


# Hydrochloric acid

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Hydrochloric acid	
	
<a href="#">IUPAC name</a>	Hydrochloric acid
Other names	Muriatic acid, Spirit of salt
Identifiers	
<a href="#">CAS number</a>	<span>7647-01-0</span>
<a href="#">RTECS number</a>	MW4025000
Properties	
<a href="#">Molecular formula</a>	HCl

<a href="#">Molar mass</a>	36.46 g/mol
Appearance	Clear colorless to light-yellow liquid
<a href="#">Melting point</a>	−26 °C (38% solution)
<a href="#">Boiling point</a>	110 °C (20.2% solution); 48 °C (38% solution)
<a href="#">Solubility in water</a>	Fully miscible.
<a href="#">Viscosity</a>	1.9 mPa·s at 25 °C, 31.5% solution
<b>Hazards</b>	
<a href="#">MSDS</a>	<a href="#">External MSDS</a>
<a href="#">MSDS</a>	<a href="#">External MSDS</a>
<a href="#">R-phrases</a>	R34 , R37 , S26 , S36 , S45
<a href="#">Flash point</a>	Non-flammable.
<b><a href="#">Supplementary data page</a></b>	
<a href="#">Structure and properties</a>	<i>n</i> , <i>ε<sub>r</sub></i> , etc.
<a href="#">Thermodynamic data</a>	Phase behaviour Solid, liquid, gas
<a href="#">Spectral data</a>	<a href="#">UV</a> , <a href="#">IR</a> , <a href="#">NMR</a> , <a href="#">MS</a>
Except where noted otherwise, data are given for materials in their <a href="#">standard state</a> (at 25 °C, 100 kPa) <a href="#">Infobox disclaimer and references</a>	

The [chemical compound](#) **hydrochloric acid** is the [aqueous](#) ([water](#)-based) [solution](#) of [hydrogen chloride](#) gas ([HCl](#)). It is a [strong acid](#), the major component of [gastric acid](#) and of wide industrial use. Hydrochloric acid must be handled with appropriate [safety](#) precautions because it is a highly [corrosive liquid](#).

Hydrochloric acid, or **muriatic acid** by its historical but still occasionally used name, has been an important and frequently used chemical from early history and was discovered by the [alchemist Jabir ibn Hayyan](#) around the year 800. It was used throughout the

[Middle Ages](#) by alchemists in the quest for the [philosopher's stone](#), and later by several European [scientists](#) including [Glauber](#), [Priestley](#), and [Davy](#), to help establish modern chemical knowledge.

From the [Industrial Revolution](#), it became an important industrial chemical for many applications, including the large-scale production of [organic](#) compounds, such as [vinyl chloride](#) for [PVC plastic](#), and [MDI/TDI](#) for [polyurethane](#), and smaller-scale applications, such as production of [gelatin](#) and other [ingredients in food](#), and [leather](#) processing. About 20 million metric tonnes of HCl gas are produced annually.

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## [\[edit\]](#) History

Hydrochloric acid was first discovered around 800 AD by the [alchemist Jabir ibn Hayyan \(Geber\)](#), by mixing [common salt](#) with [vitriol \(sulfuric acid\)](#). Jabir discovered many important chemicals, and recorded his findings in over twenty books, which carried his chemical knowledge of hydrochloric acid and other basic chemicals for hundreds of years. Jabir's invention of the gold-dissolving [aqua regia](#), consisting of hydrochloric acid and [nitric acid](#), was of great interest to alchemists searching for the [philosopher's stone](#).



Jabir ibn Hayyan, medieval manuscript drawing

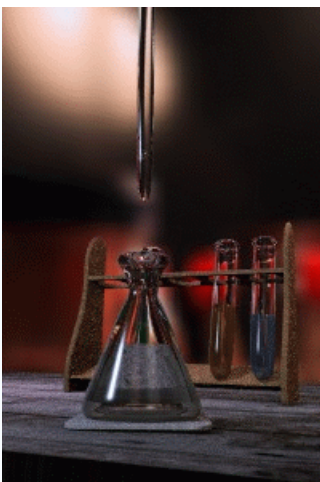
In the [Middle Ages](#), hydrochloric acid was known to European alchemists as *spirit of salt* or *acidum salis*. Gaseous HCl was called *marine acid air*. The old (pre-[systematic](#)) name *muriatic acid* has the same origin (*muriatic* means "pertaining to brine or salt"), and this name is still sometimes used. Notable production was recorded by [Basilus Valentinus](#), the alchemist-[canon](#) of the [Benedictine priory](#) Sankt Peter in [Erfurt, Germany](#) in the fifteenth century. In the seventeenth century, [Johann Rudolf Glauber](#) from [Karlstadt am Main, Germany](#) used sodium chloride salt and sulfuric acid for the preparation of [sodium sulfate](#) in the [Mannheim process](#), releasing [hydrogen chloride](#) gas. [Joseph Priestley](#) of [Leeds, England](#) prepared pure hydrogen chloride in 1772, and in 1818 [Humphry Davy](#) of [Penzance, England](#) proved that the chemical composition included [hydrogen](#) and [chlorine](#).

During the [Industrial Revolution](#) in Europe, demand for [alkaline](#) substances such as [soda ash](#) increased, and the new industrial soda process by [Nicolas Leblanc](#) ([Issoudun, France](#)) enabled cheap large-scale production. In the [Leblanc process](#), salt is converted to soda ash, using sulfuric acid, limestone, and coal, releasing hydrogen chloride as a by-product. Until the [Alkali Act](#) of 1863, excess HCl was vented to the air. After the passage of the act, soda ash producers were obliged to absorb the waste gas in water, producing hydrochloric acid on an industrial scale.

When early in the twentieth century the Leblanc process was effectively replaced by the [Solvay process](#) without the hydrochloric acid by-product, hydrochloric acid was already fully settled as an important chemical in numerous applications. The commercial interest initiated other production methods which are still used today, as described below. Today, most hydrochloric acid is made by absorbing hydrogen chloride from [industrial organic compounds production](#).

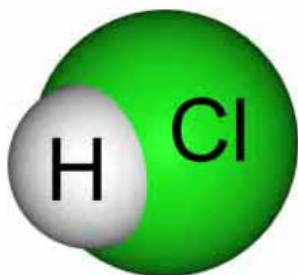
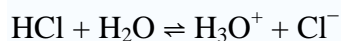
Hydrochloric acid is listed as a Table II precursor under the 1988 [Convention Against Illicit Traffic in Narcotic Drugs and Psychotropic Substances](#) because of its use in the production of [heroin](#), [cocaine](#), and [methamphetamine](#).<sup>[1]</sup>

**[[edit](#)] Chemistry**



Acid titration

Hydrogen chloride (HCl) is a [monoprotic acid](#), which means it can [dissociate](#) (*i.e.*, ionize) only once to give up one H<sup>+</sup> ion (a single [proton](#)). In aqueous hydrochloric acid, the H<sup>+</sup> joins a water molecule to form a [hydronium](#) ion, H<sub>3</sub>O<sup>+</sup>:



Molecular model of hydrogen chloride.

The other ion formed is Cl<sup>-</sup>, the [chloride ion](#). Hydrochloric acid can therefore be used to prepare salts called *chlorides*, such as [sodium chloride](#). Hydrochloric acid is a [strong acid](#), since it is fully dissociated in water.

Monoprotic acids have one [acid dissociation constant](#), K<sub>a</sub>, which indicates the level of dissociation in water. For a strong acid like HCl, the K<sub>a</sub> is large. Theoretical attempts to assign a K<sub>a</sub> to HCl have been made.<sup>[2]</sup> When chloride salts such as NaCl are added to aqueous HCl they have practically no effect on [pH](#), indicating that Cl<sup>-</sup> is an exceedingly weak [conjugate base](#) and that HCl is fully dissociated in aqueous solution. For intermediate to strong solutions of hydrochloric acid, the assumption that H<sup>+</sup> [molarity](#) (a unit of [concentration](#)) equals HCl molarity is excellent, agreeing to four significant digits.

Of the seven common strong acids in chemistry, all of them [inorganic](#), hydrochloric acid is the monoprotic acid least likely to undergo an interfering [oxidation-reduction](#) reaction. It is one of the least hazardous strong acids to handle; despite its acidity, it produces the

less reactive and non-toxic chloride ion. Intermediate strength hydrochloric acid solutions are quite stable, maintaining their concentrations over time. These attributes, plus the fact that it is available as a pure [reagent](#), mean that hydrochloric acid makes an excellent acidifying reagent and acid titrant (for determining the amount of an unknown quantity of [base](#) in [titration](#)). Strong acid titrants are useful because they give more distinct endpoints in a titration, making the titration more precise. Hydrochloric acid is frequently used in [chemical analysis](#) and to digest samples for analysis. Concentrated hydrochloric acid will dissolve some [metals](#) to form oxidized metal chlorides and [hydrogen](#) gas. It will produce metal chlorides from basic compounds such as [calcium carbonate](#) or [copper\(II\) oxide](#). It is also used as a simple acid [catalyst](#) for some [chemical reactions](#).

### [\[edit\]](#) Physical properties

The [physical properties](#) of hydrochloric acid, such as [boiling](#) and [melting points](#), [density](#), and [pH](#) depend on the [concentration](#) or [molarity](#) of HCl in the acid solution. They can range from those of water at 0% HCl to values for fuming hydrochloric acid at over 40% HCl.

<a href="#">Conc.</a> <a href="#">(w/w)</a> c : kg HCl/kg	<a href="#">Conc.</a> <a href="#">(w/v)</a> c : kg HCl/m <sup>3</sup>	<a href="#">Conc.</a> <a href="#">Baumé</a>	<a href="#">Density</a> ρ : kg/l	<a href="#">Molarity</a> M	<a href="#">pH</a>	<a href="#">Viscosity</a> η : mPa·s	<a href="#">Specific heat</a> s : kJ/(kg·K)	<a href="#">Vapor pressure</a> P <sub>HCl</sub> : Pa	<a href="#">Boiling point</a> b.p.	<a href="#">Melting point</a> m.p.
10%	104.80	6.6	1.048	2.87 M	-0.5	1.16	3.47	0.527	103 °C	-18 °C
20%	219.60	13	1.098	6.02 M	-0.8	1.37	2.99	27.3	108 °C	-59 °C
30%	344.70	19	1.149	9.45 M	-1.0	1.70	2.60	1,410	90 °C	-52 °C
32%	370.88	20	1.159	10.17 M	-1.0	1.80	2.55	3,130	84 °C	-43 °C
34%	397.46	21	1.169	10.90 M	-1.0	1.90	2.50	6,733	71 °C	-36 °C
36%	424.44	22	1.179	11.64 M	-1.1	1.99	2.46	14,100	61 °C	-30 °C
38%	451.82	23	1.189	12.39 M	-1.1	2.10	2.43	28,000	48 °C	-26 °C

The reference [temperature](#) and [pressure](#) for the above table are 20 °C and 1 atmosphere (101 kPa).

Hydrochloric acid as the binary (two-component) mixture of HCl and H<sub>2</sub>O has a constant-boiling [azeotrope](#) at 20.2% HCl and 108.6 °C (227 °F). There are four constant-[crystallization eutectic points](#) for hydrochloric acid, between the [crystal](#) form of HCl·H<sub>2</sub>O (68% HCl), HCl·2H<sub>2</sub>O (51% HCl), HCl·3H<sub>2</sub>O (41% HCl), HCl·6H<sub>2</sub>O (25% HCl), and [ice](#)

(0% HCl). There is also a metastable eutectic point at 24.8% between ice and the HCl·3H<sub>2</sub>O crystallization

## [\[edit\]](#) Production

*Main article: [hydrogen chloride](#)*

Hydrochloric acid is prepared by dissolving hydrogen chloride in water. Hydrogen chloride can be generated in many ways, and thus several different precursors to hydrochloric acid exist. The large scale [production](#) of hydrochloric acid is almost always integrated with other industrial scale [chemicals production](#).

## [\[edit\]](#) Industrial market

Hydrochloric acid is produced in solutions up to 38% HCl (concentrated grade). Higher [concentrations](#) up to just over 40% are chemically possible, but the [evaporation](#) rate is then so high that [storage](#) and handling need extra precautions, such as [pressure](#) and low [temperature](#). Bulk industrial-grade is therefore 30% to 34%, optimized for effective [transport](#) and limited product loss by HCl [vapors](#). Solutions for household purposes, mostly cleaning, are typically 10% to 12%, with strong recommendations to dilute before use.

Major producers worldwide include [Dow Chemical](#) at 2 million metric tonnes annually (2 Mt/year), calculated as HCl gas, and [FMC](#), [Georgia Gulf Corporation](#), [Tosoh Corporation](#), [Akzo Nobel](#), and [Tessenderlo](#) at 0.5 to 1.5 Mt/year each. Total world production, for comparison purposes expressed as HCl, is estimated at 20 Mt/year, with 3 Mt/year from direct synthesis, and the rest as secondary product from organic and similar syntheses. By far, most of all hydrochloric acid is consumed captively by the producer. The open world market size is estimated at 5 Mt/year.

## [\[edit\]](#) Applications

Hydrochloric acid is a strong inorganic acid that is used in many industrial processes. The application often determines the required product quality.

## [\[edit\]](#) Regeneration of ion exchangers

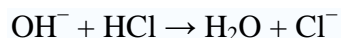
An important application of high-quality hydrochloric acid is the regeneration of [ion exchange resins](#). [Cation exchange](#) is widely used to remove [ions](#) such as Na<sup>+</sup> and Ca<sup>2+</sup> from [aqueous](#) solutions, producing [demineralized](#) water.

Na<sup>+</sup> is replaced by H<sub>3</sub>O<sup>+</sup>  
Ca<sup>2+</sup> is replaced by 2 H<sub>3</sub>O<sup>+</sup>

Ion exchangers and demineralized water are used in all chemical industries, [drinking water](#) production, and many [food](#) industries.

### [\[edit\]](#) pH Control and neutralization

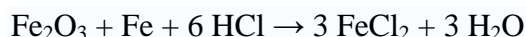
A very common application of hydrochloric acid is to regulate the [basicity \(pH\)](#) of solutions.



In industry demanding purity (food, pharmaceutical, drinking water), high-quality hydrochloric acid is used to control the pH of process water streams. In less-demanding industry, technical-quality hydrochloric acid suffices for [neutralizing](#) waste streams and [swimming pool](#) treatment.

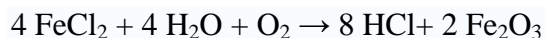
### [\[edit\]](#) Pickling of steel

[Pickling](#) is an essential step in [metal](#) surface treatment, to remove [rust](#) or [iron oxide](#) scale from [iron](#) or [steel](#) before subsequent processing, such as [extrusion](#), [rolling](#), [galvanizing](#), and other techniques. Technical-quality HCl at typically 18% concentration is the most commonly-used pickling agent for the pickling of [carbon steel](#) grades.



The [spent acid](#) has long been re-used as [ferrous chloride](#) solutions, but high [heavy-metal](#) levels in the pickling liquor has decreased this practice.

In recent years, the steel pickling industry has however developed [hydrochloric acid regeneration](#) processes, such as the spray roaster or the fluidized bed HCl regeneration process, which allow the recovery of HCl from spent pickling liquor. The most common regeneration process is the [pyrohydrolysis](#) process, applying the following formula:



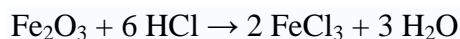
By recuperation of the spent acid, a closed acid loop is established. The ferric oxide by product of the regeneration process is a valuable by-product, used in a variety of secondary industries.

HCl is not a common pickling agent for [stainless steel](#) grades.

### [\[edit\]](#) Production of inorganic compounds

Numerous products can be produced with hydrochloric acid in normal [acid-base reactions](#), resulting in [inorganic](#) compounds. These include water treatment chemicals such as [iron\(III\) chloride](#) and [polyaluminium chloride \(PAC\)](#).





Both iron(III) chloride and PAC are used as [flocculation](#) and coagulation agents in [wastewater treatment](#), [drinking water](#) production, and [paper](#) production.

Other inorganic compounds produced with hydrochloric acid include road application salt [calcium chloride](#), [nickel\(II\) chloride](#) for [electroplating](#), and [zinc chloride](#) for the [galvanizing](#) industry and [battery](#) production.

## [\[edit\]](#) Production of organic compounds

The largest hydrochloric acid consumption is in the production of [organic compounds](#) such as [vinyl chloride](#) for [PVC](#), and [MDI](#) and [TDI](#) for [polyurethane](#). This is often captive use, consuming locally-produced hydrochloric acid that never actually reaches the open market. Other [organic](#) compounds produced with hydrochloric acid include [bisphenol A](#) for [polycarbonate](#), [activated carbon](#), and [ascorbic acid](#), as well as numerous [pharmaceutical](#) products.

## [\[edit\]](#) Other applications

Hydrochloric acid is a fundamental chemical, and as such it is used for a large number of small-scale applications, such as [leather](#) processing, household [cleaning](#), and [building construction](#). In addition, a way of stimulating [oil production](#) is by injecting hydrochloric acid into the rock formation of an [oil well](#), dissolving a portion of the rock, and creating a large-pore structure. Oil-well acidizing is a common process in the [North Sea oil](#) production industry.

Many chemical reactions involving hydrochloric acid are applied in the production of [food](#), food [ingredients](#), and [food additives](#). Typical products include [aspartame](#), [fructose](#), [citric acid](#), [lysine](#), hydrolyzed (vegetable) [protein](#) as food enhancer, and in [gelatin](#) production. Food-grade (extra-pure) hydrochloric acid can be applied when needed for the final product.

## [\[edit\]](#) Presence in living organisms

### [\[edit\]](#) Physiology and pathology

Hydrochloric acid constitutes the majority of [gastric acid](#), the human [digestive fluid](#). In a complex process and at a large energetic burden, it is secreted by [parietal cells](#) (also known as oxyntic cells). These cells contain an extensive secretory network (called canaliculi) from which the HCl is secreted into the [lumen](#) of the stomach. They are part of the [fundic glands](#) (also known as oxyntic glands) in the [stomach](#).

Safety mechanisms that prevent the damage of the [epithelium](#) of digestive tract by hydrochloric acid are the following:

- Negative regulators of its release
- A thick [mucus](#) layer covering the epithelium
- [Sodium bicarbonate](#) secreted by gastric epithelial cells and pancreas
- The structure of epithelium ([tight junctions](#))
- Adequate blood supply
- [Prostaglandins](#) (many different effects: they stimulate mucus and bicarbonate secretion, maintain epithelial barrier integrity, enable adequate blood supply, stimulate the healing of the damaged mucous membrane)

When, due to different reasons, these mechanisms fail, [heartburn](#) or [peptic ulcers](#) can develop. Drugs called [proton pump inhibitors](#) prevent the body from making excess acid in the stomach, while [antacids](#) neutralize existing acid.

In some instances, the stomach does not produce enough hydrochloric acid. These pathologic states are denoted by the terms [hypochlorhydria](#) and [achlorhydria](#). Potentially they can lead to [gastroenteritis](#).

## [\[edit\]](#) Chemical weapons

[Phosgene](#) ( $\text{COCl}_2$ ) was a common [chemical warfare](#) agent used in [World War I](#). The main effect of [phosgene](#) results from the dissolution of the gas in the mucous membranes deep in the [lung](#), where it is converted by [hydrolysis](#) into [carbonic acid](#) and the corrosive hydrochloric acid. The latter disrupts the [alveolar-capillary membranes](#) so that the lung becomes filled with fluid ([pulmonary edema](#)).

Hydrochloric acid is also partly responsible for the harmful or blistering effects of [mustard gas](#). In the presence of [water](#), such as on the moist surface of the eyes or lungs, mustard gas breaks down forming hydrochloric acid.

## [\[edit\]](#) Safety

Hydrochloric acid in high concentrations forms acidic mists. Both the mist and the solution have a corrosive effect on human tissue, potentially damaging respiratory organs, eyes, skin and intestines. Upon mixing hydrochloric acid with common oxidizing chemicals, such as [bleach](#) ( $\text{NaClO}$ ) or [permanganate](#) ( $\text{KMnO}_4$ ), the toxic gas [chlorine](#) is produced. To minimize the risks while working with hydrochloric acid, appropriate precautions should be taken, including wearing rubber or PVC gloves, protective eye goggles, and chemical resistant clothing.

The hazards of solutions of hydrochloric acid depend on the concentration. The following table lists the [EU classification](#) of hydrochloric acid solutions:



<a href="#">Concentration by weight</a>	Classification	<a href="#">R-Phrases</a>
10%–25%	Irritant (Xi)	R36/37/38
>25%	Corrosive (C)	R34 R37

The [Environmental Protection Agency](#) rates and regulates hydrochloric acid as a [toxin](#).<sup>[3]</sup>

## [\[edit\]](#) See also

- [List of chemistry topics](#)
- [List of inorganic compounds](#)

Related chemical substances

- [Hydrochloride](#), organic salts of hydrochloric acid
- HClO [Hypochlorous acid](#), and its salt [hypochlorite](#)
- HClO<sub>2</sub> [Chlorous acid](#), and its salt [chlorite](#)
- HClO<sub>3</sub> [Chloric acid](#), and its salt [chlorate](#)
- HClO<sub>4</sub> [Perchloric acid](#), and its salt [perchlorate](#)

## [\[edit\]](#) References and notes

[\[edit\]](#) Notes

1. <sup>^</sup> [List of precursors and chemicals frequently used in the illicit manufacture of narcotic drugs and psychotropic substances under international control](#) (PDF). [International Narcotics Control Board](#).
2. <sup>^</sup> [Dissociation constants pKa and pKb](#). ChemBuddy.com.
3. <sup>^</sup> [HCl score card](#). [Environmental Protection Agency](#). Retrieved on [2007-09-12](#).

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## [\[edit\]](#) External links

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### [More spoken articles](#)

- [Density table for hydrochloric acid](#)
- [NIST WebBook, general link](#)

### General safety information

- [EPA Hazard Summary](#)
- [NIH Description and Hazard Summary](#)
- [Hydrochloric acid MSDS by Jones-Hamilton](#)
- [Hydrochloric acid MSDS by Hampton Research](#)
- [Hydrochloric acid MSDS by American Bioanalytical](#)
- [Hydrochloric acid MSDS by Georgia Institute of Technology](#)
- [Hydrochloric acid MSDS by Akzo Nobel](#)

### Manufacturer information

- [Hydrochloric acid product information of Akzo Nobel](#)
- [Hydrochloric acid product information of Tessenderlo](#)
- [Hydrochloric acid product information of Solvay](#)
- [Dow Chemical](#)
- [Chlor-Alkali information of Tosoh](#)
- [Hydrochloric acid product information of Bayer MaterialScience in North America](#)

### Pollution information

- [National Pollutant Inventory - Hydrochloric Acid Fact Sheet](#)

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