

= Hydrochloric acid =

Hydrochloric acid is a clear , colorless , highly pungent solution of hydrogen chloride (  $\text{HCl}$  ) in water . It is a highly corrosive , strong mineral acid with many industrial uses . Hydrochloric acid is found naturally in gastric acid . When it reacts with an organic base it forms a hydrochloride salt .

It was historically called acidum salis , muriatic acid , and spirits of salt because it was produced from rock salt and green vitriol ( by Basilius Valentinus in the 15th century ) and later from the chemically similar common salt and sulfuric acid ( by Johann Rudolph Glauber in the 17th century ) . Free hydrochloric acid was first formally described in the 16th century by Libavius . Later , it was used by chemists such as Glauber , Priestley , and Davy in their scientific research .

With major production starting in the Industrial Revolution , hydrochloric acid is used in the chemical industry as a chemical reagent in the large @-@ scale production of vinyl chloride for PVC plastic , and MDI / TDI for polyurethane . It has numerous smaller @-@ scale applications , including household cleaning , production of gelatin and other food additives , descaling , and leather processing . About 20 million tonnes of hydrochloric acid are produced worldwide annually .

= = Etymology = =

Hydrochloric acid was known to European alchemists as spirits of salt or acidum salis ( salt acid ) . Both names are still used , especially in other languages , such as German : Salzsäure , Dutch : Zoutzuur , Swedish : Saltsyra , Turkish : Tuz Ruhı , Polish : kwas solny and Chinese : 盐酸 . Gaseous  $\text{HCl}$  was called marine acid air . The old ( pre @-@ systematic ) name muriatic acid has the same origin ( muriatic means " pertaining to brine or salt " , hence muriate means hydrochloride ) , and this name is still sometimes used . The name hydrochloric acid was coined by the French chemist Joseph Louis Gay @-@ Lussac in 1814 .

= = History = =

Aqua regia , a mixture consisting of hydrochloric and nitric acids , prepared by dissolving sal ammoniac in nitric acid , was described in the works of Pseudo @-@ Geber , a 13th @-@ century European alchemist . Other references suggest that the first mention of aqua regia is in Byzantine manuscripts dating to the end of the 13th century .

Free hydrochloric acid was first formally described in the 16th century by Libavius , who prepared it by heating salt in clay crucibles . Other authors claim that pure hydrochloric acid was first discovered by the German Benedictine monk Basil Valentine in the 15th century , when he heated common salt and green vitriol , whereas others argue that there is no clear reference to the preparation of pure hydrochloric acid until the end of the 16th century .

In the 17th 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 by 1808 Humphry Davy of Penzance , England had proved that the chemical composition included hydrogen and chlorine .

During the Industrial Revolution in Europe , demand for alkaline substances increased . A new industrial process developed by Nicolas Leblanc of Issoudun , France enabled cheap large @-@ scale production of sodium carbonate ( soda ash ) . In this Leblanc process , common salt is converted to soda ash , using sulfuric acid , limestone , and coal , releasing hydrogen chloride as a by @-@ product . Until the British Alkali Act 1863 and similar legislation in other countries , the excess  $\text{HCl}$  was vented into 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 .

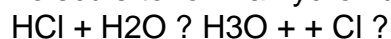
In the 20th century , the Leblanc process was effectively replaced by the Solvay process without a hydrochloric acid by @-@ product . Since hydrochloric acid was already fully settled as an important chemical in numerous applications , the commercial interest initiated other production methods , some of which are still used today . After the year 2000 , hydrochloric acid is mostly made by

absorbing by @-@ product hydrogen chloride from industrial organic compounds production .

Since 1988 , hydrochloric acid has been listed as a Table II precursor under the 1988 United Nations Convention Against Illicit Traffic in Narcotic Drugs and Psychotropic Substances because of its use in the production of heroin , cocaine , and methamphetamine .

### = = Chemical properties and reactions = =

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



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 essentially completely 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 . 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 concentrated solutions of hydrochloric acid , the assumption that H + molarity ( a unit of concentration ) equals HCl molarity is excellent , agreeing to four significant digits .

Of the six common strong mineral acids in chemistry , 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 consists of the non @-@ reactive and non @-@ toxic chloride ion . Intermediate @-@ strength hydrochloric acid solutions are quite stable upon storage , maintaining their concentrations over time . These attributes , plus the fact that it is available as a pure reagent , make hydrochloric acid an excellent acidifying reagent .

Hydrochloric acid is the preferred acid in titration for determining the amount of bases . Strong acid titrants give more precise results due to a more distinct endpoint . Azeotropic , or " constant @-@ boiling " , hydrochloric acid ( roughly 20 @.@ 2 % ) can be used as a primary standard in quantitative analysis , although its exact concentration depends on the atmospheric pressure when it is prepared .

Hydrochloric acid is frequently used in chemical analysis to prepare ( " digest " ) samples for analysis . Concentrated hydrochloric acid dissolves many metals and forms oxidized metal chlorides and hydrogen gas . It also reacts with basic compounds such as calcium carbonate or copper ( II ) oxide , forming the dissolved chlorides that can be analyzed .

### = = Physical properties = =

Physical properties of hydrochloric acid , such as boiling and melting points , density , and pH , depend on the concentration or molarity of HCl in the aqueous solution . They range from those of water at very low concentrations approaching 0 % HCl to values for fuming hydrochloric acid at over 40 % HCl .

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 .

### = = Production = =

Hydrochloric acid is prepared by dissolving hydrogen chloride in water . Hydrogen chloride can be

generated in many ways , and thus several precursors to hydrochloric acid exist . The large @-@ scale production of hydrochloric acid is almost always integrated with the industrial scale production of other chemicals .

= = = 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 require extra precautions , such as pressurization and cooling . Bulk industrial @-@ grade is therefore 30 % to 35 % , optimized to balance transport efficiency and product loss through evaporation . In the United States , solutions of between 20 % and 32 % are sold as muriatic acid . Solutions for household purposes in the US , mostly cleaning , are typically 10 % to 12 % , with strong recommendations to dilute before use . In the United Kingdom , where it is sold as " Spirits of Salt " for domestic cleaning , the potency is the same as the US industrial grade .

Major producers worldwide include Dow Chemical at 2 million metric tons annually ( 2 Mt / year ) , calculated as HCl gas , 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 hydrochloric acid is consumed captively by the producer . The open world market size is estimated at 5 Mt / year .

= = Applications = =

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

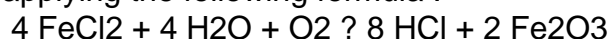
= = = Pickling of steel = = =

One of the most important applications of hydrochloric acid is in the pickling of steel , 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 reused as iron ( II ) chloride ( also known as ferrous chloride ) solutions , but high heavy @-@ metal levels in the pickling liquor have decreased this practice .

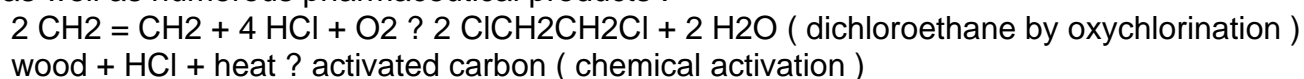
The steel pickling industry has developed hydrochloric acid regeneration processes , such as the spray roaster or the fluidized bed HCl regeneration process , which allow the recovery of HCl from spent pickling liquor . The most common regeneration process is the pyrohydrolysis process , applying the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



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

= = = Production of organic compounds = = =

Another major use of hydrochloric acid is in the production of organic compounds , such as vinyl chloride and dichloroethane for PVC . 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 .



## == 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 ) .

$\text{Fe}_2\text{O}_3 + 6 \text{HCl} \rightarrow 2 \text{FeCl}_3 + 3 \text{H}_2\text{O}$  ( iron ( III ) chloride from magnetite )

Both iron ( III ) chloride and PAC are used as flocculation and coagulation agents in sewage 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 .

$\text{CaCO}_3 + 2 \text{HCl} \rightarrow \text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$  ( calcium chloride from limestone )

## == pH Control and neutralization ==

Hydrochloric acid can be used to regulate the acidity ( pH ) of solutions .

$\text{OH}^- + \text{HCl} \rightarrow \text{H}_2\text{O} + \text{Cl}^-$

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 pH control .

## == Regeneration of ion exchangers ==

High @-@ quality hydrochloric acid is used in the regeneration of ion exchange resins . Cation exchange is widely used to remove ions such as  $\text{Na}^+$  and  $\text{Ca}^{2+}$  from aqueous solutions , producing demineralized water . The acid is used to rinse the cations from the resins .  $\text{Na}^+$  is replaced with  $\text{H}^+$  and  $\text{Ca}^{2+}$  with  $2 \text{H}^+$  .

Ion exchangers and demineralized water are used in all chemical industries , drinking water production , and many food industries .

## == Other ==

Hydrochloric acid is used for a large number of small @-@ scale applications , such as leather processing , purification of common salt , household cleaning , and building construction . Oil production may be stimulated 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 .

Hydrochloric acid has been used for dissolving calcium carbonate , i.e. such things as de @-@ scaling kettles and for cleaning mortar off brickwork , but it is a hazardous liquid which must be used with care . When used on brickwork the reaction with the mortar only continues until the acid has all been converted , producing calcium chloride , carbon dioxide , and water :

$2\text{HCl} + \text{CaCO}_3 \rightarrow \text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$

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 .

## == Presence in living organisms ==

Gastric acid is one of the main secretions of the stomach . It consists mainly of hydrochloric acid and acidifies the stomach content to a pH of 1 to 2 .

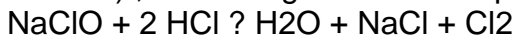
Chloride (  $\text{Cl}^-$  ) and hydrogen (  $\text{H}^+$  ) ions are secreted separately in the stomach fundus region at the top of the stomach by parietal cells of the gastric mucosa into a secretory network called canaliculi before it enters the stomach lumen .

Gastric acid acts as a barrier against microorganisms to prevent infections and is important for the digestion of food . Its low pH denatures proteins and thereby makes them susceptible to degradation by digestive enzymes such as pepsin . The low pH also activates the enzyme precursor pepsinogen into the active enzyme pepsin by self @-@ cleavage . After leaving the stomach , the hydrochloric acid of the chyme is neutralized in the duodenum by sodium bicarbonate .

The stomach itself is protected from the strong acid by the secretion of a thick mucus layer , and by secretin induced buffering with sodium bicarbonate . Heartburn or peptic ulcers can develop when these mechanisms fail . Drugs of the antihistaminic and proton pump inhibitor classes can inhibit the production of acid in the stomach , and antacids are used to neutralize existing acid .

= = Safety = =

Concentrated hydrochloric acid ( fuming hydrochloric acid ) forms acidic mists . Both the mist and the solution have a corrosive effect on human tissue , with the potential to damage respiratory organs , eyes , skin , and intestines irreversibly . Upon mixing hydrochloric acid with common oxidizing chemicals , such as sodium hypochlorite ( bleach ,  $\text{NaClO}$  ) or potassium permanganate (  $\text{KMnO}_4$  ) , the toxic gas chlorine is produced .



Personal protective equipment such as latex gloves , protective eye goggles , and chemical @-@ resistant clothing and shoes will minimize risks when handling hydrochloric acid . The United States Environmental Protection Agency rates and regulates hydrochloric acid as a toxic substance .

The UN number or DOT number is 1789 . This number will be displayed on a placard on the container .