the titrator. The signal is thus not affected by electrostatic interferences and is therefore of low noise.

Important sensor data, such as article and serial numbers, calibration data, calibration history, working life, and calibration validity period are automatically saved on the integrated memory chip. Therefore, the sensor can easily be used on another instrument without having to repeat the calibration. This also eliminates the danger of mixing up sensors.

LED for sensor status

When connecting a dTrode to the OMNIS titrator, the sensor is automatically recognized by the software and saved in its sensor list. Immediately, all sensor data is transferred to the software and checked for its validity. A problem with the sensor, e.g., an invalid parameter, can be recognized immediately by the color of the integrated LED. Sensor management at its best!

Ordering information	
dUnitrode with Pt1000	6.00200.300
dEcotrode plus	6.00201.300
dAquatrode plus with Pt1000	6.00202.300
dSolvotrode	6.00203.300
dProfitrode	6.00204.300
dAg-Titrode	6.00404.300
dAg-Titrode with Ag_2S coating	6.00404.300S
dPt-Titrode	6.00401.300
dAg ring electrode	6.00402.300
dPt ring electrode	6.00403.300
dCalcium-ISE, combined	6.00502.300
Digital measuring module	6.02100.010


6.00502.300
6.00402.300
6.00204.300
6.00404.300
6.02100.010
602100010 Measuring Module Digital
Metrohm

iTrodes – Intelligent electrodes for the Titrando generation

Easy digital identification

The iTrodes contain a memory chip which enables the storage of all relevant sensor data, such as article and serial number, calibration data, calibration history, working live and calibration validity period.

All of the sensor data are uploaded automatically when the iTrode is connected to an instrument. This means, that the possibility of any mix-up or editing error is eliminated and each analysis result is traceable to the used electrode.

Digital data transmission

When connected to the sensor, the analog/digital converter in the 854 iConnect (2.854.0010) converts the analog measuring signal into binary code. Digital data transmission means that the measuring signal is no longer susceptible to electrostatic influences. Interference-free transmission can now be guaranteed, no matter how long the electrode cable is.

iTrodes can be used with the 913 and 914 pH meter, the 916 Ti-Touch or the 888 and 90x Titrandos.

Ordering information	
iAquatrode Plus with Pt1000	6.0277.300
iUnitrode with Pt1000	6.0278.300
iSolvotrode	6.0279.300
iEcotrode Plus	6.0280.300
iAg-Titrode	6.00470.300
iAg-Titrode with Ag_2S coating	6.00470.300S
iPt-Titrode	6.0471.300
iAg-ring electrode, combined	6.00450.300
iPt-ring electrode, combined	6.0451.300
iConnect	2.854.0010

Unitrode and Solvotrode *easy*Clean – Cleaning at the touch of a button

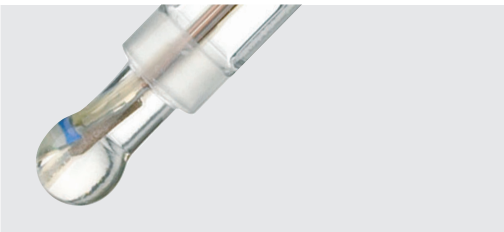
Easy cleaning of the diaphragm: Just press once on the electrode head and the electrolyte flows out. The diaphragm does not need to be touched any more for cleaning.

Highlights

- Easy contact-free cleaning of the diaphragm
- Greater accuracy and reproducibility of the electrolyte flow (glass on glass, the spring in the head returns to the defined starting point)
- Reduced immersion depth of the sensor through optimization of the membrane shape

Ordering information	
Unitrode *easy*Clean with Pt1000, fixed cable, plug F	6.0260.010
Unitrode *easy*Clean with Pt1000, fixed cable 2 m, plug F	6.0260.020
Solvotrode *easy*Clean, fixed cable, plug F	6.0229.010
Solvotrode *easy*Clean, fixed cable 2 m, plug F	6.0229.020

Electrodes for pH measurement/pH titration



Fine-tune your measurements!

The greatest precision and ease of care – these are the two outstanding properties of Unitrode and Aquatrode Plus. The constant electrolyte outflow of the fixed ground-joint diaphragm (which is largely insensitive to contamination) guarantees a low-noise measuring signal, even in difficult samples and independent of the measuring conditions. Further details can be found in the theoretical section on page 111.

Separate pH glass electrodes

Separate pH glass electrode

- Electrically shielded
- Blue T glass for reliable results, e.g. in differential potentiometry in non-aqueous media
- Optimal length for sample changer applications

Technical specifications	
pH range	0...14
Temperature range	0...80 °C
Installation length	142 mm
Shaft diameter	12 mm
Minimum immersion depth	15 mm
Electrode plug-in head	Metrohm plug-in head G

Differential potentiometry

In addition to the measuring electrode, a reference electrode and an auxiliary electrode are required for differential potentiometry. The shielding of the reference electrode must be identical to that of the measuring electrode.

Reference electrodes for differential potentiometry (see «Reference electrodes» section)

- Ag/AgCl DJ reference electrode, length 100 mm, Metrohm plug-in head G
  Without electrolyte filling, without cable 6.0729.100

- Ag/AgCl DJ reference electrode, length 138 mm, Metrohm plug-in head G
  Without electrolyte filling, without cable 6.0729.110

Auxiliary electrodes for differential potentiometry, Metrohm plug-in head B (see «Separate metal electrodes» section)

Separate Pt wire electrode	6.0301.100
Separate Pt rod electrode	6.1241.040 + 6.1248.000
Separate Pt ring electrode	6.0351.100

Ordering information	
Separate pH glass electrode, without cable	6.0150.100

Electrodes for pH measurement

Primatrode with NTC – the economical entry to GLP-compliant pH measurement

- For solutions that do not contain precipitates, proteins or sulfides
- Long-lasting standard electrode
- Unbreakable plastic shaft
- Impact protection for the glass membrane
- LL reference system with long-term stability
- Variant 6.0228.020 with waterproof plug I for use with the 913/914 pH meter (IP67))

Technical specifications Primatrode	
Shaft material	PP
pH range	0...14
Temperature range	0...80 °C
Temperature sensor	NTC
Diaphragm	Ceramic pin
Installation length	113 mm
Shaft diameter	12 mm
Minimum immersion depth	15 mm

Solitrode with Pt1000 – robust and reliable, ideal for routine laboratory use

- For solutions that do not contain precipitates, proteins or sulfides
- Long-lasting standard electrode
- Unbrekable plastic shaft
- Impact protection for the glass membrane
- LL reference system with long-term stability

Technical specifications Solitrode	
Shaft material	PP
pH range	0...14
Temperature range	0...80 °C
Temperature sensor	Pt1000
Diaphragm	Ceramic pin
Installation length	113 mm
Shaft diameter	12 mm
Minimum immersion depth	15 mm

Ecotrode Gel – the maintenance-free solution

- Ideal for routine measurements in similar samples
- Specialist for measurement in polymer dispersions (water-based dispersion paints and adhesive dispersions on basis of acrylic acid esters and styrene; butyl acrylates)
- Maintenance-free
- Lifetime indicator
- LL reference system with long-term stability

Technical specifications Ecotrode Gel	
Shaft material	Glass
pH range	1...11
Temperature range	0...60 °C
Temperature sensor	NTC
Diaphragm	Twin pore
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	20 mm
Electrode plug-in head	Metrohm plug-in head U

How to store your electrodes correctly:

Rapid response is not a matter of magic, but rather a question of storage! Metrohm recommends the patented storage solution (6.2323.000) for all combined pH glass electrodes which use c(KCl) = 3 mol/L as the reference electrolyte. This prevents the aging of the glass membrane and, as a result, guarantees response times short as they were on the first day. More information on this can be found in the theoretical section in Chapter 1.3.1. «pH glass electrodes.»

Primatrode
The economical entry to GLP-compliant pH measurement

Solitrode
Robust and reliable, ideal for routine laboratory use

Ecotrode Gel
The maintenance-free solution

Ordering information	
Primatrode with NTC, fixed cable (1.2 m) with plug F + 1 x B (2 mm)	6.0228.010
Primatrode with NTC, fixed cable (1.2 m) with plug I (IP67) + 1 x B (2 mm)	6.0228.020
Solitrode with Pt1000, without cable, plug-in head U	6.0228.600
Solitrode without temperature sensor, without cable	6.0220.100
Ecotrode Gel with NTC, without cable, plug-in head U	6.0221.600
Ecotrode Gel without temperature sensor, without cable	6.0221.100

Electrodes for pH measurement

Unitrode with Pt1000 – high performance in difficult samples and at high pH values

- For universal use, even in dyes, pigments, inks, suspensions, resins and polymers
- Fixed ground-joint diaphragm insensitive to contamination
- High temperature resistance and very low alkali error
- Rapid response to temperature changes
- Outer electrolyte Idrolyte for temperatures of 80...100 °C
- LL reference system with long-term stability

Technical specifications Unitrode	
Shaft material	Glass
pH range	0...14
Temperature range	0...100 °C
Temperature sensor	Pt1000
Diaphragm	Fixed ground-joint
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	25 mm

Aquatrode Plus with Pt1000 – ideal for weekly buffered aqueous solutions

- Special electrode membrane glass: precise measuring values and very rapid response times, even in weekly buffered solutions such as drinking water, surface water and rain water and other poorly conducting solutions
- Maintenance-free inner reference electrolyte (gel)
- Variable bridge electrolyte for special applications
- Fixed ground-joint diaphragm insensitive to contamination
- Optimized length for sample changer applications
- LL reference system with long-term stability

Technical specifications Aquatrode Plus	
Shaft material	Glass
pH range	0...13
Temperature range	0...60 °C
Temperature sensor	Pt1000
Diaphragm	Fixed ground-joint
Installation length	135 mm
Shaft diameter	12 mm
Minimum immersion depth	20 mm

EtOH-Trode – the specialist for ethanol

- Developed for pHe measurement in ethanol
- Special membrane glass
- Very precise ground-joint diaphragm
- Double-junction system for free choice of electrolytes (e.g. 3 M KCl in ASTM D 6423, 1 M LiCl in EN 15490).
- LL reference system with long-term stability

Technical specifications EtOH-Trode	
Shaft material	Glass
pH range	0...13
Temperature range	0...80 °C
Diaphragm	Fixed ground-joint
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	20 mm
Electrode plug-in head	Metrohm plug-in head G

Wellness for the electrode

Reliable measuring results over long periods of time can only be guaranteed if the glass membrane and the diaphragm receive preventative and regular care. Cleaning by means of etching with toxic chemicals or a mechanical treatment of the diaphragm is not only complicated and expensive, it also accelerates the aging of the pH glass electrode as well. The care kit (6.2325.000, pg. 92) was developed for simple, gentle cleaning of pH glass electrodes with a liquid electrolyte. Regular application can considerably prolong its lifetime.

EtOH-Trode
The specialist for
pHe measurement

Unitrode
High performance, even in
difficult samples and at high
temperatures

Aquatrode Plus
Rapid response times
and greatest precision in
poorly buffered solutions due to
special electrode glass and fixed
ground-joint diaphragm

Ordering information	
Unitrode easyClean with Pt1000, fixed cable (1.2 m) plug F + 1 x B (2mm)	6.0260.010
Unitrode easyClean with Pt1000, fixed cable (2 m) plug F + 1 x B (2 mm)	6.0260.020
Unitrode without temperature sensor, without cable	6.0259.100
Unitrode with Pt1000, without cable, plug-in head U	6.0258.600
iUnitrode with Pt1000	6.0278.300[1]
dUnitrode with Pt1000	6.00200.300[2]
Aquatrode Plus with Pt1000, without cable, plug-in head U	6.0257.600
Aquatrode Plus without temperature sensor, without cable	6.0253.100
iAquatrode Plus with Pt1000	6.0277.300[1]
dAquatrode Plus with Pt1000	6.00202.300[2]
EtOH-Trode without temperature sensor, without cable	6.0269.100

[1] Further information about iTrodes can be found on pg. 10.
[2] Further information about dTrodes can be found on pg. 8.

Electrodes for pH titration

Ecotrode Gel – the maintenance-free solution
- Ideal for routine measurements in similar samples
- Maintenance-free
- Lifetime indicator
- LL reference system with long-term stability

Technical specifications Ecotrode Gel	
Shaft material	Glass
pH range	1...11
Temperature range	0...60 °C
Diaphragm	Twin pore
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	20 mm
Electrode plug-in head	Metrohm plug-in head G

Ecotrode Plus – high durability in routine use at a fair price
- For acid/base titrations in various kinds of solutions
- Fixed ground-joint diaphragm insensitive to contamination
- Ideal for routine laboratory use
- LL reference system with long-term stability

Technical specifications Ecotrode Plus	
Shaft material	Glass
pH range	0...13
Temperature range	0...80 °C
Diaphragm	Fixed ground-joint
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	20 mm
Electrode plug-in head	Metrohm plug-in head G

Profitrode – professional working in the most difficult of matrices
- For difficult matrices (galvanic baths, precipitates, samples containing sulfides, etc.)
- Flexible ground-joint diaphragm, particularly easy to clean
- Double-junction construction
- Available in various lengths (113/170/310 mm)
- LL reference system with long-term stability

Technical specifications Profitrode	
Shaft material	Glass
pH range	0...14
Temperature range	0...80 °C
Diaphragm	Flexible ground-joint
Installation length	113/170/310 mm
Shaft diameter	12 mm
Minimum immersion depth	30 mm
Electrode plug-in head	Metrohm plug-in head G

Unitrode – high performance in difficult samples and at high pH values
- For universal use, even in dyes, pigments, inks, suspensions, resins and polymers
- Fixed ground-joint diaphragm insensitive to contamination
- High temperature resistance and very low alkali error
- Rapid response to temperature changes
- Outer electrolyte Idrolyte for temperatures of 80...100 °C
- LL reference system with long-term stability

Technical specifications Unitrode	
Shaft material	Glass
pH range	0...14
Temperature range	0...100 °C
Diaphragm	Fixed ground-joint
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	25 mm

Ecotrode Gel
Maintenance-free
Routine

Ecotrode Plus
High durability in routine use at a fair price

Profitrode
Professional working in the most difficult matrices

Unitrode
High performance in difficult samples and at high pH values

Ordering information	
Ecotrode Gel without temperature sensor, without cable	6.0221.100
Ecotrode Plus, without temperature sensor, without cable	6.0262.100
iEcotrode Plus without temperature sensor	6.0280.300[1]
dEcotrode Plus, without temperature sensor	6.00201.300[2]
Profitrode, length 113 mm, without cable	6.0255.100
Profitrode, length 170 mm, without cable	6.0255.110
Profitrode, length 310 mm, without cable	6.0255.120
dProfitrode, without temperature sensor	6.00204.300[2]
Unitrode easyClean with Pt1000, fixed cable (1.2 m) plug F + 1 x B (2 mm)	6.0260.010
Unitrode easyClean with Pt1000, fixed cable (2 m) plug F + 1 x B (2 mm)	6.0260.020
Unitrode without temperature sensor, without cable	6.0259.100
Unitrode with Pt1000, without cable, plug-in head U	6.0258.600
iUnitrode with Pt1000	6.0278.300[1]
dUnitrode with Pt1000	6.00200.300[2]

[1] Further information about iTrodes can be found on pg. 10.
[2] Further information about dTrodes can be found on pg. 8.

Electrodes for pH titration

Aquatrode Plus – ideal for aqueous, weekly buffered solutions

- Precise measuring values and very rapid response times in ion-deficient or weekly buffered solutions – such as drinking water, surface water and rain water – thanks to special membrane glass and optimized, fixed ground-joint diaphragm insensitive to contamination
- Maintenance-free inner reference electrolyte (gel)
- Variable bridge electrolyte for special applications
- LL reference system with long-term stability

Technical specifications Aquatrode Plus	
Shaft material	Glass
pH range	0...13
Temperature range	0...60 °C
Diaphragm	Fixed ground-joint
Installation length	135 mm
Shaft diameter	12 mm
Minimum immersion depth	20 mm
Electrode plug-in head	Metrohm plug-in head G

Solvotrode easyClean – space-saving alternative for titration in non-aqueous media

- For non-aqueous titrations in the pharmaceutical sector
- For determination of TAN/TBN in compliance with ASTM D4739, D2896 and D664 and DIN ISO 3771 and DIN EN 12634
- Reference electrolyte: LiCl(sat) in ethanol
- Rapid response and stable measuring values in organic solvents
- Shielding against electrostatic effects
- EasyClean diaphragm, particularly easy and contactless cleaning
- LL reference system with long-term stability

Technical specifications Solvotrode easyClean	
Shaft material	Glass
pH range	0...14
Temperature range	0...70 °C
Diaphragm	Flexible ground-joint
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	20 mm

Drinking water analysis – Does it matter at which stirring rate titration is performed?

When stirring in ion-deficient solutions, streaming potentials occur at pH electrodes with ceramic pin diaphragms which falsify measuring values. In the case of a SET titration, e.g. to a defined pH value, a considerable error can be produced if an incorrect value is measured at the start or at the endpoint of the titration. See page 111 to find out why you can forget about this problem when using the Aquatrode Plus.

Solvotrode easyClean
Space-saving alternative for titration in non-aqueous media

Aquatrode Plus
Fast response and excellent precision in weekly buffered solutions thanks to special membrane glass and fixed ground-joint diaphragm

Ordering information	
Aquatrode Plus without temperature sensor, without cable	6.0253.100
Aquatrode Plus with Pt1000, without cable, plug-in head U	6.0257.600
iAquatrode Plus with Pt1000	6.0277.300[1]
dAquatrode Plus with Pt1000	6.00202.300[2]
Solvotrode easyClean, fixed cable (1.2 m) plug F	6.0229.010
Solvotrode easyClean, fixed cable (2 m) plug F	6.0229.020
iSolvotrode	6.0279.300[1]
dSolvotrode	6.00203.300[2]

[1] Further information about iTrodes can be found on pg. 10.
[2] Further information about dTrodes can be found on pg. 8.

Special electrodes for pH measurement/pH titration

Biotrode – pH measurement in small volumes

- Very low immersion depth and very small diameter of the electrode tip (3 mm), exceptionally suited to small measuring vessels
- For protein-containing samples and solutions with organic components
- Very low electrolyte outflow (Idrolyte)
- LL reference system with long-term stability

Technical specifications Biotrode	
Shaft material	Glass
pH range	1...11
Temperature range	0...60 °C
Diaphragm	Platinum wire
Installation length	113 mm
Shaft diameter	12 mm
Shaft diameter bottom	3 mm
Minimum immersion depth	7 mm
Electrode plug-in head	Metrohm plug-in head G

Spearhead electrode – pH measurement in semi-solid samples

- Robust electrode tip for measurements in semi-solid samples such as cheese, meat, fruits, etc.
- Maintenance-free reference electrolyte (gel)
- Easy-to-clean diaphragm
- LL reference system with long-term stability
- With or without integrated temperature sensor
- Lifetime indicator

Technical specifications Spearhead electrode	
Shaft material	Glass
pH range	1...11
Temperature range	0...60 °C
Temperature sensor	none / Pt1000
Diaphragm	Twin pore
Installation length	98 mm
Shaft diameter	12 mm
Shaft diameter bottom	6 mm
Minimum immersion depth	10 mm
Electrode plug-in head	Metrohm plug-in head G

Flat-membrane electrode – pH measurement on surfaces and in small sample volumes

- For pH measurement on surfaces such as paper, textiles, leather or soil samples (aqueous suspensions)
- Measurement/titration in small sample volumes
- Completely made of glass with extremely fine-grounded surface
- LL reference system with long-term stability

Technical specifications Flat-membrane electrode	
Shaft material	Glass
pH range	0...13
Temperature range	0...80 °C
Diaphragm	Fixed ground-joint
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	1 mm
Electrode plug-in head	Metrohm plug-in head G

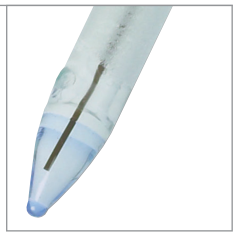
Porotrode – pH measurement in protein containing samples

- For pH measurement in very contaminated, protein-containing or viscous samples
- Low-maintenance capillary diaphragm
- Polymer electrolyte Porolyte for uniform electrolyte outflow
- LL reference system with long-term stability

Technical specifications Porotrode	
Shaft material	Glass
pH range	0...14
Temperature range	0...80 °C
Diaphragm	Ceramic capillaries
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	20 mm
Electrode plug-in head	Metrohm plug-in head G

Biotrode
pH measurement
in small volumes

Spearhead electrode
pH measurement in
semisolid samples



Flat-membrane electrode
pH measurement on surfaces

Porotrode
pH measurement in
protein containing samples

Ordering information	
Biotrode, without cable	6.0224.100
Spearhead electrode without temperature sensor, without cable	6.0226.100
Spearhead electrode with Pt1000, without cable	6.00226.600
Flat-membrane electrode, without cable	6.0256.100
Porotrode, without cable	6.0235.200

Special electrodes for pH measurement/pH titration

Microelectrode – routine use with sample changers and small vials

- For simple acid/base titrations in aqueous solutions
- Available in various lengths (113/168 mm)
- LL reference system with long-term stability

Technical specifications Microelectrode	
Shaft material	Glass
pH range	0...14
Temperature range	0...80 °C
Diaphragm	Ceramic pin
Installation length	113/168 mm
Shaft diameter	12 mm
Shaft diameter bottom	6.4 mm
Minimum immersion depth	20 mm
Electrode plug-in head	Metrohm plug-in head G

Viscotrode – universal application in viscous media

- For viscous protein- or sulfides- containing media
- Flexible ground-joint diaphragm, particularly easy to clean
- LL reference system with long-term stability

Technical specifications Viscotrode	
Shaft material	Glass
pH range	0...14
Temperature range	0...80 °C
Diaphragm	Flexible ground-joint
Installation length	113 mm
Shaft diameter	12 mm
Minimum immersion depth	30 mm
Electrode plug-in head	Metrohm plug-in head G

Syntrode with Pt1000 – use in synthesis and in bioreactors

- Low-maintenance thanks to storage vessel for reference electrolytes
- Fixed ground-joint diaphragm insensitive to contamination
- High temperature resistance
- Available in various lengths (288/438 mm)
- LL reference system with long-term stability

Technical specifications Syntrode	
Shaft material	Glass
pH range	0...14
Temperature range	0...100 °C
Temperature sensor	Pt1000
Diaphragm	Fixed ground-joint
Installation length	288/438 mm
Shaft diameter	12 mm
Minimum immersion depth	25 mm

Microelectrode
Routine use with sample changers and small vials

Viscotrode
Universal use in viscous media

Syntrode with Pt1000
For use in synthesis and in bioreactors

Ordering information	
Microelectrode, length 113 mm, without cable	6.0234.100
Microelectrode, length 168 mm, without cable	6.0234.110
Viscotrode, without cable	6.0239.100
Syntrode with Pt1000, length 288 mm, without cable, plug-in head U	6.0248.600
Syntrode with Pt1000, length 438 mm, without cable, plug-in head U	6.00249.600

Electrodes for pH titration in HF-containing solutions

Solitrode HF

- pH-glass sensor with good resistance in HF-containing solutions
- Unbreakable plastic shaft
- Fast response time

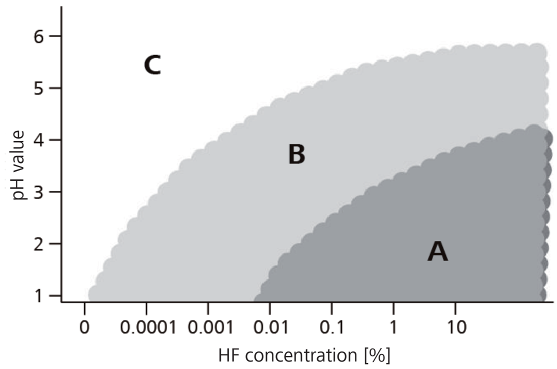
Technical Specifications	
Solitrode HF	
Shaft material	PP
pH range	1...12
Temperature range	0...40 °C
Reference system	LL-System
Reference electrolyte	c(KCl) = 3 mol/L
Diaphragm	Ceramic pin
Installation length	113 mm
Shaft diameter	12 mm
Minimum immersion depth	15 mm
Electrode plug-in head	Metrohm plug-in head G

Combined Sb-electrode

- For pH titration in very hygroscopic matrices or in matrices containing hydrofluoric acid
- Unbreakable plastic shaft

Technical Specifications	
Combined Sb-electrode	
Shaft material	PP
pH range	2...11
Temperature range	0...70 °C
Reference system	LL-System
Reference electrolyte	c(KCl) = 3 mol/L
Diaphragm	Ceramic pin
Installation length	113 mm
Shaft diameter	12 mm
Minimum immersion depth	10 mm
Electrode plug-in head	Metrohm plug-in head G

The recommended fields of application of the electrodes are illustrated in the following graph:



A Sb-electrode
B Solitrode HF
C pH-glass electrode

Ordering information	
Solitrode HF, without cable	6.0223.100
Combined Sb-electrode, without cable	6.0421.100

Metal electrodes

High-performance metal electrodes for redox and precipitation titration, and water determination according to Karl Fischer.

Separate metal electrodes

Separate Pt-wire electrode
- Electrode tip made of Pt-wire (0.8 x 6 mm)
- Auxiliary electrode for differential potentiometry

Technical specifications	
Separate Pt-wire electrode	
Shaft material	Glass
Measuring range	-2000...2000 mV
Temperature range	-20...70 °C
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	10 mm
Electrode plug-in head	Metrohm plug-in head B

Double Pt-sheet electrode
- For bivoltammetric titrations

Technical specifications	
Double Pt-sheet electrode	
Shaft material	Glass
Measuring range	-2000...2000 mV
Temperature range	-20...70 °C
Installation length	101 mm
Shaft diameter	12 mm
Minimum immersion depth	10 mm
Electrode plug-in head	Metrohm plug-in head G

Separate Ag-ring electrode
- For precipitation titrations of halides, sulfides, hydrogen sulfide, mercaptans and cyanides
- Available with or without Ag_2S coating (specify when ordering)

Separate Pt-ring electrode
- For all standard redox titrations

Double Au-ring electrode
- For bivoltammetric titrations
- Well suited for Vitamin C determination with DPIP (2,6-Dichlorophenolindophenol)
- Minimum immersion depth 20 mm

Technical specifications	
Separate metal-ring electrodes	
Shaft material	Glass
Measuring range	-2000...2000 mV
Temperature range	-20...80 °C
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	7 mm
Electrode plug-in head	Metrohm plug-in head G

Separate metal-rod electrodes
- Consisting of separate electrode shaft made of PP and exchangeable metal-rod (76 mm x 2 mm) made of platinum, silver, gold, tungsten or glassy carbon

Degree of purity	
Pt	99.90%
Ag	99.99%
Gold	99.99%
W	99.95%

Technical specifications	
Separate metal-rod electrodes	
Total length	162 mm
Installation length	140 mm
Shaft diameter	12 mm
Shaft diameter bottom	8 mm
Electrode plug-in head	Metrohm plug-in head B

Ordering information	
Separate Pt-wire electrode, without cable plug-in head B	6.0301.100
Double Pt-sheet electrode, without cable	6.0309.100
Separate Ag-ring electrode, without cable	6.00350.100
Separate Pt-ring electrode, without cable	6.0351.100
Double Au-ring electrode, without cable	6.00353.100
Shaft for separate metal-rod electrode, without cable, plug-in head B	6.1241.040
Electrode rod Pt	6.1248.000
Electrode rod Ag	6.1248.010
Electrode rod Au	6.1248.030
Electrode rod glassy carbon	6.1248.040
Electrode rod W	6.1248.050

Titrodes – the maintenance-free metal electrodes

Pt-Titrode / Pt-Micro Titrode

- For redox titrations without alteration of the pH value
- For bromatometry, iodometry and cerimetry in compliance with Pharm. Europe & USP
- Maintenance-free reference system (pH glass membrane)

Ag-Titrode / Ag-Micro Titrode

- For precipitation titrations without alteration of the pH value
- For precipitation titrations of halides, sulfides, hydrogen sulfide, mercaptans and cyanides
- For titrations in compliance with Pharm. Europe & USP
- Available with or without Ag_2S, AgCl or AgBr coating (specify when ordering)
- Maintenance-free reference system (pH glass membrane)

Au-Micro Titrode

- For ferrometry (determination of the chemical oxygen demand, COD)
- For the determination of penicillin and ampicillin
- For titrations with $Hg(NO_3)_2$
- For redox titrations in the presence of chromium or iron
- Maintenance-free reference system (pH glass membrane)
- Available in two length (178 mm / 308 mm)

Technical specifications

Titrodes	
Shaft material	Glass
Measuring range	-2000...2000 mV
pH range	0...14
Temperature range	0...80 °C
Reference system	pH glass electrode
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	20 mm
Electrode plug-in head	Metrohm plug-in head G

Micro Titrodes	
Shaft material	Glass
Measuring range	-2000...2000 mV
pH range	0...14
Temperature range	0...80 °C
Reference system	pH glass electrode
Installation length	178 mm
Shaft diameter	12 mm
Shaft diameter bottom	6.4 mm
Minimum immersion depth	20 mm
Electrode plug-in head	Metrohm plug-in head G

Ag-Titrodes: available with or without coating

Depending on the application (see application lists), the use of an Ag-Titrode with or without Ag_2S, AgBr or AgCl coating is recommended. We would be happy to supply you with your Ag-Titrode with the respective coating at an additional charge; please specify when ordering.

Titrodes
High performance in redox and precipitation titrations without alteration of the pH value

Micro Titrodes
Optimized length and diameter of the lower part of the electrode for use in earlier Metrohm sample changer systems

Ordering information

Ag-Titrode, without cable	6.00430.100
Ag-Titrode, with Ag_2S coating, without cable	6.00430.100S
Ag-Titrode, with AgBr coating, without cable	6.00430.100Br
iAg-Titrode	6.00470.300
iAg-Titrode with Ag_2S coating	6.00470.300S
dAg-Titrode	6.00404.300
dAg-Titrode with Ag_2S coating	6.00404.300S
Pt-Titrode, without cable	6.0431.100
iPt-Titrode	6.0471.300[1]
dPt-Titrode	6.00401.300[2]
Micro Ag-Titrode, without cable	6.0433.110
Micro Pt-Titrode, without cable	6.0434.110
Micro Au-Titrode, length 178 mm, without cable	6.0435.110
Micro Au-Titrode, length 308 mm, without cable	6.00435.120

[1] Further information about iTrodes can be found on pg. 10.
[2] Further information about dTrodes can be found on pg. 8.

Combined metal electrodes

Combined Ag-ring electrode

- For precipitation titrations of halides, sulfides, hydrogen sulfide, mercaptans and cyanides with alteration of the pH value
- Available with or without Ag_2S or AgBr coating (specify when ordering)

Combined Pt-ring electrode

- For redox titrations with alteration of the pH value

Combined Au-ring electrode

- For ferrometry (determination of the chemical oxygen demand COD)
- For determination of penicillin and ampicillin

Technical specifications

Combined Ag-ring electrode

Shaft material	Glass
Measuring range	-2000...2000 mV
Temperature range	0...70 °C
Reference system	LL system
Reference electrolyte	$c(KNO_3)$ = 1 mol/L
Diaphragm	Fixed ground-joint
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	15 mm
Electrode plug-in head	Metrohm plug-in head G

Combined Pt-ring electrode / Au-ring electrode

Shaft material	Glass
Measuring range	-2000...2000 mV
Temperature range	-5...80 °C
Reference system	LL system
Reference electrolyte	c(KCl) = 3 mol/L
Diaphragm	Ceramic pin
Installation length	113 mm
Shaft diameter	12 mm
Minimum immersion depth	15 mm
Electrode plug-in head	Metrohm plug-in head G

Combined metal-ring electrodes
High performance with redox and precipitation titrations with alteration of the pH value

Ordering information	
Combined Ag-ring electrode, without cable	6.00450.100
Combined Ag-ring electrode, with Ag_2S coating, without cable	6.00450.100S
iAg-ring electrode, combined	6.00450.300
dAg-ring electrode, combined	6.00402.300[2]
Combined Pt-ring electrode, without cable	6.0451.100
iPt-ring electrode, combined	6.0451.300[1]
dPt-ring electrode, combinded	6.00403.300[2]
Combined Au-ring electrode, without cable	6.0452.100

[1] Further information about iTrodes can be found on pg. 10.
[2] Further information about dTrodes can be found on pg. 8.

Electrodes for Karl Fischer titration

Double Pt-wire electrodes

Indicator electrode for volumetric KF determination

- For «I_{pol}» and «U_{pol}»-mode titrations

Technical specifications	
Measuring range	-2000...2000 mV
Temperature range	-20...70 °C
Installation length	96 mm
Shaft diameter	8 mm
Minimum immersion depth	5 mm
Electrode plug-in head	Metrohm plug-in head G

Indicator electrode for coulometric KF determination

- With standard ground-joint 14/15

Technical specifications	
Measuring range	-2000...2000 mV
Temperature range	-20...70 °C
Installation length	101 mm
Shaft diameter	12 mm
Shaft diameter bottom	8.75 mm
Minimum immersion depth	10 mm
Electrode plug-in head	Metrohm plug-in head G

Indicator electrode for KF Sample Changers

- Fixed cable (length 2 m with plug F)

Technical specifications	
Measuring range	-2000...2000 mV
Temperature range	-20...70 °C
Installation length	103 mm
Shaft diameter	5.3 mm
Minimum immersion depth	10 mm

Generator electrodes

Generator electrode with diaphragm

- Standard ground-joint 29/22 and Metrohm plug-in head G
- Requires cable 6.2104.120 for connection with KF Coulometers

Technical specifications	
Temperature range	-20...70 °C
Installation length	108 mm
Shaft diameter	24 mm
Minimum immersion depth	15 mm

Generator electrode without diaphragm

- Standard ground-joint 29/22 and Metrohm plug-in head G
- Requires cable 6.2104.120 for connection with KF Coulometers

Technical specifications	
Temperature range	-20...70 °C
Installation length	108 mm
Shaft diameter	24 mm
Minimum immersion depth	15 mm

6.0344.100

6.0345.100

Ordering information	
Indicator electrode for KF volumetry, without cable	6.0338.100
Indicator electrode for KF coulometry, without cable	6.0341.100
Indicator electrode for KF Sample Changers, fixed cable (2 m), plug F	6.0340.000
Generator electrode with diaphragm, without cable	6.0344.100
Generator electrode without diaphragm, without cable	6.0345.100


TEGOtrant
c = 0.005 mol/L
DISTILLED
WATER
Stirrer

Electrodes for ion and surfactant analysis

Ion-selective electrodes

Crystal-membrane electrodes
- Robust construction
- Can also be used for brief periods in organic solvents
- Simple cleaning and renewal of electrode surface with polishing set

Polymer-membrane electrodes for K^+, NO_3^-, Na^+ and Ca^{2+}
- Robust construction
- High selectivity due to ionophores immobilized in the membrane
- Short preparation time after conditioning in a standard solution
- For aqueous solutions

Ammonia-selective gas-membrane electrode
- Robust construction
- Short preparation time after conditioning in a standard solution
- The gas-permeable membrane ensures high selectivity and prevents interferences by the measuring solution

Choose the right sensor for your application:

NH_3-ISE (Low) 6.0506.100 / 6.1255.000
- Clean samples (e.g., drinking water, boiler feed water, etc.)
- Faster response time at the detection limit
- Lower detection limits
- Individually tested and certified
- Complete modules for simple exchange

NH_3-ISE (High) 6.0506.150 / 6.1255.050
- Waste water samples
- For long-term measurements, monitoring
- Faster response times after measuring high ammonium
  concentrations
- Better signal stability at high ammonium concentrations
- Affordable exchange of contaminated membranes (e.g., oil residues)

Ion	Article no.	Membrane material	Min. immersion depth (mm)	Installation-length (mm)	Shaft-diameter (mm)	Tempera-ture range (°C)	Measure-ment range (mol/L)	pH range
Ag^+	6.0502.180	Crystal	1	125	12	0...80	10^{-7}...1	2...8
Br^-	6.0502.100	Crystal	1	125	12	0...50	10^{-6}...1	0...14
Ca^{2+}	6.0510.100	Polymer[2]	10	113	12	0...40	$5*10^{-7}$...1	2...12
Cl^-	6.0502.120	Crystal	1	125	12	0...50	10^{-5}...1	0...14
CN^-	6.0502.130	Crystal	1	125	12	0...80	$8*10^{-6}$...10^{-2}	10...14
Cu^{2+}	6.0502.140	Crystal	1	125	12	0...80	10^{-8}...10^{-1}	2...12
F^-	6.0502.150	Crystal	1	125	12	0...80	10^{-6}...sat.	5...7
I^-	6.0502.160	Crystal	1	125	12	0...50	$5*10^{-8}$...1	0...14
K^+	6.0510.110	Polymer[3]	10	113	12	0...40	10^{-7}...1	2.5...11
Na^+	6.0508.100	Polymer	1	125	12	0...40	$5*10^{-6}$...1	2...12
NH_4^+	6.0506.100	Gas membrane	5	125	12	0...50	$5*10^{-6}$...10^{-2}	11
NH_4^+	6.0506.150	Gas membrane	5	125	12	0...50	10^{-4}...1	11
NO_3^-	6.00510.120	Polymer[1]	10	113	12	0...40	10^{-6}...1	2.5...11
Pb^{2+}	6.0502.170	Crystal	1	125	12	0...80	10^{-6}...10^{-1}	4...7
S^{2-}	6.0502.180	Crystal	1	125	12	0...80	10^{-7}...1	2...12

[1] Combined sensor. Ceramic pin diaphragm; electrolyte c(KCl) = 3 mol/L.
[2] Combined sensor. Ceramic pin diaphragm; electrolyte c(NH_4NO_3) = 1 mol/L.
[3] Combined sensor. Ceramic pin diaphragm; electrolyte c(CH_3COOLi) = 1 mol/L.

Accessories for ion-selective electrodes

LL ISE reference 6.0750.100
Double-junction Ag/AgCl reference electrode with fixed ground-joint diaphragm and optimized length for sample changer applications. Standard bridge electrolyte: c(KCl) = 3 mol/L.

LL ISE Reference
A stable, reproducible reference potential is very important at low ion concentrations, low ionic strengths and especially with repeated determinations using sample changer systems. For this reason Metrohm recommends reference electrodes with a fixed ground-joint diaphragm for working with ion-selective electrodes. In addition to a constant electrolyte outflow of approx. 5...30 µL/h, these electrodes are also considerably less influenced by either the ionic strength of the sample solution or the stirring speed than other types of reference electrodes.

Accessories for ion-selective electrodes

6.1255.000	Membrane module kit „low" for 6.0506.1X0, consisting of 3 certified, complete membrane modules + 50 mL inner electrolyte
6.1255.050	Membrane module kit „high" for 6.0506.1X0 consisting of 1 module and 20 membranes
6.2316.030	Inner filling solution for NH_3-sensors
6.2328.000	Electrolyte $c(CH_3COOLi)$ = 1 mol/L for combined K-ISE
6.2327.000	Electrolyte solution $c(NH_4NO_3)$ = 1 mol/L for combined Ca-ISE
6.2308.020	Electrolyte solution c(KCl) = 3 mol/L for combined NO_3-ISE

6.2802.000	Polishing set for crystal-membrane electrodes 6.0502.1X0 (approx. 2 g Al_2O_3 and polishing cloth)

Ion standards

6.2301.060	Potassium chloride standard, c(KCl) = 0.1 mol/L, 250 mL

Spoilt for choice!

To what must I pay particular attention in an ion determination? Precision? Time needed? Costs?

Which method is the most suitable for my application? Titration? Direct measurement? Standard addition?

ISA? TISAB? When is their use advisable? Which solution do I need for my application? You will find the answers to these questions along with many other useful tips for ion determination with ion-selective electrodes from Metrohm in the theoretical part in section 1.3.3. «Ion-selective electrodes.»

Electrodes for surfactant titration

Surfactant electrodes for two-phase titration

Surfactrode Refill

- Refillable surfactant electrode for the titration of ionic surfactants in non-aqueous solvents
- Renewable electrode surface, therefore practically unlimited working life
- Resistant to virtually all conventional solvents used in surfactant analysis (not to chloroform)
- Particularly suitable for titration of detergents and soap

Technical specifications	
Shaft material	PEEK
pH range	0...13
Temperature range	0...40 °C
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	1 mm
Electrode plug-in head	Metrohm plug-in head G

Surfactrode Resistant

- Durable surfactant electrode for the two-phase titration of anionic and cationic surfactants in non-aqueous solvents
- Easy to clean and low-maintenance, therefore particularly suitable for use in sample changer systems
- Resistant to chloroform and all solvents used in surfactant analysis
- Particularly suitable for samples containing oil such as drilling and cutting oils or cooling lubricants

Technical specifications	
Shaft material	POM
pH range	0...10
Temperature range	10...50 °C
Installation length	108 mm
Shaft diameter	12 mm
Minimum immersion depth	5 mm
Electrode plug-in head	Metrohm plug-in head G

Polymer-membrane surfactant electrodes for environmentally-friendly surfactant titration

Cationic Surfactant electrode

- For the titration of cationic and anionic surfactants in aqueous matrices
- Optimized for cationic surfactants
- Excellent response due to ionophores immobilized in the membrane
- Long working life with normal use

Ionic Surfactant electrode

- For the titration of anionic and cationic surfactants in aqueous matrices
- Excellent response due to ionophores immobilized in the membrane
- Long working life with normal use

NIO Surfactant electrode

- For the titration of non-ionic surfactants in aqueous matrices
- For the titration of surfactants based on polyoxyethylene adducts
- For the titration of pharmaceutical ingredients
- Long working life with normal use

Technical specifications

Cationic Surfactant electrode
Ionic Surfactant electrode
NIO Surfactant electrode

Shaft material	PVC
pH range	0...12
Temperature range	0...40 °C
Installation length	125 mm
Shaft diameter	12 mm
Shaft diameter bottom	2.5 mm
Minimum immersion depth	20 mm
Electrode plug-in head	Metrohm plug-in head G

Ordering information	
Surfactrode Refill, without cable	6.0507.140
Surfactrode Resistant, without cable	6.0507.130
Cationic Surfactant electrode, without cable	6.0507.150
Ionic Surfactant electrode, without cable	6.0507.120
NIO Surfactant electrode, without cable	6.0507.010

Accessories for surfactant electrodes

Refill set for Surfactrode Refill

Paste for Surfactrode Refill, 3.5 g	6.2319.000
Filling tool	6.2826.010

Reagents for surfactant titration

TEGO trant A100, titrant for anionic surfactants

18 g	6.2317.030

TEGO add, additive for two-phase titration

250 mL	6.2317.120


6.2319.000
Metrohm
6.2317.000
Metrohm
1078.0002
6.2317.100
TEGO® add
1098.0001


KCl 3mol/L

Reference electrodes – our best references

Double-junction reference electrodes

Ag/AgCl reference electrode with Metrohm plug-in head B

- Easy to change reference and bridge electrolytes
- Variable electrolyte outflow at the flexible ground-joint diaphragm
- Available with 125 mm or 162 mm shaft length
- With standard ground-joint 14/15

Technical specifications	
Shaft material	Glass
Temperature range	0...80 °C
Diaphragm	Flexible ground-joint
Installation length	100/138 mm
Shaft diameter	12 mm
Shaft diameter bottom	12/8 mm
Minimum immersion depth	10 mm
Reference system	Ag wire + AgCl
Electrode plug-in head	Metrohm plug-in head B

Ag/AgCl reference electrode with Metrohm plug-in head G

- For differential potentiometry with Metrohm titrators
- Easy to change reference and bridge electrolytes
- Variable electrolyte outflow at the flexible ground-joint diaphragm
- Available with 125 mm or 162 mm shaft length
- With standard ground-joint 14/15

Technical specifications	
Shaft material	Glass
Temperature range	0...80 °C
Diaphragm	Flexible ground-joint
Installation length	100/138 mm
Shaft diameter	12 mm
Minimum immersion depth	10 mm
Reference system	Ag wire + AgCl
Electrode plug-in head	Metrohm plug-in head G

LL ISE Reference

- Double-junction Ag/AgCl reference electrode
- High signal stability thanks to constant, reproducible electrolyte outflow, therefore particularly suitable for sample changer applications
- Fixed ground-joint diaphragm insensitive to contamination
- Minimum immersion depth of 1 mm

Technical specifications	
Shaft material	Glass
Temperature range	0...80 °C
Diaphragm	Fixed ground-joint
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	1 mm
Reference system	LL system
Electrode plug-in head	Metrohm plug-in head B

Ordering information

Ag/AgCl DJ reference electrode, without cable, plug-in head B	
Length 100 mm, without electrolyte filling	6.0726.100
Length 100 mm, filled with c(KCl) = 3 mol/L	6.0726.107
Length 138 mm, without electrolyte filling	6.0726.110
Ag/AgCl DJ reference electrode, without cable, plug-in head G	
Length 100 mm, without electrolyte filling	6.0729.100
Length 138 mm, without electrolyte filling	6.0729.110
LL ISE reference, without cable, plug-in head B	6.0750.100

Reference electrodes

Modular reference system

- Consisting of Ag/AgCl reference system with standard ground-joint 14/15 and exchangeable electrolyte vessel
- Electrolyte vessels without storage vessels, with ceramic diaphragm, various diaphragm diameters

Technical specifications

Ag/AgCl reference system

Shaft material	Glass
Temperature range	0...80 °C
Shaft length	50 mm
Length to the upper edge	
Standard ground-joint	43 mm
Shaft diameter top	12 mm
Shaft diameter bottom	8 mm
Minimum immersion depth	20 mm
Reference system	Ag wire + AgCl
Electrode plug-in head	Metrohm plug-in head B

Electrolyte vessels without storage container

Length to the upper edge	
Standard ground-joint	101 mm
Shaft material	PTFE/glass
Diaphragm	Ceramic pin
Shaft diameter	3/5.5 mm
Diaphragm diameter	3 mm (PTFE)/1 mm (glass)

Ordering information	
Ag/AgCl reference system, without cable, plug-in head B	6.0724.140
Electrolyte vessel made of PTFE without storage vessel, diaphragm diameter 3 mm	6.1240.000
Electrolyte vessel made of glass without storage vessel, diaphragm diameter 1 mm	6.1240.020


max. fill
Metrohm
6.1246.120
min. fill

Electrodes for electrochemistry

Electrodes for voltammetric trace analysis, cyclic voltammetric stripping (CVS), cyclic voltammetry and other electrochemical techniques in Metrohm VA instruments or in combination with potentiostats from Metrohm Autolab or Metrohm DropSens.

Working electrodes for trace analysis and CVS

The electrodes described in the following can be used in various Metrohm voltammetry instruments: 663 VA Stand, 747 VA Stand, 757 VA Computrace, 797 VA Computrace, 884 Professional VA, and 894 Professional CVS.

Multi-Mode Electrode pro

- Universally applicable working electrode for polarography and voltammetry
- Determination of heavy metal ions, organic substances, anions
- Supplied without glass capillaries

Glass capillaries for Multi-Mode Electrode pro

Non-silanized glass capillaries

- Standard capillary for polarography and stripping voltammetry in alkaline solutions
- For universal use with all pH values in aqueous and non-aqueous solutions

Silanized glass capillaries

- Silanized capillaries for stripping voltammetry in acidic to mildly alkaline solutions
- Long lifetime

Ordering information	
Multi-Mode Electrode pro	6.1246.120
Glass capillaries, not silanized, 10 units	6.1226.030
Glass capillaries, silanized, 10 units	6.1226.050

6.1246.120

Electrodes for mercury-free trace analysis

scTRACE Gold

- Combined gold microwire electrode
- Determination of arsenic, mercury, copper, lead and additional heavy metals
- For laboratory instruments and the 946 Portable VA Analyzer with scTRACE Gold measuring head

Screen-printed electrodes (SPE)

- Cost effective screen-printed electrodes
- Determination of various heavy metals
- Applicable: Electrode standard type and «Work in solution» type
- For laboratory instruments with SPE electrode holder and for the 946 Portable VA Analyzer with SPE measuring head

Ordering information	
scTRACE Gold (set of 4)	6.1258.000
Holder for scTRACE Gold	6.1241.080
Carbon screen-printed electrode	DRP-C11L
SPE electrode holder	6.1241.090

6.1241.080 + 6.1258.000

6.1241.090 + DRP-C11L


6.1204.510

RDE – rotating disk electrodes

An RDE consists of a driving axle and an exchangeable electrode tip.

6.1204.600

Ordering information	
Drive for rotating disk electrode (RDE):	
for VA measuring stands	6.1204.210
with mercury contact for VA measuring stands	6.1204.220
for Professional VA/CVS systems	6.1204.510
with mercury contact for Professional VA/CVS systems	6.1204.520

Electrode tips for the RDE

Order number	Electrode tip	Applications	Determination range
6.1204.600	Glassy carbon Ø 2 mm Shaft made of glass	Determination of heavy metals with anodic stripping voltammetry (mercury film technique), kinetic and thermodynamic studies in electrochemistry	ppb to ppt
6.1204.130	Silver	Determination of halides and pseudohalides	ppb to ppt
6.1204.140	Gold	Determination of mercury and other metal ions with anodic stripping voltammetry	ppb to ppt
6.1204.170	Platinum Ø 3 mm polished	Determination of organic additives in electroplating baths with cyclic voltammetric stripping technique (CVS), kinetic and thermodynamic studies in electrochemistry	ppm to ppt
6.1204.190	Platinum Ø 1 mm polished Shaft made of glass	Determination of organic additives in electroplating baths with cyclic voltammetric stripping technique (CVS), kinetic and thermodynamic studies in electrochemistry	ppm to ppt
6.1204.610	Platinum Ø 2 mm polished Shaft made of glass	Determination of organic additives in electroplating baths with cyclic voltammetric stripping technique (CVS), kinetic and thermodynamic studies in electrochemistry	ppm to ppt

Reference and auxiliary electrodes for trace analysis and CVS

Reference electrodes

Reference electrode made of plastic with ceramic diaphragm, filled

- Universal double-junction reference electrode for voltammetry
- Inner system filled with c(KCl) = 3 mol/L
- Aqueous solutions, trace and ultra trace ranges
- Low carry-over effects, low blank values

Ordering information

Ag/AgCl reference electrode	6.0728.120
Electrolyte vessel for reference electrode	6.1245.010

Reference electrode made of plastic with ceramic diaphragm, dry

- Double-junction reference electrode. Reference system dry
- Studies in organic solvents with any electrolyte solution
- Low carry-over effects, low blank values

Ag/AgCl reference electrode (dry)	6.0728.110
Electrolyte vessel for reference electrode	6.1245.010

LL reference electrode made of plastic with ceramic diaphragm, filled

- Double-junction reference electrode for the analysis of electroplating baths with cyclic voltammetric stripping (CVS)
- Inner system filled with c(KCl) = 3 mol/L
- Very stable reference potential

LL-Ag/AgCl reference electrode	6.0728.130
Electrolyte vessel for reference electrode	6.1245.010

LL reference electrode made of glass, filled

- Double-junction reference electrode for the studies of electroplating baths with cyclic voltammetric stripping (CVS)
- Very stable reference potential
- Maintenance-free

LL-Ag/AgCl (gel) reference electrode	6.0730.100

Reference electrode made of glass with ground-joint diaphragm

- Double-junction reference electrode with dry reference system
- For aqueous as well as non-aqueous solutions
- Simple electrolyte replacement, low outflow rate

Ag/AgCl reference electrode glass	6.0728.100
Electrolyte vessel for reference electrode	6.1245.000

Auxiliary electrodes

Platinum auxiliary electrode

- Universal auxiliary electrode for voltammetry
- For all applications with the MME as well as with the rotating platinum disc electrode
- Robust, easy maintenance

Platinum auxiliary electrode	6.0343.100

Glassy carbon auxiliary electrode

- For all applications with rotating disc electrodes as well as with the MME
- Inert surface, no contamination of the measuring cell by platinum

Auxiliary electrode holder	6.1241.120
Glassy carbon rod	6.1247.000


6.1245.010
6.0728.110 + 6.0728.120
6.0728.130
6.0728.100
6.0730.100
Metrohm
6.1245.000
6.0343.100
6.1241.120
6.1247.000

Electrodes for Metrohm Autolab RDE and RRDE

Rotating disk electrode and rotating ring disk electrode measurements are powerful experimental methods in which the electrode rotates while immersed in the solution. This creates a well-defined convective drag towards the surface of the electrode as long as a laminar flow is present. Under these conditions, mass transport occurs through convection and diffusion, with both components directly influenced by the angular frequency of the electrode.

Measurements under hydrodynamic conditions provide great benefits with respect to static measurements. Because of the increase in mass transport, the relative contributions from the electron transfer kinetics increase. Electrochemical experiments therefore can provide access to kinetic or mechanistic information.

PT.SHEET

RDE/RRDE electrode tips

The rotating disk electrode (RDE) consists of an electrode disk inserted in an electrode shaft. The rotating ring disc electrode (RRDE) is based on a similar design with an additional ring electrode located around the disk. The gap between the ring and the disk is typically very small.

Metrohm Autolab provides a range of electrodes for RDE measurements with a wide choice of materials. An empty electrode holder suitable for RDE measurement is also available. RRDE electrodes with a Pt ring are available with a choice of disk material.

Technical specifications

RDE tips

Shaft material	PEEK
Length	52.5 mm
Shaft diameter	10 mm
Disk diameter	3 or 5 mm
Disk material	Pt, Ag, Au, GC, Cu, Zn, stainless steel, empty
Connector	M4 thread

RRDE tips

Shaft material	PEEK
Length	52.5 mm
Shaft diameter	10 mm
Disk diameter	5 mm
Disk material	Pt, Au, GC
Ring material	Pt
Connector	M4 thread

Counter electrode

- Pt-sheet counter electrode (8 x 7 mm)

Technical specifications

Pt sheet electrode

Shaft material	Glass
Temperature range	-20…70 °C
Installation length	101 mm
Shaft diameter	12 mm
Minimum immersion depth	10 mm
Electrode plug-in head	B (4 mm)

Order number	Electrode tip	Applications
6.1204.300	Glassy carbon disk (3 mm)	Interfacial electrochemistry
6.1204.310	Platinum disk (3 mm)	Interfacial electrochemistry
6.1204.320	Gold disk (3 mm)	Interfacial electrochemistry
6.1204.330	Silver disk (3 mm)	Interfacial electrochemistry
RRDE.PTPT	Platinum disk (5 mm) and platinum ring	Electrocatalysis
RRDE.AUPT	Gold disk (5 mm) and platinum ring	Electrocatalysis
RRDE.GCPT	Glassy carbon disk (5 mm) and platinum ring	Electrocatalysis
RDE.AU50	Gold disk (5 mm)	Interfacial electrochemistry
RDE.AG50	Silver disk (5 mm)	Interfacial electrochemistry
RDE.GC50	Glassy carbon disk (5 mm)	Interfacial electrochemistry
RDE.CU50	Copper disk (5 mm)	Interfacial electrochemistry
RDE.ZN50	Zinc disk (5 mm)	Interfacial electrochemistry
RDE.STEEL	Stainless steel disk (5 mm)	Interfacial electrochemistry
RDE.BLANK	Empty disk (5 mm)	–
RDE.PT50	Platinum disk (5 mm)	Interfacial electrochemistry

Microelectrodes

Microelectrodes or ultramicroelectrode are electrodes whose dimensions are small enough that their properties become a function of size. These working electrodes are much smaller than typical metallic electrodes. When the dimensions are in the range of 25 µm or lower, the term ultramicroelectrode is preferred. The most common geometry of these electrodes is a disk.

Because of their very small size, these electrodes exhibit particularities with respect to their macroscopic counterparts:

- Mass transport of electroactive species changes from a linear to a spherical diffusion (in case of disk electrodes). This results in an enhancement of the mass transport to and from the electrode surface.
- The current measured at such electrodes becomes smaller but is not proportional to the surface area.
- The current density increases.

Moreover, these electrodes are less affected by charging or capacitive currents with the RC constant decreasing with the radius of the disk. This makes them particularly suitable for studying electrochemical reactions with rapid kinetics. These electrodes are also less affected by ohmic drop, which in turn facilitates measurements in low conductivity media.

Metrohm Autolab offers a wide range of glass-sealed disk microelectrodes and ultramicroelectrodes of different sizes and materials. Special electrodes can be manufactured upon request.

Technical specifications Microelectrodes	
Shaft material	Glass
Temperature range	0…40 °C
Length	51.5 mm
Shaft diameter	5 mm
Disk diameter	8…1000 µm
Disk material	Pt, Ag, Au, GC, Ir, Pd
Connector	B (2 mm)

Order number	Electrode tip	Applications
PT.10	Platinum disk (10 µm)	Interfacial electrochemistry
PT.20	Platinum disk (20 µm)	Interfacial electrochemistry
PT.25	Platinum disk (25 µm)	Interfacial electrochemistry
PT.50	Platinum disk (50 µm)	Interfacial electrochemistry
PT.100	Platinum disk (100 µm)	Interfacial electrochemistry
PT.200	Platinum disk (200 µm)	Interfacial electrochemistry
PT.300	Platinum disk (300 µm)	Interfacial electrochemistry
PT.500	Platinum disk (500 µm)	Interfacial electrochemistry
PT.1000	Platinum disk (1000 µm)	Interfacial electrochemistry
AU.10	Gold disk (10 µm)	Interfacial electrochemistry
AU.25	Gold disk (25 µm)	Interfacial electrochemistry
AU.40	Gold disk (40 µm)	Interfacial electrochemistry
AU.50	Gold disk (50 µm)	Interfacial electrochemistry
AU.100	Gold disk (100 µm)	Interfacial electrochemistry
AU.200	Gold disk (200 µm)	Interfacial electrochemistry
AU.300	Gold disk (300 µm)	Interfacial electrochemistry
AU.500	Gold disk (500 µm)	Interfacial electrochemistry
AG.25	Silver disk (25 µm)	Interfacial electrochemistry
AG.30	Silver disk (30 µm)	Interfacial electrochemistry
AG.100	Silver disk (100 µm)	Interfacial electrochemistry
AG.300	Silver disk (300 µm)	Interfacial electrochemistry
IR.75	Iridium disk (75 µm)	Interfacial electrochemistry
PD.25	Palladium disk (25 µm)	Interfacial electrochemistry
PD.100	Palladium disk (100 µm)	Interfacial electrochemistry
PD.300	Palladium disk (300 µm)	Interfacial electrochemistry
PD.500	Palladium disk (500 µm)	Interfacial electrochemistry

Electrodes for the electrochemical quartz crystal microbalance

The electrochemical quartz crystal microbalance (EQCM) is widely used to monitor, simultaneously with the electrochemical signal, the change in frequency which is directly related to the mass changes due to deposition or adsorption of a species to or dissolution of a species from the working electrode.

The principle of operation of the EQCM relies on the piezoelectric properties of the quartz which will oscillate at a given frequency when a sinusoidal external electric field is applied to it. The oscillation frequency of the crystal depends on a number of parameters such as size, the thickness of the crystal, temperature and the oscillating media.

EQCM.CE

Quartz crystals

The crystals provided for the Autolab EQCM are AT-cut crystals (with a small temperature coefficient). They are coated with different metals on top of an adhesion layer (e.g. Ti or Cr oxides). The crystals will also act as working electrodes (WE) being in contact with the electrolyte solution, broadening in this way the application areas of this technique.

Technical specifications	
Quartz crystals	
Material	Quartz
Quartz diameter	13.66 mm
Quartz thickness	250 µm
Electrode diameter	6.80 mm
Electrode material	Gold, Platinum, Carbon
Nominal frequency	6 MHz

Reference electrode

- Single junction reference electrode for EQCM

Technical specifications	
Reference electrode	
Reference system	LL Ag/AgCl
Shaft material	Glass
Shaft length	55 mm
Shaft diameter	4 mm
Diaphragm	Ceramics
Temperature range	0…40 °C
Connector	B (4 mm)

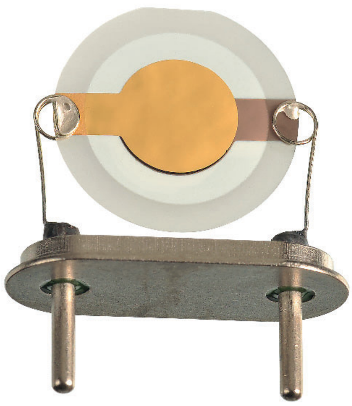
Counter electrode

- Gold coil counter electrode for EQCM

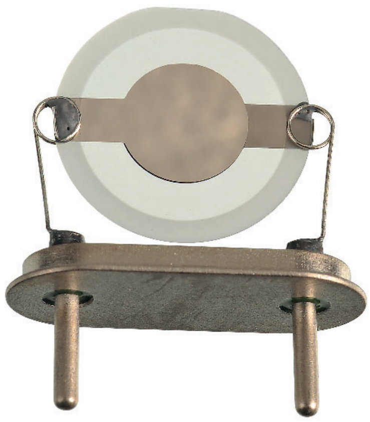
Technical specifications	
Counter electrode	
Material	Gold wire
Wire diameter	1 mm
Length	37.5 mm
Coil diameter	8 mm

EQCM.REF.EL

EQCM.Au



EQCM.Pt



Order number	Electrode tip	Applications
EQCM.Au	EQCM 6 MHz Au/TiO2 quartz crystal, polished	Interfacial electrochemistry, electrodeposition
EQCM.Pt	EQCM 6 MHz Pt/TiO2 quartz crystal, polished	Interfacial electrochemistry, electrodeposition
EQCM.CE	EQCM gold counter electrode	Interfacial electrochemistry, electrodeposition
EQCM.REF.EL	EQCM Ag/AgCl 3 M KCl reference electrode	Interfacial electrochemistry, electrodeposition

Screen-printed electrodes

Screen-printed electrodes (SPEs) are cost-effective disposable electrodes specially designed to work with microvolumes of sample which is ideal for research purposes and also for teaching electrochemistry.

There is a wide range of SPEs classified below by its working electrode (WE) material and differentiated by the configuration of the electrochemical cell. The reference electrode (RE) material in all of them is silver (unless electrode ref. C11L which is silver / silver chloride) and, depending on the model, the auxiliary electrode (AUX) material can be carbon, gold or platinum. Also depending on the model, the substrate material can be ceramics, glass, transparent plastic or white plastic. There are also customized designs available upon request.

Working electrode made of carbon

- Standard type
- Work in solution type
- MultiAnalysis configuration - dual
- MultiAnalysis configuration - 8X electrochemical cells
- MultiAnalysis configuration - 96X electrochemical cells
- MultiAnalysis configuration - 4WE sharing AUX and REF
- MultiAnalysis configuration - 8WE sharing AUX and REF
- Integrated flow-cell

Working electrode made of gold

- Standard type
- Work in solution type
- WE of 1.6 mm
- MultiAnalysis configuration - 8X electrochemical cells
- MultiAnalysis configuration - 96X electrochemical cells
- Integrated flow-cell

Working electrode made of platinum

- Standard type
- Work in solution type
- MultiAnalysis configuration - 8X electrochemical cells
- MultiAnalysis configuration - 96X electrochemical cells
- Integrated flow-cell

Working electrode made of silver

- WE of 1.6 mm
- Standard type

Transparent working electrode

Materials: ITO, PEDOT, gold, carbon

- Standard type

Mediator modified working electrode

Materials: Co-phthalocyanine, meldola's blue, prussian blue, ferrocyanide

- Standard type
- MultiAnalysis configuration – dual

Biomodified working electrode

Materials: Streptavidin, extravidin, glucose sensor, lactate, uric acid

- Standard type
- MultiAnalysis configuration – dual

Nanomodified working electrode

Materials: Graphene, graphene oxide, reduced graphene oxide, multi-walled carbon nanotubes, single-walled carbon nanotubes, carbon nanofibers, mesoporous carbon, ordered mesoporous carbon, gold nanoparticles, silver nanoparticles, quantum dots, core-shell quantum dots, graphene-gold nanoparticles, carbon nanotubes-gold nanoparticles, carbon nanofibres-gold nanoparticles, gold nanoparticles-streptavidin

- Standard type
- MultiAnalysis configuration – dual

Other working electrodes

Materials: Bismuth oxide, nickel oxide, polyaniline, polypyrrole

- Standard type
- MultiAnalysis configuration – dual

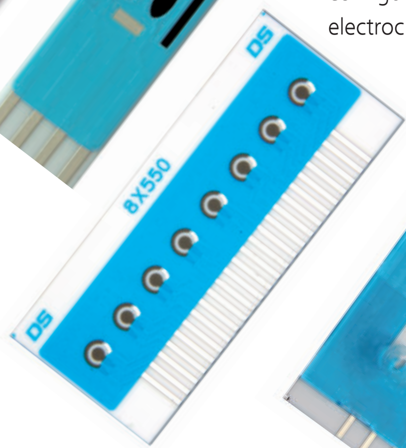
DRP-110
Standard Type

DRP-C220AT
Work in solution Type

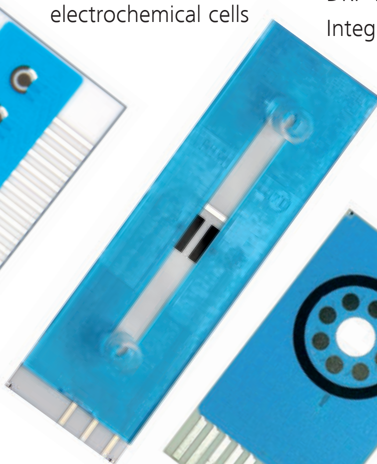
DRP-C013
WE of 1.6 mm

DRP-X1110
MultiAnalysis configuration – dual

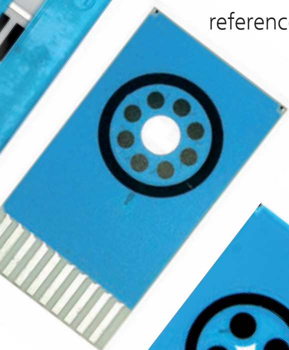
DRP-8X550
MultiAnalysis configuration – 8X electrochemical cells



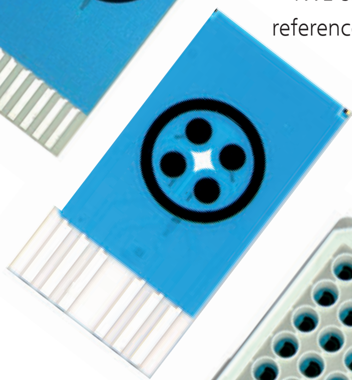
DRP-TLFCL110
Integrated flow-cell



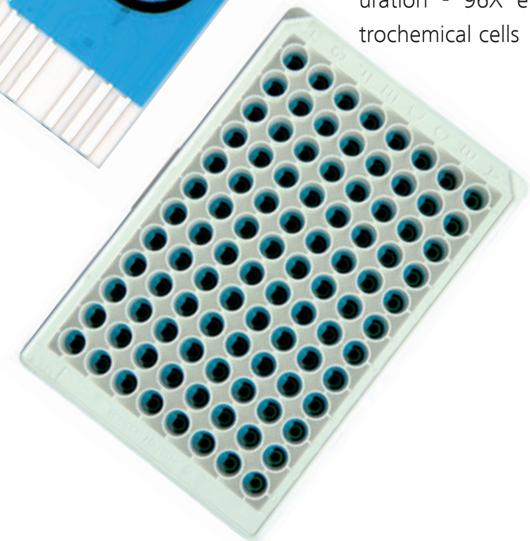
8W110
MultiAnalysis configuration - 8WE sharing auxiliary and reference electrode



4W110
MultiAnalysis configuration - 4WE sharing auxiliary and reference electrode



96X110
MultiAnalysis configuration - 96X electrochemical cells



Ordering information	
Screen-printed carbon electrode	DRP-110
Screen-printed gold electrode / ink AT / work in solution	DRP-C220AT
Screen-printed silver electrode / d 1.6 mm	DRP-C013
Dual screen-printed carbon electrode	DRP-X1110
8X Screen-printed platinum electrode	DRP-8X550
Thin-layer flow-cell integrated screen-printed carbon electrode (Aux.: C ; Ref.: Ag)	DRP-TLFCL110
8 WEs screen-printed carbon electrode (1 AUX.:C; 1 REF.:Ag)	DRP-8W110
4 WEs screen-printed carbon electrode (1 AUX.:C; 1 REF.:Ag)	DRP-4W110
96X screen-printed carbon electrode	DRP-96X110

Interdigitated electrodes/microelectrodes

Interdigitated electrodes and microelectrodes offer several advantages, such as working with low volumes of sample and avoiding tedious polishing of solid electrodes. In addition, the interdigitated configuration typically enhances sensitivity and detection limits.

Depending on the model, substrate materials can be ceramics, transparent plastic, white plastic or glass. AUX and REF electrodes, in models which have them, are made of gold or platinum.

Interdigitated electrodes: gold, platinum

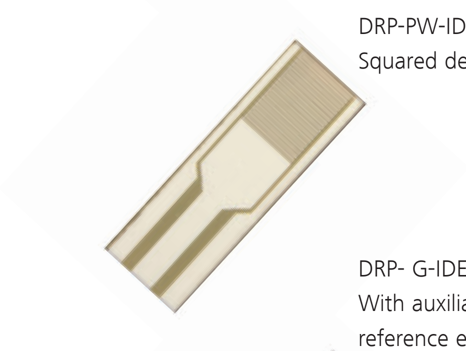
- Squared design
- Concentric design
- With auxiliary and reference electrode
- With a platinum heater

Interdigitated electrodes: silver, copper

- Squared design

Microelectrodes: gold, platinum

DRP-G-IDECONPT10
Concentric design



DRP-PW-IDEAU100
Squared design

DRP- G-IDE222
With auxiliary and reference electrode

DRP-G-MEA555
Microelectrodes

Ordering information	
Interdigitated platinum concentric electrode / 10 microns lines and gaps / glass substrate	DRP-G-IDECONPT10
Interdigitated gold electrode / 100 microns lines and gaps / plastic substrate	DRP-PW-IDEAU100
Interdigitated gold electrode (Aux.:Au; Ref.:Au) / 10 microns lines and gaps / glass substrate	DRP- G-IDE222
Platinum microelectrode array d. 3mm / microholes 10 microns / glass substrate	DRP-G-MEA555


856 Conductivity Module
801 Stirrer

Conductivity measuring cells and temperature sensors

Conductivity measuring cells for 912/914 meters

Four-electrode measuring technique

Historically, conductivity measuring cells consists of two platinized platinum electrodes (Kohlrausch cell). If other electrode materials are used instead of platinized platinum, errors in measurement results due to polarization are most likely to occur.

However, platinization has drawbacks, platinized electrodes are susceptible to encrustation, inclusions and also growth of algae, bacteria or mold leading to changes in the cell constant. Additionally, the two-electrode measuring technique is affected by field effects thus falsifying conductivity values measured close to a wall.

Therefore, Metrohm introduced the multi-electrode measurement technique for their instruments. For the 912/914 meters, an electrode based on four-electrode measurement was developed (6.0917.080). This cell consists of two pairs of electrodes, one pair is used for introducing the generator current, and the other pair is recording the measurement voltage.

The current flowing in the solution causes a drop in the measured voltage. By knowing this voltage and the generator current, the conductance and from that the conductivity can be calculated.

In summary, the four-electrode measuring technique allows an almost polarization free recording of the conductance and determinations are more reproducible. Additionally, it enables a very large measuring range. Another benefit of this sensor is its PEEK shaft which makes the sensor more robust.

Technical specifications
6.0918.040

Shaft material	Stainless steel
Ideal measuring range	0…300 µS/cm
Temperature range	0...70 °C
Temperature sensor	Pt1000
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	35 mm
Cell constant	0.1 cm^{-1}

Technical specifications
6.0917.080

Shaft material	PEEK
Ideal measuring range	15...2.5*10^5 µS/cm
Temperature range	0...70 °C
Temperature sensor	Pt1000
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	30 mm
Cell constant	0.5 cm^{-1}

Technical specifications
6.0919.140

Shaft material	Glass
Ideal measuring range	10^2...10^6 µS/cm
Temperature range	0...70 °C
Temperature sensor	Pt1000
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	40 mm
Cell constant	1.6 cm^{-1}

Ordering information	
Conductivity measuring cell (stainless steel) with Pt1000, c = 0.1 cm^{-1}, fixed cable (1.2 m) plug K	6.0918.040
Four-ring conductivity measuring cell with Pt1000, c = 0.5 cm^{-1}, fixed cable (1.2 m) plug K	6.0917.080
Three-ring conductivity measuring cell with Pt1000, c = 1.6 cm^{-1}, fixed cable (1.2 m) plug K	6.0919.140

Conductivity measuring cells for 856 Conductivity Module

Five-ring conductivity measuring cells

Modern five-ring conductivity measuring cells have linearity ranges that are wider than those of classic conductivity measuring cells and require no additional platinization. The current applied to the inner electrode generates a current flow to the outer, grounded electrodes, so that external influences and measuring errors are minimized.

Five-ring conductivity measuring cells supply precise measuring values, independent of positioning in the beaker (wall effect). Interferences with the potentiometric measurements are now a thing of the past; conductivity and pH value can now be measured simultaneously in the same beaker.

The measuring cells are equipped with a fixed cable and plug N for direct connection to the 856 Conductivity Module.

Technical specifications 6.0915.100/6.0920.100

Shaft material	PEEK
Ideal measuring range	5...2 x 10^4 µS/cm
Temperature range	0...70 °C
Temperature sensor	Pt1000
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	34 mm
Cell constant	0.7 cm^{-1}

Technical specifications 6.0915.130/6.0920.130

Shaft material	PEEK
Ideal measuring range	5...10^5 µS/cm
Temperature range	0...70 °C
Temperature sensor	Pt1000
Installation length	142 mm
Shaft diameter	12 mm
Minimum immersion depth	50 mm
Cell constant	1 cm^{-1}

Ordering information

Five-ring conductivity measuring cell c = 0.7 cm^{-1} with Pt1000, fixed cable (1.2 m) plug N	6.0915.100
Five-ring conductivity measuring cell c = 1.0 cm^{-1} with Pt1000, fixed cable (1.2 m) plug N	6.0915.130
Five-ring conductivity measuring cell c = 0.7 cm^{-1} with Pt1000, fixed cable (2 m) plug N	6.0920.100
Five-ring conductivity measuring cell c = 1.0 cm^{-1} with Pt1000, fixed cable (2 m) plug N	6.0920.130
Conductivity measuring cell (stainless steel) with Pt1000, c = 0.1 cm^{-1}, fixed cable (1.2 m) plug N	6.0916.040

Conductivity measuring cells

Conductivity measuring cells with temperature sensor

Conductivity measuring cell with Pt1000, c = 0.8 cm^{-1}

- Platinized

Technical specifications	
Shaft material	PP
Measuring range	1...10^5 µS/cm
Temperature range	5...70 °C
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	35 mm

Conductivity measuring cells without temperature sensor

Conductivity measuring cell c = 10 cm^{-1}

- Platinized

Technical specifications	
Shaft material	Glass
Measuring range	10...10^6 µS/cm
Temperature range	5...70 °C
Installation length	125 mm
Shaft diameter	12 mm
Shaft diameter bottom	20 mm
Minimum immersion depth	80 mm

Conductivity measuring cell c = 0.9 cm^{-1}

- Platinized
- With standard ground-joint 14/15
- Metrohm plug-in head G
- Optimum length for sample changer systems

Technical specifications	
Shaft material	Glass
Measuring range	1...10^5 µS/cm
Temperature range	5...70 °C
Installation length	120 mm
Shaft diameter	12 mm
Minimum immersion depth	16 mm

Accessories for conductivity measuring cells:

Conductivity standard κ = 12.87 mS/cm (25° C), 250 mL	6.2301.060
Conductivity standard κ = 100 µS/cm (25 °C), 250 mL with DKD certificate	6.2324.010
Conductivity standard κ = 100 µS/cm (25 °C), 5 x 30 mL with DKD certificate	6.2324.110

Ordering information	
Conductivity measuring cell, c = 0.1 cm^{-1}, fixed cable (1 m) plug 2 x B (4 mm)	6.0901.040
Conductivity measuring cell, c = 10 cm^{-1}, fixed cable (1 m) plug 2 x B (4 mm)	6.0901.260
Conductivity measuring cell for sample changer, c = 0.9 cm^{-1}, without cable	6.0910.120

Sensors for stability measurement

The oxidation stability characterizes the resistance of oils and fats and fatty foods to oxidation. It is a standard parameter for quality control in the production of oils and fats in the food industry or for incoming goods inspection in processing plants. Biodiesel and PVC are also subject to oxidation, which can be determined by stability measurement with biodiesel Rancimats or PCV Thermomats.
The determination of the oxidation stability takes place automatically and is measured by means of a conductivity sensor. The exact temperature is of central importance for the measurement. We offer two temperature sensors for determining the temperature compensation in the reaction vessel. A short version for the measurement in the short test tubes and a longer version for the determination of the temperature compensation in longer biodiesel test tubes.

Conductometric measuring cell for 743 Rancimat, 873 Biodiesel Rancimat, 892 Professional Rancimat, 893 Professional Biodiesel Rancimat, 763 PVC Thermomat and 895 Professional PVC Thermomat

Technical specifications	
Shaft material	PP
Measuring range	0…400 µS/cm
Cell constant	1.1 cm^{-1}

Temperature sensor Pt100 for 743 Rancimat, 763 PVC Thermomat, 892 Professional Rancimat or 895 Professional PVC Thermomat

- Sensor class B according to EN 60751 (ITS 90), certified
- Fixed cable with mini DIN plug
- Stainless steel shaft

Technical specifications	
Shaft material	Stainless steel (AISI 304)
Measuring range	-200…300 °C
Installation length	175 mm
Minimum immersion depth	20 mm
Shaft diameter	2 mm

Temperature sensor Pt100 for 873 Biodiesel Rancimat or 893 Professional Biodiesel Rancimat

- Sensor class B according to EN 60751 (ITS 90), certified
- Fixed cable with mini DIN plug
- Stainless steel shaft

Technical specifications	
Shaft material	Stainless steel (AISI 304)
Measuring range	-200…300 °C
Installation length	300 mm
Minimum immersion depth	20 mm
Shaft diameter	2 mm

Ordering information	
Conductometric measuring cell for 743, 763, 873, 892, 893 and 895	6.0913.130
Pt100 temperature sensor short for 743, 763, 892, 895	6.1111.010
Pt100 temperature sensor long for biodiesel Rancimats 873, 893	6.1111.020
Accessories	
SET to determine temperature correction for 743, 763, 892, 895	6.5616.100
SET to determine the temperature correction at 873, 893	6.5616.110
Silicone oil for stability measuring instruments (50 mL)	6.2326.000

Temperature sensor

Temperature sensor Pt1000

- Rapid, precise temperature setting
- Available in various lengths (90/125/178 mm)

Technical specifications	
Shaft material	Glass
Temperature range	-50...180 °C
Installation length	90/125/178 mm
Shaft diameter	12 mm
Shaft diameter bottom	5/6.4 mm
Minimum immersion depth	20 mm
Electrode plug-in head	Metrohm plug-in head G

Temperature sensor Pt1000 steel

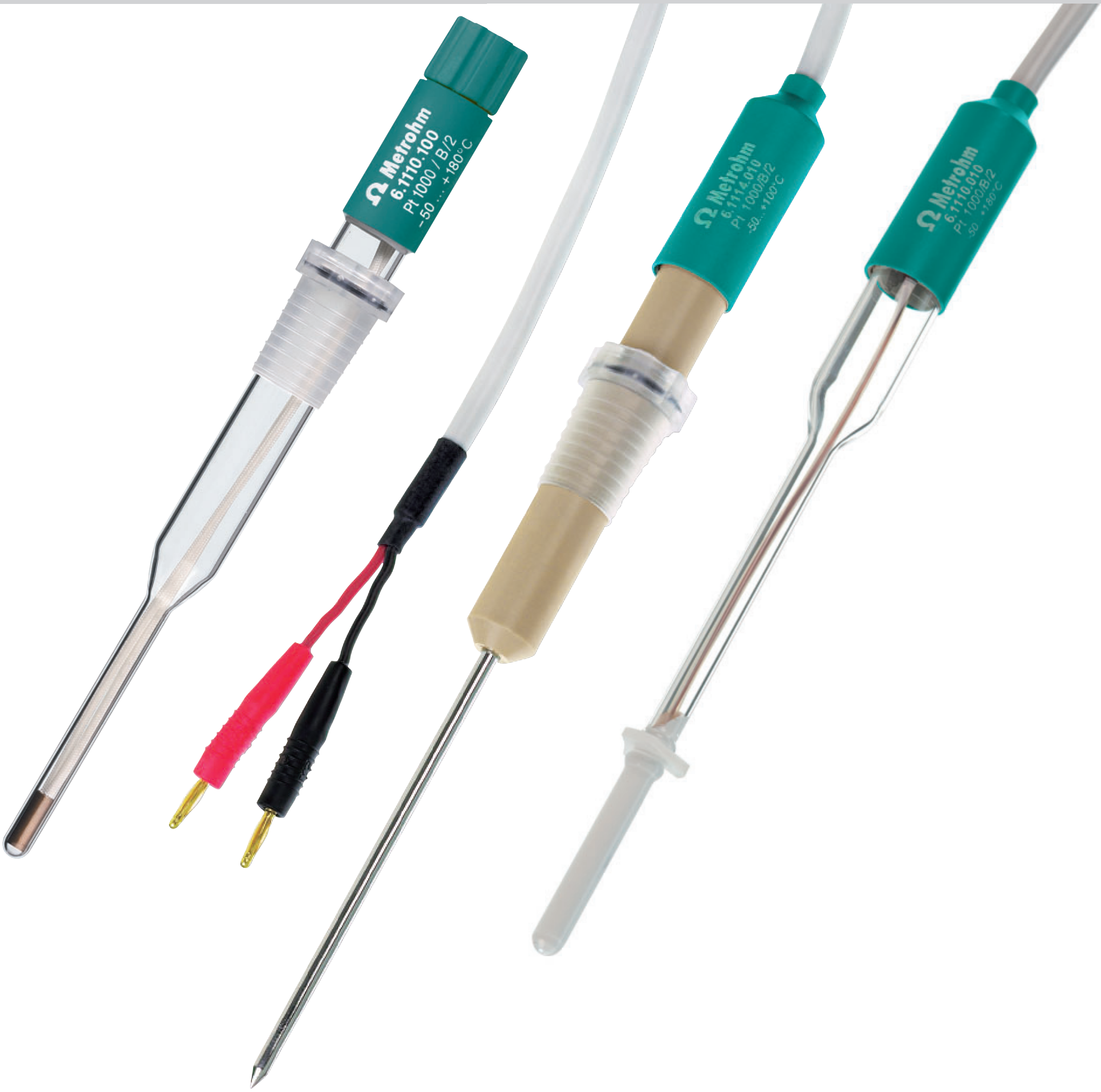
- The glass-free alternative
- Shaft made of PEEK
- For use in non-oxidizing media pH 1 - 13
- For temperature measurement in semi-solid materials such as cheese, not in frozen meat or similar

Technical specifications	
Shaft material	PEEK
Temperature range	-50...100 °C
Installation length	140 mm
Shaft diameter	12 mm
Shaft diameter bottom	(75 mm) 3 mm
Minimum immersion depth	10 mm

Temperature sensor Pt1000 for 909 UV Digester

- Shaft made of glass
- Fixed cable with 2 x B (2 mm) plug

Technical specifications	
Shaft material	Glass
Temperature range	-50...180 °C
Installation length	120 mm
Shaft diameter	12 mm
Shaft diameter bottom	5 mm
Minimum immersion depth	20 mm



Ordering information	
Temperature sensor Pt1000, length 125 mm, without cable	6.1110.100
Temperature sensor Pt1000, length 178 mm, without cable	6.1110.110
Temperature sensor Pt1000, length 90 mm, without cable	6.1110.120
Temperature sensor Pt1000, steel, length 140 mm, fixed cable (1.2 m) plug 2 x B (2 mm)	6.1114.010
Temperature sensor Pt1000 for 909, length 120 mm, fixed cable (0.5 m) plug 2 x B (2 mm)	6.1110.010

Sensor for themormetric titration

Next to potentiometric titration where a suitable electrode is used to measure a potential difference, thermometric titration exists. Thermometric titration monitors the change in temperature caused by the reaction enthalpy of the titrant with the analyte (exothermic or endothermic reaction). For this, a very sensitive temperature sensor is used, a thermistor.

The thermistor is manufactured from sintered mixed metal oxide which exhibits a large change of electrical resistance for a small temperature change. The thermistor is then encapsulated in a suitable electrically insulating medium with satisfactory heat transfer characteristics and acceptable chemical resistance. Typically, the encapsulating material is glass, however, when either chemical attack or mechanical stress is expected encapsulation in an epoxy resin might be possible.

Furthermore, a quick electronic circuit is used to maximize the sensitivity for smallest temperature changes. With this, a resolution of 10^{-5} K can be achieved.

Thermometric titration may be the choice where conventional titration sensors are not suitable for the titration environment or when they deliver unsatisfactory titration results.

Technical specifications

6.9011.020

Shaft material	Glass
Measuring range	0...60 °C
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	15 mm

6.9011.040

Shaft material	PEEK and PVDF coated glass
Measuring range	0...60 °C
Installation length	125 mm
Shaft diameter	12 mm
Minimum immersion depth	15 mm

Examples for thermometric titration:

- Total acid number (TAN) according to ASTM D8045
- Total base number (TBN)
- Phosphate determination
- Sodium determination
- Titration of plating baths

Ordering information	
Thermoprobe	6.9011.020
Thermoprobe HF	6.9011.040

Sensor for photometry

Titration with photometric endpoint detection is an integral part of many titration methods. The Optrode is a handy sensor that can be used like any other Metrosensor. Both new and existing titration systems can be equipped with the Optrode. The power supply comes directly via the USB port of a Metrohm instrument (Titrino plus, Ti-Touch, Titrando, USB sample changer). In the case of models without a USB port the power can also be supplied via an optional USB power adapter.

Technical specifications Optrode	
Shaft diameter	12 mm
Installation length	135 mm
Shaft material	Glass
Measuring range	
Dark voltage	min. 0 mV
Bright voltage	max. 800 mV
Temperature range	0...40 °C
pH range	0...14
Min. immersion depth	30 mm

Optrode
- Eight wavelengths: 470, 502, 520, 574, 590, 610, 640 and 660 nm
- 100% solvent resistant (glass shaft)
- Compact and space-saving
- Very easy cleaning
- Easy change of wavelength with a magnet or software controlled (tiamo 2.5 or higher)

Photometric titrations with the Optrode, examples:
- Nonaqueous titrations according to USP and EP
- Determination of the carboxyl end groups (nonaqueous)
- TAN/TBN according to ASTM D974 (nonaqueous)
- Chloride in silicone products (nonaqueous)
- Sulfate determination
- Fe, Al, Ca in cement
- Water hardness (total hardness and Ca/Mg)
- Chondroitin sulfate according to USP

Ordering information	
Optrode, fixed cable plug F, USB	6.1115.000
Optional	
USB power adapter 5V 1A (for titrators without USB- connection)	6.2166.000


pH 4.00
Metrohm

Accessories for Metrosensors

Accessories for Metrosensors

SGJ sleeves for Metrohm electrodes

6.1236.020	SGJ sleeve made of PP, standard ground-joint 14/15 with O-ring
6.1236.030	SGJ sleeve made of PP, standard ground-joint 14/15 with O-ring, for sample changer
6.1236.040	SGJ sleeve made of silicone rubber, standard ground-joint 14/15
6.1236.050	SGJ sleeve made of EVA, standard ground-joint 14/15

Other accessories

6.2008.040 Storage vessel made of PP

Length	105 mm
Diameter	13 mm
Ground-joint	taper or standard ground-joint 14/15

6.1243.020 Spare ground-joint diaphragm for Profitrode 6.0255.1XX (glass sleeve and plastic ring)

6.1243.030 Spare ground-joint for reference electrodes 6.0726.1XX and 6.0729.1XX

6.2615.050 Electrode holder for 11 electrodes and 3 x 50 ml buffer bottles


6.1236.020


6.1236.030


6.1236.040


6.1236.050

Ion standards, buffer solutions, electrolytes

Ion standards (traceable to NIST)

Ion	Concentration	Amount	Ordering number
KCl	0.1000 ± 0.0005 mol/L	250 mL	6.2301.060
Conductivity standard	κ = 12.87 mS/cm (25 °C)	250 mL	6.2301.060
Conductivity standard with DKD-certificate	for USP <645> and EP 2.2.38 κ = 100 µS/cm (25 °C)	250 mL	6.2324.010
		5 x 30 mL (sachets)	6.2324.110

Buffer and calibration solutions (traceable to NIST)

Article		Amount	Ordering number
Ready-to-use buffer solution in bottles, colored, with paper seal	pH 4.00	500 mL	6.2307.100
	pH 7.00	500 mL	6.2307.110
	pH 9.00	500 mL	6.2307.120
Ready-to-use buffer solution in sachets with DKD-certificate	pH 4.00	30 x 30 mL	6.2307.200
	pH 7.00	30 x 30 mL	6.2307.210
	pH 9.00	30 x 30 mL	6.2307.220
	pH 4.00, 7.00, 9.00	10 x 30 mL each	6.2307.230
Redox standard yields with reference electrode Ag/AgCl/c(KCl) = 3 mol/L U = +250 ± 5 mV (20 °C); can also be used as buffer pH 7		250 mL	6.2306.020

Storage solution, cleaning solution, pHit Kit

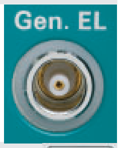
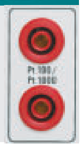
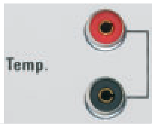
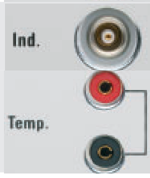
Electrolyte		Amount	Ordering number
Storage solution	for combined pH glass electrodes with reference electrolyte c(KCl) = 3 mol/L	250 mL	6.2323.000
pHit kit	Care kit for electrodes, containing 50 mL each of cleaning solution, reference electrolyte c(KCl) = 3 mol/L, storage solution, and 2 storage vessels	50 mL each	6.2325.000
Cleaning solution	As addition to the pHit Kit to clean combined pH glass electrodes	3 x 50 mL	6.2325.100

Electrolytes

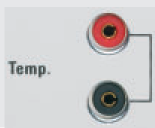
Electrolyte		Amount	Ordering number
KCl 3 mol/L	for Ag/AgCl reference systems	250 mL	6.2308.020
		1000 mL	6.2313.000
KCl-gel sat.	thickened	250 mL	6.2308.030
Idrolyte	for 6.0224.100 Biotrode or for pH-measurement > 80 °C with Unitrode/Syntrode	250 mL	6.2308.040
Porolyte	for 6.0235.200 Porotrode	50 mL	6.2318.000
KNO_3 1 mol/L	reference electrolyte for combined Ag-electrode and bridge electrolyte for Ag/AgCl reference systems	250 mL	6.2310.010
$LiCl_{sat}$ in ethanol	bridge electrolyte for titrations in nonaqueous solutions and reference electrolyte for Solvotrodes	250 mL	Contact your Metrohm representative
LiCl 2 mol/L in ethanol	bridge electrolyte for titrations in nonaqueous solutions and reference electrolyte for Solvotrodes	250 mL	Contact your Metrohm representative
Tetraethylammonium bromide 0.4 mol/L in ethylene glycol	bridge electrolyte for titrations in nonaqueous solutions and reference electrolyte for Solvotrodes	250 mL	6.2320.000
KCl-gel 3 mol/L	only as bridge electrolyte for VA reference electrodes	50 mL	6.2308.060
NH_4NO_3 1 mol/L	reference electrolyte for 6.0510.100 combined Ca-ISE	50 mL	6.2327.000
CH_3COOLi 1 mol/L	reference electrolyte for 6.0510.110 combined K-ISE	50 mL	6.2328.000
Electrolyte for NH_3-electrodes	inner electrolyte for NH_3-electrodes	50 mL	6.2316.030
KCl sat.	storage of gel electrodes	250 mL	6.2308.000

Electrical connections

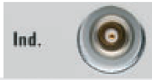
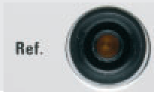
Connection of pH electrodes, ion-selective electrodes (ISE) and metal electrodes on Metrohm instruments

Electrode plug-in head	Cable	Order number	Measuring device
Plug-in head G 	Plug-in head G – plug F, 1 m	6.2104.020	For pH/ISE and Ind measuring inputs, Titrinos and Titrandos, pH-/ion meter from 691 
	Plug-in head G – plug F, 2 m	6.2104.030	
	Plug-in head G – plug F, 3 m	6.2104.040	
	Plug-in head G – plug E (DIN 19262), 1 m	6.2104.050	For Metrohm pH Meter < 691
	Plug-in head G – plug E (DIN 19262), 2 m	6.2104.060	
	Plug-in head G – plug E (DIN 19262), 3 m	6.2104.070	
	Electrode cables for generator electrodes 6.0342.110, 6.0344.100 and 6.0345.100	6.2104.120	KF Coulometer 
pH electrodes with fixed cable, plug B (2 mm)	Adapter plug B (2 mm)/4 mm	6.2103.150	Titrinos (Pt1000 only) pH Meter ≤ 744 (Pt1000 only) 
pH electrodes with fixed cable plug B (4 mm)	Adapter plug B (4 mm)/2 mm (red) Adapter plug B (4 mm)/2 mm (black)	6.2103.130 6.2103.140	780/781/Titrandos/ Ti-Touch/91X meters Pt1000 (2 mm) 
Plug-in head U 	Plug-in head U – plug F + 2 x B (2 mm), 1 m	6.2104.600	
	Plug-in head U – plug F + 2 x B (2 mm), 2 m	6.2104.610	

Connection of conductivity measuring cells and temperature sensors to Metrohm instruments

Electrode plug-in head	Cable	Order number	Measuring device
Plug-in head G 	Plug-in head G – plug 2 x B (4 mm), 1 m	6.2104.080	712 Conductometer, measuring inputs Pt 100/ Pt1000 (4 mm) 
	Plug-in head G – plug 2 x B (4 mm), 2 m	6.2104.110	
	Plug-in head G – plug 2 x B (2 mm), 1 m	6.2104.140	780/781/Titrandos/ Ti-Touch/91X meters Pt1000 (2 mm) 
	Plug-in head G – plug 2 x B (2 mm), 2 m	6.2104.150	

Connection of reference electrodes and separate metal electrodes on Metrohm devices

Electrode plug-in head	Cable	Order number	Measuring device
Plug-in head G (6.0729.XXX) 	Plug-in head G – plug F, 1 m	6.2104.020	For «Ind.» measuring inputs of Titrinos and for connection to a Metrohm differential amplifier 
	Plug-in head G – plug F, 2 m	6.2104.030	
	Plug-in head G – plug F, 3 m	6.2104.040	
Plug-in head B 	Plug-in head B (4 mm) – plug B (4 mm), 1 m	6.2106.020	For measuring input «Ref.» 
	Plug-in head B (4 mm) – plug B (4 mm), 2 m	6.2106.060	
	Plug-in head B (4 mm) – plug B (4 mm), 3 m	6.2106.050	

Connection of Metrohm electrodes with plug-in head G to devices made by other manufacturers

Electrode plug-in head	Cable	Order number	Measuring device
Plug-in head G	Plug-in head G – BNC plug, 1 m 	6.2104.090	Orion, Beckman, Corning, EDT, Fisher, Hanna, Mettler-Toledo, Jenway, Philips, Radiometer, Mitsubishi, SI Analytics, Crison, Kyoto/KEM
	Plug-in head G – LEMO 	6.2104.160	Mettler
	Plug-in head G – plug E (DIN 19262), 1 m 	6.2104.050	Older Metrohm devices, WTW, Knick, SI Analytics
	Plug-in head G – Radiometer plug, 1 m 	6.2104.130	Radiometer, Crison
	Plug-in head G – US plug, 1 m 	6.2104.010	Older Orion, Beckman and Fisher devices

Connection of Metrohm electrodes to OMNIS measuring modules

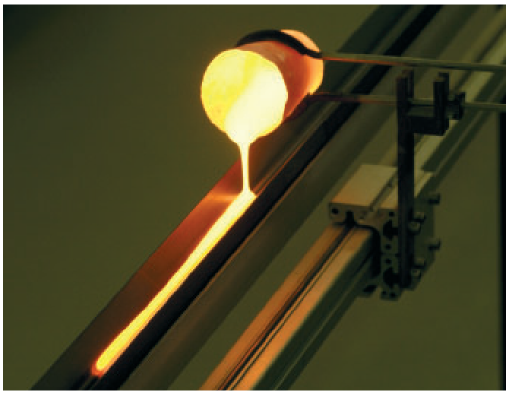
Electrode plug-in head	Cable	Order number	Measuring device
Plug-in head Q 	Plug-in head Q – plug P, 0.55 m	6.02104.300	For a digital measuring module of OMNIS
	Plug-in head Q – plug P, 1.5 m	6.02104.310	
Plug-in head G of pH electrode, ISE, metal electrodes 	Plug-in head G – plug P, 0.55 m (green)	6.02104.000	For measuring input “INPUT 1” and “INPUT 2” of an analog measuring module of OMNIS
	Plug-in head G – plug P, 1.5 m (green)	6.02104.010	
	Adapter cable for electrodes with fixed cable	6.02109.000	
Plug-in head G of temperature sensor 	Plug-in head G – plug P, 0.55 m (red)	6.02104.020	For measuring input “INPUT 1” and “INPUT 2” of an analog measuring module of OMNIS
	Plug-in head G – plug P, 1.5 m (red)	6.02104.030	
Plug-in head G of electrode used for polarized measure-ment 	Plug-in head G – plug P, 0.55 m (blue)	6.02104.040	For measuring input “INPUT 1” of an analog measuring module of OMNIS
	Plug-in head G – plug P, 1.5 m (blue)	6.02104.050	
	Adapter cable for electrodes with fixed cable	6.02109.010	
Plug-in head U 	Plug-in head U – plug P, 0.55 m (green/red)	6.02104.600	For measuring input “INPUT 1” and “INPUT 2” of an analog measuring module of OMNIS
	Plug-in head U – plug P, 1.5 m (green/red)	6.02104.610	
Plug-in head B 	Plug B (4 mm) – Plug B (2 mm), 0.55 m	6.02105.000	For measuring input “REF” of the analog measuring module of OMNIS
	Plug B (4 mm) – Plug B (2 mm), 1.5 m	6.02105.010	

How is a Metrosensor made?

Our accuracy is not accidental ...

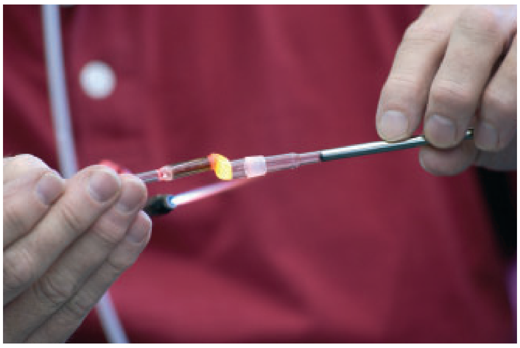
Always keep cool!

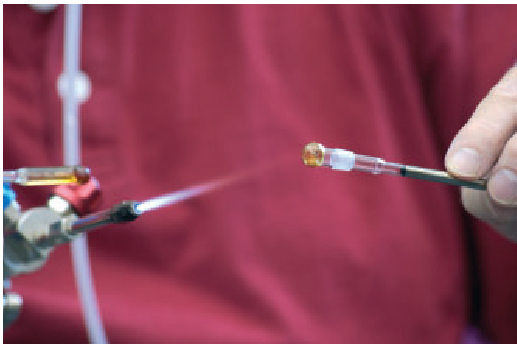
Many years of experience and a steady hand with raw materials guarantee that our chemistry is always correct. The right composition of the glass mixture and the greatest possible care during the melting process ensure the perfect quality of the membrane glass.

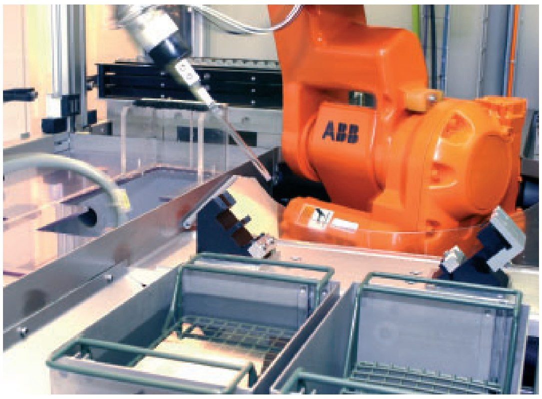


We know how to do it!

Our employees need the right feeling when fusing the membrane glass with the electrode body. That this is not just a matter of luck can be seen from our electrodes at the first glance..







Our employees are only human!

In some manufacturing processes, such as grinding our fixed ground-joint diaphragms, even a practiced eye no longer stands a chance. Such tasks are carried out with unrivalled accuracy by the most modern machines.

Tried and tested electrodes!

Before our electrodes leave our premises they are subjected to a further wet-chemistry computer-supported check. At its conclusion we provide a written confirmation so that you can have complete confidence in our electrodes: each electrode receives its own test certificate.

Certificate of origin:

Precision and guaranteed reliability – Metrohm stands for the highest quality in ion analysis. Just convince yourself!

1. Fundamentals of potentiometry

1.1. Electrode construction

In potentiometry the measuring setup always consists of two electrodes: the measuring electrode, also known as the indicator electrode, and the reference electrode. Both electrodes are half-cells. When placed in a solution together they produce a certain potential. Depending on the construction of the half-cells, the potential produced is the sum of several individual potentials. Potential-determining transitions always occur at the phase boundaries, e.g. between the solution and the electrode surface.

pH electrode

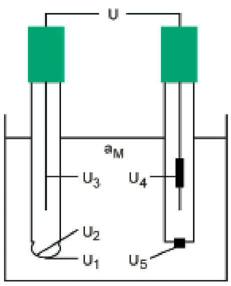


Figure 1: Schematic diagram of a pH electrode

Measuring electrode – glass electrode (left)

U_1 = Galvani potential between measuring solution and glass membrane

U_2 = Galvani potential between glass membrane and inner electrolyte

U_3 = Galvani potential between inner electrolyte and inner reference electrode

Reference electrode – silver/silver chloride (right)

U_4 = Galvani potential of reference electrode

U_5 = Diaphragm potential (diffusion potential)

a_M = Activity of measured ion in sample solution

The potentials U_2, U_3 and U_4 can be kept constant by a suitable electrode construction. Constructive measures and the selection of a suitable reference electrolyte ensure that U_5 is also kept as constant as possible. Ideally the measured potential should depend only on the potential between the glass membrane and the solution. For practical reasons the half-cells of the measuring electrode and the reference electrode are normally contained in a single electrode; this is then known as a combined pH electrode.

Redox electrode

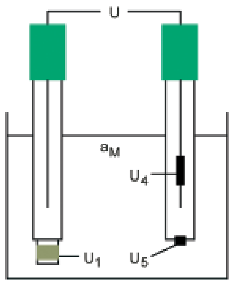


Figure 2: Schematic diagram of a redox electrode

Measuring electrode – metal electrode (left)

U_1 = redox potential between measuring solution and metal surface

Reference electrode – silver/silver chloride (right)

U_4 = Galvani potential of reference electrode

U_5 = Diaphragm potential (diffusion potential)

a_M = Activity of measured ion in sample solution

For metal electrodes the potential forming transitions U_2 and U_3 of the pH electrodes do not exist. Depending on the particular application, it may be possible to use a pH glass electrode as the reference electrode instead of the silver/silver chloride reference electrode. In the combined redox electrodes and Titrodes from Metrohm the half-cells are also contained in a single electrode.

1.2. From the measured potential to the ion concentration

As each ion is surrounded by ions with the opposite charge, it is – to put it simply – no longer as effective as a free ion (see Debye-Hückel law). This affects both the reactivity and the size of the potentials at the measuring electrode. The activity of the measuring ion a_M, which is also used in the Nernst equation, is linked to the normally interesting analytical concentration c_M via the activity coefficient γ:

$$a_M = \gamma * c_M \tag{1}$$

For dilute solutions with concentration $c_M \leq 0.001$ mol/L the activity coefficient γ tends towards 1 and the activity of the ion corresponds to its concentration as a first approximation. γ is a function of the ionic strength of the measuring solution.

The mathematical relationship between the activity a_M of a measuring ion in solution ions and the potential measured between the reference electrode and the measuring electrode is described by the Nernst equation. This applies only for the (ideal) case in which an electrode only responds to a single type of ion. Potentials U_2 to U_5 for pH electrodes and U_4 and U_5 for redox electrodes, which are normally constant, appear as potential U_0 in the Nernst equation.

$$U = U_0 + \frac{2.303 * R * T}{z * F} * \log a_M$$

(Nernst equation) (2)

U = measured potential
U_0 = temperature-dependent standard potential of electrode
R = general gas constant 8.315 J mol-1 K^{-1}
T = temperature in Kelvin
z = ionic charge including sign
F = Faraday constant 96485.3 C mol^{-1}

The term in the Nernst equation in front of the logarithm is known as the Nernst potential U_N (also Nernst slope).

$$U_N = \frac{2.303 * R * T}{z * F}$$

(Nernst potential) (3)

Its value is 0.059 V at T = 298.15 K and z = +1. As a factor in the Nernst equation it represents the theoretical electrode slope. U_N corresponds exactly to the alteration in potential caused by increasing the activity a_M by a factor of ten. From the equation it can be seen that the electrode slope for electrodes that respond to ions with a double charge (z = 2) is only half the size of that for electrodes for ions with a single charge (z = 1). In addition, the sign for cation- and anion-sensitive measuring electrodes is different, as z also takes the charge on the ion into account. The Nernst potential is directly dependent on the temperature (see Equation 3). This is why it is absolutely necessary to take the temperature into account in all direct potentiometric measurements, as otherwise no correct results will be obtained.

pH value

In practice – particularly when measuring the acid/ base equilibrium – the term pH, introduced by Sörensen in 1909, is frequently used instead of the activity of the measuring ion a_M:

$$pH = -\log a_{H^+}$$

(Definition of the pH value) (4)

The pH value is the negative common logarithm of the hydrogen ion activity of a solution. The term p is frequently used for the simplified presentation of very large or small values. In a similar way pNa^+ can be used for the activity of sodium ion, or pK_A as acid constant or pK_B as base constant for reaction constants. In each of these cases what is meant is the negative common logarithm of the particular value. If this definition is inserted in the Nernst equation then we obtain for the measured potential U:

$$U = U_0 - \frac{2.303 * R * T}{z * F} * pH$$

(pH value and potential) (5)

Redox potentials (metal electrodes)

In a similar way to the Nernst equation (Equation 2) the equation for the activity-dependent potential is obtained as follows:

$$U = U_0 + \frac{2.303 * R * T}{z * F} * \log \frac{a_{ox} * a_{H^+}}{a_{red}}$$

(6)

Equation 6 usually allows the potential generated by a redox pair at the measuring electrode to be calculated. As protons are involved in most redox reactions, the measured potential depends on the pH. If proton reactions cannot be excluded then the pH should also be determined or adjusted to a defined value.

1.3. Measuring electrodes

1.3.1. pH glass electrodes

How does a pH glass electrode work?

The glass membrane of a pH glass electrode consists of a silicate framework containing lithium ions. When a glass surface is immersed in an aqueous solution then a thin solvated layer (gel layer) is formed on the glass surface in which the glass structure is softer. This applies to both the outside and inside of the glass membrane. As the proton concentration in the inner buffer of the electrode is constant (pH 7), a stationary condition is established on the inner surface of the glass membrane. In contrast, if the proton concentration in the measuring solution changes then ion exchange will occur in the outer solvated layer and cause an alteration in the potential at the glass membrane. Only when this ion exchange has achieved a stable condition will the potential of the glass electrode also be constant. This means that the response time of a glass electrode always depends on the thickness of the solvated layer. Continuous contact with aqueous solutions causes the thickness of the solvated layer to increase continuously – even if only very slowly – which results in longer response times. This is why conditioning the electrode in a suitable electrolyte is absolutely necessary to ensure an initial solvated layer condition that is as stationary as possible so that results can be obtained that are as reproducible as possible.

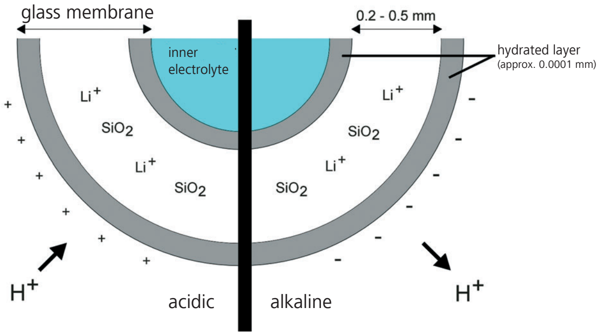


Figure 3: The silicate skeleton of the glass membrane contains lithium ions, among other things. During the formation of the solvated layer at the glass surface these are partly replaced by protons. If the concentration of the protons in the solution changes then a new stationary condition must again be achieved in the solvated layer; this results in a change in potential at the glass membrane.

Table 1: Overview of the different electrode membrane glasses used by Metrohm Ltd

Application	U glass (green)	T glass (blue)	M glass (colorless)	Aquatrode glass (yellow)	E glass (yellow)
pH range	0...14	0...14	0...14	0...13	0...13
Temperature range continuous short-term	0...80 °C 0...100 °C	0...80 °C	0...60 °C	0...80 °C	0...80 °C
Membrane surface	Electrodes with large membrane surface	Electrodes with medium to large membrane surface (mini-electrodes)	Electrodes with small membrane surface (micro-electrodes)	Large surfaces	Electrodes with medium to large membrane surface
Special features	For strongly alkaline solutions, long-term measurements and measurements at high temperatures	Measurements in non-aqueous sample solutions	Measurements in small-volume samples	Responds very quickly, so particularly suitable for measurements in ion-deficient or weakly buffered solutions	Quick response, excellent stability in continuous use
Membrane resistance (MΩ) With reference to sphere membrane 10.5 mm diameter	< 500	< 150	< 120	< 250	< 250

Why are there different types of glass for pH electrodes?

Different demands are placed on a pH glass electrode depending on the particular application. Various properties such as response time, thermal resistance, chemical stability, shape, size and electrical properties must all be taken into account in order to have an optimal electrode available to solve each problem. In order to be able to do justice to the numerous applications, different glasses are available with different properties (see table 1).

Why must a pH glass electrode be calibrated?

The potential of a measuring electrode can always only be given relative to that of a reference electrode. To be able to compare systems, the electrode zero point is defined as being 0 mV for pH 7 and 298.15 K or 25 °C. The electrode slope, i.e. the alteration in the measured value with the pH, is given by the Nernst equation and at 25 °C is 0.059 V per pH 1. These are ideal values from which Metrosensor electrodes only differ slightly. The electrode zero point is ± 0.015 V. The electrode zero point and the electrode slope may change as a result of the aging of the glass membrane or changes, (e.g contamination) on the diaphragm. For this reason the pH meter must be adapted to the characteristics of the electrode, i.e. calibrated, at regular intervals by using buffer solutions.

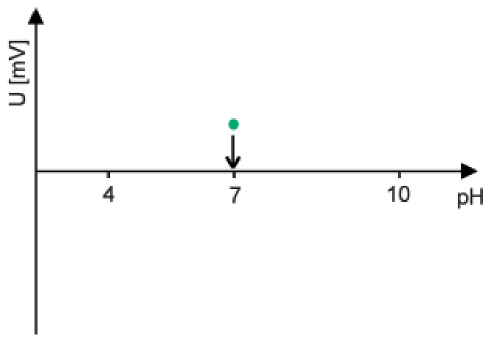


Figure 4: In the first calibration step with buffer pH = 7 the variation from the electrode zero point (= asymmetry potential) is determined and corrected.

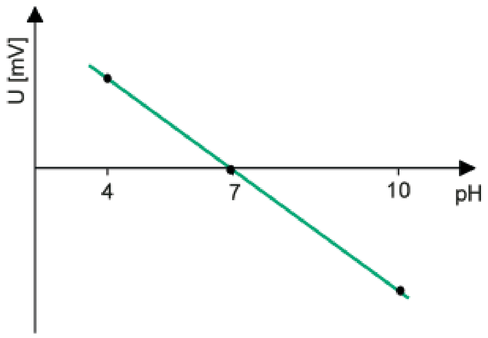


Figure 5: In the second calibration step with another buffer solution the electrode slope is determined and expressed as a percentage of the theoretical value of 0.059 V (at 25 °C).

The electrode zero point is set first (pH 7 corresponding to 0 mV for Metrosensor pH electrodes). The second and further buffer solutions are used to determine the slope of the pH electrode. This slope is expressed as a percentage of the theoretical value (100% = 0.059 V per ΔpH = 1 at 25 °C). In order to minimize subsequent measuring errors, care should be taken that the expected measured value of the sample solution always lies within the pH range covered by the buffer solutions. Modern pH and ion meters such as the 780 pH Meter, the 781 pH/Ion Meter, the 913 pH meter and 914 pH/conductivity meter do not require any manual settings to be made. The buffer solutions are recognized automatically and can be presented in any sequence.

Calibration always includes a check of the measuring electrode. The calibration buffers have a medium acid-base concentration and their ionic strength is approximately that of the most common sample solutions. The dependency of the electrode slope on the temperature means that the calibration and measuring temperatures must be known. Information about the electrode condition is provided by the electrode slope, electrode zero point, response time of the signal and its streaming dependency. With the Metrohm 781 pH/Ion Meter and 780 pH Meter an automatic electrode test can be carried out; this provides an exact statement of the electrode condition and often allows a source of error to be localized.

pH and temperature – an inseparable couple!

The temperature has a considerable influence on the pH value and the pH measurement. If an electrode is calibrated at 25 °C then it should be capable of linear measurement throughout the whole pH range and provide correct results. However, if the electrode is then used at a different temperature the electrode slope will change – in accordance with the Nernst equation – and possibly the electrode zero point as well. The point at which the two calibration curves (without correction) for different temperatures intersect is known as the isothermal intersection point. Thanks to the optimized inner buffer and «Long Life» reference system precise measurements can be made with Metrosensor pH electrodes at different temperatures. This means that, although calibration is only carried out at a single temperature, measurements can then be made throughout the whole temperature range. The real behavior of Metrosensor pH electrodes varies from the ideal behavior by maximum ±15 mV. Nevertheless it is still true that the accuracy of the measurement is increased when the electrode is calibrated at the temperature to be used for the subsequent measurements. At T = 298.16 K and z = 1, the Nernst potential U_N is equal to 59.16 mV. For other temperatures it can be corrected in the Nernst equation by using Table 2. Modern pH meters automatically take the temperature dependency of the Nernst potential into account if a temperature sensor is connected. In principle, within the context of GLP/ISO recording and documentation of the temperature is required for all measurements.

However, it must be remembered that a pH meter can only correct the temperature behavior of the electrode and never that of the solution to be measured. For correct pH measurements it is essential that the pH is measured at the temperature at which the sample was taken. For example, sodium hydroxide c(NaOH) = 0.001 mol/L at 0 °C has a pH of 11.94, at 50 °C it is pH = 10.26 and only at 25 °C is it pH = 11.00. This change in pH is caused by the dependency of the ionic product of water on the temperature.

In some conventional electrodes the temperature sensor is not located in the immediate vicinity of the membrane, i.e. in the electrode foot. This means that it cannot measure the temperature of the solution correctly and that the pH compensation will be incorrect as the temperature

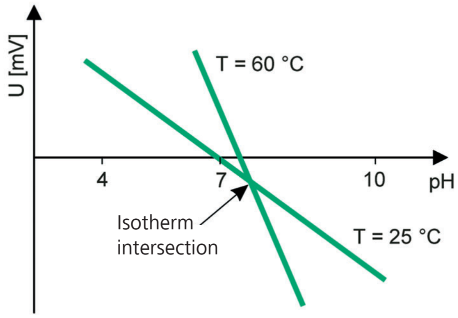


Figure 6: Isothermal intersection point

and pH are not measured at the same location. In modern pH electrodes the temperature sensor should be located within the electrode in the immediate vicinity of the glass membrane. This is the only way in which an accurate pH measurement is possible. If the sensor is located outside the membrane then problems when cleaning the electrode could easily occur.

Table 2: Dependency of the Nernst potential U_N on the temperature

Temperature T (°C)	Slope U_N (mV)	Temperature T (°C)	Slope U_N (mV)
0	54.20	50	64.12
5	55.19	55	65.11
10	56.18	60	66.10
15	57.17	65	67.09
20	58.16	70	68.08
25	59.16	75	69.07
30	60.15	80	70.07
35	61.14	85	71.06
37	61.54	90	72.05
40	62.13	95	73.04
45	63.12	100	74.03

How to store a pH glass electrode?

The swelling of the glass surface is indispensable for the use of glass as membrane for pH glass electrodes; without this solvated layer, no pH measurement would be possible. Glasses for pH glass electrodes are optimized in such a way that only protons can penetrate into the glass membrane. However, because of the very slow but steady swelling of the glass, it is unavoidable that also other ions penetrate into the glass, e.g. sodium and potassium ions. At higher concentrations, these lead to the so-called alkali error of the glass electrode. This means that the measured value is falsified at comparatively low proton concentrations. If the glass electrode is stored for a very long time in a strong solution of potassium or sodium, this leads to prolonged response times of the glass membrane since the protons must expulse the «added ions» from the solvated layer.

One of the most used electrolytes for pH measurement is c(KCl) = 3 mol/L, since the aequitransferent KCl causes only a very small diffusion potential at the diaphragm and is also economical. Normally a combined pH glass electrode is stored in c(KCl) = 3 mol/L only for this reason, as one wants to have it ready for immediate use without conditioning the diaphragm. However, on a long-term basis the storage in KCl affects the glass, since it leads to ever longer response times. For the membrane glass, storage in distilled water would be optimal, but then the diaphragm would have to be conditioned for several hours. The patented storage solution for combined pH glass electrodes (6.2323.000) solves exactly this problem. If a combined pH glass electrode is kept in this solution, the glass membrane remains unchanged regarding response time and alkali error. Moreover, if one uses c(KCl) = 3 mol/L as the reference electrolyte, the optimized composition of the storage solution keeps the pH glass electrode ready for measurement. Conditioning before the measurement is not necessary, no matter for how long the electrode has been stored.

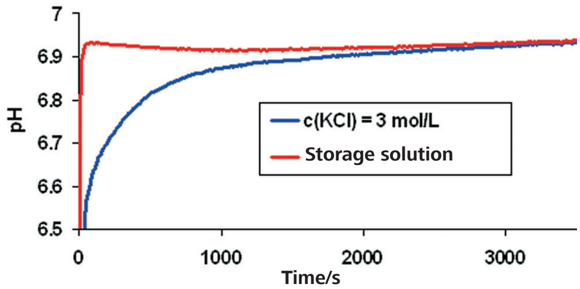


Figure 8: pH measurement in $c(NaHCO_3)$ = 0.05 mmol/L. A glass of the Aquatrode stored in the storage solution shows a substantially shorter response time than an electrode glass of the same type stored during the same period in KCl.

Table 3: The correct storage of pH glass electrodes

Electrode resp. reference electrolyte	Storage
Separate pH glass electrode	Distilled water
Combined pH glass electrode with c(KCl) = 3 mol/L, Porolyte	6.2323.000 Storage solution
Combined pH glass electrode with another reference electrolyte (Idrolyte, non aqueous)	In the respective reference electrolyte
Gel (spearhead electrode), Ecotrode Gel	6.2308.000 Electrolyte solution c(KCl) = sat.

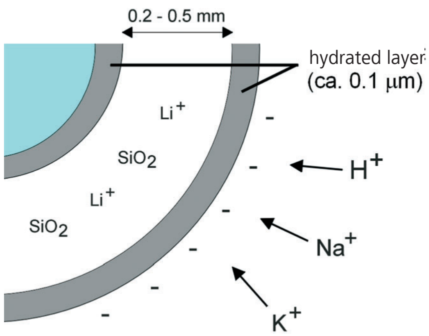


Figure 7: Cross-section of a pH glass membrane. If several kinds of cations are present in the measuring solution, these compete for the free spaces in the solvated layer. Especially potassium and sodium can penetrate into the glass membrane and prolong the response time.

Troubleshooting

The cause of most problems is not to be found in the measuring electrode and its glass membrane, but rather in the reference electrode, as much more critical diaphragm problems can occur there. To avoid incorrect measurements and to increase the working life, attention must still be paid to the following possible sources of error:

Table 4: Possible sources of error and their remedies for pH glass electrodes

Source of error	Effects	Action	Alternatives
HF-containing solutions	Etching and dissolution of the glass membrane → corrosion potential during the measurement/short working life		Use of the Sb-electrode
High pH value and high alkali content	Increased alkali error → pH too low		Use of electrodes with U glass
High temperatures	Rapid rise in membrane resistance by aging → increased polarizability and drift		Use of electrodes with U glass
Measurements at low temperature	High membrane resistance → polarization effects		Use of electrodes with T glass and Idrolyte as reference electrolyte
Dry storage	Zero point drift	Store in water overnight	Store in storage solution 6.2323.000 or reference electrolyte
Reaction of a solution component with the glass	Slow response, zero point shift, slope reduction		Try other glass types
Non-aqueous media	Reduced sensitivity	Store in water	T glass/non-aqueous electrolyte solution
Deposition of solids on membrane surface	Slow response, zero point shift, slope reduction	Solvent or strong acids	
Electrostatic charging	Slow response	No dab-drying of the electrode	Grounding of measuring instrument
Deposition of proteins on membrane surface	Slow response, zero point shift, slope reduction	5% pepsin in 0.1 mol/L HCl	

Possible sources of error and care information for diaphragm problems are given in Section 1.4. for reference electrodes.

1.3.2. Metal electrodes

How does a metal electrode work?

Metal electrodes have an exposed metal surface. If ions of this metal are contained in the sample solution then an equilibrium is formed at the metal surface that depends on the concentration of the metal ions in the solution (see «Theory of the electrical double layer» in electrochemistry textbooks). Metal ions are accepted by the metal surface and simultaneously released into the solution.

$$Me \longleftrightarrow Me^{n+} + n * e^{-} \qquad E^{0} = \ldots$$

(7)

This concentration-dependent equilibrium is characterized by a corresponding potential E^0 (Galvani potential), e.g. the Ag/Ag^+ equilibrium at a silver surface has a value of $E^0 = 0.7999$ V (25°C). If the sample solution does not contain any ions of the corresponding metal then metal electrodes can still form a Galvani potential if a redox reaction occurs in the sample solution.

$$S_{ox} + n * e^{-} \longleftrightarrow S_{red}$$

(8)

The electrode surface is inert to the redox reaction. No metal ions are released from the metal; in this case the metal surface only acts as a catalyst for the electrons. As gold and platinum electrodes are to a large extent chemically inert, they are used for the measurement of redox potentials. Silver electrodes are only used as indicator electrodes for titrations.

Calibrating a metal electrode

Redox-buffer solutions (6.2306.020) are used for quickly checking metal or redox electrodes. As the potential measured in a redox buffer solution is insensitive to the electrode's surface condition, contamination of the metal electrode is often not recognized. For this reason redox-buffer solutions are rather more suitable for checking the reference electrode. If the potential is displaced then the metal electrode is contaminated, the redox buffer partly oxidized or the functioning of the reference electrode is affected. Under no circumstances should the indicated potential be set to the theoretical value.

If measurements are made in weakly redox-buffered solutions then a suitable pretreatment of the metal electrode is recommended to adapt the surface condition as much as possible to the measurement conditions (abrasive pretreatment: carefully clean the electrode with abrasive paste). The reference electrode can either be checked against a second reference electrode that has already been checked in buffer solutions 4 and 7 (response behavior and reference potential) or by using the redox buffer.

In the literature the so-called standard redox potentials E^0 can usually be found.

Cl_2 (g) + $2e^- \rightarrow 2\ Cl^-$ $\quad E^0 = +\ 1.359$ V
$Fe^{3+} + e^- \rightarrow Fe^{2+}$ $\quad E^0 = +\ 0.771$ V
$Cd^{2+} + 2e^- \rightarrow Cd^{2-}$ $\quad E^0 = -\ 0.403$ V

The zero point of these systems is defined (arbitrarily) with the standard hydrogen electrode (SHE) which is assigned a standard potential of 0 mV. If electrons are released by a redox system to the SHE then this is reduced and the redox pair receives a negative sign; if electrons are accepted then the SHE is oxidized and the result is a redox potential with a positive sign. The standard hydrogen reference electrode is difficult to handle. The specifications of the SHE stipulate that a platinized platinum wire must be used; this is located in a stream of hydrogen gas at a partial hydrogen pressure of 1.0 bar, and that the activity of the hydrogen ions in the solution in which the platinized platinum wire is immersed is to be exactly 1.00 mol/L. The normal alternative is the Ag/AgCl/KCl reference electrode, which has a potential E^0 = +207.6 mV at c(KCl) = 3 mol/L and T = 25 °C. The Metrohm redox standard (6.2306.020) can be used for checking separate and combined metal electrodes. Platinum and gold electrodes together with the Ag/AgCl/KCl reference electrode (c(KCl) = 3 mol/L and T = 20 °C) produce a potential of +250 ± 5 mV.

Table 5: Measuring data for 6.2306.020 redox standard as a function of the temperature

Temp. (°C)	**10**	**20**	**25**	**30**	**40**	**50**	**60**	**70**
mV ± 5	+ 265	**+ 250**	+ 243	+ 236	+ 221	+ 207	+ 183	+ 178
pH ± 0.05	7.06	**7.02**	7.00	6.99	6.98	6.97	6.97	6.98

If instead of an Ag/AgCl/KCl reference electrode c(KCl) = 3 mol/L an Ag/AgCl/KCl reference electrode c(KCl) = sat. is used for the measurement then at 25 °C a correction of +10 mV must be applied; if the measurement is made using an $Hg/Hg_2Cl_2/KCl$ calomel reference electrode, which for toxicological reasons is no longer available from Metrohm, the correction to be applied is -37 mV. The Titrodes are checked by a standard titration as no suitable calibration or buffer solutions are available. For example, the certified ion standard c(NaCl) = 0.1 mol/L (6.2301.010) can be titrated with a silver nitrate standard solution.

Table 6: Problems encountered when measuring with metal electrodes

Electrode	Source of error	Effects	Cleaning	Alternatives
Ag	Electrode poisons such as S^{2-}, I^-, Br^-	Passivation of Ag layer → slow response	Cleaning with abrasives	
Pt/Au	Fats or oils	Isolating layer → slow response, incorrect potential	Cleaning with solvent	
	Weakly redox-buffered solution	Adsorbed ions on the surface (e.g. oxides) → slow response	Abrasive, oxidative (for oxidizing solutions) or reducing (for reducing solutions) pretreatment	Use of Au or Pt
	COD determination	Deactivation of Pt		Use of Au

1.3.3. Ion-selective electrodes

How does an ion-selective electrode work?

An ion-selective electrode (ISE) can selectively recognize an ion in a mixture of ions in a solution. There are various types of ion-selective electrodes, the most commonly used ones are:

Glass membrane with	framework of silicate glass interstitial sites for H^+ and Na^+
Crystal membrane	crystal lattice containing defined gaps for the ion to be measured
Polymer membrane	polymer membrane containing a molecule (= ionophore) that only binds the ion to be measured

In contrast to metal electrodes, an ISE does not measure a redox potential. If the ion to be measured is contained in the sample solution then this ion can penetrate the membrane. This alters the electrochemical properties of the membrane and causes a change in potential. One hundred percent selectivity for exactly one type of ion is only possible on rare occasions. Most ion-selective electrodes have «only» a particular sensitivity for a special type of ion, but also often react with ions with similar chemical properties or a similar structure (see Table 7). This is why the cross-sensitivity to other ions that may be contained in the sample solution must always be taken into consideration when selecting an ISE. One of the best-known examples of such a cross-sensitivity is the so-called alkali error of pH glass electrodes. With some types of glass the linear range does not extend throughout the whole pH range from 0 to 14 and at high pH values a departure from linear behavior can be observed. The reason for this is that at very low H^+-concentrations any alkali ions present in the solution (possibly released from the walls of the vessel) will falsify the measured value. Unfortunately there are only a very few ion-selective electrodes that have a linear range similar to that of pH glass electrodes. The use of an ISE is normally restricted to a concentration range of 6 to 8 powers of ten. If an ISE is used for a measurement right at the limit of the linear range then the Nernst equation (Eq. (5), Section 1.2.) must be extended by the contribution made by the particular interfering ion for the evaluation of the measured potential:

$$U = U_0 + \frac{2.303 * R * T}{z * F} * \log (a_M + K_S * a_S)$$

(Nikolsky equation) (9)

K_S is the so-called selectivity coefficient of the ion-selective electrode for interfering ion S. This is a factor that describes the influence of the interfering ion in relationship to the ion to be measured. These selectivity coefficients are known for the most important interfering ions for an ISE and therefore a simple estimation can be made as to whether an interfering ion contained in the sample solution will influence the measured value or not.

Direct measurement or standard addition?

The question often arises as to which determination method is most suitable for a particular sample. In principle there are three different ways of carrying out an ion measurement with ion-selective electrodes:

Direct measurement

Direct measurement is chiefly of benefit with high sample throughputs or with a known sample solution of a simple composition. The ion-selective electrode is calibrated with special standard solutions of the ion to be measured before the measurement itself in a similar way to the calibration of a pH glass electrode and can then be used for several determinations in series.

Standard addition

Standard addition is recommended whenever a determination only needs to be carried out occasionally or when the composition of the sample is unknown. Defined volumes of a standard solution of the ion to be measured are added to the sample solution in several steps. The concentration in the original solution can then be calculated from the initial potential and the individual potential steps after the addition of the standard. The advantage of standard addition is that the ISE is calibrated directly in the sample solution, which eliminates all matrix effects.

Sample addition

Similar to standard addition, with the difference that defined volumes of the sample solution are added to a defined amount of an ion standard.

Modern ion meters such as the 781 pH/Ion Meter from Metrohm can carry out these addition methods automatically. The addition of the standard or sample solution is automatically controlled from the ion meter – by pressing a single key – and evaluated by using the Nikolsky equation.

ISA and TISAB – when and why?

The activity coefficient of an ion (Section 1.2.) is a function of the ionic strength. For this reason care must be taken that ion-selective measurements are always carried out in solutions with approximately the same ionic strength. In order to achieve this, the so-called ISA solutions (**I**onic **S**trength **A**djustor) or TISAB solutions (**T**otal **I**onic **S**trength **A**djustment **B**uffer) should be added to the sample solution (see Table 7). These are chemically inert and have such a high ionic strength that the ionic strength of the sample solution can be neglected after their addition.

Table 7: Interfering ions and recommended ISA and TISAB solutions for ion-selective electrodes

Ion	Membrane material	pH range[1]	ISA or TISAB[2]	Most important interfering ions[3]	Remarks
Ag^+	Crystal	2...8	$c(KNO_3) = 1$ mol/L	Hg^{2+}, Proteins	1) The given pH range only applies to ion-selective electrodes from Metrohm AG
Br^-	Crystal	0...14	$c(KNO_3) = 1$ mol/L	Hg^{2+}, Cl^-, I^-, S^{2-}, CN^-	
Ca^{2+}	Polymer	2...12	$c(KCl) = 1$ mol/L	Pb^{2+}, Fe^{2+}, Zn^{2+}, Cu^{2+}, Mg^{2+}	
Cl^-	Crystal	0...14	$c(KNO_3) = 1$ mol/L	Hg^{2+}, Br^-, I^-, S^{2-}, $S_2O_3^{2-}$, CN^-	
CN^-	Crystal	10...14	$c(NaOH) = 0.1$ mol/L	Cl^-, Br^-, I^-,	2) Alternatives or more detailed compositions can be found in the manual «Ion Selective Electrodes (ISE)», order number 8.109.8042
Cu^{2+}	Crystal	2...12	$c(KNO_3) = 1$ mol/L	Ag^+, Hg^{2+}, S^{2-}	
F^-	Crystal	5...7	NaCl/glacial acetic acid/ CDTA	OH^-	
I^-	Crystal	0...14	$c(KNO_3) = 1$ mol/L	Hg^{2+}, S^{2-}, $S_2O_3^{2-}$,	
K^+	Polymer	2.5...11	$c(NaCl) = 0.1…1$ mol/L	$TRIS^+$, NH_4^+, Cs^+, H^+	3) More detailed information about interfering ions and other interferences can be found in the manual «Ion Selective Electrodes (ISE)», order number 8.109.8042
Na^+	Polymer	3...12	$c(CaCl_2) = 1$ mol/L	SCN^-, K^+, lipophilic ions	
NH_4^+	Gas membrane	11	–	–	
NO_3^-	Polymer	2.5...11	$c((NH_4)_2SO_4) = 1$ mol/L	Cl^-, Br^-, NO_2^-, OAC^-	
Pb^{2+}	Crystal	4...7	$c(NaClO_4 \cdot H_2O) = 1$ mol/L	Ag^+, Hg^{2+}, Cu^{2+}	
S^{2-}	Crystal	2...12	$c(NaOH) = 2$ mol/L	Hg^{2+}, Proteins	

Troubleshooting

Table 8: Possible sources of interference and remedies for ion-selective electrodes

Electrode	Source of interference	Effects	Action
Ion-selective crystal membrane	Dissolution processes, oxidation processes	Rough surface → slow response, poor detection limits	Polish with polishing cloth
	Electrode poisons	Formation of more sparingly soluble salts on the electrode surface than with the ion to be measured → zero point shift, reduced linearity range	Polish with polishing cloth, mask interfering ion
Ion-selective polymer membrane	Dissolution processes	Diffusion into the membrane or dissolution of membrane component	Elimination of interfering components
NH_3 sensor	Volatile bases (amines)	Electrolyte becomes contaminated → displacement of calibration line, limited linearity	Change electrolyte
	Surfactants	Membrane becomes wetted → slow response	Replace membrane

1.4. Reference electrodes

Reference electrodes are usually electrodes of the second kind. In this type of electrode a metal electrode is in contact with a sparingly soluble salt of the same metal. The potential depends only on the solubility of the salt. As a first approximation, electrodes of the second kind do not themselves react with the solution and therefore supply a constant potential.

The most frequently used reference electrode is the silver/silver chloride electrode (Ag/AgCl/ KCl). The calomel electrode ($Hg/Hg_2Cl_2/KCl$), which was formerly widely used, is hardly used at all today as mercury and its salts are extremely toxic and all the applications can also be carried out with the silver/ silver chloride reference electrode. The standard hydrogen electrode SHE is also an electrode of the second kind. It is only used for calibration purposes. Some titrations offer the possibility of using pH glass electrodes as reference electrodes. Even if protons are transferred during the titration it is usually still possible to make an accurate determination of the endpoint.

1.4.1. Silver/silver chloride reference electrode

The reference element of the silver/silver chloride reference electrode is the silver/silver chloride/potassium chloride solution system: Ag/AgCl/KCl. The reference electrode is usually filled with c(KCl) = 3 mol/L or saturated KCl solution. Tables 9 and 10 show the potentials of the reference electrode as a function of the reference electrolyte and temperature. Each of these values has been measured against the standard hydrogen electrode under isothermal conditions.

Table 9: Standard redox potentials of the silver/silver chloride reference electrode as a function of the temperature and concentration

Temp. (°C)	0	+10	+20	+25	+30	+40	+50	+60	+70	+80	+90	+95
E^0 (mV) with c(KCl) = 3 mol/L	+224.2	+217.4	+210.5	+207.0	+203.4	+196.1	+188.4	+180.3	+172.1	+163.1	+153.3	+148.1
E^0 (mV) with c(KCl) = sat.	+220.5	+211.5	+201.9	+197.0	+191.9	+181.4	+170.7	+159.8	+148.8	+137.8	+126.9	+121.5

Table 10: Standard redox potentials of the silver/silver chloride reference electrode as a function of the concentration

c(KCl) / mol/L (25 °C)	0.1	1.0	3.0	3.5	sat.
E^0 (mV)	+291.6	+236.3	+207.0	+203.7	+197.0

1.4.2. The Metrosensor «Long Life» reference system

Most electrodes are equipped with the silver/silver chloride reference system. The solubility product of silver chloride in water is very small (10^{-10} mol^2/L^2). In the concentrated, chloride-containing solution of the reference electrolyte soluble complexes of the series $(AgCl_2)^-$, $(AgCl_3)^{2-}$, $(AgCl_4)^{3-}$ are formed. This means that the reference system poses several problems. Outside the electrode the chloride concentration is frequently lower and the complexed silver chloride precipitates in the region surrounding the diaphragm («liquid junction»). The result: precipitated silver chloride blocks the diaphragm, and the response time of the pH electrode increases. A further problem is presented by the dependency of the solubility product of AgCl on the temperature. If the electrode is used at a different temperature then the equilibrium that determines the potential of the reference electrode must be reestablished. The larger the surface with solid AgCl in relationship to the electrolyte volume, the shorter the time required. The «Long Life» reference system prevents high concentrations of complexed AgCl from occurring in the outer electrolyte, as the silver chloride reservoir is connected with the outer electrolyte by a highly effective diffusion barrier. The concentration of the silver complex in the reference electrolyte remains low. Even after one year the concentration of complexated silver ions in the outer electrolyte has only reached 5% of the saturation value.

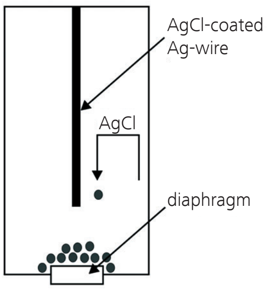


Figure 9:
Conventional Ag/AgCl/KCl system. The chloride concentration outside the electrode is usually lower than in the electrolyte chamber. The soluble silver chloride complexes precipitate out in the region surrounding the diaphragm and may block it.

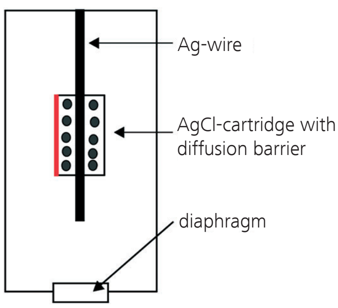


Figure 10:
The Metrohm «Long Life» reference system. The dissolved AgCl is retained in the AgCl cartridge and can no longer block the diaphragm.

The advantages of the «Long Life» reference systems at a glance:

- Long working life of the electrode
- Rapid response to changes in pH
- Rapid response to temperature changes
- Less sensitive to electrode poisons, e.g. S^{2-}

Blocking the diaphragm by crystallized AgCl also affects the electrolyte flow. If the «Long Life» reference system is used then the flow of the KCl solution through the diaphragm into deionized water only decreases slightly.

As in the «Long Life» reference system the silver chloride is present in a smaller volume of potassium chloride solution, the thermodynamic equilibrium between silver, silver chloride (solid) and silver chloride (dissolved) is established very quickly and the potential of the reference electrode becomes stable after a very short time.

1.4.3. Diaphragms

Faulty measurements, unstable measured values and very long response times usually have their source in the «liquid junction» between the sample solution and the reference electrode. The diffusion, streaming and Donnan potentials that occur there – which are normally known together as the diaphragm potential – have various causes and can result in a very incorrect measured value.

The measuring error may assume vast proportions if measurements are made under the following conditions:

- with a blocked, virtually impermeable diaphragm,
- in ion-deficient solutions with an unsuitable diaphragm,
- in strong acids and bases with an unsuitable diaphragm,
- in colloidal solutions.

In all such cases errors may occur that cannot be tolerated. This is why the following questions must be in the foreground whenever an electrode and therefore the optimal type of diaphragm are to be selected:

- Does the reference electrolyte react with the sample solution to form a precipitate in the diaphragm?
- Does the electrolyte flow alter the composition of the sample solution in an unacceptable way?
- Is there a risk of depositing sample solution components on the diaphragm?
- Is the chemical resistance assured?
- Can physical parameters such as flow, pressure or temperature cause measuring errors?
- Does the process allow cleaning/maintenance of the electrode at certain intervals?
- Is a short response time and/or high reproducibility necessary?

The time required for cleaning and maintenance can usually be considerably reduced if the correct choice of electrode is made. The most frequent cause of measuring problems is contamination of the diaphragm. This is why with pH electrodes the chief attention is paid to the diaphragm during maintenance with the pH membrane being of secondary importance. If existing means cannot be used to determine whether the indicator electrode or the reference electrode requires cleaning/regeneration, then it is usually best to treat the reference electrode. Various types of diaphragm are available to satisfy the diverse requirements. These requirements have already been taken into consideration for the electrode recommendations in the application lists on pages 6 and 7.

Ceramic pin diaphragms

Ceramic pin diaphragms are frequently used diaphragms. They are primarily suitable for clear, aqueous sample solutions. They normally have pore diameters of up to 1 µm with a length and diameter each of about 1 mm. This results in an electrolyte flow rate of up to 25 µL/h, depending on the condition of the diaphragm. This means that the reference electrolyte only requires refilling at long intervals; this is why electrodes with ceramic pin diaphragms are particularly suitable for long-term measurements. On the other hand, because of their small pores and large polar surface (>>500 mm^2), ceramic diaphragms tend to become blocked and therefore should not be used in solutions containing precipitates. An important advance with regard to the prevention of diaphragm blockages by silver chloride and silver sulfide has been achieved by the introduction of the «Long Life» reference system (see Section «The Metrosensor «Long Life» reference system»).

Ground-joint diaphragms with fixed or separable ground-joint

Ground-joint diaphragms with fixed or separable ground-joint are used in ion-deficient media, among others, as they produce a steady signal that is almost independent of sample flow conditions. The risk of blockage by silver chloride or by precipitates formed in the sample solution is relatively low because of the large surface area. Streaming potentials, which may occur in measurements in flowing or stirred solutions, remain negligibly small. These properties are particularly important for a SET titration to a defined pH or potential value. For example: the determination of the carbonate alkalinity by a SET titration to pH = 5.4 according to ISO 9963-2 is a widely used method in the routine analysis of drinking water. During a titration it is not possible to dispense with stirring, i.e. with an incorrectly measured pH or potential at the start of the titration an incorrect endpoint is the inevitable result. Figures 11 and 12 clearly show the difference between the Aquatrode Plus (6.0253.100), which was specially developed for this application, and a conventional pH glass electrode with ceramic pin diaphragm.

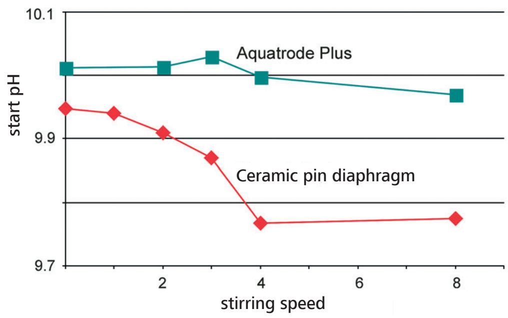


Figure 11: Measured pH of a solution with c(Na_2CO_3) = 0.14 mmol/L. Even under vigorous stirring the Aquatrode Plus deviates by only approx. 0.05 pH units (corresponding to approx. 3 mV) from the unstirred value, in contrast the pH glass electrode with ceramic pin diaphragm deviates by approx. 0.2 pH units.

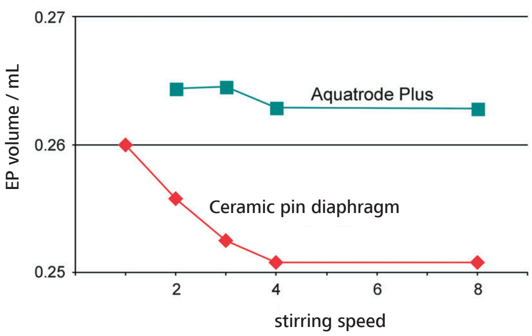


Figure 12: Endpoint volumes of a SET titration of a solution with c(Na_2CO_3) = 0.14 mmol/L with the titrant c(H_2SO_4) = 0.035 mol/L to pH 5.4. The endpoints of the Aquatrode Plus are virtually independent of the stirring speed. At higher stirring speeds the deviation from the theoretical value of the pH electrode with ceramic diaphragm amounts to approx. 5%.

Fixed ground-joint diaphragms have a uniform and reproducible electrolyte flow and are therefore particularly suitable for use with sample changers.

Separable ground-joint diaphragms are easy to clean and therefore particularly suitable for applications where contamination of the diaphragm cannot be prevented. The electrolyte flow may reach up to 100 µL/h and is normally considerably higher than the amount of electrolyte flowing from a ceramic or fixed ground-joint diaphragm.

The ring-shaped geometry and the small polar surface of the ground-joint diaphragm have a favorable effect on the measurement. The increased electrolyte flow influences the sample solution more than if a ceramic pin diaphragm was to be used, the reference electrolyte normally needs refilling on a daily basis during long-term measurements.

An alternative is the easyClean diaphragm. It allows easy, contact-free cleaning just by pressing once on the electrode head. The spring in the electrode head returns to the defined starting position thereby ensuring greater accuracy and reproducibility of the electrolyte outflow.

Capillary diaphragms

In pH measurements in critical samples the very small pores of conventional ceramic diaphragms are easily blocked. The concept that has been realized in the Porotrode (6.0235.100), with two capillaries and a flow rate of 15...25 µL/h ensures unhindered contact between the reference electrolyte and the sample solution (liquid/liquid phase boundary), while the two capillaries of the Porotrode are practically insensitive to contamination. The reference electrode is filled with Porolyte, which has been specially developed for this electrode. The constant flow of Porolyte ensures that the potential is established quickly and reproducibly. The flow rate and therefore the refilling intervals are comparable to those of conventional electrodes. Extra maintenance work is not necessary. Measurements in problematic samples can be carried out easily and reproducibly thanks to the concept that has been realized in the Porotrode. The pH of samples containing protein, such as milk and beer, can now be determined without any diaphragm problems. In contrast to traditional pH electrodes the Porotrode measures correctly even at high surfactant concentrations.

Twin pore

Measuring the pH in semi-solid samples such as cheese, meat and fruit places special demands on an electrode. Proteins, fats and carbohydrates and other semi-solid substances in foodstuffs tend to block the fine pores of the ceramic diaphragms used in most pH electrodes, as such substances adhere extremely well to the fine-pore ceramic surface. With the development of the spearhead electrode (6.0226.100) and the polymer electrolytes this problem has been elegantly eliminated: two pinhole diaphragms take over the function of the «liquid junction» between the sample and the reference electrode. The polymer electrolyte adjacent to the openings, which is spiked with potassium chloride and thickened, is to a large extent insensitive to contamination by media containing proteins and fats. This insensitivity to contamination, the efficient protection of the reference electrode against the penetration of electrode poisons and the optimized inner buffer of the measuring electrode ensure that the new spearhead electrode has an outstanding long-term behavior: even when used in difficult media the electrode zero point retains its long-term stability. The use of polymer electrolytes means that refilling a liquid reference electrolyte is no longer necessary.

The new Ecotrode Gel electrodes (6.0221.x00) are equipped with this diaphragm which keeps maintenance effort low.

Plied platinum wire

In combination with the reference electrolyte Idrolyte, which contains glycerol, the plied-platinum-wire diaphragm is outstandingly suitable for applications in biological media. The precipitation of proteins is suppressed by using an electrolyte with a low KCl content. The multi-capillary system (channels between the platinum wires) reduces contamination effects and the electrically conductive platinum reduces the response time and the diaphragm resistance. However, cross-sensitivity may occur in strongly redox-buffered solutions.

Cleaning and care of diaphragms

Table 11: Recommended ways of cleaning diaphragms

Type of diaphragm	Type of contamination	Cleaning
General	Preventiv and regular care	pHit kit (6.2325.000) according to instructions
	Precipitates of silver halides and silver sulfides	Immerse diaphragm for several hours in a solution of 7% thiourea in 0.1 mol/L HCl.
	Proteins, polypeptides	Immerse diaphragm for several hours in a solution of 5% pepsin in 0.1 mol/L HCl.
	Suspensions, solids, resins, glues, oils, fats	Clean electrode with suitable solvent
Fixed ground-joint	All types of contamination	Aspirate off reference electrolyte and immerse electrode in the corresponding cleaning solution.
Separable ground-joint	All types of contamination	Loosen the ground-joint sleeve (using hot water if necessary) and clean according to the type of contamination.
Capillary	Electrolyte flow interrupted	Apply slight counterpressure to electrolyte refilling opening

1.4.4. Reference electrolytes and bridge electrolytes

The reference or bridge electrolyte is in electrical contact with the sample solution via the diaphragm. The sample solution and electrolyte form a phase boundary with different ion concentrations on each side. This difference in concentration causes diffusion of the ions to the other side and, because of the different ion mobilities, a so-called diffusion potential occurs. In order to achieve a high degree of measuring accuracy the electrolyte composition must be selected so that any diffusion potentials formed are as negligible as possible; this is to a large extent achieved by the use of c(KCl) = 3 mol/L. On the one hand the ionic mobilities of K^+ and Cl^- are practically the same, on the other hand the ionic concentration in the sample solution is normally negligibly low in comparison to c(KCl) = 3 mol/L. This is why the equal-transference KCl electrolyte is used as standard in all combined Metrohm electrodes and reference electrodes. However, certain media require the use of other electrolyte compositions in order to suppress effects that occur in addition to the diffusion potential.

Table 12: Alternatives to the standard reference electrolyte c(KCl) = 3 mol/L

Medium	**Problems with standard electrolytes c(KCl) = 3 mol/L**	**Alternative electrolyte**
Silver ions	Reaction with Cl^- with precipitation of AgCl → slow response	c(KNO_3) = 1 mol/L (or Titrode for more or less constant pH value)
Non-aqueous	Precipitation of KCl, solutions and electrolyte immiscible → unsteady signal	c(LiCl) = 2 mol/L in ethanol or LiCl saturated in ethanol
Ion-deficient water	Contamination of the medium by salt → drift	KCl solution of lower concentration
Proteins/polypeptides	Precipitation of the proteins with KCl and AgCl → zero point shift/reduced slope	Idrolyte[1]
Semi-solid substances	Contamination of diaphragm → zero point shift/slow response	Solid electrolyte in combination with pinhole diaphragm
Surfactants (proteins)	Adsorption on diaphragm → zero point shift/reduced slope	Porolyte[2]

[1] Idrolyte is a glycerol-based electrolyte whose chloride ion activity corresponds to that of a KCl solution with c(KCl) = 3 mol/L. This means that the latter can also be readily replaced by Idrolyte. Idrolyte is excellent for use with solutions containing proteins and aqueous solutions with an organic fraction.

[2] Porolyte is a KCl solution that has been gelled by polymerization and is used in electrodes with a capillary diaphragm (Porotrode).

Table 13: Electrolyte flow rates and viscosities

Electrolyte	**Viscosity (25 °C) (mPas)**	**Flow rate µL/h (10 cm water column)**				
		Ceramic pin	**Flexible ground-joint**	**Fixed ground-joint**	**Ceramic capillary**	**Plied Pt wire**
c(KCl) = 3 mol/L	~1	Standard electrode 5...25 Microelectrode 5...15	Ø 10 mm: 20...100 Ø 5 mm: 5...30	5...30	–	–
c(KNO_3) = 1 mol/L	~1	10...25	Ø 10 mm: 20...100 Ø 5 mm: 5...30	–	–	–
Idrolyte	8...10	–	–	–	–	3...25
Porolyte	1200...1500	–	–	–	5...30	–

2. Fundamentals of conductometry

2.1. General

Conductometry means measuring the conductivity – a conductometer measures the electrical conductivity of ionic solutions. This is done by applying an electric field between two electrodes. The ions wander in this field. The anions migrate to the anode and the cations to the cathode. In order to avoid substance conversions and the formation of diffusion layers at the electrodes (polarization), work is carried out with alternating voltage. The rule of thumb is that the frequency of the alternating voltage must be increased as the ion concentration increases. Modern conductometers automatically adapt the measuring frequency to the particular measuring conditions.

Ion migration in an electric field depends on many factors. The temperature has a decisive influence on the viscosity of the solution and therefore on the mobility of the ions. As the temperature increases the viscosity decreases and the conductivity increases. Dissociation constants are also temperature-dependent quantities. This is why it is important to make measurements at a constant temperature or to compensate for changes of temperature by using the so-called temperature coefficient. The temperature coefficient of most salt solutions is approx. 2%/°C, but depends on the temperature in very dilute solutions.

The measuring unit used in conductivity measurements is the electrical resistance of the solution. This means that the conductivity is a sum parameter which includes all dissolved ions. Conductivity cannot be used for the determination of a single type of ion, unless the sample is a solution of a single salt or the concentrations of the other ions are known. The reciprocal value of the measured resistance of the solution, the so-called conductance L with the unit Siemens ($S = \Omega^{-1}$) is by itself less meaningful, as the shape of the measuring cell must be taken into account. The cell constant c of a conductometric measuring cell

$$c = \frac{\text{distance between Pt sheets}}{\text{electrode surface area}} [cm^{-1}]$$

Cell constant (10)

must be known. The result of the measurement is therefore always given as the specific conductivity K with the unit Siemens per cm ($S \cdot cm^{-1}$).

$$\kappa = L * c \quad [S\ cm^{-1}]$$

Specific conductivity (11)

This means that the conductometer must be calibrated before each measurement by determining the cell constant in a solution of known specific conductivity. The specific conductivity for various concentrations of many salts is given in tables. The specific conductivity K is linked with the concentration c_i of the individual ion i via the concentration-dependent equivalent conductivity Λ_i. The equivalent conductivity Λ_i is similar to the activity coefficient γ (see Section 1.2.) and is also a quantity that depends on the concentration.

$$\kappa = \sum_i (\Lambda_i * z_i * c_i)$$

Specific conductivity and concentration (12)

At great dilutions, i.e. $c_i \leq 0.001$ mol/L, the equivalent conductivity Λ_i can be equated with the equivalent conductivity shown in the tables for an infinite dilution.

Table 14: Conductivity κ of various substances and solutions

Conductor	T (κ)	Conductivity due to	Conductivity κ (µS cm^{-1})
Metallic copper	273	Electron conduction	645,000,000,000
Potassium hydroxide solution (c = 1 mol/L)	291	Ionic conduction resulting from the complete dissociation of KOH	184,000
KCl solution (c = 0.1 mol/L)	293	Ionic conduction resulting from the complete dissociation of KCl	11,660
Brackish water	273	Ionic conduction resulting from the dissociation of salts and carbonic acid	20,000 to 1,000,000
Acetic acid (c = 1 mol/L)	291	Ionic conduction resulting from the partial dissociation of CH_3COOH	1300
Drinking water	298	Ionic conduction resulting from the dissociation of salts and carbonic acid	10 to 2000
Graphite	273	Electronic conduction	1200
Distilled water	273	Ionic conduction resulting from contamination by salts, dissociation of water and carbonic acid	0.06...10
Ultrapure water	273	Ionic conduction resulting from low self-dissociation	0.056
Pure benzene	273	Ionic conduction resulting from the dissociation of traces of water	0.00000005

Conductometry is used for direct measurements and in titration. The theory is identical for both methods. Whereas in direct measurements it is the absolute value that is of interest, in titrations it is the change in the measured value. Direct measurement is often used for monitoring surface waters, waterworks, water desalination plants and in the preparation of ultrapure water, where particular limits must not be exceeded. Conductivity detection is mostly used for precipitation titrations, where the equivalent point is recognized by the conductivity reaching a minimum value. The absolute value is of secondary importance.

Conductivity measurements

Whereas the instruments used for potentiometry have been standardized (input impedance >1012 Ω, zero point at pH 7), this is not the case with conductometers. The influence of the cable capacity, the measuring frequency level, the conductivity range and the adjustable cell constant, the method used for conductivity measurements (phase-sensitive, frequency-dependent, bipolar pulse, etc.) vary and depend on the type of instrument. This means that the instrument must be taken into account for solving application problems. Important parameters are:

- Platinizing quality (platinum black) → high series capacity C_S
- Electrode area A → high series capacity C_S
- Cell constant c
- Measuring frequency f
- Cable capacity C_P
- Cable resistance R_C
- Instrument measuring range (resistance range)

Selecting the right cell constant

The cell constant c is defined for conductometric measuring cells. A measuring cell with two parallel electrodes at a distance of 1 cm and each with an area of 1 cm^2 theoretically has a cell constant $c = l \cdot A^{-1} = 1\ cm^{-1}$. The cell constant is never exactly $l \cdot A^{-1}$, as the electric field is not strictly homogeneous. The rules of thumb given in Table 15 are used for selecting the correct measuring cell:

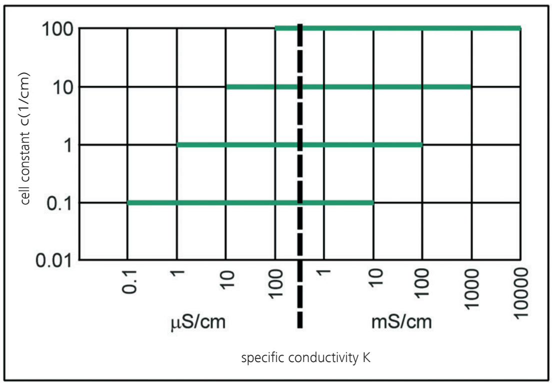


Figure 13: Cell constants and recommended conductivity intervals.

Interferences, care

Conductivity measuring cells with Pt sheets

Conductivity cells have a very porous black platinum coating in order to avoid polarization effects in media with a high conductivity. However, the properties of this coating may change in time (contamination, abrasion of the platinum coating, etc.); this could alter the cell constant. This is why it is absolutely necessary to calibrate the conductometric measuring cell before making a measurement in order to avoid measuring errors. For the exact determination of cells with a cell constant of <1 cm^{-1} a solution with a conductivity of about 100 mS/cm is recommended. If measurements are made in well conducting media then a check of the activity of the platinum layer is additionally recommended, e.g. in a 0.1 mol/L KCl solution. If a lower specific conductivity is shown then cleaning with a suitable oxidizing agent or solvent is indicated.

If measurements are made in ion-deficient water then frequent calibration is unnecessary, as in this case the activity (series capacity) of the platinum layer is not very important and the deposition of highly isolating substances is not to be expected. The measuring cell must be thoroughly cleaned after calibration in order to avoid incorrect measuring results caused by adherent KCl solution.

Table 15: Recommended cell constants

Cell constant	Sample
$c = 0.1\ cm^{-1}$	For very poorly conducting solutions such as distilled water, deionized or partly deionized water, etc. For applications according to USP 645 and EP 2.2.38
$c = 1\ cm^{-1}$	For moderately conducting solutions such as drinking water, surface water, wastewater, etc.
$c = 10\ cm^{-1}$	For solutions with good conductivity such as seawater, rinsing water, physiological solutions, etc.
$c = 100\ cm^{-1}$	For solutions with very good conductivity such as electroplating baths, salt solutions, etc.

Conductivity measuring cells (stainless steel)

These are usually substantially more insensitive to contamination or corrosion. However, also these measuring cells should be calibrated before the measurements in order to achieve the highest possible measuring accuracy. For cleaning, water and/or ethanol alone should be used.

Table 16: Conductivity measurement – interferences

Source of interference	Effects	Measures
Low conductivity with open vessel	Values too high, drift	Drive off atmospheric CO_2 with inert gas (Ar, N_2) or use flow-through cell, avoid carryover of salt solutions (e.g. too frequent calibration, inadequate rinsing)
Oils, precipitation products	Isolating layer on electrode → cell constant increases, measuring range limited to higher values	Clean with solvent or oxidizing agent
Unstable temperature	Unstable values	Temperature compensation, if temperature coefficient is known, or thermostatting (temperature coefficient generally approx. 2%/°C)
Conductance depends on electrode position	Stray fields outside electrode shaft (particularly for cells with constants >1 cm^{-1}) → measured value displaced	Watch distance from vessel during calibration and measurement or select cell constant 1 cm^{-1} Use of 5-ring conductivity measuring cells
Foreign salts	Carryover of residual salts when changing to solutions with low conductivity → drift to higher values	Thorough previous rinsing of electrode
Air bubbles	Air bubble located between electrode plates → unsteady signal	Remove air bubble by tapping

2.2. Conductivity measurement in accordance with USP and Pharm. Europe (EP)

There are special requirements for the conductivity measurement in water for pharmaceutical use («water for injections») according to USP 645, EP 2.2.38 resp. the latest EP -4.8-07/2004:0169. Besides a precision conductometer whose temperature compensation can be disabled, a conductivity measuring cell and a conductivity standard are to be used that allow to determine the cell constant with a maximum measuring error of 2%. To prevent the uptake of carbon dioxide, the measurement should be carried under exclusion of air and/or in a flow cell. The sample fulfills the specification if one of the following three conditions is met:

Stage 1:
The sample is measured directly without further pretreatment and without temperature compensation. If the water fulfills the specification indicated in table 17, the test is considered as passed.

Stage 2:
If the conditions are not fulfilled by stage 1, continue as follows: The conductivity of at least 100 mL sample is measured under strong agitation at 25 °C ±1 °C as soon as the drift caused by the uptake of carbon dioxide is smaller than 0.1 µS/cm per five minutes. If the measured value is smaller than 2.1 µS/cm, the test is considered as passed.

Stage 3:
However, if the sample does not fulfill the specification of stage 2, a sample of exactly 100 mL is mixed with 0.3 mL saturated KCl solution. Then the pH value of this solution is measured exactly to 0.1 pH units. Only if the conductivity fulfills the conditions specified in table 18 the test is considered as passed. Otherwise the water cannot be used for pharmaceutical purposes.

Table 17: First step of the conductivity measurement according to USP 645 and EP -4.8-07/2004:0169

Temperature	**Conductivity not larger than (µS/cm)**	**Temperature**	**Conductivity not larger than (µS/cm)**
0	0.6	55	2.1
5	0.8	60	2.2
10	0.9	65	2.4
15	1.0	70	2.5
20	1.1	75	2.7
25	1.3	80	2.7
30	1.4	85	2.7
35	1.5	90	2.7
40	1.7	95	2.9
45	1.8	100	3.1
50	1.9		

Table 18: pH and conductivity criteria for stage 3

pH	**Conductivity not larger than (µS/cm)**	**pH**	**Conductivity not larger than (µS/cm)**
5.0	4.7	6.1	2.4
5.1	4.1	6.2	2.5
5.2	3.6	6.3	2.4
5.3	3.3	6.4	2.3
5.4	3.0	6.5	2.2
5.5	2.8	6.6	2.1
5.6	2.6	6.7	2.6
5.7	2.5	6.8	3.1
5.8	2.4	6.9	3.8
5.9	2.4	7.0	4.6
6.0	2.4		

3. Temperature measurement

Only a few of the electrodes offered are fitted with a built-in temperature sensor. The decision whether temperature measurement/compensation is necessary depends on the required accuracy. Differing diffusion potentials, e.g. in highly concentrated or very dilute solutions, or changes to the diaphragm or the membrane glass can result in measuring errors that are far in excess of the errors caused by the absence of temperature compensation. Under such circumstances it is possible to dispense with the use of a temperature sensor.

However, if a high degree of reproducibility of the measured values is demanded or if GLP requirements have to be met then temperature measurement/compensation is absolutely necessary.

Table 19: Temperature measurement or temperature compensation: yes or no?

Measurement requirements	**Temperature compensation or measurement**
Are GLP requirements to be met?	Yes: temperature measurement
Is high measuring accuracy required?	Yes: temperature compensation (see Nernst potential)
Direct measurement?	Yes: temperature compensation (see Nernst potential)
Titration?	No: relative measurement
Is the pH of the sample about 7?	Yes: temperature compensation not absolutely necessary (low influence, as electrode zero point is at pH = 7), possibly temperature measurement
Does the pH value differ greatly from pH 7?	Yes: temperature compensation (see Nernst potential)
Are measurements made at different temperatures?	Yes: temperature compensation/measurement (see Nernst potential)
Is the pH of the sample solution very temperature-dependent?	Yes: temperature measurement (measurement temperature must be mentioned)
Does the application require a different type of diaphragm than a ceramic pin?	Yes: separate temperature sensor (electrodes with built-in temperature sensors are only available with ceramic pin and fixed ground-joint)
Is the working life of the electrode very short?	Yes: for cost reduction use separate temperature sensor

Technical specifications

6.01 - 6.02 pH glass electrodes	Max. installation length (mm)	Shaft diameter (mm)	Shaft diameter bottom (mm)	Min. immersion depth (mm)	Shaft material	Plug-in head	Temperature sensor	Temperature range short-term (°C)	Temperature range long-term (°C)	Shape	pH range
6.0150.100	142	12	12	15	Glass	G		0...80	0...80	Sphere	0...14
6.0220.100	113	12	12	15	PP	G		0...80	0...80	Hemisphere	0...14
6.0221.100	125	12	12	20	Glass	G		0...60	0...40	Hemisphere	1...11
6.0221.600	125	12	12	20	Glass	U	NTC	0...60	0...40	Hemisphere	1...11
6.0223.100	113	12	12	15	PP	G		0...40	0...40	Hemisphere	1...12
6.0224.100	113	12	3	7	Glass	G		0...60	0...60	Hemisphere	1...11
6.0226.100	98	12	6	10	Glass	G		0...60	0...40	Needle	1...11
6.0228.010	113	12	12	15	PP	Fixed cable with plug F	NTC (2 mm)	0...80	0...80	Hemisphere	0...14
6.0228.020	113	12	12	15	PP	Fixed cable with plug I (IP67)	NTC (2 mm)	0...80	0...80	Hemisphere	0...14
6.0228.600	113	12	12	15	PP	U	Pt1000	0...80	0...80	Hemisphere	0...14
6.0229.010	125	12	12	20	Glass	Fixed cable with plug F		0...70	0...70	Sphere	0...14
6.0229.020	125	12	12	20	Glass	Fixed cable with plug F		0...70	0...70	Sphere	0...14
6.0229.100	113	12	12	30	Glass	G		0...70	0...70	Sphere	0...14
6.0233.100	113	12	12	20	Glass	G		0...80	0...80	Hemisphere	0...14
6.0234.100	113	12	6.4	20	Glass	G		0...80	0...80	Hemisphere	0...14
6.0234.110	168	12	6.4	20	Glass	G		0...80	0...80	Hemisphere	0...14
6.0235.200	125	12	12	20	Glass	G		0...80	0...80	Hemisphere	0...14
6.0239.100	113	12	12	30	Glass	G		0...80	0...80	Hemisphere	0...14
6.0248.600	288	12	12	25	Glass	U	Pt1000	0...100	0...80	Cylinder	0...14
6.00249.600	438	12	12	25	Glass	U	Pt1000	0...100	0...80	Cylinder	0...14
6.0253.100	135	12	12	20	Glass	G		0...60	0...60	Sphere	0...13
6.0255.100	113	12	12	30	Glass	G		0...100	0...80	Cylinder	0...14
6.0255.110	170	12	12	30	Glass	G		0...100	0...80	Cylinder	0...14
6.0255.120	310	12	12	30	Glass	G		0...100	0...80	Cylinder	0...14
6.0256.100	125	12	12	1	Glass	G		0...60	0...60	Flat membrane	0...13
6.00257.000	135	12	12	20	Glass	Fixed cable with plug F	Pt1000 (2 mm)	0...60	0...60	Sphere	0...13
6.0257.020	260	12	12	20	Glass	Fixed cable with plug F	Pt1000 (4 mm)	0...60	0...60	Sphere	0...13
6.0257.600	135	12	12	20	Glass	U	Pt1000	0...60	0...60	Sphere	0...13
6.0258.010	125	12	12	25	Glass	Fixed cable with plug F	Pt1000 (2 mm)	0...100	0...80	Cylinder	0...14
6.0258.600	125	12	12	25	Glass	U	Pt1000	0...100	0...80	Cylinder	0...14
6.0259.100	113	12	12	25	Glass	G		0...100	0...80	Cylinder	0...14
6.0260.010	125	12	12	20	Glass	Fixed cable with plug F	Pt1000	0...100	0...100	Hemisphere	0...14
6.0260.020	125	12	12	20	Glass	Fixed cable with plug F	Pt1000	0...100	0...100	Hemisphere	0...14
6.0262.100	125	12	12	20	Glass	G		0...80	0...80	Hemisphere	0...13
6.0269.100	125	12	12	20	Glass	G		0...80	0...80	Sphere	0...13
6.0277.300	135	12	12	20	Glass	K	Pt1000	0...60	0...60	Sphere	0...13
6.0278.300	125	12	12	25	Glass	K	Pt1000	0...100	0...80	Cylinder	0...14
6.0279.300	113	12	12	30	Glass	K		0...70	0...70	Sphere	0...14
6.0280.300	125	12	12	20	Glass	K		0...80	0...80	Hemisphere	0...13
6.00200.300	125	12	12	20	Glass	Q	Pt1000	0...100	0...80	Hemisphere	0...14
6.00201.300	125	12	12	20	Glass	Q		0...80	0...80	Hemisphere	0...13
6.00202.300	125	12	12	20	Glass	Q	Pt1000	0...60	0...60	Sphere	0...13
6.00203.300	125	12	12	20	Glass	Q		0...70	0...70	Sphere	0...14
6.00204.300	125	12	12	30	Glass	Q		0...100	0...70	Cylinder	0...14
6.00226.600	98	12	6.4	10	Glass	U	Pt1000	0...60	0...40	Needle	1...11

Membrane glass	Membrane resistance (MΩ)	Electrode zero point (mV)	Electrode slope	Asymmetry potential (mV)	Diaphragm	Reference electrolyte	Electrolyte outflow (µL/h)	Reference system	Reference resistance (kΩ)
T	40…150	±15	>0.97	±15	–	–	–	–	–
T	200…500	±15	>0.97	±15	Ceramic	c(KCl)=3 mol/L	3…10	LL system	5
E	<400	±15	>0.97	±15	Twin pore	Gel	0	LL system	<20
E	<400	±15	>0.97	±15	Twin pore	Gel	0	LL system	<20
Spec.	100…650	±15	>0.97	±15	Ceramic	c(KCl)=3 mol/L	3…10	LL system	5
Spec.	300…600	±15	>0.97	±15	Platinum wire	Idrolyt	3…30	LL system	30
Spec.	200…500	±15	>0.97	±15	Twin pore	Gel	0	LL system	20
T	200…400	±15	>0.97	±15	Ceramic	c(KCl)=3 mol/L	3…10	LL system	5
T	200…400	±15	>0.97	±15	Ceramic	c(KCl)=3 mol/L	3…10	LL system	5
T	200…400	±15	>0.97	±15	Ceramic	c(KCl)=3 mol/L	3…10	LL system	5
T	50…150	0…100	>0.90	±15	EasyClean	LiCl/EtOH	3…50	LL system	<250
T	50…150	0…100	>0.90	±15	EasyClean	LiCl/EtOH	3…50	LL system	<250
T	50…150	0…100	>0.90	±15	Ground-joint	LiCl/EtOH	3…50	LL system	<250
T	150…400	±15	>0.97	±15	Ceramic	c(KCl)=3 mol/L	10…25	LL system	5
T	200…500	±15	>0.97	±15	Ceramic	c(KCl)=3 mol/L	5…15	LL system	5
T	200…500	±15	>0.97	±15	Ceramic	c(KCl)=3 mol/L	5…15	LL system	5
T	200…400	±15	>0.97	±15	Double capillary (ceramic)	Porolyt	5…30	LL system	<15
T	150…400	±15	>0.97	±15	Ground-joint	c(KCl)=3 mol/L	20…100	LL system	5
U	150…500	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L	3…30	LL system	5
U	150…500	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L	3…30	LL system	5
A	80…200	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L (gel)	5…20	LL system	50
U	150…500	±15	>0.97	±15	Ground-joint	c(KCl)=3 mol/L	20…100	LL system	5
U	150…500	±15	>0.97	±15	Ground-joint	c(KCl)=3 mol/L	20…100	LL system	5
U	150…500	±15	>0.97	±15	Ground-joint	c(KCl)=3 mol/L	20…100	LL system	5
Spec.	<2000	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L	<2	LL system	5
A	80…200	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L (gel)	5…20	LL system	50
A	80…200	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L (gel)	5…20	LL system	50
A	80…200	±15	>0.97	±15	Fixed ground-joint	c(KCL)=3 mol/L (gel)	5…20	LL system	50
U	150…500	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L	3…30	LL system	5
U	150…500	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L	3…30	LL system	5
U	150…500	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L	3…30	LL system	5
U	150…500	±15	>0.97	±15	EasyClean	c(KCl)=3 mol/L	5…50	LL system	5
U	150…500	±15	>0.97	±15	EasyClean	c(KCl)=3 mol/L	5…50	LL system	5
E	150…400	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L	5…30	LL system	5
A	80…200	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L	5…30	LL system	10
A	80…200	±15	>0.97	±15	Fixed ground-joint	c(KCl) = 3 mol/L	5…20	LL system	50
U	150…500	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L	3…30	LL system	5
T	50…150	0…100	>0.90	±15	Ground-joint	LiCl/EtOH	3…50	LL system	<250
E	<400	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L	5…30	LL system	<5
U	<600	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L	3…30	LL system	5
E	150…400	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L	3…30	LL system	5
A	80…200	±15	>0.97	±15	Fixed ground-joint	c(KCl)=3 mol/L (gel)	3…30	LL system	5
T	40…150	10…60	>0.90	±15	Ground-joint	c(LiCl in EtOH)=sat.	0.4…1.2	LL system	100
U	150…500	±15	>0.97	±15	Ground-joint	c(KCl)=3 mol/L	20…100	LL system	5
Spec.	200…500	±15	>0.97	±15	Twin pore	Gel	0	LL system	20

Technical specifications

6.03 Separate metal electrodes	Max. installation length (mm)	Shaft diameter (mm)	Shaft diameter bottom (mm)	Min. immersion depth (mm)	Shaft material	Plug-in head	Type	Temperature range short-term (°C)	Temperature range long-term (°C)	Shape	Measuring range	pH range
6.0301.100	125	12	12	10	Glass	B	Pt	-20...70	-20...70	Wire	-2000...2000 mV	0...14
6.0309.100	101	12	12	10	Glass	G	Pt	-20...70	-20...70	Sheet	-2000...2000 mV	0...14
6.0338.100	96	8	8	5	Glass	G	Pt	-20...70	-20...70	Wire	-2000...2000 mV	0...14
6.0340.000	103	5.3	5.3	10	Glass	Fixed cable/ Plug F	Pt	-20...70	-20...70	Wire	-2000...2000 mV	0...14
6.0341.100	101	12	8.75	10	Glass	G	Pt	-20...70	-20...70	Wire	-2000...2000 mV	0...14
6.0343.100	86	8	8	10	Plastic	Plug-in connector 5.5 mm	Pt	0...80	0...80	Rod	-2000...2000 mV	0...14
6.0344.100	108	24	24	15	Glass	G	Pt	-20...70	-20...70	Grid/Sheet		0...14
6.0345.100	108	24	24	15	Glass	G	Pt	-20...70	-20...70	Grid/Sheet		0...14
6.00350.100	125	12	6	7	Glass	G	Ag	-20...80	-20...80	Ring	-2000...2000 mV	0...14
6.0351.100	125	12	12	7	Glass	G	Pt	-20...80	-20...80	Ring	-2000...2000 mV	0...14
6.00353.100	125	12	6	20	Glass	G	Au	-20...80	-20...80	Ring	-2000...2000mV	0...14

6.04 Combined metal electrodes	Max. installation length (mm)	Shaft diameter (mm)	Shaft diameter bottom (mm)	Min. immersion depth (mm)	Shaft material	Plug-in head	Type	Temperature range short-term (°C)	Temperature range long-term (°C)	Shape	Measuring range	pH range	Diaphragm	Reference electrolyte	Electrolyte outflow (µL/h)	Diaphragm resistance (kΩ)	Reference system	Reference resistance (kΩ)
6.0421.100	113	12	12	10	Noryl/ PP	G	Sb-Stift	0...70	0...70			2...11	Ceramic	c(KCl)= 3 mol/L	3...10	1.2...1.8	LL system	5
6.00430.100	125	12	6	20	Glass	G	Ag/pH	0...80	0...80	Ring/hemi-sphere	-2000...2000 mV	0...14					pH	150...400
6.0431.100	125	12	12	20	Glass	G	Pt/pH	0...80	0...80	Ring/hemi-sphere	-2000...2000 mV	0...14					pH	150...400
6.0433.110	178	12	6.4	20	Glass	G	Ag/pH	0...80	0...80	Ring/hemi-sphere	-2000...2000 mV	0...14					pH	200...500
6.0434.110	178	12	6.4	20	Glass	G	Pt/pH	0...80	0...80	Ring/hemi-sphere	-2000...2000 mV	0...14					pH	200...500
6.0435.110	178	12	6.4	20	Glass	G	Au/pH	0...80	0...80	Ring/hemi-sphere	-2000...2000 mV	0...14					pH	200...500
6.00450.100	125	12	6	15	Glass	G	Ag	0...80	0...80	Ring	-2000...2000 mV	0...14	Fixed ground-joint	c(KNO_3)= 1 mol/L	10...25	0.4...0.9	LL system	5
6.00450.300	125	12	6	15	Glass	K	Ag	0...80	0...80	Ring	-2000...2000 mV	0...14	Fixed ground-joint	c(KNO_3)= 1 mol/L	10...25	0.4...0.9	LL system	5
6.0451.100	113	12	12	15	Glass	G	Pt	-5...80	-5...80	Ring	-2000...2000 mV	0...14	Ceramic	c(KCl)= 3 mol/L	10...25	0.4...0.9	LL system	5
6.0451.300	113	12	12	15	Glass	K	Pt	-5...80	-5...80	Ring	-2000...2000 mV	0...14	Ceramic	c(KCl)= 3 mol/L	10...25	0.4...0.9	LL system	5
6.0452.100	113	12	12	15	Glass	G	Au	-5...80	-5...80	Ring	-2000...2000 mV	0...14	Ceramic	c(KCl)= 3 mol/L	10...25	0.4...0.9	LL system	5
6.00470.300	125	12	6	20	Glass	K	Ag/pH	0...80	0...80	Ring/hemi-sphere	-2000...2000 mV	0...14					pH	150...400
6.0471.300	125	12	12	20	Glass	K	Pt/pH	0...80	0...80	Ring/hemi-sphere	-2000...2000 mV	0...14					pH	200...500
6.00401.300	125	12	12	20	Glass	Q	Pt/pH	0...80	0...80	Ring/hemi-sphere	-2000...2000 mV	0...14					pH	150...400
6.00402.300	125	12	12	20	Glass	Q	Ag	0...80	0...80	Ring	-2000...2000 mV	0...14	Fixed ground-joint	c(KNO_3)= 1 mol/L	3...30	< 2 kΩ	LL system	< 5 kΩ
6.00403.300	125	12	12	20	Glass	Q	Pt	-5...80	-5...80	Ring	-2000...2000 mV	0...14	Fixed ground-joint	c(KCl)= 3 mol/L	3...30	< 2 kΩ	LL system	< 5 kΩ
6.00404.300	125	12	6	20	Glass	Q	Ag/pH	0...80	0...80	Ring/hemi-sphere	-2000...2000 mV	0...14					pH	150...400
6.00435.120	308	12	6.4	20	Glass	G	Au/pH	0...80	0...80	Ring/hemi-sphere	-2000...2000 mV	0...14					pH	200...500

Technical specifications

6.05 Ion-selective electrodes	Max. installation length (mm)	Shaft diameter (mm)	Shaft diameter bottom (mm)	Min. immersion depth (mm)	Shaft material	Plug-in head	Type	Temperature range short-term (°C)	Temperature range long-term (°C)	Shape	Measuring range	pH range
6.0502.100	125	12	12	1	EP	G	Crystal (Br)	0...50	0...50	Flat	$1x10^{-6}$...1 mol/L	0...14
6.0502.120	125	12	12	1	EP	G	Crystal (Cl)	0...50	0...50	Flat	$1x10^{-5}$...1 mol/L	0...14
6.0502.130	125	12	12	1	EP	G	Crystal (CN)	0...80	0...80	Flat	$8x10^{-6}$...10^{-2} mol/L	10...14
6.0502.140	125	12	12	1	EP	G	Crystal (Cu)	0...80	0...80	Flat	$1x10^{-8}$...0.1 mol/L	2...12
6.0502.150	125	12	12	1	EP	G	Crystal (F)	0...80	0...80	Flat	$1x10^{-6}$...sat. mol/L	5...7
6.0502.160	125	12	12	1	EP	G	Crystal (I)	0...50	0...50	Flat	$5x10^{-8}$...1 mol/L	0...14
6.0502.170	125	12	12	1	EP	G	Crystal (Pb)	0...80	0...80	Flat	$1x10^{-6}$...0.1 mol/L	4...7
6.0502.180	125	12	12	1	EP	G	Crystal (Ag/S)	0...80	0...80	Flat	$1x10^{-7}$...1 mol/L	2...12
6.0506.100	125	12	12	5	PEEK/POM	G	NH_3-permeable membrane	0...50	0...50	Flat	$5x10^{-6}$...10^{-2} mol/L	11
6.0506.150	125	12	12	5	PEEK/POM	G	NH_3-permeable membrane	0...50	0...50	Flat	10^{-4}...1 mol/L	11
6.0507.010	125	12	2.5	20	PVC	G	Non-ionic surfactants	0...40	0...40	Pin	surfactant-dependent	0...12
6.0507.120	125	12	2.5	20	PVC	G	Non-ionic surfactants	0...40	0...40	Pin	surfactant-dependent	0...12
6.0507.130	125	12	12	5	POM	G	Ionic surfactants	10...50	10...50	Flat	surfactant-dependent	0...10
6.0507.140	125	12	12	1	PEEK	G	Ionic surfactants	0...40	0...40	Flat	surfactant-dependent	0...13
6.0507.150	125	12	2.5	20	PVC	G	Ionic surfactants	0...40	0...40	Pin	surfactant-dependent	0...12
6.0508.100	125	12	12	1	PVC	G	Polymer (Na)	0...40	0...40	Flat	$5x10^{-7}$...1 mol/L	3...12
6.0508.110	125	12	12	1	PVC	G	Polymer (Ca)	0...40	0...40	Flat	$5x10^{-6}$...1 mol/L	2...12
6.0510.100	113	12	12	10	PMMA/PP	G	Polymer (Ca)	0...40	0...40	Flat	$5x10^{-7}$...1 mol/L	2...12
6.0510.110	113	12	12	10	PMMA/PP	G	Polymer (K)	0...40	0...40	Flat	$1x10^{-7}$...1 mol/L	2.5...11
6.00502.300	113	12	12	10	PMMA/PP	Q	Polymer (Ca)	0...40	0...40	Flat	$5x10^{-7}$...1 mol/L	2...12
6.00510.120	113	12	12	10	PMMA/PP	G	Polymer (NO_3)	0...40	0...40	Flat	$1x10^{-6}$...1 mol/L	2.5...11

6.07 Reference electrodes	Max. installation length (mm)	Shaft diameter (mm)	Shaft diameter bottom (mm)	Min. immersion depth (mm)	Shaft material	Plug-in head	Temperature range short-term (°C)	Temperature range long-term (°C)	Diaphragm	Reference electrolyte	Bridge electrolyte	Outflow (µL/h) in relation to 3 mol/L KCl	Reference system	Reference resistance (kΩ) in relation to 3 mol/L KCl
6.0724.140	43	12	8	20	Glass	B	0...80	0...80		variable		0		<1
6.0726.100	100	12	12	10	Glass	B	0...80	0...80	Ground-joint	variable	variable	5...50	Ag wire/AgCl	<3
6.0726.107	100	12	12	10	Glass	B	0...80	0...80	Ground-joint	c(KCl)=3 mol/L	c(KCl)=3 mol/L	5...50	Ag wire/AgCl	<3
6.0726.110	138	12	8	10	Glass	B	0...80	0...80	Ground-joint	variable	variable	5...50	Ag wire/AgCl	variable
6.0727.000	83	18	18		PTCFE	Plug pin 2 mm			Ceramic	c(KCl)=3 mol/L		0		<3
6.0728.100	28	15	7	3	PTCFE	Plug-in connector 5.5 mm	0...60	0...60	Ceramic	variable		1...2,5	Ag wire/AgCl	<3
6.0728.100 +6.1245.000	58	18	9	3		Plug-in connector 5.5 mm				variable				
6.0728.110	53	15	7	3	PTCFE	Plug-in connector 5.5 mm	0...60	0...60	Ceramic	variable		1...2,5	Ag wire/AgCl	<3
6.0728.120	53	15	7	3	PTCFE	Plug-in connector 5.5 mm	0...60	0...60	Ceramic	c(KCl)=3 mol/L		1...2,5	Ag wire/AgCl	<3
6.0728.130	53	15	7	3	PTCFE	Plug-in connector 5.5 mm	0...60	0...60	Ceramic	c(KCl)=3 mol/L		1...2,5	LL system	<5
6.0728.110 -6.0728.130 +6.1245.010	65	15	5	3		Plug-in connector 5.5 mm				variable				
6.0729.100	100	12	12	10	Glass	G	0...80	0...80	Ground-joint	variable	variable	5...50	Ag wire/AgCl	<3
6.0729.110	138	12	12	10	Glass	G	0...80	0...80	Ground-joint	variable	variable	5...50	Ag wire/AgCl	<3
6.0730.100	65	12	6	3	Glass	Plug-in connector 5.5 mm	0...40	0...40	Ceramic	c(KCl)=3 mol/L (Gel)	c(KCl)=3 mol/L (Gel)		LL system	<20
6.0733.100	125	12	5	10	Glass	B	0...80	0...80	Ceramic	c(KCl)=3 mol/L		5...15	LL system	<3
6.0736.110	178	12	6.4	10	Glass	B	0...80	0...80	Ground-joint	variable	variable	5...50	Ag wire/AgCl	<3
6.0750.100	125	12	12	1	Glass	B	0...80	0...80	Fixed ground-joint	c(KCl)=3 mol/L (Gel)	c(KCl)=3 mol/L	3...30	Ag wire/AgCl	<40

Technical specifications

6.08-6.11 carbon electrodes, Conductivity cells, temperature sensors	Installation length (mm)	Shaft diameter (mm)	Shaft diameter bottom (mm)	Min. immersion depth (mm)	Shaft material	Plug-in head	Type	Temperature range short-term (°C)	Temperature range long-term (°C)	Measuring range	Temperature sensor
6.0901.040	108	12	20	50	Glass	Fixed cable 2xB (4 mm)	Pt platinized	5...70	5...70	0.1...10000 µS/cm	
6.0901.260	125	12	20	80	Glass	Fixed cable 2xB (4 mm)	Pt platinized	5...70	5...70	10...1000000 µS/cm	
6.0908.110	123	12	12	40	Glass	Fixed cable 4xB (4 mm)	Pt platinized	5...70	5...70	1...100000 µS/cm	Pt100
6.0910.120	120	12	12	16	Glass	G	Pt platinized	5...70	5...70	1...100000 µS/cm	
6.0912.110	125	12	12	35	PP	Fixed cable 4xB (4 mm)	Pt platinized	5...70	5...70	1...100000 µS/cm	Pt1000
6.0914.040	125	12	12	35	Steel, stainless	Fixed cable 4xB (4 mm)	Steel, stainless	0...70	0...70	0...300 µS/cm	Pt1000
6.0915.100	125	12	12	34	PEEK	Fixed cable, plug N	5-ring, Pt	0...70	0...70	5...20000 µS/cm (ideal)	Pt1000
6.0915.130	142	12	12	50	PEEK	Fixed cable, plug N	5-ring, Pt	0...70	0...70	5...100000 µS/cm (ideal)	Pt1000
6.0916.040	125	12	12	35	Steel, stainless	Fixed cable, plug N	Steel, stainless	0...70	0...70	0...300 µS/cm	Pt1000
6.0917.080	125	12	12	30	PEEK	Fixed cable, plug O	4-wire, Pt	0...70	0...70	0.015…250 mS/cm	Pt1000
6.0918.040	125	12	12	35	Steel, stainless	Fixed cable, plug O	Steel, stainless	0...70	0...70	0…300 uS/cm	Pt1000
6.0919.140	125	12	12	40	Glass	Fixed cable, plug O	3-ring, Pt	0...70	0...70	0.1…1000 mS/cm	Pt1000
6.0920.100	125	12	12	34	PEEK	Fixed cable, plug N	5-ring, Pt	0...70	0...70	5…20000 uS/cm	Pt1000
6.0920.130	142	12	12	50	PEEK	Fixed cable, plug N	5-ring, Pt	0...70	0...70	5 …. 100000 uS/cm	Pt1000
6.1103.000	121	12	5	20	Glass	Fixed cable		-50...100	-50...100	-50...100 °C	Pt100
6.1110.010	120	12	5	20	Glass	Fixed cable 2xB (2 mm)		-50...180	-50...180	-50...180 °C	Pt1000
6.1110.100	125	12	5	20	Glass	G		-50...180	-50...180	-50...180 °C	Pt1000
6.1110.110	178	12	6.4	20	Glass	G		-50...180	-50...180	-50...180 °C	Pt1000
6.1111.120	90	12	5	20	Glass	G		-50...180	-50...180	-50...180 °C	Pt1000
6.1114.010	140	12	3	10	PEEK	Fixed cable, plug 2x2 B	Steel, stainless	-50...100	-50...100	-50...100 °C	Pt1000
6.1115.000	135	12	12	30	Glass	Fixed cable		0...40	0...40		

RDE/RRDE tips/ microelectrodes (6.12, PT., RDE., RRDE.)	Length (mm)	Shaft diameter (mm)	Shaft material	Disk diameter (mm)	Disk material	Ring width (mm)	Ring material	Gap between ring and disk (mm)	Connector	Temperature range short-term (°C)	Temperature range long-term (°C)
6.1204.130	52.5	7	PEEK	2	Ag				M3	0…40°C	0…40°C
6.1204.140	52.5	7	PEEK	2	Au				M3	0…40°C	0…40°C
6.1204.170	52.5	7	PEEK	3	Pt				M3	0…40°C	0…40°C
6.1204.190	52.5	7	PEEK	2	Pt				M3	0…40°C	0…40°C
6.1204.300	52.5	10	PEEK	3	GC				M4	0…40°C	0…40°C
6.1204.310	52.5	10	PEEK	3	Pt				M4	0…40°C	0…40°C
6.1204.320	52.5	10	PEEK	3	Au				M4	0…40°C	0…40°C
6.1204.330	52.5	10	PEEK	3	Ag				M4	0…40°C	0…40°C
6.1204.600	52.5	8	Glass	2	GC				M3	0…50°C	0…50°C
6.1204.610	52.5	8	Glass	1	Pt				M3	0…50°C	0…50°C
AG.100	52	2	Glass	0.1	Ag				B (2 mm, male)	0…40°C	0…40°C
AG.25	52	2	Glass	0.025	Au				B (2 mm, male)	0…40°C	0…40°C
AG.30	52	2	Glass	0.03	Ag				B (2 mm, male)	0…40°C	0…40°C
AG.300	52	2	Glass	0.3	Ag				B (2 mm, male)	0…40°C	0…40°C
AU.10	52	2	Glass	0.01	Au				B (2 mm, male)	0…40°C	0…40°C
AU.100	52	2	Glass	0.1	Au				B (2 mm, male)	0…40°C	0…40°C
AU.200	52	2	Glass	0.2	Au				B (2 mm, male)	0…40°C	0…40°C
AU.25	52	2	Glass	0.025	Au				B (2 mm, male)	0…40°C	0…40°C
AU.300	52	2	Glass	0.3	Au				B (2 mm, male)	0…40°C	0…40°C
AU.40	52	2	Glass	0.04	Au				B (2 mm, male)	0…40°C	0…40°C
AU.50	52	2	Glass	0.05	Au				B (2 mm, male)	0…40°C	0…40°C
AU.500	52	2	Glass	0.5	Au				B (2 mm, male)	0…40°C	0…40°C
IR.75	52	2	Glass	0.075	Ir				B (2 mm, male)	0…40°C	0…40°C
PD.100	52	2	Glass	0.1	Pd				B (2 mm, male)	0…40°C	0…40°C
PD.25	52	2	Glass	0.025	Pd				B (2 mm, male)	0…40°C	0…40°C
PD.300	52	2	Glass	0.3	Pd				B (2 mm, male)	0…40°C	0…40°C
PD.500	52	2	Glass	0.5	Pd				B (2 mm, male)	0…40°C	0…40°C
PT.10	52	2	Glass	0.01	Pt				B (2 mm, male)	0…40°C	0…40°C
PT.100	52	2	Glass	0.1	Pt				B (2 mm, male)	0…40°C	0…40°C
PT.1000	52	2	Glass	1	Pt				B (2 mm, male)	0…40°C	0…40°C
PT.20	52	2	Glass	0.02	Pt				B (2 mm, male)	0…40°C	0…40°C
PT.200	52	2	Glass	0.2	Pt				B (2 mm, male)	0…40°C	0…40°C
PT.25	52	2	Glass	0.025	Pt				B (2 mm, male)	0…40°C	0…40°C
PT.300	52	2	Glass	0.3	Pt				B (2 mm, male)	0…40°C	0…40°C
PT.50	52	2	Glass	0.05	Pt				B (2 mm, male)	0…40°C	0…40°C
PT.500	52	2	Glass	0.5	Pt				B (2 mm, male)	0…40°C	0…40°C
RDE.AG50	52.5	10	PEEK	5	Ag				M4	0…40°C	0…40°C
RDE.AU50	52.5	10	PEEK	5	Au				M4	0…40°C	0…40°C
RDE.BLANK	52.5	10	PEEK	5	Empty				M4	0…40°C	0…40°C
RDE.CU50	52.5	10	PEEK	5	Cu				M4	0…40°C	0…40°C
RDE.GC50	52.5	10	PEEK	5	GC				M4	0…40°C	0…40°C
RDE.PT50	52.5	10	PEEK	5	Pt				M4	0…40°C	0…40°C
RDE.STEEL	52.5	10	PEEK	5	Stainless steel				M4	0…40°C	0…40°C
RDE.ZN50	52.5	10	PEEK	5	Zn				M4	0…40°C	0…40°C
RRDE.AUPT	51.5	11.5	PEEK	5	Au	0.375	Pt	0.375	M4	0…40°C	0…40°C
RRDE.GCPT	51.5	11.5	PEEK	5	GC	0.375	Pt	0.375	M4	0…40°C	0…40°C
RRDE.PTPT	51.5	11.5	PEEK	5	Pt	0.375	Pt	0.375	M4	0…40°C	0…40°C

Technical specifications

Screen-printed electrodes and interdigitated electrodes/micro-electrodes	WE material	WE dimension (mm)	AUX material	Cell configuration	Substrate size (mm)	Substrate material	Units/box
110	Carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	75 units
C110	Carbon	d. 4	Carbon	Work in solution	34 x 10 x 0.5	Ceramic	75 units
C11L	Carbon	d. 4	Carbon	Work in solution	34 x 10 x 0.5	Ceramic	75 units
150	Carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	75 units
220AT	Gold AT	d. 4	Platinum	Standard	34 x 10 x 0.5	Ceramic	75 units
220BT	Gold BT	d. 4	Gold BT	Standard	34 x 10 x 0.5	Ceramic	75 units
C220AT	Gold AT	d. 4	Gold AT	Work in solution	34 x 10 x 0.5	Ceramic	75 units
C220BT	Gold BT	d. 1.6	Gold BT	Work in solution	34 x 10 x 0.5	Ceramic	75 units
C223AT	Gold AT	d. 1.6	Gold AT	1.6 d	34 x 10 x 0.5	Ceramic	75 units
C223BT	Gold BT	d. 4	Gold BT	1.6 d	34 x 10 x 0.5	Ceramic	75 units
250AT	Gold AT	d. 4	Platinum	Standard	34 x 10 x 0.5	Ceramic	75 units
250BT	Gold BT	d. 4	Platinum	Standard	34 x 10 x 0.5	Ceramic	75 units
410	Co-phthalocyanine/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	75 units
550	Platinum	d. 4	Platinum	Standard	34 x 10 x 0.5	Ceramic	75 units
550BT	Platinum BT	d. 4	Platinum BT	Standard	34 x 10 x 0.5	Ceramic	75 units
C550	Platinum	d. 4	Carbon	Work in solution	34 x 10 x 0.5	Ceramic	75 units
610	Meldola´s blue/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	75 units
710	Prussian blue/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	75 units
F10	Ferrocyanide/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	75 units
810	Ruthenium oxide	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
910	Palladium	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
010	Silver	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	75 units
C013	Silver	d. 1.6	Carbon	1.6 d	34 x 10 x 0.5	Ceramic	75 units
110AGNP	Silver nanoparticles/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110BI	Bismuth oxide/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110CNF	Carbon nanofibres/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110CNF-GNP	Carbon nanofibres-gold Nanoparticles/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110CNT	Multi-walled carbon nanotubes/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110CNT-GNP	Multi-walled carbon Nanotubes-gold nanoparticles/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110CSQD	Core-shell quantum dots ZnS/CdSe/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110GNP	Gold nanoparticles/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110GNP-STR	Streptavidin modified gold Nanostructured/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110GPH	Graphene/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110GPH-GNP	Graphene-gold nanoparticles/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110GPHOX	Graphene oxide/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110MC	Mesoporous carbon/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110NI	Nickel oxide/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110OMC	Ordered mesoporous carbon/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110PANI	Polyaniline/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110QD	Core quantum dots CdSe/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110RGPHOX	Reduced graphene oxide/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110STR	Streptavidin/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110SWCNT	Single-walled carbon nanotubes/ Carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
110XTR	Extravidin/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
4W110	Carbon	d. 2.95	Carbon	4WE sharing AUX and REF	38 x 20 x 1.0	Ceramic	20 units
8W110	Carbon	d. 2.95	Carbon	8WE sharing AUX and REF	38 x 20 x 1.0	Ceramic	20 units
8X110	Carbon	d. 2.56	Carbon	Array of 8X ectrochemical cells	34 x 79 x 1.0	Ceramic	20 units
8X110STR	Streptavidin/Carbon	d. 2.95	Carbon	Array of 8X ectrochemical cells	34 x 79 x 1.0	Ceramic	10 units
8X220AT	Gold AT	d. 2.56	Gold	Array of 8X ectrochemical cells	34 x 79 x 1.0	Ceramic	20 units
8X550	Platinum	d. 2.56	Gold AT	Array of 8X ectrochemical cells	34 x 79 x 1.0	Ceramic	20 units
96X110	Carbon	d. 3	Carbon	ELISA 96X electrochemical cells	74 x 110 x 5.0	PCB	4 plates
96X110CNT	Multi-walled carbon nanotubes/carbon	d. 3	Carbon	ELISA 96X electrochemical cells	74 x 110 x 5.0	PCB	2 plates

Screen-printed electrodes and interdigitated electrodes/micro-electrodes	WE material	WE dimension (mm)	AUX material	Cell configuration	Substrate size (mm)	Substrate material	Units/box
96X110CNT-GNP	Multi-walled carbon Nanotubes-gold nanoparticles/carbon	d. 3	Carbon	ELISA 96X electrochemical cells	74 x 110 x 5.0	PCB	2 plates
96X110GNP	Gold nanoparticles/carbon	d. 3	Carbon	ELISA 96X electrochemical cells	74 x 110 x 5.0	PCB	2 plates
96X110GNP-STR	Streptavidin modified gold Nanostructured/carbon	d. 3	Carbon	ELISA 96X electrochemical cells	74 x 110 x 5.0	PCB	2 plates
96X110STR	Streptavidin/carbon	d. 3	Carbon	ELISA 96X electrochemical cells	74 x 110 x 5.0	PCB	2 plates
96X110SWCNT	Single-walled carbon nanotubes/carbon	d. 3	Carbon	ELISA 96X electrochemical cells	74 x 110 x 5.0	PCB	2 plates
96X110XTR	Extravidin/carbon	d. 3	Carbon	ELISA 96X electrochemical cells	74 x 110 x 5.0	PCB	2 plates
96X220	Gold	d. 3	Gold	ELISA 96X electrochemical cells	74 x 110 x 5.0	PCB	4 plates
96X550	Platinum	d. 3	Platinum	ELISA 96X electrochemical cells	74 x 110 x 5.0	PCB	4 plates
X1110	Carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	75 units
X4410	Co-phthalocyanine/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	75 units
XFF10	Ferrocyanide/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	75 units
X1110AGNP	Silver nanoparticles/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110BI	Bismuth oxide/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110CNF	Carbon nanofibres/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110CNF-GNP	Carbon nanofibres-gold Nanoparticles/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110CNT	Multi-walled carbon nanotubes/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110CNT-GNP	Multi-walled carbon nanotubes-Gold nanoparticles/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110CSQD	Core-shell quantum dots ZnS/CdSe/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110GNP	Gold nanoparticles/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110GNP-STR	Streptavidin modified Gold nanostructured/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110GPH	Graphene/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110GPH-GNP	Graphene-gold nanoparticles/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110GPHOX	Graphene oxide/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110MC	Mesoporous carbon/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110NI	Nickel oxide/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110OMC	Ordered mesoporous carbon/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110PANI	Polyaniline/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110QD	Core quantum dots CdSe/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110RGPHOX	Reduced graphene Oxide/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110STR	Streptavidin/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110SWCNT	Single-walled carbon nanotubes/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
X1110XTR	Extravidin/carbon	d. 4	Carbon	2WE sharing AUX and REF	34 x 10 x 0.5	Ceramic	50 units
GLU10	Glucose	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
LACT10	Lactate	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
UA10	Uric Acid	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	50 units
ITO10	ITO	d. 4	Carbon	Standard	34 x 10 x 0.5	Transparent Plastic	20 units
P10	PEDOT	d. 4	Carbon	Standard	34 x 10 x 0.5	Transparent Plastic	75 units
AUTR10	Transparent Gold	d. 4	Carbon	Standard	34 x 10 x 0.5	Transparent Plastic	20 units
COTE10	Transparent Carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Transparent Plastic	20 units
AL10	Aluminium	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	20 units
BIOFV1	PEDOT	d. 4	Carbon	Standard	34 x 10 x 0.5	Transparent Plastic	75 units
BDD10	Boron doped diamond	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	20 units
CBDD10	Boron doped diamond	d. 4	Carbon	Work in solution	34 x 10 x 0.5	Ceramic	20 units
BI10	Bismuth	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	20 units
CR10	Chromium	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	20 units
CST10	Carbon Steel	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	20 units
CU10	Copper	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	20 units

Technical specifications

Screen-printed electrodes and interdigitated electrodes/micro-electrodes	WE material	WE dimension (mm)	AUX material	Cell configuration	Substrate size (mm)	Substrate material	Units/box
MO10	Molybdenum	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	20 units
NI10	Nickel	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	20 units
PB10	Lead	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	20 units
SB10	Antimony	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	20 units
SN10	Tin	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	20 units
ST10	Steel	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	20 units
TA10	Tantalum	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	20 units
TI10	Titanium	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	20 units
W10	Tungsten	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	20 units
PW-AU10	Gold	d. 4	Carbon	Standard	34 x 10 x 0.5	White Plastic	20 units
TLFCL010-CIR	Silver	d. 4	Carbon	Thin layer flow-cell incorporated	80 x 25 x 0.1	Ceramic	10 units
TLFCL110	Carbon	12.6 mm^2	Carbon	Thin layer flow-cell incorporated	80 x 25 x 0.1	Ceramic	10 units
TLFCL110-CIR	Carbon	d. 4	Carbon	Thin layer flow-cell incorporated	80 x 25 x 0.1	Ceramic	10 units
TLFCL110S	Carbon	2 mm^2	Carbon	Thin layer flow-cell incorporated	80 x 25 x 0.1	Ceramic	10 units
TLFCL1110	Carbon	2 mm^2 x 2	Carbon	Thin layer flow-cell incorporated	80 x 25 x 0.1	Ceramic	10 units
TLFCL210AT-CIR	Gold AT	d. 4	Carbon	Thin layer flow-cell incorporated	80 x 25 x 0.1	Ceramic	10 units
TLFCL210BT-CIR	Gold BT	d. 4	Carbon	Thin layer flow-cell incorporated	80 x 25 x 0.1	Ceramic	10 units
TLFCL2222AT	Gold AT	0.8 x 5 (external) 0.4 x 5 (internal)	Gold AT	Thin layer flow-cell incorporated	80 x 25 x 0.1	Ceramic	10 units
TLFCL510-CIR	Platinum	d. 4	Carbon	Thin layer flow-cell incorporated	80 x 25 x 0.1	Ceramic	10 units
SPESMIX	Mix: Carbon, gold, platinum	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	100 units
AUMIX	Mix: Gold	d.4 and d.1.6	Gold	Standard, 1.6 d and work in solution	34 x 10 x 0.5	Ceramic	100 units
SERSMIX	Mix: silver, gold BT, copper and silver-coated copper	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	85 units
MEDIATORSPES	Mix: Co-phthalocyanine, meldola´s blue,prussian blue, ferrocyanide/carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Ceramic	100 units
OTEMIX	Mix: ITO, PEDOT, transparent gold and transparent carbon	d. 4	Carbon	Standard	34 x 10 x 0.5	Transparent plastic	40 units
G-IDE222	Gold	10 microns lines and gaps	Gold	Interdigitated with AUX and REF	22 x 7.0 x 0.7	Glass	20 units
G-IDE555	Platinum	10 microns lines and gaps	Platinum	Interdigitated with AUX and REF	22 x 7.0 x 0.7	Glass	20 units
G-IDEAG5	Silver	5 microns lines and gaps	Silver	Interdigitated squared format	22 x 7.0 x 0.7	Glass	20 units
G-IDEAU10	Gold	10 microns lines and gaps	Gold	Interdigitated squared format	22 x 7.0 x 0.7	Glass	20 units
G-IDEAU5	Gold	5 microns lines and gaps	Gold	Interdigitated squared format	22 x 7.0 x 0.7	Glass	20 units
G-IDECU5	Copper	5 microns lines and gaps	Copper	Interdigitated squared format	22 x 7.0 x 0.7	Glass	20 units
G-IDEPT10	Platinum	10 microns lines and gaps	Platinum	Interdigitated squared format	22 x 7.0 x 0.7	Glass	20 units
G-IDEPT5	Platinum	5 microns lines and gaps	Platinum	Interdigitated squared format	22 x 7.0 x 0.7	Glass	20 units
G-IDEMIX	Mix: Gold, platinum	5 and 10 microns lines and gaps	Mix: gold, platinum	Interdigitated:concentric; squared	22 x 7.0 x 0.7	Glass	20 units
G-IDECONAU10	Gold	10 microns lines and gaps	Gold	Interdigitated concentric format	22 x 7.0 x 0.7	Glass	20 units
G-IDECONPT10	Platinum	10 microns lines and gaps	Platinum	Interdigitated concentric format	22 x 7.0 x 0.7	Glass	20 units

Screen-printed electrodes and interdigitated electrodes/micro-electrodes	WE material	WE dimension (mm)	AUX material	Cell configuration	Substrate size (mm)	Substrate material	Units/box
G-MEA222	Gold	d. 3 / Microholes 10 microns	Gold	Interdigitated microelectrode array d. 3mm	22 x 7.0 x 0.7	Glass	20 units
G-MEA555	Platinum	d. 3 / Microholes 10 microns	Platinum	Interdigitated microelectrode array d. 3mm	22 x 7.0 x 0.7	Glass	20 units
G-MEAB222	Gold	Microband 10 microns	Gold	Interdigitated microelectrode array	22 x 7.0 x 0.7	Glass	20 units
G-MEAB555	Platinum	Microband 10 microns	Platinum	Interdigitated microelectrode array	22 x 7.0 x 0.7	Glass	20 units
IDEAU200	Gold	200 microns lines and gaps	Gold	Interdigitated squared format	22 x 7.0 x 0.7	Ceramic	20 units
IDEAU200-HPT-WB	Gold	200 microns lines and gaps	Gold	Squared design / Pt heater	22 x 7.0 x 0.7	Ceramic	50 units
P-IDEAU100	Gold	100 microns lines and gaps	Gold	Interdigitated squared format	22 x 7.0 x 0.7	Transparent plastic	50 units
PW-IDEPD100	Palladium	100 microns lines and gaps	Palladim	Interdigitated squared format	22 x 7.0 x 0.7	White plastic	50 units
PW-IDEAU100	Gold	100 microns lines and gaps	Gold	Interdigitated squared format	22 x 7.0 x 0.7	White plastic	50 units

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Subject to change without notice.
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