

Experiment N° 3

Requirements

1. Types and general characteristics of the water. Components of natural waters. Methods for water intake from natural reservoirs.
2. Technological processes used in water treatment for industrial and laboratory - general characteristics and in details:
 - the hardness of water and method of its determination,
 - Water softening - the essence of the process, methods of softening
 - schemes of apparatus
 - the demineralization of water - ion exchange, other methods
 - the use of sorbents in water treatment process
3. Quality requirements for water for municipal purposes.
4. Purification of water for municipal purposes.
5. Knowledge of the course of the experiment, knowledge of analytical methods used in the experiment: titration using redox reactions, titration using the complexation reactions, conductometry, pH-metry.

Water treatment - Overview of issues

Water¹ is a chemical substance with the chemical formula H₂O. A water molecule contains one oxygen and two hydrogen atoms connected by covalent bonds. Water is a liquid at ambient conditions, but it often co-exists on Earth with its solid state, ice, and gaseous state (water vapor or steam). Water also exists in a liquid crystal state near hydrophilic surfaces.^{2 3} Under nomenclature used to name chemical compounds, *Dihydrogen monoxide* is the scientific name for water, though it is almost never used.⁴

An ocean is a major body of saline water, and a component of the hydrosphere. Approximately 71% of the Earth's surface (an area of some 362 million square kilometers) is covered by ocean, a continuous body of water that is customarily divided into several principal oceans and smaller seas. More than half of this area is over 3,000 meters deep. Average oceanic salinity is around 35 parts per thousand (ppt) (3.5%), and

¹ <http://www.lsbu.ac.uk/water/index2.html>

² http://rmp.aps.org/pdf/RMP/v21/i2/p322_1

³ <http://en.wikipedia.org/wiki/Water>

⁴ http://science.widener.edu/svb/pset/nomen_b.html

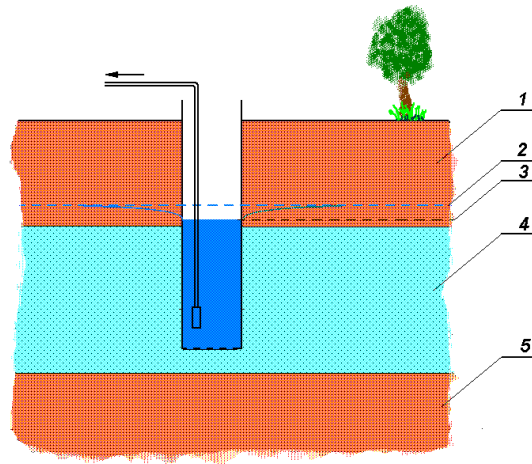
nearly all seawater has a salinity in the range of 30 to 38 ppt. Though generally recognized as several 'separate' oceans, these waters comprise one global ocean.

interconnected body of salt water often referred to as the World Ocean or global ocean.⁵
6 7 More:⁸

To be able to use the water resources that occur on Earth, use an object of engineering known as water intake. Depending on the reservoir from which water will be derived approach can be divided into:

- a) aquifers (wells)^{9 10},
- b) surface water intake (water intake from the river or lake)¹¹
- c) intakes from springs¹²

More: ¹³



⁵ <http://www.answers.com/topic/ocean#Encyclopedia>

⁶ <http://www.oceansatlas.com/>

⁷ <http://www.soest.hawaii.edu/krubin/GG425/Lect13.pdf>

⁸ http://en.wikipedia.org/wiki/Natural_environment

⁹ <http://ga.water.usgs.gov/edu/earthqwells.html>

¹⁰ http://en.wikipedia.org/wiki/Water_well

¹¹ http://en.wikipedia.org/wiki/Water_intake

¹² http://en.wikipedia.org/wiki/Drinking_water

¹³ <http://en.wikipedia.org/wiki/Groundwater>

Fig.1. Well. 1- native land, 2 - water table, 3 - cone of depression caused by pumping water from well, 4 - aquifer (gravels, sands), 5 - impermeable layer (such as clay).

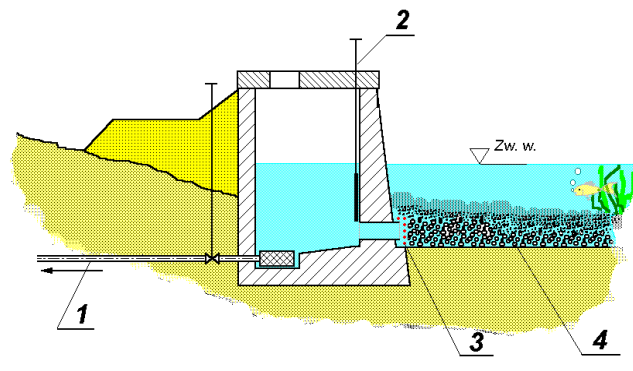


Fig. 2. Boundary water intake. 1 - suction hose, 2 - gate valve, 3 - grille, 4 - draining layer filter (gravel, crushed stone)

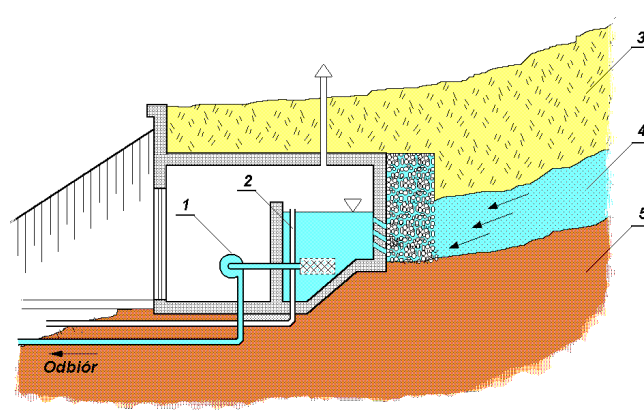


Fig. 3. Water intake from the source 1 - Pump, 2 - wire transfer, 3 - native land, 4 - aquifer, 5 - impermeable layer;¹⁴

¹⁴ <http://www.chem.uw.edu.pl/people/AMyslinski/cw3/ins3.htm#Uj%EAcia>



Fig. 4. Drainage systems shall also apply to installing them radially beneath the river (eg wells, "Thick Kaska" aqueduct Warsaw - Department of aqueduct Prague), and receiving water from the drains by gravity takes place in a centrally located shaft wells.¹⁵

Water purification is the process of removing undesirable chemicals, materials, and biological contaminants from contaminated water. The goal is to produce water fit for a specific purpose. Most water is purified for human consumption (drinking water) but water purification may also be designed for a variety of other purposes, including meeting the requirements of medical, pharmacology, chemical and industrial applications. In general the methods used include physical processes such as filtration and sedimentation, biological processes such as slow sand filters or activated sludge, chemical processes such as flocculation and chlorination and the use of electromagnetic radiation such as ultraviolet light.

The purification process of water may reduce the concentration of particulate matter including suspended particles, parasites, bacteria, algae, viruses, fungi; and a range of dissolved and particulate material derived from the surfaces that water may have made contact with after falling as rain.¹⁶

More:¹⁷

The hardness of water and method of its determination

This is the content of calcium and magnesium ions in water. Hardness is expressed in the number millival calcium and magnesium ions in a liter (dm^3) of water. Its expression is also used so-called degrees of hardness:

- German degree of hardness (⁰n) corresponding to the content of calcium and magnesium salts equivalent to 10 mg of CaO in 1 dm^3 of water,
- French degree of hardness (⁰f) corresponding to the content of calcium and magnesium

¹⁵ <http://www.chem.uw.edu.pl/people/AMyslinski/cw3/ins3.htm#Uj%EAcia>

¹⁶ http://en.wikipedia.org/wiki/Water_purification

¹⁷ <http://www.accepta.com/>



salts equivalent to 10 mg CaCO₃ in 1 dm³ of water,
- English degree of hardness (° Clark) corresponding to the content of calcium and magnesium salts equivalent to 14.3 mg CaCO₃ in 1 dm³ of water.¹⁸

An excellent way to determine water hardness is to perform a complexometric titration using a standard ethylenediaminetetraacetic acid (EDTA) solution. Due to steric hindrances, EDTA will complex with calcium and magnesium in a **one-to-one** molar ratio.

More: ¹⁹ ²⁰ ²¹

¹⁸ <http://www.chem.uw.edu.pl/people/AMyslinski/cw3/ins3.htm#Wymagania>

¹⁹ <http://www.chemistry.wustl.edu/~edudev/LabTutorials/Water/FreshWater/hardness.html>

²⁰ http://www.gannon.edu/resource/dept/sim/new/chemexp_files/Most%20used%20ChemLabs/PDF%20Files/pH%20water%20hardness.pdf

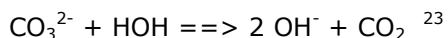
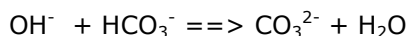
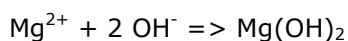
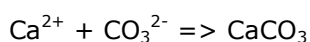
²¹ <http://www.chem.utk.edu/~chem319/Experiments/Exp6.pdf>

Water softening - the essence of the process, methods of softening

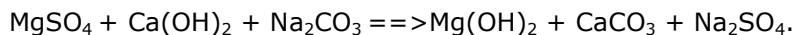
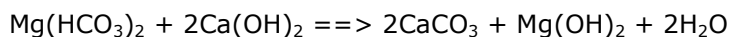
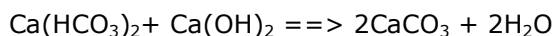
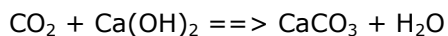
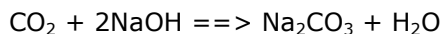
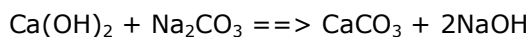
Water softeners will remove nearly all the calcium and magnesium from the raw water during the softening process. Softeners will also remove up to 10 ppm of iron and manganese. Water supplies with high levels of iron and manganese (greater than 10 ppm) may need pretreatment to prolong the lifespan of a water softener.²²

Pretreatment

Improving water is the easiest way to protect boilers against a stone. It consists in adding to the feed water carbonate or sodium hydroxide. Then the following reactions occur:



Softening by lime - soda is one of the methods of softening by precipitation. They shall be kept at an elevated temperature of about 60 - 80°C. Addition of lime $\text{Ca}(\text{OH})_2$ causes the precipitation of calcium carbonate, soda Na_2CO_3 (sodium carbonate) precipitated noncarbonate hardness. The following reactions occur:



²² <http://www.ag.ndsu.edu/pubs/h2oqual/watsys/ae1031w.htm#measure>

²³ <http://www.chem.uw.edu.pl/people/AMyslinski/cw3/ins3.htm>

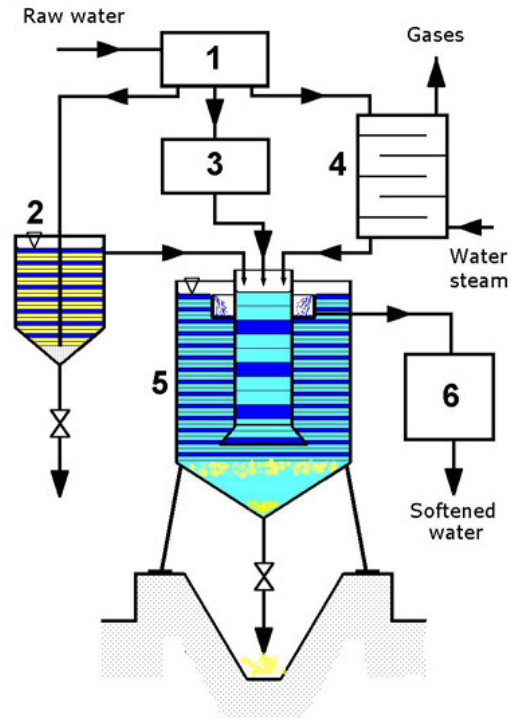


Fig. 5. Softening of water by soda & lime 1 - the main distributor of water, 2 - saturator of the solution of lime, 3 - preparation reservoir of the solution of sodium carbonate, 4 - cascade heater, 5 - reactor, 6 - filter.

Animation – click here please: http://www.chem.uw.edu.pl/people/AMyslinski/cw3/waps_c1a.gif

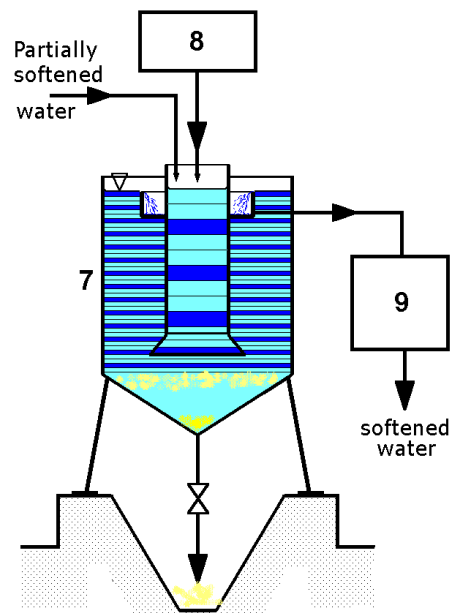
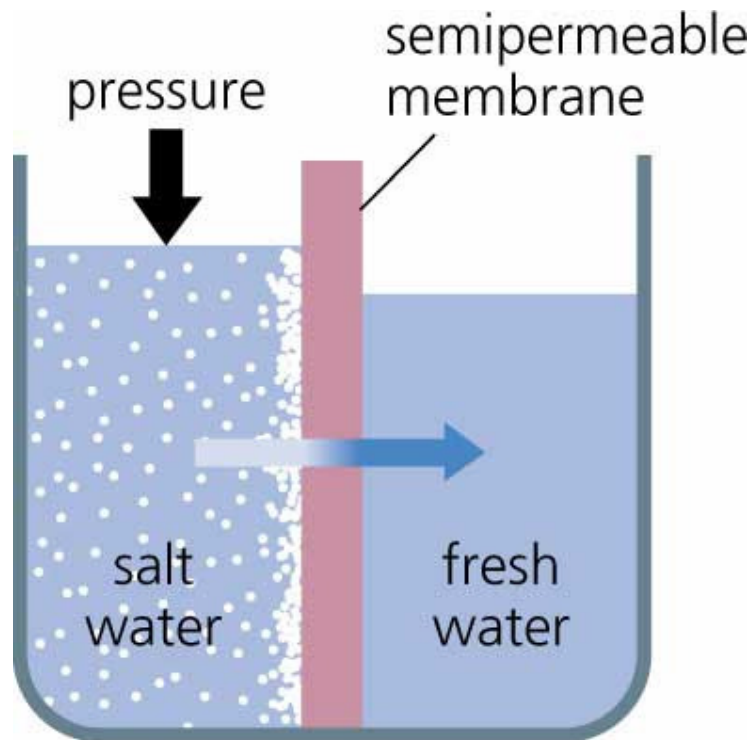


Fig. 6. Softening of water by phosphates 7 - reactor, 8 - sodium phosphate solution tank, 9 - completely softened water filter

Water treatment

Reverse osmosis (RO) is a membrane technical filtration method that removes many types of large molecules and ions from solutions by applying pressure to the solution when it is on one side of a selective membrane. The result is that the solute is retained on the pressurized side of the membrane and the pure solvent is allowed to pass to the other side. To be "selective," this membrane should not allow large molecules or ions through the pores (holes), but should allow smaller components of the solution (such as the solvent) to pass freely.²⁴



Precision Graphics

Source:²⁵

²⁴ http://en.wikipedia.org/wiki/Reverse_osmosis

²⁵ http://www.google.pl/imgres?imgurl=http://images.yourdictionary.com/images/main/A4reosmo.jpg&imgrefurl=http://images.yourdictionary.com/reverseosmosis&h=409&w=390&sz=16&tbnid=ZAv_GeSP4g2ckM:&tbnh=90&tbnw=86&prev=/search%3Fq%3Dreverse%2Bosmosis%26tbn%3Dsch%26tbo%3Du&zoom=1&q=reverse+osmosis&docid=101AtlybnwcVZM&sa=X&ei=Nd8GT-L9DpDAswas_7mCDw&ved=0CH0Q9QFwAw&dur=2237

Ion exchange

Ion exchange is a process used to remove dissolved ions from a solution by electrostatic sorption into ion exchange materials (most commonly into ion exchange resins). The removed ions are replaced with equivalent amounts of other ions of the same charge. Ion exchange is most commonly used for purification purposes, but is also widely implemented in the separation and extraction of valuable substances. Deionisation of water and water softening can be cited as the most common application.²⁶

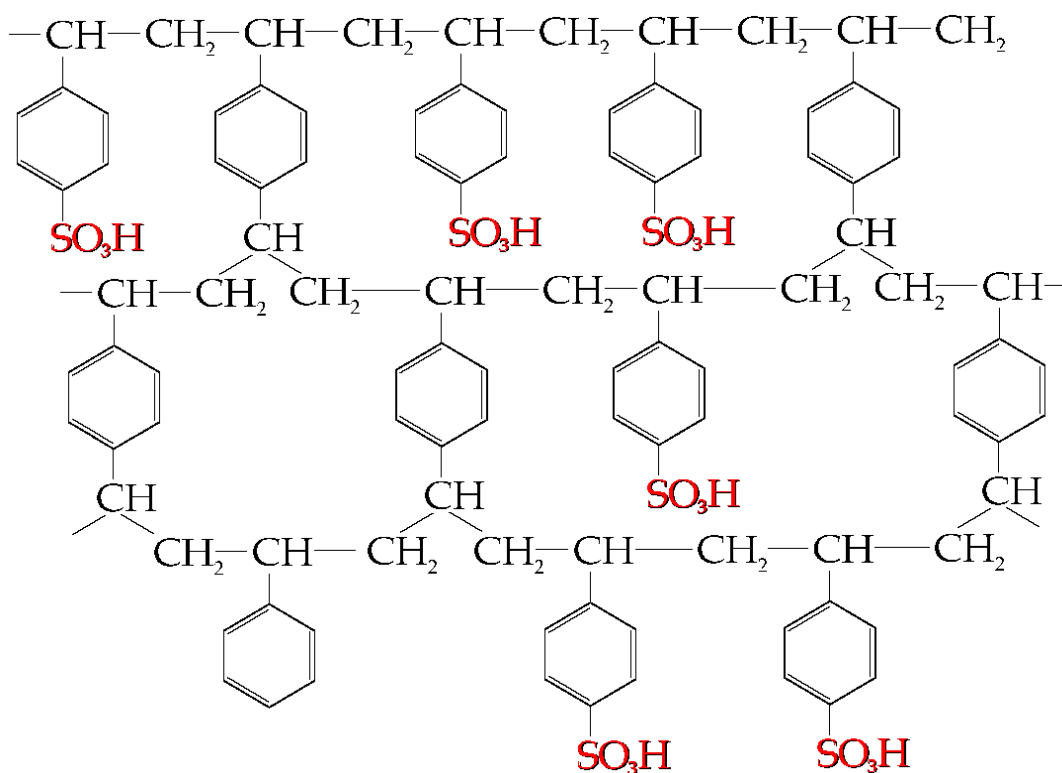


Fig. 8. Cationic resin obtained by sulfonation of a copolymer of polystyrene - divinylbenzene. To enlarge please click on <http://www.chem.uw.edu.pl/people/AMyslinski/cw3/image18.gif>

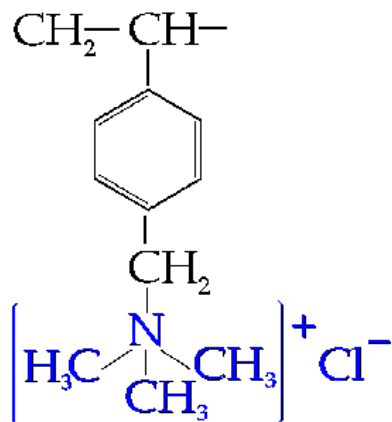


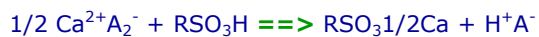
Fig. 9. Mer of the anionic resin obtained by the amination of styrene-divinylbenzene; form of Chloride. Mer derived from divinylbenzene (crosslinker) invisible.

²⁶ http://wiki.biomine.skelleftea.se/wiki/index.php/Ion_exchange

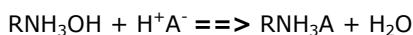


Reactions:

Cationic resin



Anionic resin



More:^{27 28} & many more²⁹

Sorbents in water purifying

[Activated] Carbon is a substance that has a long history of being used to absorb impurities and is perhaps the most powerful absorbent known to man. One pound [453,59 g] of carbon contains a surface area of roughly 125 acres [505 857.053 m² = ~50,6 ha] and can absorb literally thousands of different chemicals. Activated carbon is carbon which has a slight electro-positive charge added to it, making it even more attractive to chemicals and impurities. As the water passes over the positively charged carbon surface, the negative ions of the contaminants are drawn to the surface of the carbon granules.³⁰

Advances in nanoscale science and engineering suggest that many of the current problems involving water quality could be resolved or greatly ameliorated using **nanosorbents**, nanocatalysts, bioactive nanoparticles, nanostructured catalytic membranes and nanoparticle enhanced filtration among other products and processes resulting from the development of nanotechnology. Innovations in the development of novel technologies to desalinate water are among the most exciting and promising. Additionally, nanotechnology- derived products that reduce the concentrations of toxic compounds to sub-ppb levels can assist in the attainment of water quality standards and health advisories. This ³¹ article gives an overview of the use of nanomaterials in water purification. We highlight recent advances on the development of novel nanoscale materials and processes for treatment of surface water, groundwater and industrial wastewater contaminated by toxic metal ions, radionuclides, organic and inorganic solutes, bacteria and viruses. In addition, we discuss some challenges associated with the development of cost effective and environmentally acceptable functional nanomaterials for water purification.³¹

More: ^{32 33}

²⁷ http://en.wikipedia.org/wiki/Ion-exchange_resin

²⁸ <http://www.ianrpubs.unl.edu/live/q1491/build/q1491.pdf>

²⁹ <http://www.google.pl/search?q=water+softening+by+ionic+exchange+method&ie=utf-8&oe=utf-8&aq=t&rls=org.mozilla:pl:official&client=firefox-a>

³⁰ <http://www.home-water-purifiers-and-filters.com/carbon-water-filter.php>

³¹ <http://www.ph.ucla.edu/ehs/ehs280/articles/Savage%20Diallo%20Review%20Nanotechnology%20Water%20Quality%20%28Hoek%20%29.pdf>

³² http://en.wikipedia.org/wiki/Carbon_filtering

³³ <http://www.google.pl/search?q=o%09the+use+of+sorbents+in+water+treatment+process&ie=utf-8&oe=utf-8&aq=t&rls=org.mozilla:pl:official&client=firefox-a>

Quality requirements for water for municipal purposes

European Union³⁴

The water policy of the European Union is primarily codified in three directives:

- Directive on Urban Waste Water Treatment (91/271/EEC)³⁵ of 21 May 1991 concerning discharges of municipal and some industrial wastewaters;
- The Drinking Water Directive (98/83/EC)³⁶ of 3 November 1998 concerning potable water quality;
- Water Framework Directive (2000/60/EC)³⁷ of 23 October 2000 concerning water resources management.

Purification of water for municipal purposes.

Water that is distributed in cities or communities is treated extensively. Specific water purification steps are taken, in order to make the water meet current water standards.³⁸ Purification methods can be divided up into settling of suspended matter, physical/chemical treatment of colloids and biological treatment. All these treatment methods have several different applications.

Sedimentation is a physical water treatment process used to settle out suspended solids in water under the influence of gravity.³⁹

Filtration. A **water filter** removes impurities from water by means of a fine physical barrier, a chemical process or a biological process. Filters cleanse water to various extents for irrigation, drinking water, aquariums, and swimming pools.^{40 41}

³⁴ http://en.wikipedia.org/wiki/Directive_on_Urban_Waste_Water_Treatment#Urban_Waste_Water_Treatment_Directive_of_1991

³⁵ <http://www.igemportal.org/Resim/Council%20Directive%20Concerning%20Urban%20Wastewater%20Treatment.pdf>

³⁶ <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1998:330:0032:0054:EN:PDF>

³⁷ <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:327:0001:0072:EN:PDF>

³⁸ <http://www.lenntech.com/applications/drinking/standards/who-s-drinking-water-standards.htm>

³⁹ <http://www.ingentaconnect.com/content/els/02731223/1998/00000037/00000002/art00018>

⁴⁰ http://en.wikipedia.org/wiki/Water_filter

⁴¹ <http://www.cyber-nook.com/water/Solutions.html>



Water purification systems a Bret lake, Switzerland⁴²

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Disinfection. Public awareness of the potential for groundwater and surface water contamination and the growing interest in outdoor recreational activities in areas not serviced with safe drinking water have led to increased usage of water disinfection devices. (...)

Depending on the source of the water, conditions of use, and magnitude and extent of microbiological contamination, disinfection may be needed occasionally over short periods of time or on a continuous basis.⁴³

Read more:⁴⁴

An interesting link⁴⁵

⁴² http://en.wikipedia.org/wiki/File:Usine_Bret_MG_1643.jpg

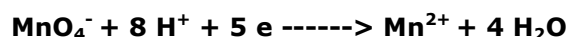
⁴³ <http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/disinfect-desinfection-eng.php>

⁴⁴ <http://www.lenntech.com/water-purification-steps-faq.htm>

⁴⁵ <http://www.chem1.com/CO/gallery.html>

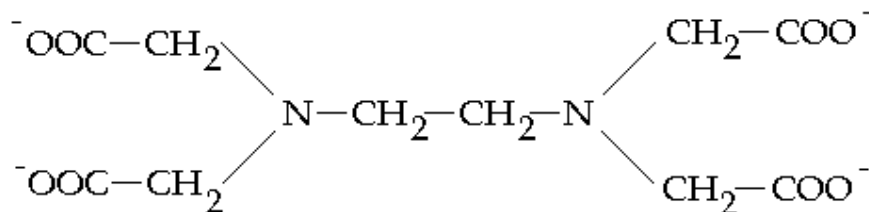


Manganometry is a quantitative oxidimetric method based on measurement of potassium permanganate (KMnO_4) spent for an oxidation of the matter in question.⁴⁶

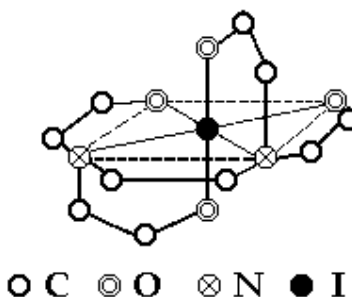
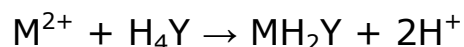


Read more:⁴⁷

Complexometric titration (sometimes **chelometry**) is a form of volumetric analysis in which the formation of a colored complex is used to indicate the end point of a titration. Complexometric titrations are particularly useful for the determination of a mixture of different metal ions in solution. An indicator capable of producing an unambiguous color change is usually used to detect the end-point of the titration.⁴⁸



EDTA, ethylenediaminetetracetic acid



The spatial structure of the complex EDTA. Central ion I. The dashed lines are not chemical bonds. Help understand the spatial arrangement of the molecule.

Read more:⁴⁹

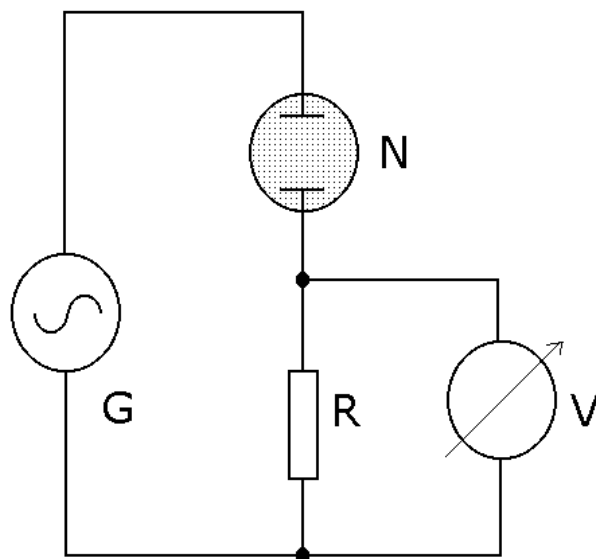
⁴⁶ <http://glossary.periodni.com/dictionary.php?en=manganometry>

⁴⁷ http://rama.one.pl/epm/epm/07_food_quality/lab_0809/Manganometry%20and%20iodometry%20-%20introduction.pdf

⁴⁸ http://en.wikipedia.org/wiki/Complexometric_titration

⁴⁹ http://en.wikipedia.org/wiki/Complexometric_titration

Conductometry



G - AC power source with constant voltage, N - conductivity cell filled with a measured solution, R - resistor connected in series with the above mentioned elements, V - voltmeter measures the voltage drop across the resistor.

The voltage drop is directly proportional to the conductivity of the solution contained in the cell.

$$L = \frac{a}{d} \sum_i c_i \lambda_i$$

where:

a - size of the surface of electrodes

d - distance between them

c - the concentration of ions in the solution

λ - the coefficient of the ion characteristic of the called ion equivalent conductivity.

Summation symbol Σ highlights the fact that the conductivity values of various ions are additive.

Read more:^{50 51}

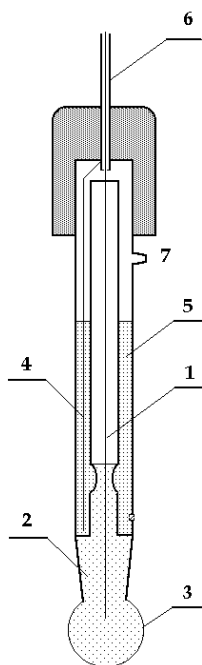
⁵⁰ http://vedyadhara.ignou.ac.in/wiki/images/e/ed/Unit_4_Conductometric_Titrations.pdf

⁵¹ <http://www.tau.ac.il/~phchlab/experiments/Conductivity/conductivity.htm>

Potentiometry

Electroanalytical techniques, which measure electrode potential utilizing the *galvanic cell* concept, fall under the general heading of potentiometry.⁵²

A **pH meter** is an electronic instrument used for measuring the pH (acidity or alkalinity) of a liquid (though special probes are sometimes used to measure the pH of semi-solid substances). A typical pH meter consists of a special measuring probe (a glass electrode) connected to an electronic meter that measures and displays the pH reading.⁵³



1 - the Ag/AgCl Reference Electrode electrode leading

2 - the solution of the Ag/AgCl Reference Electrode (0.1 mol/dm³ HCl)

3 - glass membrane (low-resistant; 100-500 Mohm)

4 - Ag/AgCl Reference Electrode

5 - the internal solution of the reference electrode (saturated KCl solution saturated with AgCl)

6 - the signal cable

7 - internal solution inlet

Nernst equation

$$E = E^0 + \frac{RT}{nF} \ln \frac{a_{M^{n+}}}{a_{M^0}}$$

where:

E^0 - normal electrode potential ($a_{M^{n+}} = 1$)

R - gas constant (8.31441 J K⁻¹ mol⁻¹)

T - absolute temperature (K)

F - Faraday constant (96486.7 ± 0.54 C mol⁻¹)

n - number of electrons taking part in the reaction

$a_{M^{n+}}$ - activity of metal ions

$a_{M^0} = 1$

⁵² <http://ull.chemistry.uakrn.edu/analytical/Potentiometry/>

⁵³ http://en.wikipedia.org/wiki/pH_meter