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## Solubility diagram at 15<sup>o</sup>C of the system Na<sup>+</sup>/Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>-H<sub>2</sub>O

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### ABSTRACT

The diagram of the ternary system Na<sup>+</sup>/Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup> - H<sub>2</sub>O was established at 15<sup>o</sup>C by means of analytical and conductimetric measurements. Three compounds were found in this diagram, which are NaCl, Na<sub>2</sub>SO<sub>4</sub> and Na<sub>2</sub>SO<sub>4</sub>.10H<sub>2</sub>O. The composition (mass %) of the invariant point determined by the two methods are: NaCl 6.00%; Na<sub>2</sub>SO<sub>4</sub> 23.40%.

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### KEYWORDS

Solubility diagram;  
Sodium sulfate hydrates;  
Oceanic salt system.

### INTRODUCTION

The sea water and brines are very complexed solutions. All systems representing these salts have to be evaluated. The major ions to be considered are Na<sup>+</sup>, K<sup>+</sup>, Mg<sup>2+</sup>, Cl<sup>-</sup> and SO<sub>4</sub><sup>2-</sup> in H<sub>2</sub>O, they form a reciprocal quinary system<sup>[1,2]</sup>.

The bibliographic data concerning this system are in large numbers and studies on a large type of temperature. Never less those studies are scarcely completed and hardly exploited. Concerning this system, more than 450 solubility data are given in literature and many isotherms were established from -21.4 to 150<sup>o</sup>C<sup>[3-19]</sup>, but the experimental points are often non-concordant. For this system four compounds are cited: ice, NaCl, Na<sub>2</sub>SO<sub>4</sub> and Na<sub>2</sub>SO<sub>4</sub>.10H<sub>2</sub>O. But most of experimental points are in total discrepancy and the coordinates of the invariant equilibrium have been determined.

In order to increase the number of data of solubility and modeling the quinary system, we proceeded in the establishment of the isotherm at 15<sup>o</sup>C of ternary system NaCl - Na<sub>2</sub>SO<sub>4</sub> - H<sub>2</sub>O

### EXPERIMENTAL

This isothermal section on Na<sup>+</sup>/Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup> - H<sub>2</sub>O at

15<sup>o</sup>C was established using several methods.

### Analytical methods

The mixtures<sup>[20]</sup> and the wet residues<sup>[21]</sup> methods were used. The mixture were stirred during two days at constant temperature at attain equilibrium and then allowed to settle. The liquid and solid were next separated and analyzed for Na<sup>+</sup>, Cl<sup>-</sup> and SO<sub>4</sub><sup>2-</sup>. The Na<sup>+</sup> content was determined by flame spectrophotometric method. A potentiometric method was used to determine the chloride ion concentration. The concentration of SO<sub>4</sub><sup>2-</sup> was measured by gravimetry.

### Synthesis method

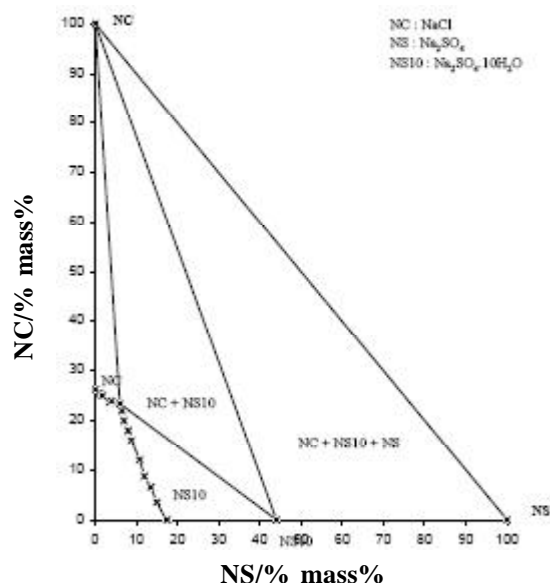
This method is used on the electric conductivity variation of an electrolyte solution with composition. Small amounts of H<sub>2</sub>O are progressively added to a saturated solution of a given formal composition, concerning an excess of solid. After each addition, the resistance is measured when equilibrium is reached (i.e. when there is no change with time in resistance). The curve of resistance versus added H<sub>2</sub>O volume is plotted. It presents a break at each phase change, the last one corresponding to the dissolution of the last crystal of salt. An invariant equilibrium is characterized by a plateau in the curve. The temperature was controlled by means of a thermostat jacket maintained at 15 ± 0.2<sup>o</sup>C by

**TABLE 1: Ternary system Na<sup>+</sup>/Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup> - H<sub>2</sub>O at 15°C (Analytical method)**

Density/ gcm <sup>-3</sup>	Saturated solution composition/ mass-%			Solid phases
	Na <sub>2</sub> SO <sub>4</sub>	NaCl	H <sub>2</sub> O	
1.1849	0.00	26.25	73.75	NC
1.1895	1.50	25.20	73.30	„
1.2056	3.50	23.70	72.80	„
1.2135	6.00	23.40	70.60	NC+NS10
1.2041	6.50	22.00	71.50	NS10
1.2147	7.00	20.00	73.00	„
1.2163	8.00	18.00	74.00	„
1.2138	10.80	12.00	77.2	„
1.2159	12.08	8.00	79.20	„
1.1584	15.00	4.00	81.00	„
1.0978	17,50	0.00	82.50	„

**TABLE 2: Ternary system Na<sup>+</sup>/Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup> - H<sub>2</sub>O at 15°C (Synthetic method)**

Density/gcm <sup>-3</sup>	Saturated solution composition / mass-%			Solid phases
	Na <sub>2</sub> SO <sub>4</sub>	NaCl	H <sub>2</sub> O	
1.1848	0.00	26.00	74.00	NC
1.1895	1.00	25.50	73.50	„
1.2056	1.80	25.00	73.20	„
1.2163	4.00	24.00	72.00	„
1.2138	8.80	16.00	75.20	NS10
1.2159	12.00	8.70	79.30	„
1.2065	13.50	6.50	80.00	„
1.1584	15.00	3.50	81.50	„
1.0978	17.20	0.00	82.80	„

**Figure 1: Ternary system Na<sup>+</sup>/Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup> - H<sub>2</sub>O at 15°C**

circulation of H<sub>2</sub>O. In order to identify the solid phase, X-ray diffraction was used.

## RESULTS AND DISCUSSIONS

The solubility data obtained by analytical and synthetic methods are gathered in table 1 and 2 and presented in figure 1. They are expressed in mass %.

Two solid phases, NaCl: (NC) and Na<sub>2</sub>SO<sub>4</sub>.10H<sub>2</sub>O: (NS10) were observed at 15°C (Figure 1).

The compositions of the isothermal invariant points of the isotherm at 15°C determined by the tow methods is NaCl 6.00%; Na<sub>2</sub>SO<sub>4</sub> 23.40%.

### Superscripts

NC – NaCl; NS - Na<sub>2</sub>SO<sub>4</sub>; NS10- Na<sub>2</sub>SO<sub>4</sub>.10H<sub>2</sub>O

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