The University of Texas at Austin
Department of Chemistry
College of Natural Sciences

Sodium & Chlorine: Making Table Salt

Performer's Version

Safety Hazards

- Personal Protective Equipment:
  - Safety glasses/goggles
  - Nitrile gloves
  - Work glove(s)
  - Chemical & flame retardant lab coat
- Physical Hazards
  - In contact with water, sodium releases flammable gasses which may ignite spontaneously.
  - Trichlor may intensify fire; oxidizer.
  - Hexanes is a highly flammable liquid and vapor.
  - Chlorine gas may cause or intensify fire; oxidizer.
- Chemical Hazards
  - Sodium metal causes severe skin burns and eye damage.
  - Trichlor is harmful if swallowed and causes serious eye irritation; may cause respiratory irritation; very toxic to aquatic life with long lasting effects.
  - Hexanes may be fatal if swallowed or if it enters airways; cause skin irritation and may cause drowsiness or dizziness; suspected of damaging fertility or the unborn child and may cause damage to organs (Nervous system) through prolonged or repeated exposure if inhaled. Toxic to aquatic life with long lasting effects.
  - Chlorine gas causes skin irritation and serious eye irritation; fatal if inhaled; may cause respiratory irritation; very toxic to aquatic life with long lasting effects.

Materials

- 1" HTH Chlorine Tablet (approx. 15.4 g, 92.4% trichloroisocyanuric acid/trichlor)
- 7 – 10 mL concentrated hydrochloric acid (12M)
- Sodium metal, ~ 0.8 g
- 10 mL hexanes
- Disposable pipette
- Blowtorch
- 2L Erlenmeyer flask
- Ring stand & three-pronged clamp
- Mortar and pestle
- Specialty glassware piece (quartz sodium basket and suspension piece)

Safety Data Sheet(s)

- Trichloroisocyanuric acid (trichlor)
- Sodium metal
- Chlorine gas
- Cyanuric acid
- Hexanes
- Propane

Extra Safety Notes

- Sodium metal is highly corrosive and water reactive. When it touches water, it releases highly flammable gas. Handle with extreme caution and wear full PPE.
- Sodium metal is preserved in mineral oil, which must be cleaned off using hexanes. If the sample of sodium metal looks wet at all, do not use it! This may indicate either oil residue or remaining hexanes. Hexanes are extremely flammable, and can cause the sodium to ignite and burn more aggressively.
- Trichloroisocyanuric acid is an oxidizing solid. Use with extreme caution and wear full PPE.
- Chlorine gas is a highly poisonous gas. Before conducting the experiment, ensure that your fume hood flow is sufficient and that the flask is no closer to the sash/experimenter than the midline of the fume hood's depth. Keep the sash as low as possible at all times.
- The reaction of sodium and chlorine is highly exothermic. There is a risk of fire and/or breaking glass. Wear full PPE and step away from the fume hood while the reaction is progressing.
- If the basket of ignited sodium hits the bottom of the flask (instead of remaining suspended), it may pop/combust more aggressively. Try to keep the basket suspended to encourage a more steady reaction.

Procedure

This demonstration MUST be done inside of a functioning fume hood. The generation of chlorine gas poses a serious hazard due to the toxic nature of chlorine. A member of the Demonstrations Team must be present for this demonstration.

1. Check to make sure the fume hood flow is adequate and that the sash is lowered as far as it can go without obstructing your movement.
2. Pour the hydrochloric acid aliquot into the 2L flask and quickly lower the sash entirely. You will immediately notice a greenish-yellow gas being liberated. This is chlorine gas and is extremely hazardous! Allow a few moments for all of the hydrochloric acid to react with the trichlor powder and for the generation of gas to slow down.
    a. *Note: Chlorine gas is denser than air, so it should sit inside of the flask. Do not tilt or agitate the flask, as it may result in the release of chlorine gas from the flask.*
3. Prepare to heat the sodium metal. Secure the specialty glassware piece in the three-pronged clamp on a ring stand so that the quartz basket is suspended from the benchtop of the fume hood. Place the sodium metal inside of the quartz basket, and begin slowly heating the sodium using a blowtorch. The sodium should melt and ignite.
    a. This should be off to the side of the flask, and not immediately next to it.
    b. Go slow! Make sure to keep the flame moving, but provide constant heating to the metal. The goal is to have the sodium ignited enough that, when lowered into an atmosphere of chlorine, it stays hot enough. If it is not hot enough, the flame will go out and the reaction will not progress.
4. Once the sodium has ignited, using a hand protected by a work glove, carefully pick up the glass piece from the top (as far from the sodium basket as possible) and gently lower it into the flask. Step back, lower the fume hood sash, and allow the reaction to proceed.

Pedagogy & Supplemental Information

The reaction between sodium metal and chlorine gas to form sodium chloride is a classic example of a highly exothermic chemical reaction, characterized by the formation of an ionic bond. Sodium is a highly reactive alkali metal with one electron in its outermost shell, which it readily loses to achieve a stable noble gas electron configuration. In its pure form, sodium is a soft, silvery-white metal that reacts vigorously, even explosively, with water. Chlorine is a diatomic molecule, a pale yellow-green gas with a pungent odor, and it is highly reactive due to its desire to gain an electron to complete its valence shell.

When sodium metal comes into contact with chlorine gas, a chemical reaction occurs where sodium atoms each lose one electron to become positively charged sodium ions. Concurrently, chlorine molecules each gain one electron to form negatively charged chloride ions. This transfer of electrons results in the formation of an ionic bond, creating sodium chloride, commonly known as table salt. The process can be represented by the equation:

$$2Na\ (s) + Cl_2\ (g) \rightarrow 2NaCl\ (s)$$

This reaction releases a significant amount of energy in the form of heat and light, making it exothermic. The energy release is due to the strong, stabilizing electrostatic attraction between the positively charged sodium ions and the negatively charged chloride ions.

This exothermic reaction is a clear demonstration of chemical change, where the reactants, sodium and chlorine, lose their individual properties and form a new substance with distinct characteristics. Sodium chloride, a white crystalline solid, has completely different properties from its constituent elements. Unlike the highly reactive, corrosive sodium and the toxic, oxidizing chlorine gas, sodium chloride is stable, non-reactive under normal conditions, and essential for life. This transformation illustrates the concept of ionic bonding, where the electrostatic forces between oppositely charged ions result in a compound with new, emergent properties.

Historically, chlorine gas and sodium metal have been utilized in various significant ways. Chlorine gas, discovered in 1774 by Carl Wilhelm Scheele, was infamously used as a chemical weapon during World War I beginning in the second battle at Ypres, causing severe respiratory damage and fatalities. Beyond its wartime applications, chlorine has been vital in public health as a disinfectant for drinking water and in the production of numerous household and industrial chemicals. Sodium metal, first isolated by Sir Humphry Davy in 1807, played a crucial role in the development of early batteries and in the refinement of metals such as titanium and zirconium through reduction processes. Both elements have thus significantly influenced both industrial advancements and public health measures. The formation of sodium chloride has numerous real-world applications. In the culinary world, table salt is essential for flavoring and preserving food. Industrially, sodium chloride is a key raw material in the production of chlorine gas and sodium hydroxide through the process of electrolysis. Additionally, it is used in de-icing roads during winter and in various chemical processes. Understanding the reaction between sodium and chlorine, and the principles of ionic bonding and exothermic reactions, is fundamental in fields ranging from chemistry and materials science to environmental management and food technology.