[Template:About](/wiki/Template:About" \o "Template:About) [Template:Use dmy dates](/wiki/Template:Use_dmy_dates) [Template:Use British English](/wiki/Template:Use_British_English) [Template:Chembox](/wiki/Template:Chembox)

**Ammonia** or **azane** is a [compound](/wiki/Chemical_compound) of [nitrogen](/wiki/Nitrogen) and [hydrogen](/wiki/Hydrogen) with the [formula](/wiki/Chemical_formula) NH3. It is a colourless [gas](/wiki/Gas) with a characteristic pungent smell. Ammonia contributes significantly to the [nutritional](/wiki/Nutrition) needs of terrestrial organisms by serving as a precursor to [food](/wiki/Food) and [fertilizers](/wiki/Fertilizer). Ammonia, either directly or indirectly, is also a building block for the synthesis of many [pharmaceuticals](/wiki/Pharmaceuticals) and is used in many commercial cleaning products. Although common in nature and in wide use, ammonia is both [caustic](/wiki/Caustic_(substance)) and [hazardous](/wiki/Hazard) in its concentrated form.

The global industrial production of ammonia in 2014 was [Template:Convert](/wiki/Template:Convert),<ref name=USGS2016>[Template:Cite web](/wiki/Template:Cite_web)</ref> a 16% increase over the 2006 global industrial production of [Template:Convert](/wiki/Template:Convert).<ref name=USGS2016-ds140>[Template:Cite web](/wiki/Template:Cite_web)</ref>

NH3 boils at [Template:Convert](/wiki/Template:Convert) at a pressure of one [atmosphere](/wiki/Atmosphere_(unit)), so the liquid must be stored under pressure or at low temperature. Household ammonia or [ammonium hydroxide](/wiki/Ammonium_hydroxide) is a solution of NH3 in water. The concentration of such solutions is measured in units of the [Baumé scale](/wiki/Baumé_scale) ([density](/wiki/Density)), with 26 degrees baumé (about 30% (by weight) ammonia at [Template:Convert](/wiki/Template:Convert)) being the typical high-concentration commercial product.<ref name=LaRoche>[Template:Cite web](/wiki/Template:Cite_web)</ref>

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## Natural occurrence[[edit](/index.php?title=(none)&action=edit&section=1)]

Ammonia is found in trace quantities in nature, being produced from the nitrogenous animal and vegetable matter. Ammonia and ammonium salts are also found in small quantities in rainwater, whereas [ammonium chloride](/wiki/Ammonium_chloride) ([sal ammoniac](/wiki/Sal_ammoniac)), and [ammonium sulfate](/wiki/Ammonium_sulfate) are found in volcanic districts; crystals of [ammonium bicarbonate](/wiki/Ammonium_bicarbonate) have been found in [Patagonian](/wiki/Patagonia) [guano](/wiki/Guano). The [kidneys](/wiki/Kidney) secrete ammonia to neutralize excess acid.[[1]](#cite_note-1) Ammonium salts are found distributed through fertile soil and in seawater.

Ammonia is also found throughout the [Solar System](/wiki/Solar_System) on [Mars](/wiki/Mars), [Jupiter](/wiki/Jupiter), [Saturn](/wiki/Saturn), [Uranus](/wiki/Uranus), [Neptune](/wiki/Neptune), and [Pluto](/wiki/Pluto), among other places: on smaller, icy worlds like Pluto, ammonia can act as a geologically important antifreeze, as a mixture of water and ammonia can potentially have a melting point of as low as 173 kelvins if the ammonia concentration is high enough and thus allow such worlds to retain internal oceans and active geology far longer than would be possible with water alone. [[2]](#cite_note-2) following the allied blockade that cut off the supply of nitrates from [Chile](/wiki/Chile). The ammonia was used to produce explosives to sustain war efforts.[[17]](#cite_note-17) Prior to the availability of natural gas, hydrogen as a precursor to [ammonia production](/wiki/Ammonia_production) was produced via the [electrolysis](/wiki/Electrolysis) of water or using the [chloralkali process](/wiki/Chloralkali_process).

With the advent of the steel industry in the 20th century, ammonia became a byproduct of the production of coking coal.

## Uses[[edit](/index.php?title=(none)&action=edit&section=14)]

### Fertilizer[[edit](/index.php?title=(none)&action=edit&section=15)]

Globally, approximately 88% (as of 2014) of ammonia is used as fertilizers either as its salts, solutions or anhydrously.[[18]](#cite_note-18) When applied to soil, it helps provide increased yields of crops such as maize and wheat.[Template:Citation needed](/wiki/Template:Citation_needed) 30% of agricultural nitrogen applied in the USA is in the form of anhydrous ammonia and worldwide 110 million tonnes are applied each year.[[19]](#cite_note-19)

### Precursor to nitrogenous compounds[[edit](/index.php?title=(none)&action=edit&section=16)]

Ammonia is directly or indirectly the precursor to most nitrogen-containing compounds. Virtually all synthetic nitrogen compounds are derived from ammonia. An important derivative is [nitric acid](/wiki/Nitric_acid). This key material is generated via the [Ostwald process](/wiki/Ostwald_process) by [oxidation](/wiki/Oxidation) of ammonia with air over a [platinum](/wiki/Platinum) catalyst at [Template:Convert](/wiki/Template:Convert), ~9 atm. [Nitric oxide](/wiki/Nitric_oxide) is an intermediate in this conversion:[[20]](#cite_note-20): NH3 + 2 O2 → HNO3 + H2O Nitric acid is used for the production of [fertilizers](/wiki/Fertilizer), [explosives](/wiki/Explosive), and many organonitrogen compounds.

Ammonia is also used to make the following compounds:

* [Hydrazine](/wiki/Hydrazine), in the [Olin Raschig process](/wiki/Olin_Raschig_process) and the [peroxide process](/wiki/Peroxide_process)
* [Hydrogen cyanide](/wiki/Hydrogen_cyanide), in the [BMA process](/wiki/BMA_process) and the [Andrussow process](/wiki/Andrussow_process)
* [Hydroxylamine](/wiki/Hydroxylamine) and [ammonium carbonate](/wiki/Ammonium_carbonate), in the [Raschig process](/wiki/Raschig_process)
* [Phenol](/wiki/Phenol), in the [Raschig–Hooker process](/wiki/Raschig–Hooker_process)
* [Urea](/wiki/Urea), in the [Bosch–Meiser urea process](/wiki/Bosch–Meiser_urea_process) and in [Wöhler synthesis](/wiki/Wöhler_synthesis)
* [Amino acids](/wiki/Amino_acid), using [Strecker amino-acid synthesis](/wiki/Strecker_amino-acid_synthesis)
* [Acrylonitrile](/wiki/Acrylonitrile), in the [Sohio process](/wiki/Sohio_process)

Ammonia can also be used to make compounds in reactions which are not specifically named. Examples of such compounds include: [ammonium perchlorate](/wiki/Ammonium_perchlorate), [ammonium nitrate](/wiki/Ammonium_nitrate), [formamide](/wiki/Formamide), [dinitrogen tetroxide](/wiki/Dinitrogen_tetroxide), [alprazolam](/wiki/Alprazolam), [ethanolamine](/wiki/Ethanolamine), [ethyl carbamate](/wiki/Ethyl_carbamate), [hexamethylenetetramine](/wiki/Hexamethylenetetramine), and [ammonium bicarbonate](/wiki/Ammonium_bicarbonate).

### Cleaner[[edit](/index.php?title=(none)&action=edit&section=17)]

Household ammonia is a solution of NH3 in water (i.e., [ammonium hydroxide](/wiki/Ammonium_hydroxide)) used as a general purpose cleaner for many surfaces. Because ammonia results in a relatively streak-free shine, one of its most common uses is to clean glass, porcelain and stainless steel. It is also frequently used for cleaning ovens and soaking items to loosen baked-on grime. Household ammonia ranges in concentration by weight from 5 to 10% ammonia.

### Fermentation[[edit](/index.php?title=(none)&action=edit&section=18)]

Solutions of ammonia ranging from 16% to 25% are used in the [fermentation](/wiki/Industrial_fermentation) industry as a source of nitrogen for microorganisms and to adjust pH during fermentation.

### Antimicrobial agent for food products[[edit](/index.php?title=(none)&action=edit&section=19)]

As early as in 1895, it was known that ammonia was "strongly [antiseptic](/wiki/Antiseptic) ... it requires 1.4 grams per litre to preserve [beef tea](/wiki/Beef_tea)."[[21]](#cite_note-21) In one study, anhydrous ammonia destroyed 99.999% of [zoonotic bacteria](/wiki/Zoonotic_bacteria) in 3 types of [animal feed](/wiki/Compound_feed), but not [silage](/wiki/Silage).[[22]](#cite_note-22)[Template:Primary source inline](/wiki/Template:Primary_source_inline) Anhydrous ammonia is currently used commercially to reduce or eliminate [microbial](/wiki/Microbial) contamination of [beef](/wiki/Beef).[[23]](#cite_note-23)[[24]](#cite_note-24)Lean finely textured beef in the beef industry is made from fatty [beef trimmings](/wiki/Beef_trimmings) (about 50–70% fat) by removing the fat using heat and [centrifugation](/wiki/Centrifugation), then treating it with ammonia to kill [*E. coli*](/wiki/Escherichia_coli). The process was deemed effective and safe by the [US Department of Agriculture](/wiki/US_Department_of_Agriculture) based on a study that found that the treatment reduces *E. coli* to undetectable levels.[[25]](#cite_note-25) There have been safety concerns about the process as well as consumer complaints about the taste and smell of beef treated at optimal levels of ammonia.[[26]](#cite_note-26) The level of ammonia in any final product has not come close to toxic levels to humans.

### Minor and emerging uses[[edit](/index.php?title=(none)&action=edit&section=20)]

#### Refrigeration – R717[[edit](/index.php?title=(none)&action=edit&section=21)]

Because of ammonia's vaporization properties, it is a useful [refrigerant](/wiki/Refrigerant).<ref name=Ullmann/> It was commonly used prior to the popularisation of [chlorofluorocarbons](/wiki/Chlorofluorocarbon) (Freons). Anhydrous ammonia is widely used in industrial refrigeration applications and hockey rinks because of its high [energy efficiency](/wiki/Energy_conversion_efficiency) and low cost. It suffers from the disadvantage of toxicity, which restricts its domestic and small-scale use. Along with its use in modern [vapor-compression refrigeration](/wiki/Vapor-compression_refrigeration) it is used in a mixture along with hydrogen and water in [absorption refrigerators](/wiki/Absorption_refrigerator). The [Kalina cycle](/wiki/Kalina_cycle), which is of growing importance to geothermal power plants, depends on the wide boiling range of the ammonia–water mixture.

#### For remediation of gaseous emissions[[edit](/index.php?title=(none)&action=edit&section=22)]

Ammonia is used to scrub SO2 from the burning of fossil fuels, and the resulting product is converted to ammonium sulfate for use as fertilizer. Ammonia neutralizes the nitrogen oxides (NOx) pollutants emitted by diesel engines. This technology, called SCR ([selective catalytic reduction](/wiki/Selective_catalytic_reduction)), relies on a [vanadia](/wiki/Vanadia)-based catalyst.[[27]](#cite_note-27)  
Ammonia may be used to mitigate gaseous spills of [phosgene](/wiki/Phosgene).[[28]](#cite_note-28)

#### As a fuel[[edit](/index.php?title=(none)&action=edit&section=23)]

[thumb|Ammoniacal Gas Engine](/wiki/File:AmmoniacalGasEngineStreetcarARWaud.jpeg) [Streetcar in New Orleans](/wiki/Streetcars_in_New_Orleans) drawn by [Alfred Waud](/wiki/Alfred_Waud) in 1871. [thumb|The](/wiki/File:x-15.jpg) [X-15](/wiki/X-15) [aircraft](/wiki/Aircraft) used ammonia as one component [fuel](/wiki/Fuel) of its [rocket](/wiki/Rocket) [engine](/wiki/Engine) The raw [energy density](/wiki/Energy_density) of liquid ammonia is 11.5 MJ/L,<ref name=Lan>["Ammonia as a suitable fuel for fuel cells"](http://journal.frontiersin.org/article/10.3389/fenrg.2014.00035/full), Rong Lan, Shanwen Tao, *Front. Energy Res.*, 28 August 2014,</ref> which is about a third that of [diesel](/wiki/Diesel_fuel). Although it can be used as a fuel, for a number of reasons this has never been common or widespread.

Ammonia engines or ammonia motors, using ammonia as a [working fluid](/wiki/Working_fluid), have been proposed and occasionally used.[[29]](#cite_note-29) The principle is similar to that used in a [fireless locomotive](/wiki/Fireless_locomotive), but with ammonia as the working fluid, instead of steam or compressed air. Ammonia engines were used experimentally in the 19th century by [Goldsworthy Gurney](/wiki/Goldsworthy_Gurney) in the UK and the [St. Charles Avenue Streetcar](/wiki/St._Charles_Avenue_Streetcar) line in New Orleans in the 1870s and 1880s,[[30]](#cite_note-30) and during [World War II](/wiki/World_War_II) ammonia was used to power buses in Belgium.<ref name=c1/>

Ammonia is sometimes proposed as a practical alternative to [fossil fuel](/wiki/Fossil_fuel) for [internal combustion engines](/wiki/Internal_combustion_engines).<ref name=c1>[Template:Cite news](/wiki/Template:Cite_news)</ref> Its high octane rating of 120[[31]](#cite_note-31) and low flame temperature allows the use of high compression ratios without a penalty of high NOx production.  Since ammonia contains no carbon, its combustion cannot produce carbon monoxide, hydrocarbons or soot.

However ammonia cannot be easily used in existing [Otto cycle](/wiki/Otto_cycle) engines because of its very narrow [flammability range](/wiki/Ammonia#Combustion) and there are also other barriers to widespread automobile usage. In terms of raw ammonia supplies, plants would have to be built to increase production levels, requiring significant capital and energy sources. Although it is the second most produced chemical, the scale of ammonia production is a small fraction of world petroleum usage. It could be manufactured from renewable energy sources, as well as coal or nuclear power. The 60 MW [Rjukan dam](/wiki/Norsk_Hydro_Rjukan) in [Telemark](/wiki/Telemark), Norway produced ammonia via electrolysis of water for many years from 1913 producing fertilizer for much of Europe.

Despite this, several tests have been done. In 1981, a Canadian company converted a 1981 Chevrolet Impala to operate using ammonia as fuel.[[32]](#cite_note-32)[[33]](#cite_note-33) In 2007, a University of Michigan pickup powered by ammonia drove from Detroit to San Francisco as part of a demonstration, requiring only one fill-up in Wyoming.[[34]](#cite_note-34) Compared to [hydrogen as a fuel](/wiki/Hydrogen_as_a_fuel), ammonia is much more energy efficient, and it would be a much lower cost to produce, store, and deliver hydrogen as ammonia than as compressed and/or cryogenic hydrogen.<ref name=Lan/> The conversion of ammonia to hydrogen via the sodium-amide process,[[35]](#cite_note-35) either as a catalyst for combustion or as fuel for a [proton exchange membrane fuel cell](/wiki/Proton_exchange_membrane_fuel_cell),<ref name=Lan/> is another possibility.  Conversion to hydrogen would allow the storage of hydrogen at nearly 18 wt% compared to ~5% for gaseous hydrogen under pressure.

Rocket engines have also been fueled by ammonia. The [Reaction Motors XLR99](/wiki/Reaction_Motors_XLR99) rocket engine that powered the [Template:Nowrap](/wiki/Template:Nowrap) hypersonic research aircraft used liquid ammonia. Although not as powerful as other fuels, it left no soot in the reusable rocket engine and its density approximately matches the density of the oxidizer, liquid oxygen, which simplified the aircraft's design.

#### As a stimulant[[edit](/index.php?title=(none)&action=edit&section=24)]

[thumb|Anti-](/wiki/File:Meth_ammonia_tank_Otley_iowa.JPG)[meth](/wiki/Methamphetamine) sign on tank of anhydrous ammonia, [Otley, Iowa](/wiki/Otley,_Iowa). Anhydrous ammonia is a common farm fertilizer that is also a critical ingredient in making methamphetamine. In 2005, Iowa state used grant money to give out thousands of locks to prevent criminals from getting into the tanks.[[36]](#cite_note-36) Ammonia, as the vapor released by [smelling salts](/wiki/Smelling_salts), has found significant use as a respiratory stimulant. Ammonia is commonly used in the illegal manufacture of [methamphetamine](/wiki/Methamphetamine) through a [Birch reduction](/wiki/Birch_reduction).[[37]](#cite_note-37) The Birch method of making methamphetamine is dangerous because the alkali metal and liquid ammonia are both extremely reactive, and the temperature of liquid ammonia makes it susceptible to explosive boiling when reactants are added.[Template:Citation needed](/wiki/Template:Citation_needed)

#### Textile[[edit](/index.php?title=(none)&action=edit&section=25)]

Liquid ammonia is used for treatment of cotton materials, giving properties like [mercerisation](/wiki/Mercerisation), using alkalis. In particular, it is used for prewashing of wool.[[38]](#cite_note-38)

#### Lifting gas[[edit](/index.php?title=(none)&action=edit&section=26)]

At standard temperature and pressure, ammonia is less dense than atmosphere, and has approximately 60% of the lifting power of hydrogen or [helium](/wiki/Helium). Ammonia has sometimes been used to fill weather balloons as a [lifting gas](/wiki/Lifting_gas). Because of its relatively high boiling point (compared to helium and hydrogen), ammonia could potentially be refrigerated and liquefied aboard an [airship](/wiki/Airship) to reduce lift and add ballast (and returned to a gas to add lift and reduce ballast).

#### Woodworking[[edit](/index.php?title=(none)&action=edit&section=27)]

[Template:See also](/wiki/Template:See_also) Ammonia has been used to darken quartersawn white oak in Arts & Crafts and Mission-style furniture. Ammonia fumes react with the natural tannins in the wood and cause it to change colours.[[39]](#cite_note-39)

## Safety precautions[[edit](/index.php?title=(none)&action=edit&section=28)]

[thumb|The world's longest ammonia](/wiki/File:Ammiakoprovod_NS.jpg) [pipeline](/wiki/Pipeline_transport), running from the [TogliattiAzot](/wiki/TogliattiAzot) plant in [Russia](/wiki/Russia) to [Odessa](/wiki/Odessa) in [Ukraine](/wiki/Ukraine). The U. S. [Occupational Safety and Health Administration (OSHA)](/wiki/Occupational_Safety_and_Health_Administration) has set a 15-minute exposure limit for gaseous ammonia of 35 ppm by volume in the environmental air and an 8-hour exposure limit of 25 ppm by volume.<ref name=ToxFaqSheet>[Template:Cite news](/wiki/Template:Cite_news)</ref> NIOSH recently reduced the IDLH from 500 to 300 based on recent more conservative interpretations of original research in 1943. IDLH (Immediately Dangerous to Life and Health) is the level to which a healthy worker can be exposed for 30 minutes without suffering irreversible health effects. Other organizations have varying exposure levels. U.S. Navy Standards [U.S. Bureau of Ships 1962] maximum allowable concentrations (MACs):continuous exposure (60 days): 25 ppm / 1 hour: 400 ppm[[40]](#cite_note-40) Ammonia vapour has a sharp, irritating, pungent odour that acts as a warning of potentially dangerous exposure. The average odour threshold is 5 ppm, well below any danger or damage. Exposure to very high concentrations of gaseous ammonia can result in lung damage and death.<ref name=ToxFaqSheet/> Although ammonia is regulated in the United States as a non-flammable gas, it still meets the definition of a material that is toxic by inhalation and requires a hazardous safety permit when transported in quantities greater than 13,248 L (3,500 gallons).[[41]](#cite_note-41)

### Toxicity[[edit](/index.php?title=(none)&action=edit&section=29)]

The toxicity of ammonia solutions does not usually cause problems for humans and other mammals, as a specific mechanism exists to prevent its build-up in the bloodstream. Ammonia is converted to [carbamoyl phosphate](/wiki/Carbamoyl_phosphate) by the enzyme [carbamoyl phosphate synthetase](/wiki/Carbamoyl_phosphate_synthetase), and then enters the [urea cycle](/wiki/Urea_cycle) to be either incorporated into [amino acids](/wiki/Amino_acid) or excreted in the urine [Template:Citation needed](/wiki/Template:Citation_needed). [Fish](/wiki/Fish) and [amphibians](/wiki/Amphibian) lack this mechanism, as they can usually eliminate ammonia from their bodies by direct excretion. Ammonia even at dilute concentrations is highly toxic to aquatic animals, and for this reason it is [classified](/wiki/Directive_67/548/EEC) as *dangerous for the environment*.

#### Coking wastewater[[edit](/index.php?title=(none)&action=edit&section=30)]

Ammonia is present in coking wastewater streams, as a liquid by-product of the production of [coke](/wiki/Coke_(fuel)) from [coal](/wiki/Coal).[[42]](#cite_note-42) In some cases, the ammonia is discharged to the [marine environment](/wiki/Marine_environment) where it acts as a pollutant. The [Whyalla steelworks](/wiki/Whyalla_steelworks) in [South Australia](/wiki/South_Australia) is one example of a coke-producing facility which discharges ammonia into marine waters.

#### Aquaculture[[edit](/index.php?title=(none)&action=edit&section=31)]

Ammonia toxicity is believed to be a cause of otherwise unexplained losses in fish hatcheries. Excess ammonia may accumulate and cause alteration of metabolism or increases in the body pH of the exposed organism. Tolerance varies among fish species.[[43]](#cite_note-43) At lower concentrations, around 0.05 mg/L, un-ionised ammonia is harmful to fish species and can result in poor growth and feed conversion rates, reduced fecundity and fertility and increase stress and susceptibility to bacterial infections and diseases.[[44]](#cite_note-44) Exposed to excess ammonia, fish may suffer loss of equilibrium, hyper-excitability, increased respiratory activity and oxygen uptake and increased heart rate.[[43]](#cite_note-43) At concentrations exceeding 2.0 mg/L, ammonia causes gill and tissue damage, extreme lethargy, convulsions, coma, and death.[[43]](#cite_note-43)[[45]](#cite_note-45) Experiments have shown that the lethal concentration for a variety of fish species ranges from 0.2 to 2.0 mg/l.[[45]](#cite_note-45) During winter, when reduced feeds are administered to aquaculture stock, ammonia levels can be higher. Lower ambient temperatures reduce the rate of algal photosynthesis so less ammonia is removed by any algae present. Within an aquaculture environment, especially at large scale, there is no fast-acting remedy to elevated ammonia levels. Prevention rather than correction is recommended to reduce harm to farmed fish[[45]](#cite_note-45) and in open water systems, the surrounding environment.

### Storage information[[edit](/index.php?title=(none)&action=edit&section=32)]

Similar to [propane](/wiki/Propane), [anhydrous](/wiki/Anhydrous) ammonia boils below room temperature when at atmospheric pressure. A storage vessel capable of [Template:Convert](/wiki/Template:Convert) is suitable to contain the liquid.[[46]](#cite_note-46) Ammonium compounds should never be allowed to come in contact with [bases](/wiki/Base_(chemistry)) (unless in an intended and contained reaction), as dangerous quantities of ammonia gas could be released.

### Household use[[edit](/index.php?title=(none)&action=edit&section=33)]

Solutions of ammonia (5–10% by weight) are used as household cleaners, particularly for glass. These solutions are irritating to the eyes and [mucous membranes](/wiki/Mucous_membrane) (respiratory and digestive tracts), and to a lesser extent the skin. Caution should be used that the chemical is never mixed into any liquid containing bleach, as a poisonous gas may result. Mixing with [chlorine](/wiki/Chlorine)-containing products or strong oxidants, such as household [bleach](/wiki/Bleach), can lead to hazardous compounds such as [chloramines](/wiki/Chloramine).[[47]](#cite_note-47)

### Laboratory use of ammonia solutions[[edit](/index.php?title=(none)&action=edit&section=34)]

[thumb|Hydrochloric acid sample releasing HCl fumes, which are reacting with ammonia fumes to produce a white smoke of ammonium chloride.](/wiki/Image:Hydrochloric_acid_ammonia.jpg) The hazards of ammonia solutions depend on the concentration: "dilute" ammonia solutions are usually 5–10% by weight (<5.62 mol/L); "concentrated" solutions are usually prepared at >25% by weight. A 25% (by weight) solution has a density of 0.907 g/cm3, and a solution that has a lower density will be more concentrated. The [European Union classification](/wiki/Directive_67/548/EEC) of ammonia solutions is given in the table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| [**Concentration**](/wiki/Concentration) **by weight (w/w)** | [**Molarity**](/wiki/Molarity) | [**Concentration**](/wiki/Concentration) **mass/volume (w/v)** | **Classification** | [**R-Phrases**](/wiki/List_of_R-phrases) |
| 5–10% | 2.87–5.62 mol/L | 48.9–95.7 g/L | Irritant (**Xi**) | [Template:R36/37/38](/wiki/Template:R36/37/38) |
| 10–25% | 5.62–13.29 mol/L | 95.7–226.3 g/L | Corrosive (**C**) | [Template:R34](/wiki/Template:R34) |
| >25% | >13.29 mol/L | >226.3 g/L | Corrosive (**C**) Dangerous for the environment (**N**) | [Template:R34](/wiki/Template:R34), [Template:R50](/wiki/Template:R50) |

[*S-Phrases*](/wiki/List_of_S-phrases)*:* [*Template:S1/2*](/wiki/Template:S1/2)*,* [*Template:S16*](/wiki/Template:S16)*,* [*Template:S36/37/39*](/wiki/Template:S36/37/39)*,* [*Template:S45*](/wiki/Template:S45)*,* [*Template:S61*](/wiki/Template:S61)*.*

The ammonia vapour from concentrated ammonia solutions is severely irritating to the eyes and the respiratory tract, and these solutions should only be handled in a fume hood. Saturated ("0.880") solutions can develop a significant pressure inside a closed bottle in warm weather, and the bottle should be opened with care; this is not usually a problem for 25% ("0.900") solutions.

Ammonia solutions should not be mixed with [halogens](/wiki/Halogen), as toxic and/or explosive products are formed. Prolonged contact of ammonia solutions with [silver](/wiki/Silver), [mercury](/wiki/Mercury_(element)) or [iodide](/wiki/Iodide) salts can also lead to explosive products: such mixtures are often formed in [qualitative inorganic analysis](/wiki/Qualitative_inorganic_analysis), and should be lightly acidified but not concentrated (<6% w/v) before disposal once the test is completed.

### Laboratory use of anhydrous ammonia (gas or liquid)[[edit](/index.php?title=(none)&action=edit&section=35)]

Anhydrous ammonia is classified as toxic (**T**) and dangerous for the environment (**N**). The gas is flammable ([autoignition temperature](/wiki/Autoignition_temperature): 651 °C) and can form explosive mixtures with air (16–25%). The [permissible exposure limit](/wiki/Permissible_exposure_limit) (PEL) in the United States is 50 [ppm](/wiki/Parts_per_million) (35 mg/m3), while the [IDLH](/wiki/IDLH) concentration is estimated at 300 ppm. Repeated exposure to ammonia lowers the sensitivity to the smell of the gas: normally the odour is detectable at concentrations of less than 50 ppm, but desensitised individuals may not detect it even at concentrations of 100 ppm. Anhydrous ammonia corrodes [copper](/wiki/Copper)- and [zinc](/wiki/Zinc)-containing [alloys](/wiki/Alloy), and so [brass](/wiki/Brass) fittings should not be used for handling the gas. Liquid ammonia can also attack [rubber](/wiki/Rubber) and certain plastics.

Ammonia reacts violently with the halogens. [Nitrogen triiodide](/wiki/Nitrogen_triiodide), a [primary](/wiki/Primary_explosive) [high explosive](/wiki/High_explosive), is formed when ammonia comes in contact with [iodine](/wiki/Iodine). Ammonia causes the explosive [polymerisation](/wiki/Polymerisation) of [ethylene oxide](/wiki/Ethylene_oxide). It also forms explosive [fulminating](/wiki/Fulminating) compounds with compounds of [gold](/wiki/Gold), [silver](/wiki/Silver), [mercury](/wiki/Mercury_(element)), [germanium](/wiki/Germanium) or [tellurium](/wiki/Tellurium), and with [stibine](/wiki/Stibine). Violent reactions have also been reported with [acetaldehyde](/wiki/Acetaldehyde), [hypochlorite](/wiki/Hypochlorite) solutions, [potassium ferricyanide](/wiki/Potassium_ferricyanide) and [peroxides](/wiki/Peroxide).

## Synthesis and production[[edit](/index.php?title=(none)&action=edit&section=36)]

[Template:See also](/wiki/Template:See_also) *This section is about industrial synthesis. For synthesis in certain organisms, see section* [*Template:Section link*](/wiki/Template:Section_link) *below.* [thumb|300px|right|Production trend of ammonia between 1947 and 2007](/wiki/File:Production_of_ammonia.svg) Because of its many uses, ammonia is one of the most highly produced inorganic chemicals. Dozens of [chemical plants](/wiki/Chemical_plant) worldwide produce ammonia. Consuming more than 1% of all man-made power, [ammonia production](/wiki/Ammonia_production) is a significant component of the world energy budget.<ref name=Ullmann/> The USGS reports global ammonia production in 2014 was 176 million tonnes.[[18]](#cite_note-18) China accounted for 32.6% of that (increasingly from coal as part of [urea](/wiki/Urea) synthesis), followed by Russia at 8.1%, India at 7.6%, and the United States at 6.4%.[[18]](#cite_note-18) About 88% of the ammonia produced was used for fertilizing agricultural crops.[[18]](#cite_note-18) Before the start of [World War I](/wiki/World_War_I), most ammonia was obtained by the [dry distillation](/wiki/Dry_distillation)[[48]](#cite_note-48) of nitrogenous vegetable and animal waste products, including [camel](/wiki/Camel) [dung](/wiki/Manure), where it was [distilled](/wiki/Distillation) by the reduction of [nitrous acid](/wiki/Nitrous_acid) and [nitrites](/wiki/Nitrite) with hydrogen; in addition, it was produced by the distillation of [coal](/wiki/Coal), and also by the decomposition of ammonium salts by [alkaline](/wiki/Alkaline) hydroxides[[49]](#cite_note-49) such as [quicklime](/wiki/Calcium_oxide), the salt most generally used being the chloride ([sal ammoniac](/wiki/Sal_ammoniac)) thus:

2 NH4Cl + 2 CaO → CaCl2 + Ca(OH)2 + 2 NH3

Hydrogen for ammonia synthesis could also be produced economically by using the [water gas](/wiki/Water_gas) reaction followed by the [water gas shift](/wiki/Water_gas_shift) reaction, produced by passing steam through red-hot [coke](/wiki/Coke_(fuel)), to give a mixture of hydrogen and carbon dioxide gases, followed by removal of the carbon dioxide "washing" the gas mixture with water under pressure ([Template:Convert](/wiki/Template:Convert));[[50]](#cite_note-50) or by using other sources like coal or coke gasification.

Modern ammonia-producing plants depend on industrial [hydrogen production](/wiki/Hydrogen_production) to react with atmospheric nitrogen using a [magnetite](/wiki/Magnetite) [catalyst](/wiki/Catalyst) or over a promoted Fe catalyst under high pressure ([Template:Convert](/wiki/Template:Convert)) and temperature (450 °C) to form anhydrous liquid ammonia. This step is known as the ammonia synthesis loop (also referred to as the [Haber–Bosch process](/wiki/Haber_process)):[[51]](#cite_note-51)

3 H2 + N2 → 2 NH3

Hydrogen required for ammonia synthesis could also be produced economically using other sources like coal or coke gasification or less economically from the electrolysis of water into oxygen + hydrogen and other alternatives that are presently impractical for large scale. At one time, most of Europe's ammonia was produced from the Hydro plant at [Vemork](/wiki/Vemork), via the electrolysis route. Various renewable energy electricity sources are also potentially applicable.

As a sustainable alternative to the relatively inefficient [electrolysis](/wiki/Electrolysis), hydrogen can be generated from organic wastes (such as biomass or food-industry waste), using [catalytic reforming](/wiki/Catalytic_reforming). This releases hydrogen from carbonaceous substances at only 10-20% of energy used by electrolysis and may lead to hydrogen being produced from municipal wastes at below zero cost (allowing for the tipping fees and efficient catalytic reforming, such as cold-plasma). Catalytic (thermal) reforming is possible in small, distributed (even mobile) plants, to take advantage of low-value, stranded biomass/biowaste or natural gas deposits. Conversion of such wastes into ammonia solves the problem of hydrogen storage, as hydrogen can be released economically from ammonia on-demand, without the need for high-pressure or cryogenic storage.

It is also easier to store ammonia on board vehicles than to store hydrogen, as ammonia is less flammable than petrol or LPG.

For small scale laboratory synthesis, one can heat urea and Ca(OH)2

(NH2)2CO + Ca(OH)2 → CaCO3 + 2 NH3

## Liquid ammonia as a solvent[[edit](/index.php?title=(none)&action=edit&section=37)]

[Template:See also](/wiki/Template:See_also) Liquid ammonia is the best-known and most widely studied nonaqueous ionising solvent. Its most conspicuous property is its ability to dissolve alkali metals to form highly coloured, electrically conductive solutions containing [solvated electrons](/wiki/Solvated_electron). Apart from these remarkable solutions, much of the chemistry in liquid ammonia can be classified by analogy with related reactions in aqueous solutions. Comparison of the physical properties of NH3 with those of water shows NH3 has the lower melting point, boiling point, density, [viscosity](/wiki/Viscosity), [dielectric constant](/wiki/Dielectric_constant) and [electrical conductivity](/wiki/Electrical_conductivity); this is due at least in part to the weaker hydrogen bonding in NH3 and because such bonding cannot form cross-linked networks, since each NH3 molecule has only one lone pair of electrons compared with two for each H2O molecule. The ionic self-[dissociation constant](/wiki/Dissociation_constant) of liquid NH3 at −50 °C is about 10−33 mol2·l−2.

### Solubility of salts[[edit](/index.php?title=(none)&action=edit&section=38)]

{| |- ! ! Solubility (g of salt per 100 g liquid NH3) |- | [Ammonium acetate](/wiki/Ammonium_acetate) | 253.2 |- | [Ammonium nitrate](/wiki/Ammonium_nitrate) | 389.6 |- | [Lithium nitrate](/wiki/Lithium_nitrate) | 243.7 |- | [Sodium nitrate](/wiki/Sodium_nitrate) | 97.6 |- | [Potassium nitrate](/wiki/Potassium_nitrate) | 10.4 |- | [Sodium fluoride](/wiki/Sodium_fluoride) | 0.35 |- | [Sodium chloride](/wiki/Sodium_chloride) | 157.0 |- | [Sodium bromide](/wiki/Sodium_bromide) | 138.0 |- | [Sodium iodide](/wiki/Sodium_iodide) | 161.9 |- | [Sodium thiocyanate](/wiki/Sodium_thiocyanate) | 205.5 |}

Liquid ammonia is an ionising solvent, although less so than water, and dissolves a range of ionic compounds, including many [nitrates](/wiki/Nitrate), [nitrites](/wiki/Nitrite), [cyanides](/wiki/Cyanide) and [thiocyanates](/wiki/Thiocyanate). Most ammonium salts are soluble and act as acids in liquid ammonia solutions. The solubility of [halide](/wiki/Halide) salts increases from [fluoride](/wiki/Fluoride) to [iodide](/wiki/Iodide). A saturated solution of [ammonium nitrate](/wiki/Ammonium_nitrate) contains 0.83 mol solute per mole of ammonia and has a [vapour pressure](/wiki/Vapour_pressure) of less than 1 bar even at [Template:Convert](/wiki/Template:Convert).

### Solutions of metals[[edit](/index.php?title=(none)&action=edit&section=39)]

[Template:See also](/wiki/Template:See_also) Liquid ammonia will dissolve the [alkali metals](/wiki/Alkali_metal) and other [electropositive](/wiki/Electronegativity) metals such as [magnesium](/wiki/Magnesium), [calcium](/wiki/Calcium), [strontium](/wiki/Strontium), [barium](/wiki/Barium), [europium](/wiki/Europium) and [ytterbium](/wiki/Ytterbium). At low concentrations (<0.06 mol/l), deep blue solutions are formed: these contain metal cations and [solvated electrons](/wiki/Solvated_electron), free electrons that are surrounded by a cage of ammonia molecules.

These solutions are very useful as strong reducing agents. At higher concentrations, the solutions are metallic in appearance and in electrical conductivity. At low temperatures, the two types of solution can coexist as [immiscible](/wiki/Wiktionary:immiscible) phases.

### Redox properties of liquid ammonia[[edit](/index.php?title=(none)&action=edit&section=40)]

[Template:See also](/wiki/Template:See_also) {| cellpadding="5" style="text-align:center" |- ! ! [*E*°](/wiki/Standard_electrode_potential) (V, ammonia) ! [*E*°](/wiki/Standard_electrode_potential) (V, water) |- | Li+ + e− ⇌ Li | −2.24 | −3.04 |- | K+ + e− ⇌ K | −1.98 | −2.93 |- | Na+ + e− ⇌ Na | −1.85 | −2.71 |- | Zn2+ + 2e− ⇌ Zn | −0.53 | −0.76 |- | NH4+ + e− ⇌ ½ H2 + NH3 | 0.00 | — |- | Cu2+ + 2e− ⇌ Cu | +0.43 | +0.34 |- | Ag+ + e− ⇌ Ag | +0.83 | +0.80 |}

The range of thermodynamic stability of liquid ammonia solutions is very narrow, as the potential for oxidation to dinitrogen, [*E*°](/wiki/Standard_electrode_potential) (N2 + 6NH4+ + 6e− ⇌ 8NH3), is only +0.04 V. In practice, both oxidation to dinitrogen and reduction to dihydrogen are slow. This is particularly true of reducing solutions: the solutions of the alkali metals mentioned above are stable for several days, slowly decomposing to the [metal amide](/wiki/Amide) and dihydrogen. Most studies involving liquid ammonia solutions are done in reducing conditions; although oxidation of liquid ammonia is usually slow, there is still a risk of explosion, particularly if transition metal ions are present as possible catalysts.

## Ammonia's role in biological systems and human disease[[edit](/index.php?title=(none)&action=edit&section=41)]

[thumb|250px|Main symptoms of hyperammonemia (ammonia reaching toxic concentrations).](/wiki/File:Symptoms_of_hyperammonemia.svg)[[52]](#cite_note-52)

Ammonia is both a [metabolic waste](/wiki/Metabolic_waste) and a metabolic input throughout the [biosphere](/wiki/Biosphere). It is an important source of nitrogen for living systems. Although atmospheric nitrogen abounds (more than 75%), few living creatures are capable of using this atmospheric nitrogen in its diatomic form, N2 gas. Therefore, [nitrogen fixation](/wiki/Nitrogen_fixation) is required for the synthesis of amino acids, which are the building blocks of [protein](/wiki/Protein). Some plants rely on ammonia and other nitrogenous wastes incorporated into the soil by decaying matter. Others, such as nitrogen-fixing [legumes](/wiki/Legume), benefit from [symbiotic](/wiki/Symbiosis) relationships with [rhizobia](/wiki/Rhizobia) that create ammonia from atmospheric nitrogen.[[53]](#cite_note-53)

### Biosynthesis[[edit](/index.php?title=(none)&action=edit&section=42)]

In certain organisms, ammonia is produced from atmospheric nitrogen by [enzymes](/wiki/Enzyme) called [nitrogenases](/wiki/Nitrogenase). The overall process is called [nitrogen fixation](/wiki/Nitrogen_fixation). Although it is unlikely that biomimetic methods that are competitive with the [Haber process](/wiki/Haber_process) will be developed,[Template:Citation needed](/wiki/Template:Citation_needed) intense effort has been directed toward understanding the mechanism of biological nitrogen fixation. The scientific interest in this problem is motivated by the unusual structure of the active site of the enzyme, which consists of an Fe7MoS9 ensemble.

Ammonia is also a metabolic product of [amino acid](/wiki/Amino_acid) [deamination](/wiki/Deamination) catalyzed by enzymes such as [glutamate dehydrogenase 1](/wiki/Glutamate_dehydrogenase_1#Function). Ammonia excretion is common in aquatic animals. In humans, it is quickly converted to [urea](/wiki/Urea), which is much less toxic, particularly less [basic](/wiki/#Basicity). This urea is a major component of the dry weight of [urine](/wiki/Urine). Most reptiles, birds, insects, and snails excrete [uric acid](/wiki/Uric_acid) solely as nitrogenous waste.

### In physiology[[edit](/index.php?title=(none)&action=edit&section=43)]

Ammonia also plays a role in both normal and abnormal animal [physiology](/wiki/Physiology). It is biosynthesised through normal amino acid metabolism and is toxic in high concentrations.[[54]](#cite_note-54) The [liver](/wiki/Liver) converts ammonia to urea through a series of reactions known as the [urea cycle](/wiki/Urea_cycle). Liver dysfunction, such as that seen in [cirrhosis](/wiki/Cirrhosis), may lead to elevated amounts of ammonia in the blood ([hyperammonemia](/wiki/Hyperammonemia)). Likewise, defects in the enzymes responsible for the urea cycle, such as [ornithine transcarbamylase](/wiki/Ornithine_transcarbamylase), lead to hyperammonemia. Hyperammonemia contributes to the confusion and [coma](/wiki/Coma) of [hepatic encephalopathy](/wiki/Hepatic_encephalopathy), as well as the neurologic disease common in people with urea cycle defects and [organic acidurias](/wiki/Organic_aciduria).[[55]](#cite_note-55) Ammonia is important for normal animal acid/base balance. After formation of ammonium from [glutamine](/wiki/Glutamine), [α-ketoglutarate](/wiki/Α-ketoglutarate) may be degraded to produce two molecules of [bicarbonate](/wiki/Bicarbonate), which are then available as buffers for dietary acids. Ammonium is excreted in the urine, resulting in net acid loss. Ammonia may itself diffuse across the renal tubules, combine with a hydrogen ion, and thus allow for further acid excretion.[[56]](#cite_note-56)

### Excretion[[edit](/index.php?title=(none)&action=edit&section=44)]

[Template:Main](/wiki/Template:Main) Ammonium ions are a [toxic](/wiki/Toxic) waste product of [metabolism](/wiki/Metabolism) in [animals](/wiki/Animal). In fish and aquatic invertebrates, it is excreted directly into the water. In mammals, sharks, and amphibians, it is converted in the [urea cycle](/wiki/Urea_cycle) to [urea](/wiki/Urea), because it is less toxic and can be stored more efficiently. In birds, reptiles, and terrestrial snails, metabolic ammonium is converted into [uric acid](/wiki/Uric_acid), which is solid, and can therefore be excreted with minimal water loss.[[57]](#cite_note-57)[Template:Clear](/wiki/Template:Clear) [Template:Wide image](/wiki/Template:Wide_image)

## In astronomy[[edit](/index.php?title=(none)&action=edit&section=45)]

[thumb||Ammonia occurs in the](/wiki/Image:Jupiter.jpg) [atmospheres](/wiki/Celestial_body_atmosphere) of the outer gas planets such as [Jupiter](/wiki/Jupiter) (0.026% ammonia) and [Saturn](/wiki/Saturn) (0.012% ammonia). Ammonia has been detected in the atmospheres of the [gas giant](/wiki/Gas_giant) planets, including [Jupiter](/wiki/Jupiter), along with other gases like methane, hydrogen, and [helium](/wiki/Helium). The interior of Saturn may include frozen crystals of ammonia.[[58]](#cite_note-58) It is naturally found on [Deimos](/wiki/Deimos_(moon)) and [Phobos](/wiki/Phobos_(moon)) – the two [moons of Mars](/wiki/Moons_of_Mars).

### Interstellar space[[edit](/index.php?title=(none)&action=edit&section=46)]

Ammonia was first detected in interstellar space in 1968, based on [microwave](/wiki/Microwave) emissions from the direction of the [galactic core](/wiki/Milky_Way).[[59]](#cite_note-59) This was the first [polyatomic](/wiki/Polyatomic) molecule to be so detected. The sensitivity of the molecule to a broad range of excitations and the ease with which it can be observed in a number of regions has made ammonia one of the most important molecules for studies of [molecular clouds](/wiki/Molecular_cloud).<ref name=ho>[Template:Cite journal](/wiki/Template:Cite_journal)</ref> The relative intensity of the ammonia lines can be used to measure the temperature of the emitting medium.

The following isotopic species of ammonia have been detected:

NH3, 15NH3, NH2[D](/wiki/Deuterium), NHD2, and ND3

The detection of triply [deuterated](/wiki/Deuterium) ammonia was considered a surprise as deuterium is relatively scarce. It is thought that the low-temperature conditions allow this molecule to survive and accumulate.[[60]](#cite_note-60) Since its interstellar discovery, NH3 has proved to be an invaluable spectroscopic tool in the study of the interstellar medium. With a large number of transitions sensitive to a wide range of excitation conditions, NH3 has been widely astronomically detected – its detection has been reported in hundreds of journal articles. Listed below is a sample of journal articles that highlights the range of detectors that have been used to identify ammonia.

The study of interstellar ammonia has been important to a number of areas of research in the last few decades. Some of these are delineated below and primarily involve using ammonia as an interstellar thermometer.

#### Interstellar formation mechanisms[[edit](/index.php?title=(none)&action=edit&section=47)]

[thumb||250px|Ball-and-stick model of the diamminesilver(I) cation, [Ag(NH3)2]+](/wiki/Image:Diamminesilver(I)-3D-balls.png) The interstellar abundance for ammonia has been measured for a variety of environments. The [NH3]/[H2] ratio has been estimated to range from 10−7 in small dark clouds[[61]](#cite_note-61) up to 10−5 in the dense core of the [Orion Molecular Cloud Complex](/wiki/Orion_Molecular_Cloud_Complex).[[62]](#cite_note-62) Although a total of 18 total production routes have been proposed,[[63]](#cite_note-63) the principal formation mechanism for interstellar NH3 is the reaction:

NH4+ + e− → NH3 + H·

The rate constant, *k*, of this reaction depends on the temperature of the environment, with a value of 5.2×10−6 at 10 K.[[64]](#cite_note-64) The rate constant was calculated from the formula *k = a(T/300)B*. For the primary formation reaction, *a* = 1.05×10−6 and *B* = −0.47. Assuming an NH4+ abundance of 3×10−7 and an electron abundance of 10−7 typical of molecular clouds, the formation will proceed at a rate of 1.6×10−9 cm−3s−1 in a molecular cloud of total density 105 cm−3.[[65]](#cite_note-65) All other proposed formation reactions have rate constants of between 2 and 13 orders of magnitude smaller, making their contribution to the abundance of ammonia relatively insignificant.[[66]](#cite_note-66) As an example of the minor contribution other formation reactions play, the reaction:

H2 + NH2 → NH3 + H

has a rate constant of 2.2×10−15. Assuming H2 densities of 105 and NH2/H2 ratio of 10−7, this reaction proceeds at a rate of 2.2×10−12, more than 3 orders of magnitude slower than the primary reaction above.

Some of the other possible formation reactions are:

H− + NH4+ → NH3 + H2

PNH3+ + e− → P + NH3

#### Interstellar destruction mechanisms[[edit](/index.php?title=(none)&action=edit&section=48)]

There are 113 total proposed reactions leading to the destruction of NH3. Of these, 39 were tabulated in extensive tables of the chemistry among C, N, and O compounds.[[67]](#cite_note-67) A review of interstellar ammonia cites the following reactions as the principal dissociation mechanisms:<ref name=ho/>

(1) NH3 + H3+ → NH4+ + H2

(2) NH3 + HCO+ → NH4+ + CO

with rate constants of 4.39×10−9[[68]](#cite_note-68) and 2.2×10−9,[[69]](#cite_note-69) respectively. The above equations (1,2) run at a rate of 8.8×10−9 and 4.4×10−13, respectively. These calculations assumed the given rate constants and abundances of [NH3]/[H2] = 10−5, [H3+]/[H2] = 2×10−5, [HCO+]/[H2] = 2×10−9, and total densities of n = 105, typical of cold, dense, molecular clouds.[[70]](#cite_note-70) Clearly, between these two primary reactions, equation (1) is the dominant destruction reaction, with a rate ~10,000 times faster than equation (2). This is due to the relatively high abundance of H3+.

#### Single antenna detections[[edit](/index.php?title=(none)&action=edit&section=49)]

Radio observations of NH3 from the [Effelsberg 100-m Radio Telescope](/wiki/Effelsberg_100-m_Radio_Telescope) reveal that the ammonia line is separated into two components – a background ridge and an unresolved core. The background corresponds well with the locations previously detected CO.[[71]](#cite_note-71) The 25 m Chilbolton telescope in England detected radio signatures of ammonia in [H II regions](/wiki/H_II_region), HNH2O [masers](/wiki/Maser), H-H objects, and other objects associated with star formation. A comparison of emission line widths indicates that turbulent or systematic velocities do not increase in the central cores of molecular clouds.[[72]](#cite_note-72) Microwave radiation from ammonia was observed in several galactic objects including W3(OH), [Orion A](/wiki/Orion_(constellation)), W43, W51, and five sources in the galactic centre. The high detection rate indicates that this is a common molecule in the interstellar medium and that high-density regions are common in the galaxy.[[73]](#cite_note-73)

#### Interferometric studies[[edit](/index.php?title=(none)&action=edit&section=50)]

[VLA](/wiki/Very_Large_Array) observations of NH3 in seven regions with high-velocity gaseous outflows revealed condensations of less than 0.1 [pc](/wiki/Parsec) in L1551, S140, and [Cepheus A](/wiki/Cepheus_(constellation)). Three individual condensations were detected in Cepheus A, one of them with a highly elongated shape. They may play an important role in creating the bipolar outflow in the region.[[74]](#cite_note-74) Extragalactic ammonia was imaged using the VLA in [IC 342](/wiki/IC_342). The hot gas has temperatures above 70 K, which was inferred from ammonia line ratios and appears to be closely associated with the innermost portions of the nuclear bar seen in CO.[[75]](#cite_note-75) NH3 was also monitored by VLA toward a sample of four galactic ultracompact HII regions: G9.62+0.19, G10.47+0.03, G29.96−0.02, and G31.41+0.31. Based upon temperature and density diagnostics, it is concluded that in general such clumps are likely to be the sites of massive star formation in an early evolutionary phase prior to the development of an ultracompact HII region.[[76]](#cite_note-76)

#### Infrared detections[[edit](/index.php?title=(none)&action=edit&section=51)]

Absorption at 2.97 micrometres due to solid ammonia was recorded from interstellar grains in the [Becklin-Neugebauer Object](/wiki/Becklin-Neugebauer_Object) and probably in NGC 2264-IR as well. This detection helped explain the physical shape of previously poorly understood and related ice absorption lines.[[77]](#cite_note-77) A spectrum of the disk of Jupiter was obtained from the [Kuiper Airborne Observatory](/wiki/Kuiper_Airborne_Observatory), covering the 100 to 300 cm−1 spectral range. Analysis of the spectrum provides information on global mean properties of ammonia gas and an ammonia ice haze.[[78]](#cite_note-78) A total of 149 dark cloud positions were surveyed for evidence of 'dense cores' by using the (J,K) = (1,1) rotating inversion line of NH3. In general, the cores are not spherically shaped, with aspect ratios ranging from 1.1 to 4.4. It is also found that cores with stars have broader lines than cores without stars.[[79]](#cite_note-79) Ammonia has been detected in the [Draco Nebula](/wiki/Draco_(constellation)) and in one or possibly two molecular clouds, which are associated with the high-latitude galactic [infrared cirrus](/wiki/Infrared_cirrus). The finding is significant because they may represent the birthplaces for the Population I metallicity B-type stars in the galactic halo that could have been borne in the galactic disk.[[80]](#cite_note-80)

#### Observations of nearby dark clouds[[edit](/index.php?title=(none)&action=edit&section=52)]

By balancing and stimulated emission with spontaneous emission, it is possible to construct a relation between [excitation temperature](/wiki/Excitation_temperature) and density. Moreover, since the transitional levels of ammonia can be approximated by a 2-level system at low temperatures, this calculation is fairly simple. This premise can be applied to dark clouds, regions suspected of having extremely low temperatures and possible sites for future star formation. Detections of ammonia in dark clouds show very narrow lines—indicative not only of low temperatures, but also of a low level of inner-cloud turbulence. Line ratio calculations provide a measurement of cloud temperature that is independent of previous CO observations. The ammonia observations were consistent with CO measurements of rotation temperatures of ~10 K. With this, densities can be determined, and have been calculated to range between 104 and 105 cm−3 in dark clouds. Mapping of NH3 gives typical clouds sizes of 0.1 [pc](/wiki/Parsec) and masses near 1 solar mass. These cold, dense cores are the sites of future star formation.

#### UC HII regions[[edit](/index.php?title=(none)&action=edit&section=53)]

Ultra-compact HII regions are among the best tracers of high-mass star formation. The dense material surrounding UCHII regions is likely primarily molecular. Since a complete study of massive star formation necessarily involves the cloud from which the star formed, ammonia is an invaluable tool in understanding this surrounding molecular material. Since this molecular material can be spatially resolved, it is possible to constrain the heating/ionising sources, temperatures, masses, and sizes of the regions. Doppler-shifted velocity components allow for the separation of distinct regions of molecular gas that can trace outflows and hot cores originating from forming stars.

#### Extragalactic detection[[edit](/index.php?title=(none)&action=edit&section=54)]

Ammonia has been detected in external galaxies, and by simultaneously measuring several lines, it is possible to directly measure the gas temperature in these galaxies. Line ratios imply that gas temperatures are warm (~50 K), originating from dense clouds with sizes of tens of pc. This picture is consistent with the picture within our [Milky Way](/wiki/Milky_Way) galaxy—hot dense molecular cores form around newly forming stars embedded in larger clouds of molecular material on the scale of several hundred pc (giant molecular clouds; GMCs).

## See also[[edit](/index.php?title=(none)&action=edit&section=55)]

* [Ammonia (data page)](/wiki/Ammonia_(data_page))
* [Ammonia fountain](/wiki/Ammonia_fountain)
* [Ammonia production](/wiki/Ammonia_production)
* [Cost of electricity by source](/wiki/Cost_of_electricity_by_source)
* [Forming gas](/wiki/Forming_gas)
* [Haber process](/wiki/Haber_process)
* [Water purification](/wiki/Water_purification)

## Notes[[edit](/index.php?title=(none)&action=edit&section=56)]

[Template:Reflist](/wiki/Template:Reflist)

## References[[edit](/index.php?title=(none)&action=edit&section=57)]

* [Template:Cite web](/wiki/Template:Cite_web)

Attribution

* [Template:EB1911](/wiki/Template:EB1911)

## Further reading[[edit](/index.php?title=(none)&action=edit&section=58)]

* [Template:Cite book](/wiki/Template:Cite_book)
* [Template:Greenwood&Earnshaw2nd](/wiki/Template:Greenwood&Earnshaw2nd)
* [Template:Housecroft1st](/wiki/Template:Housecroft1st)
* [Template:RubberBible53rd](/wiki/Template:RubberBible53rd)

## External links[[edit](/index.php?title=(none)&action=edit&section=59)]

[Template:Commons category](/wiki/Template:Commons_category)

* [International Chemical Safety Card 0414](http://www.inchem.org/documents/icsc/icsc/eics0414.htm) (anhydrous ammonia), ilo.org.
* [International Chemical Safety Card 0215](http://www.inchem.org/documents/icsc/icsc/eics0215.htm) (aqueous solutions), ilo.org.
* [Template:PubChemLink](/wiki/Template:PubChemLink)
* [Template:Cite web](/wiki/Template:Cite_web)
* [Emergency Response to Ammonia Fertilizer Releases (Spills)](http://www.ammoniaspills.org/) for the Minnesota Department of Agriculture.ammoniaspills.org
* [National Institute for Occupational Safety and Health – Ammonia Page](http://www.cdc.gov/niosh/topics/ammonia), cdc.gov
* [NIOSH Pocket Guide to Chemical Hazards - Ammonia](http://www.cdc.gov/niosh/npg/npgd0028.html), cdc.gov
* [Ammonia, video](http://www.mozalearn.com/Extra-Videos-Ammonia_NH3-210353)

[Template:Molecules detected in outer space](/wiki/Template:Molecules_detected_in_outer_space) [Template:Nitrogen compounds](/wiki/Template:Nitrogen_compounds) [Template:Authority control](/wiki/Template:Authority_control)

[Category:Bases](/wiki/Category:Bases) [Category:Household chemicals](/wiki/Category:Household_chemicals) [Category:Industrial gases](/wiki/Category:Industrial_gases) [Category:Inorganic amines](/wiki/Category:Inorganic_amines) [Category:Inorganic solvents](/wiki/Category:Inorganic_solvents) [Category:Nitrogen hydrides](/wiki/Category:Nitrogen_hydrides) [Category:Nitrogen cycle](/wiki/Category:Nitrogen_cycle) [Category:Refrigerants](/wiki/Category:Refrigerants) [Category:Toxicology](/wiki/Category:Toxicology) [Category:Gaseous signaling molecules](/wiki/Category:Gaseous_signaling_molecules) [Category:nitrogen compounds](/wiki/Category:nitrogen_compounds)