

# Hydrogen chloride

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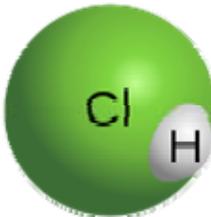
The compound **hydrogen chloride** has the formula HCl. At room temperature, it is a colorless gas, which forms white fumes of hydrochloric acid upon contact with atmospheric humidity. Hydrogen chloride gas and hydrochloric acid are important in technology and industry. The formula HCl is often used to refer, somewhat misleadingly, to hydrochloric acid, an aqueous solution that can be derived from hydrogen chloride.

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## Chemistry

Hydrogen chloride is composed of diatomic molecules, each consisting of a hydrogen atom H and a chlorine atom Cl connected by a covalent single bond. Since the chlorine atom is much more electronegative than the hydrogen atom, the covalent bond between the two atoms is quite polar. Consequently, the molecule has a large dipole moment with a negative partial charge  $\delta^-$  at the

<b>Hydrogen chloride</b>	
	
	
<b>IUPAC name</b>	
Hydrogen chloride Chlorane	
<b>Other names</b>	
Chlorohydric acid Hydrochloride Hydrochloric acid Hydrochloric acid gas	
<b>Identifiers</b>	
CAS number	7647-01-0 <span style="color: green;">✓</span>
PubChem	313
ChemSpider	307 <span style="color: green;">✓</span>
UNII	QTT17582CB <span style="color: green;">✓</span>
EC number	231-595-7
RTECS number	MW4025000
SMILES	Cl
InChI	InChI=1/ClH/h1H
InChI key	VEXZGXHMUGYJMC-UHFFFAOYAT
<b>Properties</b>	
Molecular formula	HCl
Molar mass	36.46 g/mol
Appearance	Colorless gas, hygroscopic.
Density	1.477 g/L, gas (25 °C)
Melting point	−114.2 °C (158.8 K)

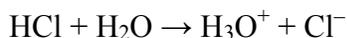


Hydrochloric acid fumes turning pH paper red showing that the fumes are acidic

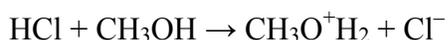
chlorine atom and a positive partial charge  $\delta^+$  at the hydrogen atom. In part due to its high polarity, HCl is very soluble in water (and in other polar solvents).

Upon contact,

$\text{H}_2\text{O}$  and HCl combine to form hydronium cations  $\text{H}_3\text{O}^+$  and chloride anions  $\text{Cl}^-$  through a reversible chemical reaction:

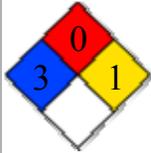


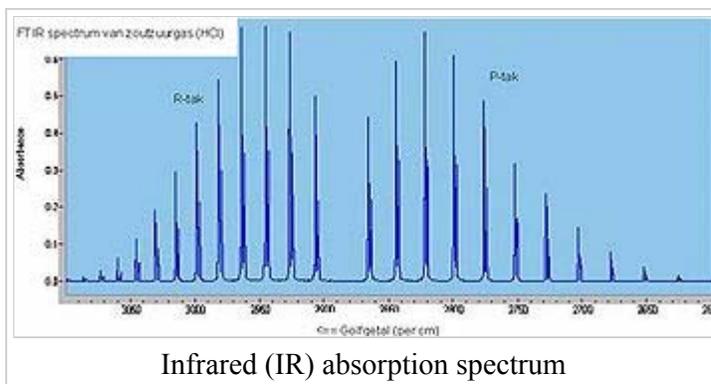
The resulting solution is called hydrochloric acid and is a strong acid. The acid dissociation or ionization constant,  $K_a$ , is large, which means HCl dissociates or ionizes practically completely in water. Even in the absence of water, hydrogen chloride can still act as an acid. For example, hydrogen chloride can dissolve in certain other solvents such as methanol, protonate molecules or ions, and serve as an acid-catalyst for chemical reactions where anhydrous (water-free) conditions are desired.



Because of its acidic nature, hydrogen chloride is corrosive, particularly in the presence of moisture.

## Structure and properties

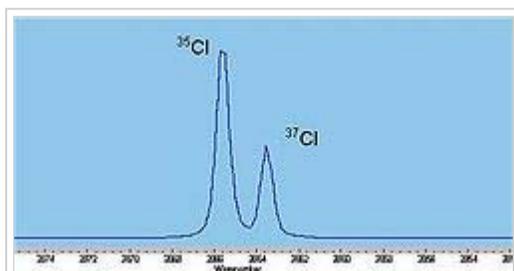
Boiling point	−85.1 °C (187.9 K)
Solubility in water	720 g/L (20 °C)
Acidity (p <i>K</i> <sub>a</sub> )	−7.0
<b>Structure</b>	
Molecular shape	Linear
Dipole moment	1.05 D
<b>Thermochemistry</b>	
Std enthalpy of formation $\Delta_f H^\ominus_{298}$	−2.351 kJ/g
Std enthalpy of combustion $\Delta_c H^\ominus_{298}$	−2.614 kJ/g
Specific heat capacity, <i>C</i>	0.7981 J/g K
<b>Hazards</b>	
MSDS	JT Baker MSDS ( <a href="http://www.jtbaker.com/msds/englishhtml/H3880.htm">http://www.jtbaker.com/msds/englishhtml/H3880.htm</a> )
EU Index	017-002-00-2
EU classification	Toxic (T) Corrosive (C)
R-phrases	<a href="#">R23</a> , <a href="#">R35</a>
S-phrases	<a href="#">(S1/2)</a> , <a href="#">S9</a> , <a href="#">S26</a> , <a href="#">S36/37/39</a> , <a href="#">S45</a>
NFPA 704	
Flash point	Non-flammable
<b>Related compounds</b>	
Other anions	Hydrogen fluoride Hydrogen bromide Hydrogen iodide
Other cations	Sodium chloride
Related compounds	Hydrochloric acid
<p><span style="color: green;">✓</span> (what is this?) (verify) (<a href="http://en.wikipedia.org/w/index.php?title=Hydrogen_chloride&amp;diff=cur&amp;oldid=390493179">http://en.wikipedia.org/w/index.php?title=Hydrogen_chloride&amp;diff=cur&amp;oldid=390493179</a>)            Except where noted otherwise, data are given for materials in their standard state (at 25 °C, 100 kPa)</p>	
Infobox references	



The infrared spectrum of gaseous hydrogen chloride consists of a number of sharp absorption lines grouped around  $2886\text{ cm}^{-1}$  (wavelength  $\sim 3.47\text{ }\mu\text{m}$ ). At room temperature, almost all molecules in the ground vibrational state  $v = 0$ . To promote an HCl molecule to the  $v = 1$  state, we would expect to see an infrared absorption about  $2880\text{ cm}^{-1}$ . This absorption corresponding to the Q-branch is not observed due to it being forbidden due to symmetry. Instead, two sets of signals (P- and R-branches) are seen due to rotation of the molecules. Due to quantum mechanical rules, only certain rotational modes are permitted. They are characterized by the rotational quantum number  $J = 0, 1, 2, 3, \dots$   $\Delta J$  can only take values of  $\pm 1$ .

$$E(J) = h \cdot B \cdot J(J+1)$$

The value of  $B$  is much smaller than  $\nu_e$ , such that a much smaller amount of energy is required to rotate the molecule; for a typical molecule, this lies within the microwave region. However, due to the vibrational energy of this molecule, the set of absorptions lie within the infrared region, allowing a spectrum showing the rovibrational modes of this molecule to be easily collected using an ordinary infrared spectrometer with a conventional gas cell.



One doublet in the IR spectrum due to isotopic composition of Chlorine.

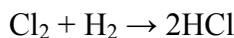
Naturally abundant chlorine consists of two isotopes,  $^{35}\text{Cl}$  and  $^{37}\text{Cl}$ , in a ratio of approximately 3:1. While the spring constants are very similar, the reduced masses are different causing significant differences in the rotational energy, thus doublets are observed on close inspection of each absorption line, weighted in the same ratio of 3:1.

## Production

Most hydrogen chloride produced on an industrial scale is used for hydrochloric acid production.

### Direct synthesis

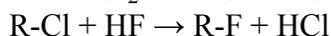
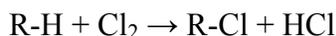
In the chlor-alkali industry, brine (mixture of sodium chloride and water) solution is electrolyzed producing chlorine ( $\text{Cl}_2$ ), sodium hydroxide, and hydrogen ( $\text{H}_2$ ). The pure chlorine gas can be combined with hydrogen to produce hydrogen chloride.



As the reaction is exothermic, the installation is called an HCl oven or HCl burner. The resulting hydrogen chloride gas is absorbed in deionized water, resulting in chemically pure hydrochloric acid. This reaction can give a very pure product, e.g. for use in the food industry.

## Organic synthesis

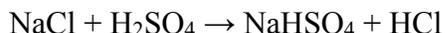
The largest production of hydrochloric acid is integrated with the formation of chlorinated and fluorinated organic compounds, e.g., Teflon, Freon, and other CFCs, as well as chloroacetic acid, and PVC. Often this production of hydrochloric acid is integrated with captive use of it on-site. In the chemical reactions, hydrogen atoms on the hydrocarbon are replaced by chlorine atoms, whereupon the released hydrogen atom recombines with the spare atom from the chlorine molecule, forming hydrogen chloride. Fluorination is a subsequent chlorine-replacement reaction, producing again hydrogen chloride.



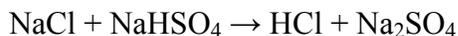
The resulting hydrogen chloride gas is either reused directly, or absorbed in water, resulting in hydrochloric acid of technical or industrial grade.

## Laboratory methods

Small amounts of HCl gas for laboratory use can be generated in a *HCl generator* by dehydrating hydrochloric acid with either sulfuric acid or anhydrous calcium chloride. Alternatively, HCl can be generated by the reaction of sulfuric acid with sodium chloride:<sup>[1]</sup>



This reaction occurs at room temperature. Provided there is salt remaining in the generator and it is heated above 200 degrees Celsius, the reaction proceeds to;

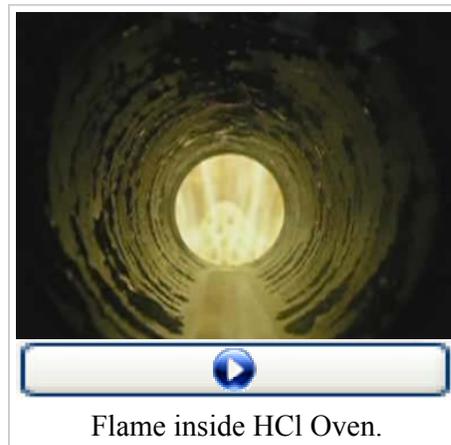


For such generators to function, the reagents should be dry.

HCl can also be prepared by the hydrolysis of certain reactive chloride compounds such as phosphorus chlorides, thionyl chloride (SOCl<sub>2</sub>), and acyl chlorides. For example, cold water can be gradually dripped onto phosphorus pentachloride (PCl<sub>5</sub>) to give HCl in this reaction:



High purity streams of the gas require lecture bottles or cylinders, both of which can be expensive. In comparison, the use of a generator requires only apparatus and materials commonly available in a laboratory.



Flame inside HCl Oven.

## Applications

Most hydrogen chloride is used in the production of hydrochloric acid. It is also an important reagent in other industrial chemical transformations, e.g.:

- Hydrochlorination of rubber
- Production of vinyl and alkyl chlorides

In the semiconductor industry, it is used to both etch semiconductor crystals and to purify silicon via  $\text{SiHCl}_3$ .

It may also be used to treat cotton to delint it, and to separate it from wool.<sup>[*citation needed*]</sup>

In the laboratory, anhydrous forms of the gas are particularly useful for generating chloride based Lewis acids, which must be absolutely dry for their Lewis sites to function. It can also be used to dry the corresponding hydrates forms of these materials, by passing it over as they are heated; the materials would otherwise fume  $\text{HCl}(\text{g})$  themselves and decompose. Neither can these hydrates be dried using standard desiccator methods.

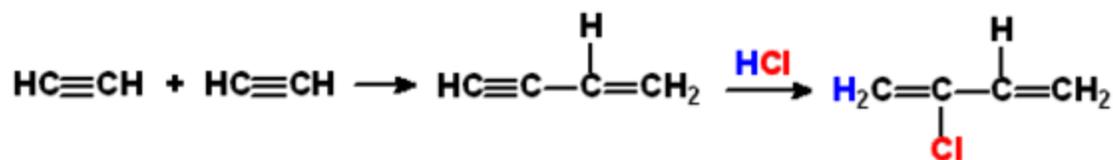
## History

Alchemists of the Middle Ages recognized that hydrochloric acid (then known as *spirit of salt* or *acidum salis*) released vaporous hydrogen chloride, which was called *marine acid air*. In the 17th century, Johann Rudolf Glauber used salt (sodium chloride) and sulfuric acid for the preparation of sodium sulfate, releasing hydrogen chloride gas (see production, below). In 1772, Carl Wilhelm Scheele also reported this reaction and is sometimes credited with its discovery. Joseph Priestley prepared hydrogen chloride in 1772, and in 1810 Humphry Davy established that it is composed of hydrogen and chlorine.<sup>[2]</sup>

During the Industrial Revolution, demand for alkaline substances such as soda ash increased, and Nicolas Leblanc developed a new industrial-scale process for producing the soda ash. In the Leblanc process, salt was converted to soda ash, using sulfuric acid, limestone, and coal, giving hydrogen chloride as by-product. Initially, this gas was vented to air, but the Alkali Act of 1863 prohibited such release, so then soda ash producers absorbed the  $\text{HCl}$  waste gas in water, producing hydrochloric acid on an industrial scale. Later, the Hargreaves process was developed, which is similar to the Leblanc process except sulfur dioxide, water, and air are used instead of sulfuric acid in a reaction which is exothermic overall. In the early 20th century the Leblanc process was effectively replaced by the Solvay process, which did not produce  $\text{HCl}$ . However, hydrogen chloride production continued as a step in hydrochloric acid production.

Historical uses of hydrogen chloride in the 20th century include hydrochlorinations of alkynes in producing the chlorinated monomers chloroprene and vinyl chloride, which are subsequently polymerized to make polychloroprene (Neoprene) and polyvinyl chloride (PVC), respectively. In the production of vinyl chloride, acetylene ( $\text{C}_2\text{H}_2$ ) is hydrochlorinated by adding the  $\text{HCl}$  across the triple bond of the  $\text{C}_2\text{H}_2$  molecule, turning the triple into a double bond, yielding vinyl chloride.

The "acetylene process", used until the 1960s for making chloroprene, starts out by joining two acetylene molecules, and then adds  $\text{HCl}$  to the joined intermediate across the triple bond to convert it to chloroprene as shown here:



This "acetylene process" has been replaced by a process which adds Cl<sub>2</sub> to one of the double bonds in 1,3-butadiene instead, and subsequent elimination produces HCl instead, as well as chloroprene.

## Safety

Hydrogen chloride forms corrosive hydrochloric acid on contact with water found in body tissue. Inhalation of the fumes can cause coughing, choking, inflammation of the nose, throat, and upper respiratory tract, and in severe cases, pulmonary edema, circulatory system failure, and death. Skin contact can cause redness, pain, and severe skin burns. Hydrogen chloride may cause severe burns to the eye and permanent eye damage.

The gas, being strongly hydrophilic, can be easily scrubbed from the exhaust gases of a reaction by bubbling it through water, producing useful hydrochloric acid as a byproduct.

Any equipment handling hydrogen chloride gas must be checked on a routine basis; particularly valve stems and regulators. The gas requires the use of specialized materials on all wetted parts of the flow path, as it will interact with or corrode numerous materials hydrochloric acid alone will not; such as stainless and regular polymers.

## See also

- Chloride, inorganic salts of hydrochloric acid
- Hydrochloride, organic salts of hydrochloric acid
- Gastric acid, hydrochloric acid secreted into the stomach to aid digestion of proteins

## References

1. ^ Francisco J. Arnsliiz (1995). "A Convenient Way To Generate Hydrogen Chloride in the Freshman Lab" (<http://jchemed.chem.wisc.edu/journal/Issues/1995/Dec/abs1139.html>) . *J. Chem. Ed.* **72**: 1139. doi:10.1021/ed072p1139 (<http://dx.doi.org/10.1021%2Fed072p1139>) . <http://jchemed.chem.wisc.edu/journal/Issues/1995/Dec/abs1139.html>.
2. ^ Hartley, Harold (1960). "The Wilkins Lecture. Sir Humphry Davy, Bt., P.R.S. 1778-1829". *Proceedings of the Royal Society of London (A)* **255** (1281): 153 – 180. doi:10.1098/rspa.1960.0060 (<http://dx.doi.org/10.1098%2Frspa.1960.0060>) . Bibcode: 1960RSPSA.255..153H (<http://adsabs.harvard.edu/abs/1960RSPSA.255..153H>) .

- Thames & Kosmos Chem C2000 Experiment Manual

## External links

- International Chemical Safety Card 0163 (<http://www.inchem.org/documents/icsc/icsc/eics0163.htm>)

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