



## THE NATURE OF SALT

**Unit:** *Salinity Patterns & the Water Cycle* | **Grade Level:** *High school* | **Time Required:** *One 45 min. period* | **Content Standard:** *NSES Physical Science Structure & properties of matter: Bonds are created when electrons are transferred or shared among elements. Atoms or ions may bind together to form molecules or crystalline solids (e.g., salts).* | **Ocean Literacy Principle 1e:** *Most of Earth's water (97%) is in the ocean. Seawater has unique properties: it is saline, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic.*

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### Big Idea

Sodium chloride or common salt is the chemical compound NaCl, composed of the elements sodium and chloride. Salt occurs naturally in many parts of the world as the mineral halite. Seawater has lots of salt; it contains an average of 2.6% (by weight) NaCl, or 78 million metric tons per cubic kilometer.

### Key Concepts

- Molecular compounds are made of individual molecules that are bound together by shared electrons (i.e., covalent bonds).
- Ionic compounds consist of two or more ions that are held together by electrical attraction. One of the ions has a positive charge (called a "cation") and the other has a negative charge ("anion").
- Salt is an ionic compound, consisting of a crystal, lattice structure of the two ions *Na<sup>+</sup> and Cl<sup>-</sup>*.

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### Essential Questions

- Where does salt come from?
- Why is the ocean salty?
- What is salt used for?
- Why does salt dissolve in water and not gasoline?

### Knowledge and Skills

- Explain the general relationship between an element's Periodic Table Group Number and its tendency to gain or lose electron(s).
- Explain the difference between molecular compounds and ionic compounds.
- Use a model, to demonstrate sodium chloride's cubic form which results from its microscopic crystal lattice.
- Describe the nature of the electrostatic attraction of the oppositely charged ions that holds the structure of salt together.

### Prior Knowledge

- Atoms may stick together in well-defined molecules, or may be packed together in large arrays. Different arrangements of atoms into groups compose all substances.
- When substances interact to form new substances, the elements composing them combine in new ways. In such recombinations, the properties of the new combinations may be very different from those of the old.
- Atoms are made of a positive nucleus surrounded by negative electrons.

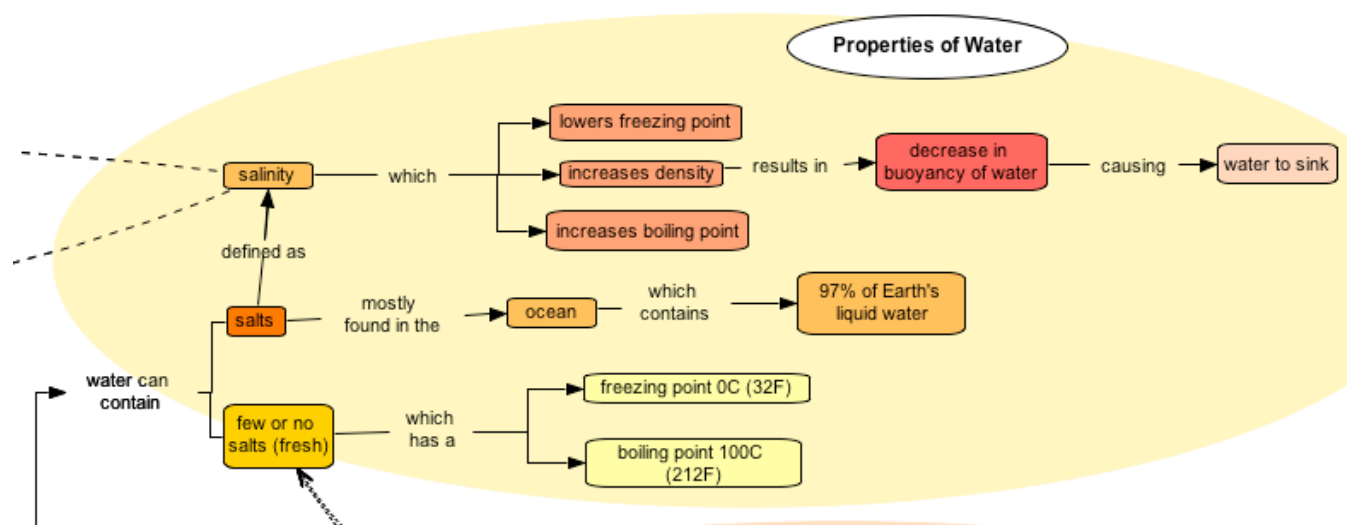
### Common Preconceptions

- **"Salt water is full of sodium chloride molecules."** Salt is not made of NaCl molecules. Salt is made of a three-dimensional checkerboard of oppositely charged atoms of sodium and chlorine. A salt crystal is like a single gigantic molecule of ClNaClNaClNaClNaClNaClNa. When salt dissolves, it turns into independent atoms. Salt water is not full of "sodium chloride." Instead it is full of sodium and chlorine! The atoms are not poisonous and reactive like sodium metal and chlorine gas because they are electrically charged atoms called "ions." The sodium atoms are missing their outer electron. Because of this, the remaining electrons behave as a filled electron shell, so they cannot easily react and form chemical bonds with other atoms except by electrical attraction. The chlorine has one extra electron and its outer electron shell is complete, so like sodium it too cannot bond with other atoms.

These oppositely charged atoms can attract each other and form a salt crystal, but when that crystal dissolves in water, the electrified atoms are pulled away from each other as the water molecules surround them, and they float through the water separately.

### Concept Map

Primarily for the teacher's use, the map provided here relates to the branch "Properties of Water" from the comprehensive Aquarius Concept Map - Water & its patterns on Earth's surface.



### Background

Chemically, table salt consists of two elements, sodium (Na) and chloride (Cl). Neither element occurs separately and free in nature, but are found bound together as the compound sodium chloride. It occurs naturally in many parts of the world as the mineral halite and as mixed evaporites in salt lakes. Seawater contains an average of 2.6% (by weight) sodium chloride, or 78 million metric tons per cubic kilometer, an inexhaustible supply. Table salt, when viewed with a magnifying glass, can be seen to consist of tiny, cube-shaped flakes. The microscope image at right shows table salt crystals magnified by 100. - From The Salt Institute <http://www.saltinstitute.org/15.html>

Did you ever wonder why the oceans are filled with salt water instead of fresh? Just where did the salt come from? And is it the same salt you find on a dining room table? Most of the salt in the oceans came from land. Over millions of years, rain, rivers, and streams have washed over rocks containing the compound sodium chloride (NaCl), and carried it into the sea. Some of the salt in the oceans comes from undersea volcanoes and hydrothermal vents. When water **evaporates** from the surface of the ocean, the salt is left behind. - From the Office of Naval Research <http://www.onr.navy.mil/Focus/ocean/water/salinity1.htm>

**Materials:** Periodic Table; Chemistry reference book or web access (optional); Spheres of styrofoam (some spheres should be about twice the size of others), clay, etc.; Toothpicks, straws, etc.

**Preparation:** This is a good precursor to the "Electrolysis of Salt Water" activity.

- Have the students read the "Background" section (above) and then find sodium and chlorine on a Periodic Table. Ask them to record the following information on their Student Worksheet (provided at bottom): Atomic Weight, Atomic Number, and Periodic Table Group Number. If appropriate resources are available (e.g., reference books, web access), also ask the students to research the "State" (i.e., solid, liquid, or gas) and "Color" of these elements at room temperature.
- If students are not already familiar with the general relationship between an element's Periodic Table Group Number and its tendency to gain or lose electron(s), have them research this topic. The relevant Groups for the elements (i.e., Na and Cl) under consideration in this activity:

- **Group 1 (or I) Elements** – Have one electron in their outer shell. Each element in this group has a tendency to lose a single electron to form a singly charged positive ion. Elements in this group include Lithium, **Sodium**, Potassium, Rubidium, Caesium, and Francium. These are known as "Alkali Metals" and are so reactive with water they must be stored under oil.
- **Group 17 (or VIIA) Elements** – Have seven electrons in their outer shell. Each element in this group has a tendency to gain a single electron to form a singly charged negative ion. Elements in this group include Fluorine, **Chlorine**, Bromine, and Iodine. These are known as "Halogens" or "salt formers." They form ionic compounds with metals such as sodium.
- This information should help students classify whether Na and Cl are cations (i.e., positively charged) or anions (i.e., negatively charged) on the Student Worksheet. Likewise, the students should also be able to supply the chemical formula for sodium chloride on the Worksheet (NaCl).
- In chemistry, a compound is a pure substance that consists of atoms or ions of two or more different elements that cannot be readily separated by physical means.
  - **Molecular compounds** are made of individual molecules – not ions. Atoms in the compound are bound together by shared electrons (i.e., covalent bonds). Water (H<sub>2</sub>O) and carbon dioxide (CO<sub>2</sub>) are examples.
  - **Ionic compounds** are made of ions – not molecules. Cations and anions are held together by electrostatic forces (i.e., ionic bonds). Potassium bromide (KBr) and magnesium chloride (MgCl<sub>2</sub>) are examples.
- Ask the students: "Are salts molecular compounds or ionic compounds?" (*Ionic compounds.*)
- In ionic compounds, the strong electrostatic force of attraction reaches out in all directions. Thus each ion is surrounded by other ions of opposite charge. The term "crystal lattice" is often used to describe the structure of the cations and anions in ionic compounds. Look at the microscope image (above) of table salt. What type of structure would you expect it to have at the atomic level? (Cubic lattice.)
- On the Student Worksheet, Atomic Radius data have been provided for Na and Cl. These measurements are in nanometers (nm), one billionth of one meter (i.e., 10,000 times smaller than the width of a human hair). These data can be used to answer the question posed in the Student Worksheet: "What is the size ratio between sodium and chlorine ions?" (*0.186 : 0.099 or about 2 : 1*)
- Given all the information they've acquired, challenge the students to construct a model of a typical sodium chloride compound. They may choose to use toothpicks, straws, styrofoam balls, clay spheres, etc. The most accurate models will have Na<sup>+</sup> ions about twice the size of the Cl<sup>-</sup> ions.
- Students can check their results by viewing the Naval Research Laboratory's 3-D interactive salt crystal lattice structure, found online at <http://cst-www.nrl.navy.mil/lattice/struc/b1.html> (click on "visualize the structure").

### Assessment / Questions

- Using data from the Student Worksheet, answer the following questions:
  - What is the molecular weight of sodium chloride? (58.4428)
  - What is the relative weight percentage of Na in sodium chloride? (39.34%)
  - What is the relative weight percentage of Cl in sodium chloride? (60.66%)
- Table salt is usually clear or white at room temperature. How does this compare to the state / color of Na and Cl at room temperature? Investigate salts' constituent elements to understand how the properties of Alkali Metals and Halogens change with increasing Atomic Number (i.e., from top to bottom of their column in the Periodic Table). What combinations of Alkali Metals and Halogens are found in nature? What are these salts used for?

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### Vocabulary

- **atom:** A chemical unit, composed of protons, neutrons, and electrons, that cannot further break down by chemical means.
- **compound:** A pure substance composed of more than one element.
- **covalent bond:** A chemical bond that involves sharing of electron pairs.
- **electron:** A negatively charged subatomic particle with a mass of 0.0055 atomic mass units (AMU). By definition, one AMU is one-twelfth the mass of a carbon-12 atom.

- **ion:** A charged particle.
  - **ionic bond:** An electrostatic interaction between a cation (+ charged ion) and an anion (- charged ion).
  - **molecule:** A pure substance which results when two or more atoms of a single element share electrons, for example O<sub>2</sub>. It can also more loosely refer to a compound, which is a combination of two or more atoms of two or more different elements, for example H<sub>2</sub>O.
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**Original source:** *Adapted with permission from the Salt Institute's activity "Salt: The Essence of Life"* (<http://www.saltinstitute.org>); Glossary definitions from "EverythingBio.com"

**Aquarius Education & Public Outreach URL:** <http://aquarius.nasa.gov/>

<b>STUDENT WORKSHEET</b>		
<b>PROPERTY</b>	<b>SODIUM (Na)</b>	<b>CHLORINE (Cl)</b>
Atomic Weight		
Atomic Number		
Periodic Table Group Number		
State / color at room temperature (optional)		
Cation (+) or Anion (-)		
Atomic radius (nm or $10^{-9}$ m)	0.186	0.099
What is the chemical formula for sodium chloride?		
What is the size ratio between sodium and chlorine ions? (Approx.)		

<b>STUDENT WORKSHEET - ANSWER KEY</b>		
<b>PROPERTY</b>	<b>SODIUM (Na)</b>	<b>CHLORINE (Cl)</b>
Atomic Weight	22.98977	35.4527
Atomic Number	11	17
Periodic Table Group Number (any acceptable)	1 or IA or 1A	17 or VIIA or 7A
State / Color at room temperature (optional)	Solid / silvery grey	Gas / green
Cation (+) or Anion (-)	Cation (+)	Anion (-)
Atomic radius (nm or $10^{-9}$ m)	0.186	0.099
What is the chemical formula for sodium chloride?		NaCl
What is the size ratio between sodium and chlorine ions? (Approx.)		0.186 : 0.099 or about 2 : 1