**Ammonia**

**Ammonia** is an [inorganic](https://en.wikipedia.org/wiki/Inorganic) [compound](https://en.wikipedia.org/wiki/Chemical_compound) of [nitrogen](https://en.wikipedia.org/wiki/Nitrogen) and [hydrogen](https://en.wikipedia.org/wiki/Hydrogen) with the [formula](https://en.wikipedia.org/wiki/Chemical_formula) NH3. A [stable binary hydride](https://en.wikipedia.org/wiki/Binary_compounds_of_hydrogen), and the simplest [pnictogen hydride](https://en.wikipedia.org/wiki/Pnictogen_hydride), ammonia is a colorless [gas](https://en.wikipedia.org/wiki/Gas) with a distinct pungent smell. Biologically, it is a common [nitrogenous waste](https://en.wikipedia.org/wiki/Metabolic_waste#Nitrogen_wastes), particularly among aquatic organisms, and it contributes significantly to the [nutritional](https://en.wikipedia.org/wiki/Nutrition) needs of terrestrial organisms by serving as a precursor to 45 percent of the world's [food](https://en.wikipedia.org/wiki/Food)[[12]](https://en.wikipedia.org/wiki/Ammonia#cite_note-12) and [fertilizers](https://en.wikipedia.org/wiki/Fertilizer). Around 70% of ammonia is used to make fertilisers [[13]](https://en.wikipedia.org/wiki/Ammonia#cite_note-13) in various forms and composition, such as [urea](https://en.wikipedia.org/wiki/Urea) and [Diammonium phosphate](https://en.wikipedia.org/wiki/Diammonium_phosphate). Ammonia in pure form is also applied directly into the soil. It is estimated that around 40% of the nitrogen in human beings originally comes from industrial ammonia production. As such, its importance can hardly be overstated.

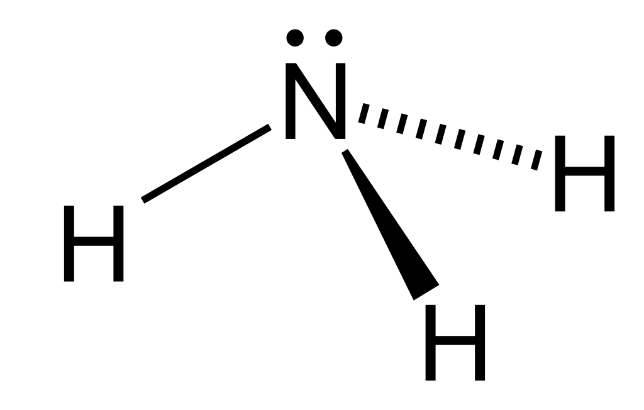


Figure Stereo structural formula of the ammonia molecule

Ammonia, either directly or indirectly, is also a building block for the synthesis of many [pharmaceutical products](https://en.wikipedia.org/wiki/Pharmaceuticals) and is used in many commercial cleaning products. It is mainly collected by downward displacement of both air and water.

Although common in nature—both terrestrially and in the [outer planets](https://en.wikipedia.org/wiki/Solar_System#Outer_Solar_System) of the [Solar System](https://en.wikipedia.org/wiki/Solar_System)—and in wide use, ammonia is both [caustic](https://en.wikipedia.org/wiki/Caustic_(substance)) and [hazardous](https://en.wikipedia.org/wiki/Hazard) in its concentrated form. In many countries it is classified as an [extremely hazardous substance](https://en.wikipedia.org/wiki/List_of_extremely_hazardous_substances), and is subject to strict reporting requirements by facilities which produce, store, or use it in significant quantities.[[14]](https://en.wikipedia.org/wiki/Ammonia#cite_note-gov-right-know-14)

The global industrial production of ammonia in 2018 was 175 million tonnes,[[15]](https://en.wikipedia.org/wiki/Ammonia#cite_note-USGS2020-15) with no significant change relative to the 2013 global industrial production of 175 million tonnes.[[16]](https://en.wikipedia.org/wiki/Ammonia#cite_note-16) In 2021 this was 235 million tonnes, with very little being made within the United States.[[17]](https://en.wikipedia.org/wiki/Ammonia#cite_note-17)[[18]](https://en.wikipedia.org/wiki/Ammonia#cite_note-18) Industrial ammonia is sold either as [ammonia liquor](https://en.wikipedia.org/wiki/Ammonia_liquor) (usually 28% ammonia in water) or as pressurized or refrigerated anhydrous liquid ammonia transported in tank cars or cylinders.[[19]](https://en.wikipedia.org/wiki/Ammonia#cite_note-19)

**Ammonia solution**, also known as **ammonia water**, **ammonium hydroxide**, **ammoniacal liquor**, **ammonia liquor**, **aqua ammonia**, **aqueous ammonia**, or (inaccurately) **ammonia**, is a solution of [ammonia](https://en.wikipedia.org/wiki/Ammonia) in water. It can be denoted by the symbols NH3(aq). Although the name ammonium hydroxide suggests an alkali with [composition](https://en.wikipedia.org/wiki/Chemical_formula) [NH4+][OH−], it is actually impossible to isolate samples of NH4OH. The ions NH+  
4 and OH− do not account for a significant fraction of the total amount of ammonia except in extremely dilute solutions.[[6](https://en.wikipedia.org/wiki/Ammonia_solution#cite_note-6)

For fundamental reasons, the production of ammonia from the elements hydrogen and nitrogen is difficult, requiring high pressures and high temperatures. The [Haber process](https://en.wikipedia.org/wiki/Haber_process) that enabled industrial production was invented at the beginning of the twentieth century, revolutionizing agriculture.

NH3 boils at −33.34 °C (−28.012 °F) at a pressure of one [atmosphere](https://en.wikipedia.org/wiki/Atmosphere_(unit)), so the liquid must be stored under pressure or at low temperature. Household ammonia or [ammonium hydroxide](https://en.wikipedia.org/wiki/Ammonium_hydroxide) is a solution of NH3 in water. The concentration of such solutions is measured in units of the [Baumé scale](https://en.wikipedia.org/wiki/Baum%C3%A9_scale) ([density](https://en.wikipedia.org/wiki/Density)), with 26 degrees Baumé (about 30% (by weight) ammonia at 15.5 °C or 59.9 °F) being the typical high-concentration commercial product.[[20]](https://en.wikipedia.org/wiki/Ammonia#cite_note-LaRoche-20)

## Properties

Ammonia is a colourless [gas](https://en.wikipedia.org/wiki/Gas) with a characteristically [pungent smell](https://en.wikipedia.org/wiki/Pungency). It is [lighter than air](https://en.wikipedia.org/wiki/Lighter_than_air), its density being 0.589 times that of [air](https://en.wikipedia.org/wiki/Earth%27s_atmosphere). It is easily liquefied due to the strong [hydrogen bonding](https://en.wikipedia.org/wiki/Hydrogen_bond) between molecules; the [liquid](https://en.wikipedia.org/wiki/Liquid) [boils](https://en.wikipedia.org/wiki/Boiling_point) at −33.1 °C (−27.58 °F), and [freezes](https://en.wikipedia.org/wiki/Melting_point) to white crystals[[23]](https://en.wikipedia.org/wiki/Ammonia#cite_note-FOOTNOTEChisholm1911861-23) at −77.7 °C (−107.86 °F).

**Solid**

The crystal symmetry is cubic, [Pearson symbol](https://en.wikipedia.org/wiki/Pearson_symbol) cP16, [space group](https://en.wikipedia.org/wiki/Space_group) P213 No.198, lattice constant 0.5125 [nm](https://en.wikipedia.org/wiki/Nanometre).[[27]](https://en.wikipedia.org/wiki/Ammonia#cite_note-27)

**Liquid**

[Liquid](https://en.wikipedia.org/wiki/Liquid) ammonia possesses strong [ionising](https://en.wikipedia.org/wiki/Ion" \o "Ion) powers reflecting its high [ε](https://en.wikipedia.org/wiki/Dielectric_constant) of 22. Liquid ammonia has a very high [standard enthalpy change of vaporization](https://en.wikipedia.org/wiki/Enthalpy_of_vaporization) (23.35 [kJ/mol](https://en.wikipedia.org/wiki/KJ/mol), *cf.* [water](https://en.wikipedia.org/wiki/Properties_of_water) 40.65 kJ/mol, methane 8.19 kJ/mol, [phosphine](https://en.wikipedia.org/wiki/Phosphine) 14.6 kJ/mol) and can therefore be used in laboratories in uninsulated vessels without additional refrigeration. See [liquid ammonia as a solvent](https://en.wikipedia.org/wiki/Ammonia#Solvent).

**Solvent properties**

Ammonia readily [dissolves](https://en.wikipedia.org/wiki/Solubility) in water. In an aqueous solution, it can be expelled by boiling. The [aqueous](https://en.wikipedia.org/wiki/Water) solution of ammonia is [basic](https://en.wikipedia.org/wiki/Base_(chemistry)). The maximum concentration of ammonia in water (a [saturated solution](https://en.wikipedia.org/wiki/Saturated_solution)) has a [density](https://en.wikipedia.org/wiki/Density) of 0.880 g/cm3 and is often known as '.880 ammonia'.

**Combustion**

Ammonia does not burn readily or sustain [combustion](https://en.wikipedia.org/wiki/Combustion), except under narrow fuel-to-air mixtures of 15–25% air. When mixed with [oxygen](https://en.wikipedia.org/wiki/Oxygen), it burns with a pale yellowish-green flame. Ignition occurs when [chlorine](https://en.wikipedia.org/wiki/Chlorine) is passed into ammonia, forming nitrogen and [hydrogen chloride](https://en.wikipedia.org/wiki/Hydrogen_chloride); if chlorine is present in excess, then the highly explosive [nitrogen trichloride](https://en.wikipedia.org/wiki/Nitrogen_trichloride) (NCl3) is also formed.

**Decomposition**

At high temperature and in the presence of a suitable catalyst or in a pressurized vessel with constant volume and high temperature (e.g. 1,100 °C (2,010 °F)), ammonia is decomposed into its constituent elements.[[28]](https://en.wikipedia.org/wiki/Ammonia#cite_note-28) Decomposition of ammonia is a slightly endothermic process requiring 23 kJ/mol (5.5 [kcal/mol](https://en.wikipedia.org/wiki/Kcal/mol)) of ammonia, and yields [hydrogen](https://en.wikipedia.org/wiki/Hydrogen) and [nitrogen](https://en.wikipedia.org/wiki/Nitrogen) gas. Ammonia can also be used as a source of hydrogen for acid [fuel cells](https://en.wikipedia.org/wiki/Fuel_cell) if the unreacted ammonia can be removed. [Ruthenium](https://en.wikipedia.org/wiki/Ruthenium) and [platinum](https://en.wikipedia.org/wiki/Platinum) [catalysts](https://en.wikipedia.org/wiki/Catalysts) were found to be the most active, whereas supported [Ni](https://en.wikipedia.org/wiki/Nickel) catalysts were less active.

### Structure

The ammonia molecule has a [trigonal pyramidal](https://en.wikipedia.org/wiki/Trigonal_pyramid_(chemistry)) shape as predicted by the [valence shell electron pair repulsion theory](https://en.wikipedia.org/wiki/Valence_shell_electron_pair_repulsion_theory) (VSEPR theory) with an experimentally determined bond angle of 106.7°.[[29]](https://en.wikipedia.org/wiki/Ammonia#cite_note-CRC_94th-29) The central nitrogen atom has five outer electrons with an additional electron from each hydrogen atom. This gives a total of eight electrons, or four electron pairs that are arranged [tetrahedrally](https://en.wikipedia.org/wiki/Tetrahedron). Three of these [electron pairs](https://en.wikipedia.org/wiki/Electron_pair) are used as bond pairs, which leaves one [lone pair](https://en.wikipedia.org/wiki/Lone_pair) of electrons. The lone pair repels more strongly than bond pairs, therefore the bond angle is not 109.5°, as expected for a regular tetrahedral arrangement, but 106.8°.[[29]](https://en.wikipedia.org/wiki/Ammonia#cite_note-CRC_94th-29) This shape gives the molecule a [dipole](https://en.wikipedia.org/wiki/Dipole) moment and makes it [polar](https://en.wikipedia.org/wiki/Polar_molecule). The molecule's polarity, and especially, its ability to form [hydrogen bonds](https://en.wikipedia.org/wiki/Hydrogen_bond), makes ammonia highly miscible with water. The lone pair makes ammonia a [base](https://en.wikipedia.org/wiki/Base_(chemistry)), a proton acceptor. Ammonia is moderately basic; a 1.0 M [aqueous solution](https://en.wikipedia.org/wiki/Aqueous_solution) has a [pH](https://en.wikipedia.org/wiki/PH) of 11.6, and if a strong acid is added to such a solution until the solution is neutral (pH = 7), 99.4% of the ammonia molecules are [protonated](https://en.wikipedia.org/wiki/Protonation). Temperature and [salinity](https://en.wikipedia.org/wiki/Salinity) also affect the proportion of NH+4. The latter has the shape of a regular [tetrahedron](https://en.wikipedia.org/wiki/Tetrahedron) and is [isoelectronic](https://en.wikipedia.org/wiki/Isoelectronic) with [methane](https://en.wikipedia.org/wiki/Methane).

The ammonia molecule readily undergoes [nitrogen inversion](https://en.wikipedia.org/wiki/Nitrogen_inversion) at room temperature; a useful analogy is an [umbrella](https://en.wikipedia.org/wiki/Umbrella) turning itself inside out in a strong wind. The [energy barrier](https://en.wikipedia.org/wiki/Activation_energy) to this inversion is 24.7 kJ/mol, and the [resonance frequency](https://en.wikipedia.org/wiki/Resonance_frequency) is 23.79 [GHz](https://en.wikipedia.org/wiki/Hertz), corresponding to [microwave](https://en.wikipedia.org/wiki/Microwave) radiation of a [wavelength](https://en.wikipedia.org/wiki/Wavelength) of 1.260 cm. The absorption at this frequency was the first [microwave spectrum](https://en.wikipedia.org/wiki/Microwave_spectroscopy) to be observed [[30]](https://en.wikipedia.org/wiki/Ammonia#cite_note-Cleeton-30) and was used in the first [maser](https://en.wikipedia.org/wiki/Maser).

### Amphotericity

One of the most characteristic properties of ammonia is its [basicity](https://en.wikipedia.org/wiki/Basicity). Ammonia is considered to be a weak base. It combines with [acids](https://en.wikipedia.org/wiki/Acid) to form [salts](https://en.wikipedia.org/wiki/Salt_(chemistry)); thus with [hydrochloric acid](https://en.wikipedia.org/wiki/Hydrochloric_acid) it forms [ammonium chloride](https://en.wikipedia.org/wiki/Ammonium_chloride) (sal ammoniac); with [nitric acid](https://en.wikipedia.org/wiki/Nitric_acid), [ammonium nitrate](https://en.wikipedia.org/wiki/Ammonium_nitrate), etc. Perfectly dry ammonia gas will not combine with perfectly dry [hydrogen chloride](https://en.wikipedia.org/wiki/Hydrogen_chloride) gas; moisture is necessary to bring about the reaction.[[31]](https://en.wikipedia.org/wiki/Ammonia#cite_note-FOOTNOTEChisholm1911862-31)[[32]](https://en.wikipedia.org/wiki/Ammonia#cite_note-32)

As a demonstration experiment under air with ambient moisture, opened bottles of concentrated ammonia and [hydrochloric acid](https://en.wikipedia.org/wiki/Hydrochloric_acid) solutions produce a cloud of [ammonium chloride](https://en.wikipedia.org/wiki/Ammonium_chloride), which seems to appear "out of nothing" as the salt [aerosol](https://en.wikipedia.org/wiki/Aerosol) forms where the two [diffusing](https://en.wikipedia.org/wiki/Diffusion) clouds of reagents meet between the two bottles.

NH3 + HCl → [NH4]Cl

The salts produced by the action of ammonia on acids are known as the [ammonium salts](https://en.wikipedia.org/wiki/Category:Ammonium_compounds) and all contain the [ammonium ion](https://en.wikipedia.org/wiki/Ammonium) (NH+4).[[31]](https://en.wikipedia.org/wiki/Ammonia#cite_note-FOOTNOTEChisholm1911862-31)

Although ammonia is well known as a weak base, it can also act as an extremely weak acid. It is a [protic substance](https://en.wikipedia.org/wiki/Protic) and is capable of formation of [amides](https://en.wikipedia.org/wiki/Amide) (which contain the NH−2 ion). For example, [lithium](https://en.wikipedia.org/wiki/Lithium) dissolves in [liquid ammonia](https://en.wikipedia.org/wiki/Liquid_ammonia) to give a blue solution ([solvated electron](https://en.wikipedia.org/wiki/Solvated_electron)) of [lithium amide](https://en.wikipedia.org/wiki/Lithium_amide):

2 Li + 2 NH3 → 2 LiNH2 + H2

### Self-dissociation

Like water, liquid ammonia undergoes [molecular autoionisation](https://en.wikipedia.org/wiki/Molecular_autoionisation) to form its [acid and base conjugates](https://en.wikipedia.org/wiki/Conjugate_acid):

2 NH3 ⇌ NH+4 + NH−2

Ammonia often functions as a [weak base](https://en.wikipedia.org/wiki/Weak_base), so it has some [buffering](https://en.wikipedia.org/wiki/Buffer_solution) ability. Shifts in pH will cause more or fewer [ammonium](https://en.wikipedia.org/wiki/Ammonium) cations (NH+4) and [amide anions](https://en.wikipedia.org/wiki/Azanide) (NH−2) to be present in [solution](https://en.wikipedia.org/wiki/Solution_(chemistry)). At standard pressure and temperature, K = [NH4+] × [NH2-] = 10−30  
.

### Combustion

The [combustion](https://en.wikipedia.org/wiki/Combustion) of ammonia to form nitrogen and water is [exothermic](https://en.wikipedia.org/wiki/Exothermic):

4 NH3 + 3 O2 → 2 N2 + 6 H2O(g), [Δ](https://en.wikipedia.org/wiki/Standard_enthalpy_of_reaction" \o "Standard enthalpy of reaction)*[H](https://en.wikipedia.org/wiki/Standard_enthalpy_of_reaction" \o "Standard enthalpy of reaction)*[°](https://en.wikipedia.org/wiki/Standard_enthalpy_of_reaction" \o "Standard enthalpy of reaction)[r](https://en.wikipedia.org/wiki/Standard_enthalpy_of_reaction" \o "Standard enthalpy of reaction) = −1267.20 kJ (or −316.8 kJ/mol if expressed per mol of NH3)

The [standard enthalpy change of combustion](https://en.wikipedia.org/wiki/Standard_enthalpy_change_of_combustion), Δ*H*°c, expressed per [mole](https://en.wikipedia.org/wiki/Mole_(unit)) of ammonia and with condensation of the water formed, is −382.81 kJ/mol. Dinitrogen is the thermodynamic product of [combustion](https://en.wikipedia.org/wiki/Combustion): all [nitrogen oxides](https://en.wikipedia.org/wiki/Nitrogen_oxide) are unstable with respect to N2 and O2, which is the principle behind the [catalytic converter](https://en.wikipedia.org/wiki/Catalytic_converter). Nitrogen oxides can be formed as [kinetic products](https://en.wikipedia.org/wiki/Chemical_kinetics) in the presence of appropriate [catalysts](https://en.wikipedia.org/wiki/Catalysis), a reaction of great industrial importance in the production of [nitric acid](https://en.wikipedia.org/wiki/Nitric_acid):

4 NH3 + 5 O2 → 4 NO + 6 H2O

A subsequent reaction leads to NO2:

2 NO + O2 → 2 NO2

The combustion of ammonia in air is very difficult in the absence of a [catalyst](https://en.wikipedia.org/wiki/Catalysis) (such as [platinum](https://en.wikipedia.org/wiki/Platinum) gauze or warm [chromium(III) oxide](https://en.wikipedia.org/wiki/Chromium(III)_oxide)), due to the relatively low [heat of combustion](https://en.wikipedia.org/wiki/Heat_of_combustion), a lower laminar burning velocity, high [auto-ignition temperature](https://en.wikipedia.org/wiki/Auto-ignition_temperature), high [heat of vaporization](https://en.wikipedia.org/wiki/Heat_of_vaporization), and a narrow [flammability range](https://en.wikipedia.org/wiki/Flammability_limit). However, recent studies have shown that efficient and stable combustion of ammonia can be achieved using swirl combustors, thereby rekindling research interest in ammonia as a fuel for thermal power production.[[33]](https://en.wikipedia.org/wiki/Ammonia#cite_note-Kobayashi-33) The flammable range of ammonia in dry air is 15.15–27.35% and in 100% relative humidity air is 15.95–26.55%.[[34]](https://en.wikipedia.org/wiki/Ammonia#cite_note-34) For studying the [kinetics](https://en.wikipedia.org/wiki/Chemical_kinetics) of ammonia combustion, knowledge of a detailed reliable reaction mechanism is required, but this has been challenging to obtain.[[35]](https://en.wikipedia.org/wiki/Ammonia#cite_note-35)

### Formation of other compounds

Ammonia is a direct or indirect precursor to most [manufactured nitrogen-containing compounds](https://en.wikipedia.org/wiki/Ammonia#Precursor_to_nitrogenous_compounds).

In [organic chemistry](https://en.wikipedia.org/wiki/Organic_chemistry), ammonia can act as a [nucleophile](https://en.wikipedia.org/wiki/Nucleophile) in [substitution](https://en.wikipedia.org/wiki/Nucleophilic_substitution) reactions. [Amines](https://en.wikipedia.org/wiki/Amine) can be formed by the reaction of ammonia with [alkyl halides](https://en.wikipedia.org/wiki/Alkyl_halide) or with [alcohols](https://en.wikipedia.org/wiki/Alcohol_(chemistry)). The resulting −NH2 group is also nucleophilic so [secondary and tertiary amines](https://en.wikipedia.org/wiki/Amine) are often formed. When such multiple substitution is not desired, an excess of ammonia helps minimise it. For example, [methylamine](https://en.wikipedia.org/wiki/Methylamine) is prepared by the reaction of ammonia with [chloromethane](https://en.wikipedia.org/wiki/Chloromethane) or with [methanol](https://en.wikipedia.org/wiki/Methanol). In both cases, [dimethylamine](https://en.wikipedia.org/wiki/Dimethylamine) and [trimethylamine](https://en.wikipedia.org/wiki/Trimethylamine) are co-produced. [Ethanolamine](https://en.wikipedia.org/wiki/Ethanolamine) is prepared by a ring-opening reaction with [ethylene oxide](https://en.wikipedia.org/wiki/Ethylene_oxide), and when the reaction is allowed to go further it produces [diethanolamine](https://en.wikipedia.org/wiki/Diethanolamine) and [triethanolamine](https://en.wikipedia.org/wiki/Triethanolamine). The reaction of ammonia with 2-bromopropanoic acid has been used to prepare [racemic](https://en.wikipedia.org/wiki/Racemic) [alanine](https://en.wikipedia.org/wiki/Alanine) in 70% yield.

[Amides](https://en.wikipedia.org/wiki/Amide) can be prepared by the reaction of ammonia with [carboxylic acid](https://en.wikipedia.org/wiki/Carboxylic_acid) derivatives. For example, ammonia reacts with [formic acid](https://en.wikipedia.org/wiki/Formic_acid) (HCOOH) to yield [formamide](https://en.wikipedia.org/wiki/Formamide) (HCONH2) when heated. [Acyl chlorides](https://en.wikipedia.org/wiki/Acyl_chloride) are the most reactive, but the ammonia must be present in at least a twofold excess to neutralise the [hydrogen chloride](https://en.wikipedia.org/wiki/Hydrogen_chloride) formed. [Esters](https://en.wikipedia.org/wiki/Ester) and [anhydrides](https://en.wikipedia.org/wiki/Anhydride) also react with ammonia to form amides. Ammonium salts of carboxylic acids can be [dehydrated](https://en.wikipedia.org/wiki/Dehydration_reaction) to amides by heating to 150–200 °C as long as no thermally sensitive groups are present.

The hydrogen in ammonia is susceptible to replacement by a myriad of substituents. When dry ammonia gas is heated with metallic [sodium](https://en.wikipedia.org/wiki/Sodium) it converts to [sodamide](https://en.wikipedia.org/wiki/Sodamide" \o "Sodamide), NaNH2.[[31]](https://en.wikipedia.org/wiki/Ammonia#cite_note-FOOTNOTEChisholm1911862-31) With chlorine, [monochloramine](https://en.wikipedia.org/wiki/Monochloramine) is formed.

Pentavalent ammonia is known as λ5-amine or, more commonly, ammonium hydride. This crystalline solid is only stable under high pressure and decomposes back into trivalent ammonia and hydrogen gas at normal conditions. This substance was once investigated as a possible solid rocket fuel in 1966.

## History

The ancient Greek historian [Herodotus](https://en.wikipedia.org/wiki/Herodotus) mentioned that there were [outcrops](https://en.wikipedia.org/wiki/Outcrop) of salt in an area of Libya that was inhabited by a people called the "Ammonians" (now: the [Siwa oasis](https://en.wikipedia.org/wiki/Siwa_oasis" \o "Siwa oasis) in northwestern Egypt, where salt lakes still exist).[[42]](https://en.wikipedia.org/wiki/Ammonia#cite_note-42)[[43]](https://en.wikipedia.org/wiki/Ammonia#cite_note-43) The Greek geographer [Strabo](https://en.wikipedia.org/wiki/Strabo) also mentioned the salt from this region. However, the ancient authors [Dioscorides](https://en.wikipedia.org/wiki/Pedanius_Dioscorides" \o "Pedanius Dioscorides), [Apicius](https://en.wikipedia.org/wiki/Apicius" \o "Apicius), [Arrian](https://en.wikipedia.org/wiki/Arrian), [Synesius](https://en.wikipedia.org/wiki/Synesius" \o "Synesius), and [Aëtius of Amida](https://en.wikipedia.org/wiki/A%C3%ABtius_of_Amida" \o "Aëtius of Amida) described this salt as forming clear crystals that could be used for cooking and that were essentially [rock salt](https://en.wikipedia.org/wiki/Halite_(mineral)).[[44]](https://en.wikipedia.org/wiki/Ammonia#cite_note-44) *Hammoniacus sal* appears in the writings of [Pliny](https://en.wikipedia.org/wiki/Pliny_the_Elder),[[45]](https://en.wikipedia.org/wiki/Ammonia#cite_note-45) although it is not known whether the term is identical with the more modern sal ammoniac (ammonium chloride).[[23]](https://en.wikipedia.org/wiki/Ammonia#cite_note-FOOTNOTEChisholm1911861-23)[[46]](https://en.wikipedia.org/wiki/Ammonia#cite_note-Mineral_Data-46)[[47]](https://en.wikipedia.org/wiki/Ammonia#cite_note-47)

The fermentation of urine by bacteria produces a [solution of ammonia](https://en.wikipedia.org/wiki/Ammonia_solution); hence fermented urine was used in [Classical Antiquity](https://en.wikipedia.org/wiki/Classical_Antiquity) to wash cloth and clothing, to remove hair from hides in preparation for tanning, to serve as a [mordant](https://en.wikipedia.org/wiki/Mordant) in dying cloth, and to remove rust from iron.[[48]](https://en.wikipedia.org/wiki/Ammonia#cite_note-48) It was also used by [ancient dentists](https://en.wikipedia.org/wiki/Dentistry_in_ancient_Rome) to wash teeth.[[49]](https://en.wikipedia.org/wiki/Ammonia#cite_note-49)[[50]](https://en.wikipedia.org/wiki/Ammonia#cite_note-50)[[51]](https://en.wikipedia.org/wiki/Ammonia#cite_note-51)

In the form of sal ammoniac *(نشادر, nushadir)*, ammonia was important to the [Muslim alchemists](https://en.wikipedia.org/wiki/Alchemy_and_chemistry_in_medieval_Islam). It was mentioned in the *Book of Stones*, likely written in the 9th century and attributed to [Jābir ibn Hayyān](https://en.wikipedia.org/wiki/J%C4%81bir_ibn_Hayy%C4%81n" \o "Jābir ibn Hayyān).[[52]](https://en.wikipedia.org/wiki/Ammonia#cite_note-Haq1995-52) It was also important to the European [alchemists](https://en.wikipedia.org/wiki/Alchemy) of the 13th century, being mentioned by [Albertus Magnus](https://en.wikipedia.org/wiki/Albertus_Magnus).[[23]](https://en.wikipedia.org/wiki/Ammonia#cite_note-FOOTNOTEChisholm1911861-23) It was also used by [dyers](https://en.wikipedia.org/wiki/Dye) in the [Middle Ages](https://en.wikipedia.org/wiki/Middle_Ages) in the form of fermented [urine](https://en.wikipedia.org/wiki/Urine) to alter the colour of vegetable dyes. In the 15th century, [Basilius Valentinus](https://en.wikipedia.org/wiki/Basilius_Valentinus" \o "Basilius Valentinus) showed that ammonia could be obtained by the action of alkalis on sal ammoniac.[[53]](https://en.wikipedia.org/wiki/Ammonia#cite_note-53) At a later period, when sal ammoniac was obtained by distilling the hooves and horns of oxen and neutralizing the resulting carbonate with [hydrochloric acid](https://en.wikipedia.org/wiki/Hydrochloric_acid), the name "spirit of hartshorn" was applied to ammonia.[[23]](https://en.wikipedia.org/wiki/Ammonia#cite_note-FOOTNOTEChisholm1911861-23)[[54]](https://en.wikipedia.org/wiki/Ammonia#cite_note-54)

Gaseous ammonia was first isolated by [Joseph Black](https://en.wikipedia.org/wiki/Joseph_Black) in 1756 by reacting *sal ammoniac* ([ammonium chloride](https://en.wikipedia.org/wiki/Ammonium_chloride)) with *calcined magnesia* ([magnesium oxide](https://en.wikipedia.org/wiki/Magnesium_oxide)).[[55]](https://en.wikipedia.org/wiki/Ammonia#cite_note-55)[[56]](https://en.wikipedia.org/wiki/Ammonia#cite_note-56) It was isolated again by [Peter Woulfe](https://en.wikipedia.org/wiki/Peter_Woulfe) in 1767,[[57]](https://en.wikipedia.org/wiki/Ammonia#cite_note-57)[[58]](https://en.wikipedia.org/wiki/Ammonia#cite_note-58) by [Carl Wilhelm Scheele](https://en.wikipedia.org/wiki/Carl_Wilhelm_Scheele) in 1770[[59]](https://en.wikipedia.org/wiki/Ammonia#cite_note-59) and by [Joseph Priestley](https://en.wikipedia.org/wiki/Joseph_Priestley) in 1773 and was termed by him "alkaline air".[[23]](https://en.wikipedia.org/wiki/Ammonia#cite_note-FOOTNOTEChisholm1911861-23)[[60]](https://en.wikipedia.org/wiki/Ammonia#cite_note-60) Eleven years later in 1785, [Claude Louis Berthollet](https://en.wikipedia.org/wiki/Claude_Louis_Berthollet) ascertained its composition.[[61]](https://en.wikipedia.org/wiki/Ammonia#cite_note-61)[[23]](https://en.wikipedia.org/wiki/Ammonia#cite_note-FOOTNOTEChisholm1911861-23)

The [Haber–Bosch process](https://en.wikipedia.org/wiki/Haber%E2%80%93Bosch_process) to produce ammonia from the nitrogen in the air was developed by [Fritz Haber](https://en.wikipedia.org/wiki/Fritz_Haber) and [Carl Bosch](https://en.wikipedia.org/wiki/Carl_Bosch) in 1909 and patented in 1910. It was first used on an industrial scale in Germany during [World War I](https://en.wikipedia.org/wiki/World_War_I),[[62]](https://en.wikipedia.org/wiki/Ammonia#cite_note-Ullmann-62) following the allied blockade that cut off the supply of nitrates from [Chile](https://en.wikipedia.org/wiki/Chile). The ammonia was used to produce explosives to sustain war efforts.[[63]](https://en.wikipedia.org/wiki/Ammonia#cite_note-Conquering-63)

Before the availability of natural gas, hydrogen as a precursor to [ammonia production](https://en.wikipedia.org/wiki/Ammonia_production) was produced via the [electrolysis](https://en.wikipedia.org/wiki/Electrolysis) of water or using the [chloralkali process](https://en.wikipedia.org/wiki/Chloralkali_process" \o "Chloralkali process).

With the advent of the steel industry in the 20th century, ammonia became a byproduct of the production of [coking](https://en.wikipedia.org/wiki/Coking) coal.

## Applications

### Fertilizer

In the US as of 2019, approximately 88% of ammonia was used as fertilizers either as its salts, solutions or anhydrously.[[15]](https://en.wikipedia.org/wiki/Ammonia#cite_note-USGS2020-15) When applied to soil, it helps provide increased yields of crops such as maize and wheat.[[67]](https://en.wikipedia.org/wiki/Ammonia#cite_note-67) 30% of agricultural nitrogen applied in the US is in the form of anhydrous ammonia and worldwide 110 million tonnes are applied each year.[[68]](https://en.wikipedia.org/wiki/Ammonia#cite_note-68)

### Precursor to nitrogenous compounds

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](https://en.wikipedia.org/wiki/Nitric_acid). This key material is generated via the [Ostwald process](https://en.wikipedia.org/wiki/Ostwald_process) by [oxidation](https://en.wikipedia.org/wiki/Oxidation) of ammonia with air over a [platinum](https://en.wikipedia.org/wiki/Platinum) catalyst at 700–850 °C (1,292–1,562 °F), ≈9 atm. [Nitric oxide](https://en.wikipedia.org/wiki/Nitric_oxide) is an intermediate in this conversion:[[69]](https://en.wikipedia.org/wiki/Ammonia#cite_note-69)

NH3 + 2 O2 → HNO3 + H2O

Nitric acid is used for the production of [fertilizers](https://en.wikipedia.org/wiki/Fertilizer), [explosives](https://en.wikipedia.org/wiki/Explosive), and many organonitrogen compounds.

Ammonia is also used to make the following compounds:

* [Hydrazine](https://en.wikipedia.org/wiki/Hydrazine), in the [Olin Raschig process](https://en.wikipedia.org/wiki/Olin_Raschig_process) and the [peroxide process](https://en.wikipedia.org/wiki/Peroxide_process)
* [Hydrogen cyanide](https://en.wikipedia.org/wiki/Hydrogen_cyanide), in the [BMA process](https://en.wikipedia.org/wiki/BMA_process) and the [Andrussow process](https://en.wikipedia.org/wiki/Andrussow_process" \o "Andrussow process)
* [Hydroxylamine](https://en.wikipedia.org/wiki/Hydroxylamine) and [ammonium carbonate](https://en.wikipedia.org/wiki/Ammonium_carbonate), in the [Raschig process](https://en.wikipedia.org/wiki/Raschig_hydroxylamine_process)
* [Phenol](https://en.wikipedia.org/wiki/Phenol), in the [Raschig–Hooker process](https://en.wikipedia.org/wiki/Raschig%E2%80%93Hooker_process)
* [Urea](https://en.wikipedia.org/wiki/Urea), in the [Bosch–Meiser urea process](https://en.wikipedia.org/wiki/Bosch%E2%80%93Meiser_urea_process) and in [Wöhler synthesis](https://en.wikipedia.org/wiki/W%C3%B6hler_synthesis" \o "Wöhler synthesis)
* [Amino acids](https://en.wikipedia.org/wiki/Amino_acid), using [Strecker amino-acid synthesis](https://en.wikipedia.org/wiki/Strecker_amino-acid_synthesis)
* [Acrylonitrile](https://en.wikipedia.org/wiki/Acrylonitrile), in the [Sohio process](https://en.wikipedia.org/wiki/Sohio_process" \o "Sohio process)

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

### Fuel

The raw [energy density](https://en.wikipedia.org/wiki/Energy_density) of liquid ammonia is 11.5 MJ/L,[[82]](https://en.wikipedia.org/wiki/Ammonia#cite_note-Lan-82) which is about a third that of [diesel](https://en.wikipedia.org/wiki/Diesel_fuel). There is the opportunity to convert ammonia back to hydrogen, where it can be used to power hydrogen fuel cells, or it may be used directly within high-temperature [solid oxide](https://en.wikipedia.org/wiki/Solid_oxide_fuel_cell) direct ammonia fuel cells to provide efficient power sources that do not emit [greenhouse gases](https://en.wikipedia.org/wiki/Greenhouse_gas).[[83]](https://en.wikipedia.org/wiki/Ammonia#cite_note-83)[[84]](https://en.wikipedia.org/wiki/Ammonia#cite_note-AmmoniaFuelCellReview2016-84)

The conversion of ammonia to hydrogen via the [sodium amide](https://en.wikipedia.org/wiki/Sodium_amide) process,[[85]](https://en.wikipedia.org/wiki/Ammonia#cite_note-American_Chemical_Society-85) either for combustion or as fuel for a [proton exchange membrane fuel cell](https://en.wikipedia.org/wiki/Proton_exchange_membrane_fuel_cell),[[82]](https://en.wikipedia.org/wiki/Ammonia#cite_note-Lan-82) is possible. Another method is the catalytic decomposition of ammonia using solid catalysts.[[86]](https://en.wikipedia.org/wiki/Ammonia#cite_note-86) Conversion to hydrogen would allow the storage of hydrogen at nearly 18 [wt%](https://en.wikipedia.org/wiki/Mass_fraction_(chemistry)" \o "Mass fraction (chemistry)) compared to ≈5% for gaseous hydrogen under pressure.

Ammonia engines or ammonia motors, using ammonia as a [working fluid](https://en.wikipedia.org/wiki/Working_fluid), have been proposed and occasionally used.[[87]](https://en.wikipedia.org/wiki/Ammonia#cite_note-87) The principle is similar to that used in a [fireless locomotive](https://en.wikipedia.org/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](https://en.wikipedia.org/wiki/Goldsworthy_Gurney) in the UK and the [St. Charles Avenue Streetcar](https://en.wikipedia.org/wiki/St._Charles_Avenue_Streetcar) line in New Orleans in the 1870s and 1880s,[[88]](https://en.wikipedia.org/wiki/Ammonia#cite_note-The_Streetcars_of_New_Orleans-88) and during [World War II](https://en.wikipedia.org/wiki/World_War_II) ammonia was used to power buses in Belgium.[[89]](https://en.wikipedia.org/wiki/Ammonia#cite_note-c1-89)



Figure Ammoniacal Gas Engine Streetcar in New Orleans drawn by Alfred Waud in 1871.

Ammonia is sometimes proposed as a practical alternative to [fossil fuel](https://en.wikipedia.org/wiki/Fossil_fuel) for [internal combustion engines](https://en.wikipedia.org/wiki/Internal_combustion_engine).[[89]](https://en.wikipedia.org/wiki/Ammonia#cite_note-c1-89)[[90]](https://en.wikipedia.org/wiki/Ammonia#cite_note-Lee-90)[[91]](https://en.wikipedia.org/wiki/Ammonia#cite_note-Brohi-91)[[92]](https://en.wikipedia.org/wiki/Ammonia#cite_note-92)

Its high [octane rating](https://en.wikipedia.org/wiki/Octane_rating) of 120[[93]](https://en.wikipedia.org/wiki/Ammonia#cite_note-Chemistry_department,_University_of_Bristol-93) and low flame temperature[[94]](https://en.wikipedia.org/wiki/Ammonia#cite_note-Zacharakis-94) allows the use of high compression ratios without a penalty of high NO*x* production. Since ammonia contains no carbon, its combustion cannot produce [carbon dioxide](https://en.wikipedia.org/wiki/Carbon_dioxide), [carbon monoxide](https://en.wikipedia.org/wiki/Carbon_monoxide), [hydrocarbons](https://en.wikipedia.org/wiki/Hydrocarbons), or [soot](https://en.wikipedia.org/wiki/Soot).

Ammonia production currently creates 1.8% of global CO2 emissions. "Green ammonia" is ammonia produced by using green hydrogen (hydrogen produced by electrolysis), whereas "blue ammonia" is ammonia produced using blue hydrogen (hydrogen produced by steam methane reforming where the carbon dioxide has been captured and stored).[[95]](https://en.wikipedia.org/wiki/Ammonia#cite_note-95)

However, ammonia cannot be easily used in existing [Otto cycle](https://en.wikipedia.org/wiki/Otto_cycle) engines because of its very narrow [flammability range](https://en.wikipedia.org/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 (after sulfuric acid), 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](https://en.wikipedia.org/wiki/Norsk_Hydro_Rjukan) in [Telemark](https://en.wikipedia.org/wiki/Telemark), Norway, produced ammonia for many years from 1913, providing fertilizer for much of Europe.

Despite this, several tests have been run. In 1981, a Canadian company converted a 1981 Chevrolet Impala to operate using ammonia as fuel.[[96]](https://en.wikipedia.org/wiki/Ammonia#cite_note-96)[[97]](https://en.wikipedia.org/wiki/Ammonia#cite_note-97) 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.[[98]](https://en.wikipedia.org/wiki/Ammonia#cite_note-98)

Compared to [hydrogen as a fuel](https://en.wikipedia.org/wiki/Hydrogen_as_a_fuel), **ammonia is much more energy efficient**, and could be produced, stored, and delivered at a much lower cost than hydrogen, which must be kept compressed or as a cryogenic liquid.[[82]](https://en.wikipedia.org/wiki/Ammonia#cite_note-Lan-82)[[99]](https://en.wikipedia.org/wiki/Ammonia#cite_note-99)

Rocket engines have also been fueled by ammonia. The [Reaction Motors XLR99](https://en.wikipedia.org/wiki/Reaction_Motors_XLR99) rocket engine that powered the [X-15](https://en.wikipedia.org/wiki/X-15) 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.



Figure The X-15 aircraft used ammonia as one component fuel of its rocket engine

In early August 2018, scientists from [Australia](https://en.wikipedia.org/wiki/Australia)'s [Commonwealth Scientific and Industrial Research Organisation](https://en.wikipedia.org/wiki/Commonwealth_Scientific_and_Industrial_Research_Organisation) (CSIRO) announced the success of developing a process to release hydrogen from ammonia and harvest that at ultra-high purity as a fuel for cars. This uses a special membrane. Two demonstration [fuel cell vehicles](https://en.wikipedia.org/wiki/Fuel_cell_vehicle) have the technology, a [Hyundai Nexo](https://en.wikipedia.org/wiki/Hyundai_Nexo) and [Toyota Mirai](https://en.wikipedia.org/wiki/Toyota_Mirai).[[100]](https://en.wikipedia.org/wiki/Ammonia#cite_note-2018-08-08_ABC-100)

In 2020, [Saudi Arabia](https://en.wikipedia.org/wiki/Saudi_Arabia) shipped forty [metric tons](https://en.wikipedia.org/wiki/Metric_tons) of liquid "blue ammonia" to Japan for use as a fuel.[[101]](https://en.wikipedia.org/wiki/Ammonia#cite_note-101) It was produced as a by-product by petrochemical industries, and can be burned without giving off [greenhouse gases](https://en.wikipedia.org/wiki/Greenhouse_gas). Its energy density by volume is nearly double that of liquid hydrogen. If the process of creating it can be scaled up via purely renewable resources, producing green ammonia, it could make a major difference in [avoiding climate change](https://en.wikipedia.org/wiki/Climate_change_mitigation).[[102]](https://en.wikipedia.org/wiki/Ammonia#cite_note-102) The company [ACWA Power](https://en.wikipedia.org/wiki/ACWA_Power) and the city of [Neom](https://en.wikipedia.org/wiki/Neom) have announced the construction of a green hydrogen and ammonia plant in 2020.[[103]](https://en.wikipedia.org/wiki/Ammonia#cite_note-103)

Green ammonia is considered as a potential fuel for future container ships. In 2020, the companies [DSME](https://en.wikipedia.org/wiki/DSME) and [MAN Energy Solutions](https://en.wikipedia.org/wiki/MAN_Energy_Solutions) announced the construction of an ammonia-based ship, DSME plans to commercialize it by 2025.[[104]](https://en.wikipedia.org/wiki/Ammonia#cite_note-104) The use of ammonia as a potential alternative fuel for [aircraft](https://en.wikipedia.org/wiki/Aircraft) [jet engines](https://en.wikipedia.org/wiki/Jet_engine) is also being explored.[[105]](https://en.wikipedia.org/wiki/Ammonia#cite_note-105)

Japan is targeting to bring forward a plan to develop ammonia co-firing technology that can increase the use of ammonia in power generation, as part of efforts to assist domestic and other Asian utilities to accelerate their transition to [carbon neutrality](https://en.wikipedia.org/wiki/Carbon_neutrality).[[106]](https://en.wikipedia.org/wiki/Ammonia#cite_note-106) In October 2021, the first International Conference on Fuel Ammonia (ICFA2021) was held.[[107]](https://en.wikipedia.org/wiki/Ammonia#cite_note-107)[[108]](https://en.wikipedia.org/wiki/Ammonia#cite_note-108)

In June 2022, [IHI Corporation](https://en.wikipedia.org/wiki/IHI_Corporation) succeeded in reducing greenhouse gases by over 99% during combustion of liquid ammonia in a 2,000-kilowatt-class gas turbine achieving truly CO₂-free power generation.[[109]](https://en.wikipedia.org/wiki/Ammonia#cite_note-109) In July 2022, [Quad](https://en.wikipedia.org/wiki/Quadrilateral_Security_Dialogue) nations of Japan, the U.S., Australia and India agreed to promote technological development for clean-burning hydrogen and ammonia as fuels at the security grouping's first energy meeting.[[110]](https://en.wikipedia.org/wiki/Ammonia#cite_note-110)

### Solvent

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](https://en.wikipedia.org/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](https://en.wikipedia.org/wiki/Viscosity), [dielectric constant](https://en.wikipedia.org/wiki/Dielectric_constant) and [electrical conductivity](https://en.wikipedia.org/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](https://en.wikipedia.org/wiki/Dissociation_constant) of liquid NH3 at −50 °C is about 10−33.

### Cleansing agent

Household "ammonia" (or more correctly called ammonium hydroxide) is a [solution of NH3 in water](https://en.wikipedia.org/wiki/Ammonia_solution), and is 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.[[70]](https://en.wikipedia.org/wiki/Ammonia#cite_note-70) United States manufacturers of cleaning products are required to provide the product's [material safety data sheet](https://en.wikipedia.org/wiki/Material_safety_data_sheet) which lists the concentration used.[[71]](https://en.wikipedia.org/wiki/Ammonia#cite_note-71)

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](https://en.wikipedia.org/wiki/Mucous_membrane) (respiratory and digestive tracts), and to a lesser extent the skin. Experts advise that caution be used to ensure the substance is not mixed into any liquid containing bleach, due to the danger of toxic gas. Mixing with [chlorine](https://en.wikipedia.org/wiki/Chlorine)-containing products or strong oxidants, such as household [bleach](https://en.wikipedia.org/wiki/Bleach), can generate [chloramines](https://en.wikipedia.org/wiki/Chloramines).[[72]](https://en.wikipedia.org/wiki/Ammonia#cite_note-72)

Experts also warn not to use ammonia-based cleaners (such as glass or window cleaners) on car touchscreens, due to the risk of damage to the screen's anti-glare and anti-fingerprint coatings.[[73]](https://en.wikipedia.org/wiki/Ammonia#cite_note-73)

### Fermentation

Solutions of ammonia ranging from 16% to 25% are used in the [fermentation](https://en.wikipedia.org/wiki/Industrial_fermentation) industry as a source of nitrogen for microorganisms and to adjust pH during fermentation.[[74]](https://en.wikipedia.org/wiki/Ammonia#cite_note-74)

### Antimicrobial agent for food products

As early as in 1895, it was known that ammonia was "strongly [antiseptic](https://en.wikipedia.org/wiki/Antiseptic) ... it requires 1.4 grams per litre to preserve [beef tea](https://en.wikipedia.org/wiki/Broth) (broth)."[[75]](https://en.wikipedia.org/wiki/Ammonia#cite_note-75) In one study, anhydrous ammonia destroyed 99.999% of [zoonotic bacteria](https://en.wikipedia.org/wiki/Zoonotic_bacteria) in 3 types of [animal feed](https://en.wikipedia.org/wiki/Compound_feed), but not [silage](https://en.wikipedia.org/wiki/Silage).[[76]](https://en.wikipedia.org/wiki/Ammonia#cite_note-76)[[77]](https://en.wikipedia.org/wiki/Ammonia#cite_note-77) Anhydrous ammonia is currently used commercially to reduce or eliminate [microbial](https://en.wikipedia.org/wiki/Microbial) contamination of [beef](https://en.wikipedia.org/wiki/Beef).[[78]](https://en.wikipedia.org/wiki/Ammonia#cite_note-78)[[79]](https://en.wikipedia.org/wiki/Ammonia#cite_note-79) Lean finely textured beef (popularly known as "[pink slime](https://en.wikipedia.org/wiki/Pink_slime)") in the beef industry is made from fatty [beef trimmings](https://en.wikipedia.org/wiki/Beef_trimmings) (c. 50–70% fat) by removing the fat using heat and [centrifugation](https://en.wikipedia.org/wiki/Centrifugation), then treating it with ammonia to kill [*E. coli*](https://en.wikipedia.org/wiki/Escherichia_coli). The process was deemed effective and safe by the [US Department of Agriculture](https://en.wikipedia.org/wiki/US_Department_of_Agriculture) based on a study that found that the treatment reduces *E. coli* to undetectable levels.[[80]](https://en.wikipedia.org/wiki/Ammonia#cite_note-80) There have been safety concerns about the process as well as consumer complaints about the taste and smell of ammonia-treated beef.[[81]](https://en.wikipedia.org/wiki/Ammonia#cite_note-81)