Institute of Mathematics, Physics and Chemistry

Department of Chemistry

**Water chemistry laboratory**

**Laboratory exercise**

# Determination of chloride ion content and specific conductivity

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# EXERCISE SHEET

<table>
<tr><td>1</td><td>Relation to subjects: ESO/25, 27 DiRMiUO/25, 27 EOUNiE/25, 27
<table>
<tr><th>Specialty/Subject</th><th>Learning outcomes for the subject</th><th>Detailed learning outcomes for the subject</th></tr>
<tr><td>ESO/26 Chemistry of water, fuels and lubricants</td><td>EKP3<br>K_U014, K_U015, K_U016.</td><td>SEKP6 – Determination of selected indicators of technical water quality;</td></tr>
<tr><td>DiRMiUO/26 Chemistry of water, fuels and lubricants</td><td>EKP3<br>K_U014, K_U015, K_U016.</td><td>SEKP6 – Determination of selected indicators of technical water quality;</td></tr>
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</table></td></tr>
<tr><td>2</td><td>Purpose of the exercise:<br>teaching the student how to independently determine the content of chloride ions and the conductivity of boiler or cooling water, learning the technical requirements for these parameters, methods of their measurement and operational significance;</td></tr>
<tr><td>3</td><td>Prerequisites:<br>the student is trained in the occupational health and safety regulations in a laboratory workplace, which he confirms with his signature on the appropriate form, knows – the Mohr titration method for the determination of chloride ions and the conductivity measurement method with a conductometer and its operating principle, knows the methods of desalination and demineralization of water on the ship, as well as technical requirements and operational meaning of marked parameters;</td></tr>
<tr><td>4</td><td>Description of the laboratory workplace:<br>a typical laboratory kit for argentometric analysis, salt meter, conductivity meter, instructions for operating the instruments, water samples;</td></tr>
<tr><td>5</td><td>Risk assessment *:<br>contact with an aqueous solution of silver nitrate 0.028M – very low probability of dark spots on the skin.<br>Final assessment – VERY SMALL THREAT<br>Safety measures required:<br>a. lab coats,<br>b. health and safety cleaning products, paper towels;</td></tr>
<tr><td>6</td><td>The course of the exercise:<br>a. Read the workplace manual (appendix 1) and familiarize with the laboratory kit for the exercise,<br>b. Determine the content of chloride ions using the Mohr method and measure the salinity with a salt meter and conductivity measurements with the conductivity meter of the tested water;</td></tr>
<tr><td>7</td><td>Exercise report:<br>a. Develop an exercise in accordance with the instructions contained in the workplace manual (appendix 1),<br>b. On the basis of the obtained results of measurements and determinations, determine the quality and operational suitability of the tested water by comparing the determined parameters with their acceptable values.,<br>c. If necessary, suggest possible water treatment or appropriate corrective action,<br>d. Solve the given task and/or answer the questions included in the set of tasks and questions to be completed by the student;</td></tr>
</table>

| | | |
|---|---|---|
| 8 | **Archiving of research results:**<br>Submit a written report on the performed exercise to the teacher. |
| 9 | **Assessment method and criteria:**<br>a. EKP1, EKP2 – tasks given for independent solution and development:<br>mark 2.0 – has no basic chemical and operational knowledge concerning the determined operational parameters of the tested boiler or cooling water, i.e. the content of chloride ions, salinity and specific conductivity of the water;<br>mark 3.0 – has basic chemical and operational knowledge concerning the determined functional parameters of the tested boiler or cooling water, i.e. the content of chloride ions, salinity and specific conductivity of water, and the ability to make basic chemical calculations and solve simple tasks in the field of these parameters;<br>mark 3.5 – 4.0 – has extended chemical and operational knowledge in the field of determined utility parameters of the tested water and the ability to solve complex tasks in the field of assessing changes in these parameters;<br>mark 4.5 – 5.0 – has the ability to apply complex chemical and operational knowledge to partial evaluation of the quality and operational suitability of the tested water due to the content of chloride ions, salinity and specific conductivity of water, and the ability to make diagnostic decisions on this basis, as well as corrective and remedial actions.<br>b. EKP3 – control works:<br>mark 2.0 – does not have the ability to analyse and evaluate the results of the performed analyses and determinations and to draw conclusions;<br>mark 3.0 – has the ability to analyse the obtained results, interpret the laws and phenomena, transform formulas, and interpret charts and tables;<br>mark 3.5 – 4.0 – has the ability to broaden the analysis of results, apply laws, construct monograms and charts;<br>mark 4.5 – 5.0 – has the ability to comprehensively analyse the obtained results of determinations and measurements, make generalizations, detect cause-and-effect relationships and make appropriate operational decisions. |
| 10 | **References:**<br>1. J. Krupowies, C. Wiznerowicz, A. Kalbarczyk-Jedynak, K. Ćwirko, M. Ślaczka-Wilk, Workplace instruction for laboratory exercise: „Oznaczanie zawartości jonów chlorkowych oraz przewodnictwa właściwego”, 2022 (in Polish).<br>2. https://openstax.org/details/books/chemistry-2e (accessed: 10 July 2023).<br>3. https://planm8.io/blog/marine-boiler-water-treatment (accessed: 10 July 2023).<br>4. https://marinersgalaxy.com/boiler-water-test-on-ship-name-of-all-tests/(accessed:10 July 2023).<br>5. https://www.imo.org/en/MediaCentre/HotTopics/Pages/Implementing-the-BWM-Convention.aspx (accessed: 29 June 2023).<br>6. https://www.imo.org/en/GoogleSearch/SearchPosts/Default.aspx?q=water%20treatment%20on%20ships (accessed: 29 June 2023).<br>7. https://www.wilhelmsen.com/product-catalogue/products/marine-chemicals/test-kits-and-reagents/water-test-kits/test-kit-for-cooltreat-al/ (accessed: 29 June 2023). |

# APPENDIX 1 – MANUAL

## 1. SCOPE OF THE EXERCISE

- getting acquainted with the workplace instructions for the exercise;
- determination of chloride ions in cooling or boiler water using the argentometric method (Mohr's method);
- determination of the specific conductivity of cooling or boiler water with the use of a conductivity meter;
- assessment of the quality of the tested water and suitability for operational purposes and its possible treatment.

## 2. THEORETICAL INTRODUCTION TO THE EXERCISE

### 2.1. Chloride ion content

In terms of chemistry, sea water is a solution of many chemical compounds, mainly various salts, such as: chlorides, bromides, sulphates, carbonates, etc., occurring in various amounts depending on the considered body of water. The most abundant compound in seawater is sodium chloride NaCl (0.9 – 2.6%).

The good solubility of chlorides and their widespread occurrence in the form of natural salt deposits (NaCl, $MgCl_2$) make these salts extremely widespread in natural waters.

Chloride ions are the ingredients that induce the taste of the water. The salty taste in its pure form is caused only by sodium chloride. The bitter taste of sea water is caused by the magnesium salts.

Chloride concentration in waters for various purposes is regulated by law. The applicable national regulations limit e.g., the chloride content in drinking water and economic needs at a level not higher than 250 $mg/dm^3$. Water containing increased amounts of chloride is corrosive to concrete, cast iron and steel. For example, groundwater shows a destructive effect even at the content of 100 mg $Cl^-/dm^3$, especially in the case of soft waters and waters containing magnesium chloride.

Sea water, due to its high salinity, cannot be used as feed water for marine boilers. These boilers must be supplied with water of appropriate quality, the so-called fresh water, which is a distillate obtained in ship evaporators by evaporating seawater. Modern distillation installations used on ships produce fresh water from sea water with a salinity ranging from a few to several mg $Cl^-/dm^3$. These devices are equipped with salt meters enabling the continuous control of the content of chloride ions in the produced distillate. The control of the salinity of the distillate can also be carried out using the Mohr method.

The increase in chloride concentration in the distillate is evidence of a malfunctioning evaporator. The change in the chloride content in water is a very important indicator of the technical condition of the water system in use. In a ship's engine room, we deal with mutual contact and interaction of freshwater and sea water circuits (e.g., in coolers, condensers, etc.). In the event of failure of the heat exchangers, there is a risk of seawater entering the freshwater circuit, which is a very harmful phenomenon. The simplest method of detecting such a failure is the systematic control of the concentration of chloride ions in fresh water. The constant increase in the content of chloride ions proves the process of seawater entering the fresh water cycle. In this way, the water analysis carried out on the ship become a kind of diagnostic method for devices operating in water systems.

Thorough control of chloride ions in water is additionally dictated by the fact that chemical water treatment preparations used in shipbuilding do not reduce chloride content, but only remove hardness (descale) and prevent corrosion and water foaming. The permissible limit concentration of chloride ions depends on the type of boiler and its operating parameters. For some types of marine boilers, they are given in the auxiliary tables at the end of the manual.

Excessive salinity of boiler water causes not only increase of its electrolytic conductivity, density and tendency to foaming, but also intensification of corrosive properties. For example, excessive chloride content in water creates a risk of internal boiler corrosion due to their hydrolytic decomposition into aggressive hydrochloric acid. For example, magnesium chloride undergoes hydrolytic degradation at elevated temperatures according to the following reaction:

$$MgCl_2 \quad + \quad 2H_2O \quad \rightarrow \quad \downarrow Mg(OH)_2 \quad + \quad 2HCl$$

The hydrochloric acid thus formed is then corrosive to the metal components of the boiler according to the reaction:

$$Fe \quad + \quad 2HCl \quad \rightarrow \quad FeCl_2 \quad + \quad \uparrow H_2$$

Magnesium hydroxide as sparingly soluble, precipitates in the form of a sediment, increasing the amount of silt and limescale. Chlorides can also release hydrochloric acid by reacting with sulfates in the boiler water, according to the reaction:

$$2NaCl \quad + \quad MgSO_4 \quad + \quad 2H_2O \quad \rightarrow \quad Na_2SO_4 \quad + \quad \downarrow Mg(OH)_2 \quad + \quad 2HCl$$

## 2.2. Conductivity

The flow of electric current in the material environment consists in the transport of electric charge, the carriers of which may be electrons or ions. Due to the mechanism of current conduction, conductors are divided into: electronic or metallic conductors (metals, semiconductors, superconductors) and ion or electrolytic conductors. Typical ion conductors are solutions of salts, acids and bases, molten or solid salts.

In the case of electrolytic conductors, the current flow is related to the movement of ions. This causes chemical changes and changes in the concentration of conductive electrolytes. As a rule, electrolytes are much worse conductors of electricity than metals. Their specific conductivity is less than 1S/cm, while the best metallic conductors have a conductivity of 104 – 106 S/cm. Generally, the specific resistance of electrolytes decreases with increasing temperature. The conductivity of electrolyte solutions depends on their concentration, temperature, chemical nature of the solute (ability to dissociate into ions) and the type of solvent (ability to form solvates with the formed ions and the value of electric permeability).

The flow of current through the electrolyte solution (electrolytic conductor) is accompanied by chemical changes taking place on the contact surfaces of two types of conductors (discharge and ion release on the electrodes, secondary reactions with the electrode or solvent) and changes in the concentration of the electrolyte in the spaces near the electrodes. The chemical processes taking place in the analysed systems depend on the chemical properties of the metallic electrodes, the components of the solution and the difference in potential between the electrodes.

Conductometry is an electroanalytical method based on the study of the electrical conductivity of a solution between two electrodes. Testing the conductivity of solutions concerns primarily electrolyte solutions, this conductivity is called electrolytic conductivity or electrolytic conductance.

Direct conductometry consists in measuring the specific conductivity of electrolytes, which for electrolyte solutions is in the range $0.1 - 10^6$ µS/cm. The determination of the concentration of solutions on the basis of the conductivity test can be performed only for simple electrolyte systems for which there is a linear relationship between conductivity and concentration. The conductivity of most electrolyte solutions does not differ much (except $H^+$ and $OH^-$), therefore conductometry is a non-selective method.

Direct conductometry has been used, among others, in in the industrial analysis of solutions, both concentrated and diluted. It is often used to control technological processes, including water purification technology. It serves, among others to characterize distilled water, boiler feed water, to characterize wastewater.

The values of specific conductivity of some solutions and for water are shown in Fig. 1.

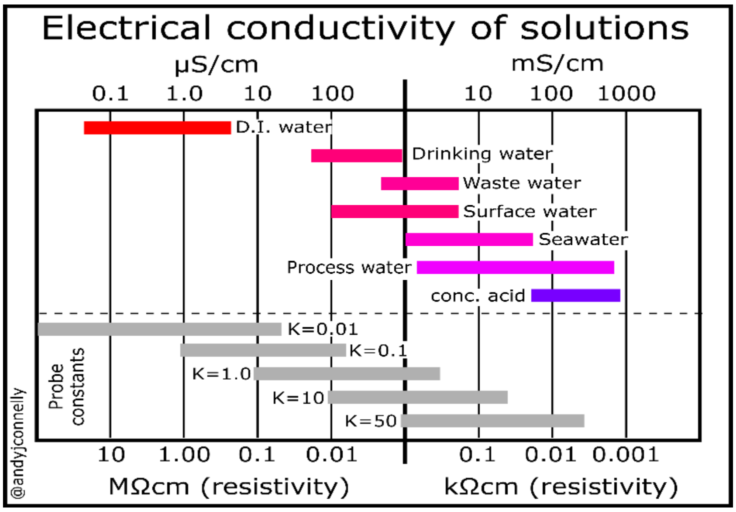


Fig. 1. Conductivity of water and some water solutions (source: https://andyjconnelly.wordpress.com/2017/07/14/conductivity-of-a-solution/) (18.10.2021)

Conductivity is a measure of the ability of a solution to conduct an electrolytic current. Pure water has very little conductivity; it grows rapidly after dissolving acids, hydroxides and salts in it (table 1). The increase in specific conductivity, always observed in the area of low concentrations, with increasing concentration is the result of an increase in the number of ions per unit volume of solution. In the range of higher concentrations, the following factors play a dominant role: interionic interactions, which reduce the mobility of ions, and changes in the value of the dissociation constant. The dependence of the conductivity on the concentration provides valuable information about the changes undergone by the electrolyte.

Table 1

Conductivity of electrolytes at 20°C

| Electrolyte | Molarity of the electrolyte | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.0001 M | | 0.0002 M | | 0.0005 M | | 0.0010 M | |
| | Electrolyte concentration – column 1, conductivity – column 2 | | | | | | | |
| | $mg/dm^3$ | μS/cm | $mg/dm^3$ | μS/cm | $mg/dm^3$ | μS/cm | $mg/dm^3$ | μS/cm |
| Formula | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| $NaNO_3$ (sodium nitrate ) | 8.50 | 10.90 | 17.0 | 21.8 | 42.5 | 54.20 | 85.0 | 107.5 |
| $KNO_3$ (potassium nitrate) | 10.10 | 13.10 | 20.2 | 26.2 | 50.5 | 64.95 | 101.0 | 129.0 |
| KCl (potassium chloride) | 7.40 | 13.50 | 14.9 | 26.9 | 37.3 | 68.00 | 74.5 | 137.0 |
| NaCl (sodium chloride) | 5.85 | 11.30 | 11.7 | 22.8 | 29.2 | 56.25 | 58.5 | 118.0 |
| KOH (potassium hydroxide) | 5.60 | 25.00 | 11.2 | 50.0 | 28.0 | 123.00 | 56.1 | 244.0 |
| NaOH (sodium hydroxide) | 4.00 | 21.60 | 8.0 | 43.2 | 20.0 | 108.00 | 40.0 | 216.0 |

## 3. Performing the exercise

Fig. 2 shows a general view of the laboratory workplace for testing the content of chloride ions in water.

Fig. 2. Laboratory workplace for determination of chloride ions by Mohr's method

### 3.1. Determination of chloride ions in boiler or cooling water by Mohr's method

The determination principle is based on the titration of chlorides with silver nitrate against potassium chromate ($K_2CrO_4$) as an indicator in a neutral or slightly alkaline sample (pH 6.5 – 10). Silver ions form sparingly soluble silver chloride AgCl with chloride ions. In the presence of chromates, silver nitrate $AgNO_3$ first precipitates AgCl (white cheese-like) of silver chloride:

$$AgNO_3 \quad + \quad NaCl \quad \rightarrow \quad \downarrow AgCl \quad + \quad NaNO_3$$
$$Ag^+ + Cl^- \rightarrow \downarrow AgCl$$

and after complete precipitation of the chloride ions, a reddish-brown silver chromate a ($Ag_2CrO_4$) precipitate is formed. The colour change of the titrated water sample indicates that the equivalence point has been reached, i.e., the end of the chloride ion precipitation reaction in the form of AgCl precipitate. Since there are no $Cl^-$ ions in the solution, the further addition of $AgNO_3$ reacts with $K_2CrO_4$ according to the reaction:

$$2AgNO_3 \quad + \quad K_2CrO_4 \quad \rightarrow \quad \downarrow Ag_2CrO_4 \quad + \quad 2KNO_3$$
$$2Ag^+ \quad + \quad CrO_4^{2-} \quad \rightarrow \quad \downarrow Ag_2CrO_4$$

The order of precipitation of AgCl and $Ag_2CrO_4$ sediments (selectivity) is determined by the values of the solubility products of these compounds ($K_{\mathrm{sp\,AgCl}} < K_{\mathrm{sp\,Ag_2CrO_4}}$). Since this value for AgCl is lower, it is less soluble and its critical value is exceeded earlier. So, practically, as long as all chloride ions are not precipitated in the form of AgCl, no $Ag_2CrO_4$ precipitate is formed – i.e., it is formed and dissolves immediately. This is the selectivity of the precipitation of the above-mentioned sparingly soluble deposits.

The determination is disturbed by acids, hydroxides colour above 30° on the platinum-cobalt scale. Bromides, iodides and cyanides precipitate like chlorides. Orthophosphates interfere above 25 mg/dm$^3$, precipitating silver phosphate. Iron content above 10 mg/dm$^3$ masks the end point of the titration. Sulphides, thiosulfates and sulfites are also disturbing.

They can be eliminated as follows: make the sample alkaline against phenolphthalein with sodium hydroxide solution, add 1 cm$^3$ of $H_2O_2$, mix, then neutralize with sulphuric acid.

If the water has a high colour, add 3 cm$^3$ of the $Al(OH)_3$ suspension to 100 cm$^3$ of the sample, mix, allow the sediment to settle, filter, wash and use the filtrate combined with the washing water for testing.

### Performing the determination

Pipette 25 cm$^3$ of the water under test into 3 conical flasks. Then add 75 cm$^3$ of distilled water to each of them. If interfering factors need to be removed, proceed as outlined above.

Perform the determination in the range of pH 6.5 – 10. If the pH of the sample is outside this range, it must be adjusted with sulphuric acid or sodium hydroxide. Then add 1 cm$^3$ of 10% $K_2CrO_4$ solution as an indicator (Fig. 3). Titrate with standard $AgNO_3$ solution. The intermediate stage of this titration is shown in Fig. 4, where the turbidity of the solution due to the formation of a white AgCl precipitate is clearly visible. Continue the titration until the colour changes from greenish-yellow to red-brown (Figures 5 and 6). In the same way, titrate the control sample containing 75 cm$^3$ of distilled water (previously used to dilute the test water). Usually, the consumption of $AgNO_3$ solution per control sample is 0.2 – 0.3cm$^3$.

Fig. 3. Sample prepared for titration

Fig. 4. Intermediate stage of titration

Fig. 5. Final titration effect

Fig. 6. Comparison of the samples after the titration with the initial one

### Calculation and reporting of results

Calculate the content of chloride ions according to the formula:

$$C_{Cl^-} = \frac{(a - b) \cdot M \cdot 35.45 \cdot \ 1000}{V} \ \text{[mg Cl}^-\text{/dm}^3\text{]}$$

where:

- $a$ – average volume of $AgNO_3$ solution used for titration of the test sample, $cm^3$,
- $b$ – volume of $AgNO_3$ solution used to titrate the control sample, $cm^3$,
- $M$ – the titre of the $AgNO_3$ solution, M = 0.028 mol/$dm^3$,
- 35.45 – atomic mass of chlorine,
- $V$ – volume of the test water sample used for the determination, $cm^3$.

The determined content of chloride ions in the tested boiler water should be converted into the equivalent content of sodium chloride, NaCl.

The method of converting the content of chloride ions into the content of NaCl.
For example, if the determined content of chloride ions in the boiler water is 120.00 mg/$dm^3$, then the conversion of this content into an equivalent amount of NaCl is as follows:

$$\mathrm{NaCl} \xrightarrow{H_2O} \mathrm{Na^+} + \mathrm{Cl^-}$$

| | | |
|---|---|---|
| 58.44 | | 35.45 |
| $x$ | | 120,00 |

$$C_{NaCl} = \frac{58.44 \cdot 120.00}{35.45} = 197.82 \ \text{[mg NaCl/dm}^3\text{]}$$

The concentration of 120.00 mg $Cl^-$/$dm^3$ corresponds to the content of 197.83 mg NaCl/$dm^3$.

Fig. 7 shows a laboratory workplace for testing water conductivity.

Fig. 7. Laboratory workplace for determination of conductivity

## 3.2. Measurement of conductivity

Measure the specific conductivity with a digital conductivity meter (Fig. 8) as follows:

Calibrate the conductivity meter before running a series of conductivity measurements.

Immerse the measuring electrode in the standard solution with a known conductivity value so that the level of the tested liquid is between the marks of min. max. on the electrode (fig. 8). Turn on the instrument, after the conductivity value has stabilized (if necessary), use the calibration screw to correct the conductivity result so that it is consistent with the conductivity content of the standard solution. Turn off the instrument, then rinse the electrode with distilled water.

**Measurement:**

1) Immerse the measuring electrode in the tested sample so that the level of the tested liquid is between the marks of min. max. on the electrode (fig. 8) and turn on the instrument;
2) After the value has stabilized, read the conductivity result on the instrument display.
3) Turn off the instrument, then rinse the electrode with distilled water.
4) Take the measurement three times.

Fig. 8. Conductivity meter

**Elaboration of the results**

With a conductivity in the range of 10 μS/cm and below, the results may differ by 10% of the smallest result.

With a conductivity above 10 μS/cm, the results may differ by 5% from the lowest result.

The arithmetic mean of at least 3 measurements should be taken as the final result of the determination.

## 4. DEVELOPMENT OF THE EXERCISES

1. Compare the obtained results of chloride ion content with their acceptable concentrations for the boiler water of the selected type of ship's boiler or for cooling water.
2. Compare the obtained conductivity measurement results with the values of the boiler water conductivity of the selected type of ship boiler or cooling water.
3. On the basis of the obtained results, assess the quality and suitability of the tested water for operation in selected types of steam boilers.
4. The auxiliary tables 2 - 4 show the technical requirements for utility water for selected types of steam boilers, and appendixes 2 - 3 show the requirements recommended by Unitor for boiler and cooling water.

## 5 THE FORM AND CONDITIONS FOR PASSING THE LABORATORY EXERCISE

1. Passing the so-called "entry" before starting the exercise.
2. Submission of a correct written report on the completed exercise, which should include:

   – short theoretical introduction,
   – operational significance of the measured parameter,
   – processing of the obtained results according to the position manual.

3. Final credit for the test at the end of the semester.

# Additional tasks

**I. Examples of tasks with solutions**

1. How many milligrams of $Cl^-$ did the salt sample contain when titrated with 35 $cm^3$ of 0.11 M n $AgNO_3$ solution?
   Solution
   The product: 35 $cm^3$ · 0.11 $mmol/cm^3$ represents the number of millimoles used in the $AgNO_3$ titration. the number of millimoles of chloride is equivalent to, because:

$$Ag^+ + Cl^- \rightleftarrows \downarrow AgCl$$

so in the analyzed sample there were: 35 · 0.11 = 3.85 mmol of chlorides. To calculate the result in milligrams, multiply the number of millimoles by the atomic mass of chlorine:

$$3.85 \cdot 35.45 = 136.5 \text{ mg } Cl^-$$

Answer: The sample contained 136.5 mg of $Cl^-$ ions.

2. Calculate the concentration of magnesium ions $Mg^{2+}$ and chloride ions $Cl^-$ in a 0.05 M solution of magnesium chloride $MgCl_2$, if its dissociation degree $\alpha$ = 75% (i.e., 0.75).
   Solution:
   In the ionic state in the solution, the following $MgCl_2$ concentration exists:

$$\alpha \cdot C_{total} = 0.75 \cdot 0.05 = 0.0375 \text{ mol/dm}^3$$

The electrolytic dissociation reaction equation has the form:

$$MgCl_2 \xrightleftharpoons{H_2O} Mg^{2+} + 2Cl^-$$

therefore, the concentration of chloride ions in the solution is 2 times higher than the $Mg^{2+}$ ions, hence the ion concentrations are respectively:

$$[Mg^{2+}] = 0.0375 \text{ mol/dm}^3, [Cl^-] = 2 \cdot 0.0375 = 0.0750 \text{ mol/dm}^3$$

Answer: The concentration of $Mg^{2+}$ is 0.0375 $mol/dm^3$, and $Cl^-$ ions is 0.0750 $mol/dm^3$.

## II. Tasks and questions to be completed by the student

### Tasks

1. How many milligrams of chloride are in a 250-milligram sample of salt if 28.5 $cm^3$ of a 0.0985 M $AgNO_3$ solution was used to titrate the chloride after dissolving it in water.
   Answer: 99.5 mg of chlorides.
2. 30.15 $cm^3$ of 0.1112 M $AgNO_3$ solution were used to titrate a sample with 0.2230 g of salt dissolved in water. How many percent of NaCl did the analysed salt sample contain?
   Answer: 87.88% of NaCl.
3. What was the molar concentration of $AgNO_3$ solution if 38.25 $cm^3$ of $AgNO_3$ solution were used for 250.5 mg of salt sample containing 89.5% KCl?
   Answer: 0.07857 M of $AgNO_3$.
4. How many $cm^3$ of 0.1515 M $AgNO_3$ solution will be used for titration of chlorides in a solution containing a weight of 0.5340 g of dissolved $SrCl_2$
   Answer: 44.46 $cm^3$ of 0.1515 M $AgNO_3$ solution.
5. 1.17g of impure sodium chloride NaCl was dissolved in water and titrated with 0.5M $AgNO_3$ silver nitrate solution. After adding 36 $cm^3$ of $AgNO_3$ solution, the precipitation ceased. Calculate the percentage of NaCl in the contaminated salt.
   Answer: 90% of NaCl.
6. The content of sodium chloride NaCl in water is 8.7 $g/dm^3$. Calculate the percentage concentration of this solution and the concentration of $Cl^-$ chloride ions in $mg/dm^3$. The density of the solution is d = 1.1 $g/cm^3$.
   Answer: the percentage concentration of the solution is 0.79%, and the content of $Cl^-$ ions is 5.28 $g/dm^3$.

### Questions

1. Report the principle of determination of chloride ions in water by Mohr's method. Write the appropriate equations of chemical reactions in molecular and ionic form.
2. What is the process of desalination and demineralization of water?
3. How is the distillate (condensate) obtained on sea vessels?
4. What is the purpose and chemistry of determining the chloride ion content in boiler water?
5. What diagnostic inference can be made on the basis of systematic control of chloride ion content in ship water systems?
6. What is the selectivity of the precipitation: AgCl and $Ag_2CrO_4$ in the determination of chloride ions by the Mohr method?
7. What is the corrosive effect of $MgCl_2$ in boiler water? Justify your answer with appropriate chemical reactions.
8. How is the salt content in water measured with a salt meter?

# Auxiliary tables

Table 2

Physicochemical values of water for
VL 512/10-01 boilers recommended by the manufacturer

| Physicochemical quantities | Type of water | | | |
|---|---|---|---|---|
| | Condensate | Distillate | Feed water | Boiler water |
| Content of $Cl^-$ in ppm | ≤ | 12 + 24 | x | ≤ 1200 |
| General hardness in °dH | x | ≤ 0.084 | ≤ 0.84 | < 0.56 |
| Alkalinity p in ppm | x | x | x | 150 + 200 |
| Content of $PO_4^{3-}$ in ppm | x | x | x | 2 + 5 |
| Exponent of the concentration of oxonium ions, pH | x | x | 6.5 + 9.5[xx] | x |
| Oil content in ppm | x | 0 | < 3 | traces |
| Total salt content in ppm | x | x | x | ≤ 3000 |

[x] Not included in the standard.
[xx] At a temperature of about 20°C.

Table 3

Acceptable ranges of physicochemical values
for "Unitor" boilers operating at various pressures

| Steam pressure in the boiler | Alkalinity | | Ions | | | $N_2H_4 \cdot 10^{-1}$ | pH |
|---|---|---|---|---|---|---|---|
| | *p* | *m* | $Cl^-$ | $PO_4^{3-}$ | $SO_4^{2-}$ | | |
| MPa | ppm | ppm | ppm | ppm | ppm | ppm | |
| 0 – 1.75 | 100 – 150 | 2*p* | 200 | 20 – 50 | 20 – 50 | 1 – 2 | 8.3 – 9 |
| 1.75 – 3.1 | 100 – 150 | 2*p* | 200 | 20 – 50 | 20 – 50 | 1 – 2 | 8.3 – 9 |
| 3.1 – 4.2 | 100 – 150 | 2*p* | 200 | 20 – 50 | 20 – 50 | 1 – 2 | 8.3 – 9 |
| 4.2 – 6,0 | 100 – 120 | 2*p* | 50 | 15 – 30 | x | 1 – 1.5 | 8.3 – 9 |
| 6.0 – 8.0 | – | – | 30 | 10 – 25 | x | 0.5 – 1 | 8.3 – 9 |

[x] Not included in the standard.

Table 4

Water quality for water-tube boilers operating under pressure up to 4 MPa according to P. Orłowski "Steam boilers in industrial power engineering"

| Physicochemical quantities | | Pressure in MPa | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1.4 | | 2.4 | | 4.0 | |
| Feed water | | average | acceptable | average | acceptable. | average | acceptable |
| General hardness °dH | | 0.02 | 0.05 | 0.015 | 0.02 | 0.01 | 0.015 |
| Content of $O_2$ | ppm | 0.03 | 0.05 | 0.02 | 0.05 | 0.02 | 0.03 |
| Content of Fe | ppm | 0.30 | – | 0.10 | 0.2 | 0.05 | 0.10 |
| Content of Cu | ppm | – | – | – | – | – | 0.01 |
| pH value at approx. | 20°C | 8.50 | 9.50 | 8.5 | 9.5 | 8.5 | 9.5 |
| Oil content | ppm | | 3.00 | | 2 | | 1 |
| Content of $CO_2$ | ppm | – | – | – | 25 | – | 25 |
| Oxidizability of $KMnO_4$ | ppm | – | – | – | – | – | 20 |
| Content of $NO_2^-$ | ppm | – | – | – | – | – | 0.02 |
| Content of $SiO_2$ | ppm | – | the size is determined according to the manufacturer's instructions | | | | |
| Conductivity | $\mu Scm^{-1}$ | – | | | | | |
| Boiler water | | | | | | | |
| Alkalinity *p* | ppm | 5 – 15 | 2 – 20 | 2 – 8 | 2 – 10 | 1 – 5 | 2 –7 |
| Content of $SiO_2$ | ppm | – | 60 | – | 40 | – | 35 |
| Content of $P_2O_5$ | ppm | – | – | 10 | 20 | 5 – 10 | 10 –20 |
| Conductivity | $\mu Scm^{-1}$ | 7000 | 9000 | 4000 | 6000 | 2000 | 3000 |

Unitor boiler water analytical control report form

**UNITOR** chemicals
c/o Kjemi Service AS
P.O. Box 49
3140 Borgheim
NORWAY

# CO-ORDINATED BOILER WATERTREATMENT PROGRAMME

SHIPBOARD LOG PAD - UP TO 42 BAR SPECTRAPAK 311 ☐ 312 ☐

Ship ____________ Flag ________ Owner ________________

Boiler ____________ Type ________ Pressure _____ Bar, Capacity _____ Tons

Make up: Shore ☐ Distilled ☐ Mixed ☐

Year ________

| | | Month | J | F | M | A | M | J | J | A | S | O | N | D | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| Hardness control | PHOSPHATE ppm as $PO_4$ limits 20-50 | ⩾70 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 60 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 50 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 40 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Dosage grammes | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Alkalinity control | P. ALKALINITY ppm as $CaCO_3$ limits 100-150 | ⩾170 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 150 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 130 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 110 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 90 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | ⩽70 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Dosage ml | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M. Alk. | | over 2xP. Alk. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | below 2xP. Alk. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Boiler pH | | over 11.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 9.5-11.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | below 9.5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Oxygen control | HYDRAZINE ppm as $N_2H_4$ limits 0.10-0.20 | ⩾0.25 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 0.20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 0.15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 0.10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | ⩽0.05 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Dosage liter | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | SULPHITE ppm as $Na_2SO_3$ limits 20-50 | ⩾60 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 50 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 40 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 0-10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Dosage liter | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Boiler Chlorides | max 200 ppm as Cl | ⩾260 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 220-240 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 180-200 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 140-160 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 100-120 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 60- 80 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 0- 40 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Blow Down T/B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Condensate pH | limits 8.3-9.0 | ⩾9.2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 8.8-9.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 8.3-8.6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 8.2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | ⩽8.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Dosage liter | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Comments

WHITE - UNITOR CHEMICALS

EDP no 109256

Unitor cooling water analytical control report form

**UNITOR** chemicals
c/o Kjemi Service AS
P.O. Box 49
3140 Borgheim
NORWAY

COOLING WATERTREATMENT PROGRAMME
SHIPBOARD LOG PAD

SPECTRAPAK 309

Ship ______________ Flag ________ Owner ______________

**MAIN ENGINE MANUFACTURER** ______________ **TYPE** ______________

Make up: Shore ☐ Distilled ☐ Mixed ☐

PRODUCT Dieselguard NB ☐
Rocor NB Liquid ☐

Year __________ Month J F M A M J J A S O N D

NORMAL CHLORIDE LEVEL 50 PPM MAX

| JACKETS | CAP. _______ TONS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| DATE | | | | | | | | |
| NITRITE as ppm $NO_2$ ≥2700 | | | | | | | | |
| 2520 | | | | | | | | |
| 2340 | | | | | | | | |
| 2160 | | | | | | | | |
| 1980 | | | | | | | | |
| 1800 | | | | | | | | |
| 1620 | | | | | | | | |
| 1440 | | | | | | | | |
| 1260 | | | | | | | | |
| 1080 | | | | | | | | |
| 900 | | | | | | | | |
| ≤720 | | | | | | | | |
| CHLORIDE ppm Cl ≥100 | | | | | | | | |
| 80 | | | | | | | | |
| 60 | | | | | | | | |
| 40 | | | | | | | | |
| 20 | | | | | | | | |
| 0 | | | | | | | | |
| pH | | | | | | | | |
| Dieselguard NB kg | | | | | | | | |
| Rocor NB liquid ltr | | | | | | | | |
| Make up ltr | | | | | | | | |

| PISTONS | CAP. _______ TONS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| DATE | | | | | | | | |
| ≥2700 | | | | | | | | |
| 2520 | | | | | | | | |
| 2340 | | | | | | | | |
| 2160 | | | | | | | | |
| 1980 | | | | | | | | |
| 1800 | | | | | | | | |
| 1620 | | | | | | | | |
| 1440 | | | | | | | | |
| 1260 | | | | | | | | |
| 1080 | | | | | | | | |
| 900 | | | | | | | | |
| ≤720 | | | | | | | | |
| ≥100 | | | | | | | | |
| 80 | | | | | | | | |
| 60 | | | | | | | | |
| 40 | | | | | | | | |
| 20 | | | | | | | | |
| 0 | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

NORMAL NITRITE LEVEL 1200-2400 PPM

| FUEL VALVES | CAP. _______ TONS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| DATE | | | | | | | | |
| NITRITE as ppm $NO_2$ ≥2700 | | | | | | | | |
| 2520 | | | | | | | | |
| 2340 | | | | | | | | |
| 2160 | | | | | | | | |
| 1980 | | | | | | | | |
| 1800 | | | | | | | | |
| 1620 | | | | | | | | |
| 1440 | | | | | | | | |
| 1260 | | | | | | | | |
| 1080 | | | | | | | | |
| 900 | | | | | | | | |
| ≤720 | | | | | | | | |
| CHLORIDE ppm Cl ≥100 | | | | | | | | |
| 80 | | | | | | | | |
| 60 | | | | | | | | |
| 40 | | | | | | | | |
| 20 | | | | | | | | |
| 0 | | | | | | | | |
| pH | | | | | | | | |
| Dieselguard NB kg | | | | | | | | |
| Rocor NB liquid ltr | | | | | | | | |
| Make up ltr | | | | | | | | |

| AUX. GENERATORS COMBINED WITH MAIN ENG. ☐ | CAP. _______ TONS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| DATE | | | | | | | | |
| ≥2700 | | | | | | | | |
| 2520 | | | | | | | | |
| 2340 | | | | | | | | |
| 2160 | | | | | | | | |
| 1980 | | | | | | | | |
| 1800 | | | | | | | | |
| 1620 | | | | | | | | |
| 1440 | | | | | | | | |
| 1260 | | | | | | | | |
| 1080 | | | | | | | | |
| 900 | | | | | | | | |
| ≤720 | | | | | | | | |
| ≥100 | | | | | | | | |
| 80 | | | | | | | | |
| 60 | | | | | | | | |
| 40 | | | | | | | | |
| 20 | | | | | | | | |
| 0 | | | | | | | | |
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| | | | | | | | | |
| | | | | | | | | |

Comments

WHITE - UNITOR CHEMICALS

EDP no 109249