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New Method for Desalination of Seawater

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Abstract: The present study explores the possibility of appealing to the laws of inorganic chemistry, i.e., the rules of precipitation to desalinate seawater. Historically, the industry has been using these techniques for the preparation of some compounds. Based on these rules, using suitable salts will react with each other. The results are evident all unwanted salts including sodium chloride are removed. In fact, it is a selective precipitation as other salts which are not harmful are kept such as potassium. The other aim of the study is to reduce the current ratio desalination/power which is very high 60,000 to 80,000 cal/L for distillation (A. Payant. P. Chiliotti L. Sainte-Marie Physic Arm and Colin, Paris, France) or 4.5 kWh/m^3 for RO (desalination and water reuse, California, USA) a cause of greenhouse gas except desalination using solar energy. Another aspect of this study, authors noticed rather than consume energy, regeneration or recycling of products provides energy. And in addition, the operation does not cause any pollution.

Key words: Water, energy, potassium.

1. Introduction

The needs for water to stimulate more efficient and less polluting agricultural production at the same time, and the need for energy in recent decades have continued to rise, to cope with a difficulty to control world population growth. And all the experts or demographers expect that the situation will remain until around the years 2030-2040. To this already problematic situation have added other situations too complicated, authors want to mention the climate issues, desertification caused by drought is one of the most obvious evidences. Concerning about the situation that threatens everyone, researchers around the world have developed ingenious solutions to draw water from the sea, including evaporation pressure, reverse osmosis, ion exchange resins, and the latest, desalination using solar energy. In addition to these useful solutions but sophisticated, the authors propose a new technique that believe easier and more accessible, able to provide energy in addition to water.

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2. Experiments

2.1 Materials

Seawater = H_2O + salts as mentioned below, and high pH,

$$Na^+ \text{ ions } (30.59\%) + Mg^{2+} \text{ ions } (3.73\%)$$
$$+ Ca^{2+} \text{ ions } (1.20\%) + K^+ \text{ ions } (1.11\%)$$
$$+ Cl^- \text{ ions } (55.29\%) + SO_4^{2-} \text{ ions } (7.69\%)$$

Bromide, carbonate, fluoride and iodide was in very small proportion [1], $CuSO_4$, $FeSO_4$, HF, BaS or $Ba(OH)_2$, H_2SO_4 and $Al_2(SO_4)_3$ as needed.

2.2 Stabilization of the Solution

Materials used such as Cu^{2+}, Fe^{2+} need stability, the pH of the marine environment is high between 7.5 and 9, it must be reduced to 6.5 or 7 to prevent their precipitation as hydroxides $Fe(OH)_2$ and $Cu(OH)_2$. This will be done with a little H_2SO_4 that can be eliminated later.

2.3 Start-Up and Operation

The second approach is the first addition of iron sulfate and copper sulfate then. Due to the inevitable formation of an insoluble copper(I) salt, iron and copper(Ⅱ) ions in the presence of Cl^- and other halogens are vice versa oxidizing and reducing, including that the ions I^- may reduce themselves the ions Cu^{2+} and the presence of the ions F^- promotes even more the reaction [2]. The reactions that will attend are as follow:

The Fe^{2+} ferrous sulfate can yield an electron e^- to become ferric sulfate.

$Fe_2(SO_4)_3$ and cupric ions Cu^{2+} copper sulfate can capture an electron e^- to become copper ions Cu^+ which are insoluble in aqueous solution; the reaction can be written:

$$Fe^{2+} + Cu^{2+} \rightarrow Fe^{3+} + Cu^+ \quad (1)$$

3. Results and Discussion

3.1 Characteristic

As a result of the transformation of Cu^{2+} ions in Cu^+, Cl^- ions from the seawater that served as catalysts for redox reaction between iron and copper are removed.

$$Cu^+ + Cl^- \rightarrow CuCl\downarrow \quad (2)$$

Solubility $10^{-6,7}$ or about 60 ppm (Charlot) and also

$$Cu^+ + I^- \rightarrow CuI\downarrow \quad (3)$$

$$Cu^+ + Br^- \rightarrow CuBr\downarrow \quad (4)$$

It is important to conduct filtration to isolate the copper compounds for the recovery of copper sulfate ($CuSO_4$) in the recycling of elements; overall authors can write:

$$2FeSO_4 + 2CuSO_4 + 2NaCl \rightarrow Fe_2(SO_4)_3 + Na_2SO_4 + 2CuCl\downarrow \quad (5)$$

3.2 Subsequent Action

After these initial operations, it will add HF and consequently it will form the complex FeF_6^{3-} which will join the Na^+ ions to form the insoluble complex salt Na_3FeF_6 according to the reaction [2, 5]:

$$FeF_6^{3-} + 3Na^+ \rightarrow Na_3FeF_6\downarrow \quad (6)$$

In theory, it is possible that it is formed, at the same time, a compound of iron and potassium fluoride, K_3FeF_6 insoluble [2], but it is immediately dissolved by the excess of iron added compared to the low amount of potassium found in the sea, and subsequently, all the iron is swept away by the large quantity of sodium. However, it is important that the amount of Fe^{2+} became Fe^{3+} to be used is calculated so as not to leave a large excess that could dissolve the fluo-ferrate insoluble sodium itself. At the same time, Ca^{2+} and Mg^{2+} ions precipitate:

$$Ca^{2+} + 2F^- \rightarrow CaF_2\downarrow \quad (7)$$

$$Mg^{2+} + 2F^- \rightarrow MgF_2\downarrow \quad (8)$$

If after total precipitation is determined that the level of Na^+ is too high, precipitation can continue to traces, using aluminum sulfate, the complex formed ions F^- and Al^{3+} will reduce the Na^+ ions remaining at lowest level after the formation of cry-o-lite: 10^{-27} [2].

$$AlF_6^{3-} + 3Na^+ \rightarrow Na_3AlF_6\downarrow \quad (9)$$

Because much Na^+ would be harmful for ground and plants [3, 6].

3.3 Purification and Recovery of Waste Ions

And after removal of Cu^+ and Fe^{3+}, it will consider exempting the environment ions waste, question to always keep intact the amount of copper and iron originally used. Magnesium itself found in the sea is the material of choice, its introduction in the environment as sticks gives the following results:

$$2Cu^+ + Mg \rightarrow Mg^{2+} + 2Cu\downarrow \quad (10)$$

$$2Fe^{3+} + 3Mg \rightarrow 3Mg^{2+} + 2Fe\downarrow \quad (11)$$

$$2Ag^+ + Mg \rightarrow Mg^{2+} + 2Ag\downarrow \quad (12)$$

For practical reasons, this should be the last before the water reaches the plants and soil. And moreover, this treatment allows us to gain minor, but in the long run substantial, since geologists and chemists estimate that there are a lot of silver dissolved in the oceans [4] up to 50 million tons, and also gold, vanadium important in the manufacture of sulfuric acid and others. So at every billion gallons of desalted water, it will be a mini extra benefit. But the gain will be the most spectacular with potassium as we shall see later. However, it is important that this operation goes last after neutralization of the sulfuric acid contained in the desalinated water, as mentioned below (in Subsections 3.4 and 3.5).

3.4 Consequences

After the precipitation of Na^+ and Fe^{3+} ions, SO_4^{2-} who accompanied became single according to the reaction:

$$Fe_2(SO_4)_3 + 3Na_2SO_4 + 12HF \rightarrow 2Na_3FeF_6\downarrow + 6H_2SO_4 \quad (13)$$

As a consequence, becomes more acidic environment. It will involve the barium sulphide or barium hydroxide to eliminate which gives the following reactions:

$$BaS + H_2SO_4 \rightarrow BaSO_4\downarrow + H_2S\uparrow \quad (14)$$

This gas can be recovered completely by bubbling nitrogen or other means, it will be used during recycling to generate sulfuric acid necessary for the manufacture of iron and copper sulfates. Using barium sulphide, there should be the precipitation of a small amount of iron sulfide (Fe_2S_3) due to the presence of ferric ions residual Fe^{3+} as noted on the left in Fig. 1, otherwise neutralization can be done with barium hydroxide $Ba(OH)_2$.

3.5 Benefits of Hydrolysis

This approach is interesting because it allows better control of gas H_2S and is more profitable in terms of energy, because after reduction of sulfate $BaSO_4$. As authors will see later, hydrolysis of BaS, neutralization of acidulated water will give considerable amount of energy, according to the following reactions:

$$BaS + 2H_2O \rightarrow H_2S\uparrow + Ba(OH)_2 \quad (15)$$

$$H_2SO_4 + Ba(OH)_2 \rightarrow BaSO_4\downarrow + 2H_2O \quad (16)$$

Release: 345,300 cal/mol [4]. However, the recovery of this energy requires a special device which will be placed downstream of the drain tanks acidulated water. In this device, it will be placed barium hydroxide, as mentioned above Subsection 3.5, the passage of sulfuric acid causes the release of considerable heat which can be captured by a pipe made of aluminum or copper (heat exchanger) and converted into electricity.

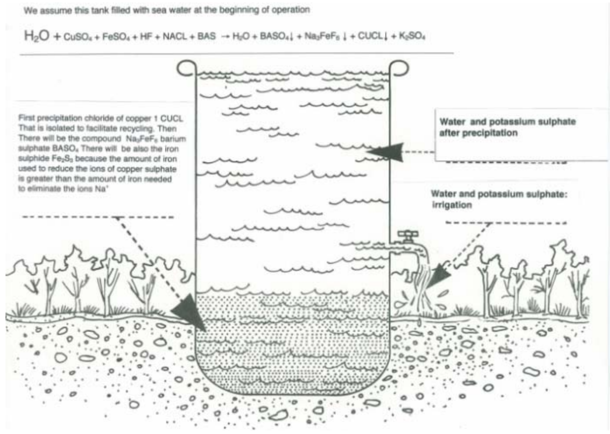

Fig. 1 An overview of the operation of desalting.

3.6 Analysis of Final Results

With these rules formulated by Berthollet, authors could eliminate all the undesirable salts that were in seawater. It is interesting to know the nature of bodies remaining. Arguably, there are K^+ (0.38 g) and SO_4^{2-} ions to a mass of 0.90 g of potassium sulfate, when the salt concentration is 35 g/L. And the question to ask: what would be best to use this water became available or drinking?

Author thinks the first use would be agriculture because obviously vital potassium for plants and increasingly expensive. With a ratio of 5 L of irrigation per m^2 to 15 days, for an area of one hectare (10,000 m^2), the amount of potassium to the soil is largely sufficient to meet the needs of any culture be 125 kg/ha K^+ [3]. Will authors need nitrogen fertilizer? Author would say no, because the marine environment is full of bacteria, plankton and other living bodies [8]. On the ground once their bodies are decomposed by bacteria (nitrobacteria and others) making the nitrogenous substances necessary to plants, if insufficient special plants such as carrot and others including rhizobium can be upstream of all cultures. Will authors need phosphorus fertilizer? Author still says no, because all these marine particles containing phosphorus. Authors can say that farming covered by the environmentalists is almost reached. And the economic aspect in this regard should not be overlooked. For example, any public or private company that desalted seawater in every km^3 will squeeze into the sea about 900,000 t of potassium sulfate; at the present price near 1,000 dollars a ton that it will be able to claim to farmers, it will be able to finance its infrastructure.

3.7 Tracking Desalinated Water

In practice after irrigation half water used is not absorbed by plants but goes into the depths where it will enrich the groundwater, where it can be pumped to other uses (Fig. 1).

3.8 Detailed Study of the Energy That Can Provide the Desalination

The calculation authors has done have shown that desalination of a liter of seawater concentration of 35 g/L requires 87 g of cooper sulfate, iron sulfate 82 g 16. 18 g 53 of hydrofluoric acid—a little more because of the precipitation of calcium and magnesium; this amount should also reflect the concentration of the acid, and barium sulfide 183 g 87.

Precisely from these calculations authors notice it takes 0.5 mol of copper sulfate and 0.5 mol of iron sulfate. To prepare these sulfates, it requires 1 mol of sulfuric acid at least. It must also provide 1 mol for the decomposition of the composed of iron and sodium Na_3FeF_6 at the time of recycling. As the preparation of this acid from sulfide gas H_2S gives off more than 160,000 cal/mol. For a specialized industry that can desalinate 2 or 3 billion L per day: 3 billion × 3,200,000 cal = 9.6 × 10^{14} cal. The potential is enormous, and more at the time of the reconstitution of the sulfate from the chloride of copper (CuCl), the operation suggests an important release of hydrogen in accordance with the reaction:

$$H_2SO_4 + CuCl \rightarrow CuSO_4 + HCL + ½H_2\uparrow \quad (17)$$

The gas can be converted into electricity or operate the vehicles. But this reaction must be conducted with prudence in an environment without oxygen to avoid the risk of explosion.

3.9 Analysis of Energy Expenditure

In fact, the only reactions that require energy are the decay of the compound sodium fluoride iron (Na_3FeF_6) by sulfuric acid and the reduction of sulfates by carbon; all these operations are at a temperature of 250 °C minimum.

$$6H_2SO_4 + 2\ Na_3FeF_6 \rightarrow 3Na_2SO_4 + Fe_2(SO_4)_3 + 12HF\uparrow \quad (18)$$

HF is ready for another cycle, energy required for this reaction 22,834 cal for an amount of 10 g of Na^+ in a liter of seawater concentration 35 g.

$$BaSO_4 + 2C \rightarrow 2CO_2\uparrow + BaS \quad (19)$$

BaS is ready for another cycle. Energy required for this reaction is approximately 80,000 cal/mol.

$$Na_2SO_4 + 2C \rightarrow 2CO_2\uparrow + Na_2S$$

Energy required for this reduction is 10,490 cal for 10.70 g Na^+ or 45,000 cal/mol (new treatise on inorganic chemistry Masson, Paris, France). This salt will be attacked by hydrochloric acid to replenish the sodium chloride, wherein salt will be returned to sea on barges to be dispersed far from the coast to not disrupt the marine ecosystem.

$$2HCl + Na_2S \rightarrow H_2S\uparrow + 2NaCl \quad (20)$$

or

$$HCl + NaOH \rightarrow NaCl + H_2O \quad (21)$$

Release 98,360 cal/mol if hydrolysis sulfide. But all the energy required for the reduction reactions may be offset by the additional growing of certain plants known for their rapid growth. In addition to heating energy, they provide the carbon necessary for sulfate reduction, including eucalyptus, bamboo which can grow particularly one meter in 24 h (Larousse encyclopedia), in addition to producing edible buds and other waste from food crops that can be converted into alcohol or biogas such as gas methane. Authors must also add the energy provided by the reconstitution required other salts: cooper sulfate 178,700 cal/mol, ferrous sulfate 217,230 cal/mol, sodium chloride 98,360 cal/mol, more energy barium sulfate recovered in drains desalinated acidulated water tanks 345,300 cal/mol [8] see Subsection 3.5.

4. Conclusions

Unpretentious, authors believe to have demonstrated that seawater can be desalinated in the best conditions, without impact on the environment which becomes more fragile. In addition to water and potassium, for a more productive and sustainable agriculture, the new method provides energy. With respect authors implore the editorial board to welcome the study so that interested parties can benefit, because if the work is not supported by a major association or editor, it will be lost.

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References

[1] Timm, J. A. *General Chemistry Simmons College Mc Graw-Hill* **1968.**

[2] Charlot, G. *Chemical Reactions in Solution Masson & Cie France* **1969,** 57-295.

[3] Binet, P.; Brunel, J. P. *Plant Physiology;* Paris, 1967; pp 389-395.

[4] Masson, New Treatise on Inorganic Chemistry; In *Pascal Paul Member of the Academy of Sciences of France;* 1985.

[5] Trémillon, B. *Analytical Chemistry;* Armand Colin: France, 1965.

[6] Duchaufour, P. *Handbook of Soil Science Masson & Cie;* France, 1970; pp 364-368.

[7] Chadefaud, H. M.; Ferré, Y.; Feldmann, J.; Gaussen, H.; Grassé, P. P.; Ozenda, P.; et al. *Botany Masson & Cie France* **1963.**

[8] Weisz Paul B: Elements of Biology Mc Graw-Hill, 1966.