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Chlorine Gas

Introduction

The combination of bleach (sodium hypochlorite) with acid produces chlorine gas, a heavy green-yellow gas with a strong, irritating, odor like household bleach. Chlorine gas can also be stored under pressure as a liquid for transportation and storage. Although chlorine gas is not flammable, it reacts explosively with many common chemicals (such as alcohols, ammonia) and may ignite some objects (such as wood, paper, oil--) Chlorine gas has also been uses such as industrial solvent and in production of bulk materials, bleached paper products, plastics such as PVC, and solvents.

→ Methods for Production of Chlorine Gas

Gas Extraction

Chlorine gas can be manufactured by the electrolysis of a sodium chloride solution (brine), which is known as Chloralkali process. The production of chlorine results in the co-products caustic soda (NaOH) and hydrogen gas (H_2) These two products, as well as chlorine itself, are highly reactive. Chlorine can also be produced by the electrolysis of a solution of KCl, in which case the co-products are hydrogen and caustic potash (KOH). There are three industrial methods for the extraction of chlorine by electrolysis of chloride solutions, involving the following equations.

Cathode : $2H^+(aq) + 2e^- \longrightarrow H_2(g)$

Anode : $2Cl^-(aq) \longrightarrow Cl_2 + 2e^-$

Overall process: $2NaCl$ (or KCl) $+ 2H_2O \longrightarrow Cl_2 + H_2 + 2NaOH$ (or KOH)

(i) **Mercury Cell Electrolysis**

Mercury cell electrolysis, also known as the Castner-Kellner process, was the first method used at the end of the nineteenth century to produce chlorine on an industrial scale. The "rocking" cells used have been improved over the years. Today, in the "primary cell", titanium anodes clad with platinum or conductive metal oxides (formerly graphite anodes) are placed in a sodium (or K) chloride solution flowing over a liquid mercury cathode. When a potential difference is applied and current flows, chlorine is released at the titanium anode and sodium dissolves in the mercury cathode forming an amalgam. This flows continuously into a separate reactor ("denuder" or "secondary cell"), where it is usually converted back to mercury by reaction with water, producing hydrogen and sodium (or K) hydroxide at a commercially useful concentration (50% by weight). The mercury is then recycled to the primary cell by a pump situated at the bottom.

(ii) Diaphragm Cell electrolysis

In diaphragm cell electrolysis, an asbestos (or polymer-fibre) diaphragm separates a cathode and an anode, preventing the chlorine forming at the anode from re-mixing with the sodium hydroxide and the hydrogen formed at the cathode. The salt solution is continuously fed to the anode compartment and flows through the diaphragm to the cathode compartment, where the caustic alkali is produced and the brine is partially depleted. As a result, diaphragm methods produce alkali that is quite dilute (about 12%) and of lower purity than do mercury cell methods.
Diaphragm cells are not burdened with the problem of preventing mercury discharge into the environment, they also operate at a lower voltage, resulting in an energy savings over the mercury cell method, but large amounts of steam are required if the caustic has to be evaporated to the commerical Concentration of 50%.

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(iii) <u>Membrane cell electrolysis</u>

Development of this technology began in the 1970s. The electrolysis cell is divided into two "sections" by a cation permeable membrane acting as a cation exchanger. Saturated sodium (or potassium) chloride solution is passed through the anode compartment, leaving at a lower concentration. Sodium (or K) hydroxide solution is circulated through the cathode compartment, exiting at a higher concentration. A portion of the conc. sodium hydroxide solution leaving the cell is diverted as product, while the remainder is diluted with deionized water and passed through the electrolysis apparatus again.
This method is more efficient than the diaphragm cell and produces very pure sodium (or potassium) hydroxide at about 32% concentration, but requires very pure brine.

- <u>Other methods</u>

→ Before electrolytic methods were used for chlorine production, the direct oxidation of hydrogen chloride with oxygen (frequently through exposure to air) was exercised in the Deacon process.

$$4\,HCl + O_2 \longrightarrow 2Cl_2 + 2H_2O$$

This reaction is accomplished with the use of copper (II) chloride ($CuCl_2$) as a catalyst and is performed at high temperature (about 400°C). The amount of extracted chlorine is approximately 80%. Due to the extremely corrosive reaction mixture, industrial use of this method is difficult.

→ Another earlier process to produce chlorine gas was to heat brine with acid and manganese dioxide.

$$2NaCl + 2H_2SO_4 + MnO_2 \longrightarrow Na_2SO_4 + MnSO_4 + 2H_2O + Cl_2$$

Using this process, chemist Carl Wilhelm Scheele was the first to isolate chlorine in a laboratory. The manganese can be recovered by the Weldon process.

→ Small amounts of chlorine gas can be made in the lab by putting conc. hydrochloric acid in a flask with a side arm and rubber tubing attached. Manganese dioxide is then added and the flask stoppered. The reaction is not greatly exothermic. As chlorine is denser than air, it can be easily collected by placing the tube inside a flask where it will displace the air. Once full, the collecting flask can be stoppered.

→ Potassium permanganate can be used to generate chlorine gas when added to hydrochloric acid.

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→ Also small amount of chlorine gas is produced by adding conc. HCl to sodium hypochlorite or sodium chlorate solution.

Uses of Chlorine gas

Chlorine chemistry helps keep families healthy and improves our environment.

→ Water

Chlorine chemistry helps keep drinking water and swimming pools safe. Before cities began routinely treating drinking water with chlorine-based disinfectants, thousands died every year from waterborne diseases such as cholera, typhoid fever etc. Chlorine-based pool and spa disinfectants helps keep recreational waters safe by destroying waterborne pathogens that can result in illnesses, such as diarrhea, swimmer's ear or skin rashes, including athlete's foot.

→ Household Disinfectant

Chlorine chemistry is used to manufacture household chlorine bleach, which whitens and disinfects clothes and disinfects kitchen & bathroom surfaces.

→ Food

Chlorine chemistry helps provide safe and abundant food by protecting crops from pests and keeping kitchen counters and other food-contact surfaces disinfected, destroying E. coli, salmonella and a host of other foodborne germs.

→ Healthcare

Chlorine chemistry is critical to manufacturing medicines we depend on, including some that helps in lowering cholesterol, control arthritis pain and relieve allergy symptoms. Chlorine chemistry is also used to manufacture contact lenses, safety glasses & respiratory inhalers.

→ Energy and Environment

Chlorine chemistry plays crucial role in harnessing solar energy, purifying the silicon in grains of sand & helping transform them into solar panel chips. Wind Turbine blades made from chlorine-based epoxy resins helps convert wind power to electricity.

→ Defense & Law enforcement

Chlorine chemistry is used to manufacture bullet-resistant vests worns by soldiers. Also used to produce parachutes and night vision goggles as well as cockpit canopies & missile guidance technologies.

→ Transportation

Chlorine chemistry is used on planes, trains, automobiles

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, and boats, in the manufacture of seat cushions, bumpers, brake fluid and airbags that help keep passengers safe and comfortable. Also used to manufacture shatter-resistant windows, wire and cable, steel hulls and navigation systems.

→ Advanced Technology
Chlorine chemistry is used to manufacture fast processors that power smart phones, tablets etc. Chlorine is also used to manufacture residential & commerical air conditioning refrigerants, hybrid car batteries & high-performance magnets.

→ Building & Construction
Plastic foam insulation, manufactured using chlorine chemistry, increases the energy efficiency of home heating & air-conditioning systems, reducing energy bills and conserving natural resources etc.