Ammonia

A very important molecule for biological organisms to make proteins or nucleic acids

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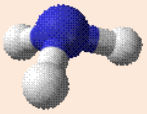
Molecule of the Month - June 2013

Introduction

Ammonia or azane is a compound of nitrogen and hydrogen with the formula NH_3. It is a colorless gas with a characteristic pungent smell, which is very common in toilets sometime. It is used in industry and commerce, and also exists naturally in humans and in the environment. Ammonia is essential for many biological processes and serves as a precursor for amino acid and nucleotide synthesis. In the environment, ammonia is part of the nitrogen cycle and is produced in soil from bacterial processes. Ammonia is also produced naturally from decomposition of organic matter, including plants and animals.



Sal Ammoniacus

Sal ammoniac is a mineral composed of ammonium chloride. The Romans called the ammonium chloride deposits they collected from near the Temple of Jupiter Amun in ancient Libya 'sal ammoniacus' (salt of Amun) because of proximity to the nearby temple. It is the earliest known mineral source of ammonia.

Fig: Sal ammoniac is a mineral

Guano & saltpeter

Later alternative sources of ammonia mineral were discovered. Guano and saltpeter played valuable roleas strategic commodity. Guano consists of ammonium oxalate and urate, phosphates, as well as some earth salts and impurities. Guano also has a high concentration of nitrates. Saltpeter is the mineral form of potassium nitrate (KNO_3). Potassium and other nitrates are of great importance for use in fertilizers, and, historically, gunpowder.

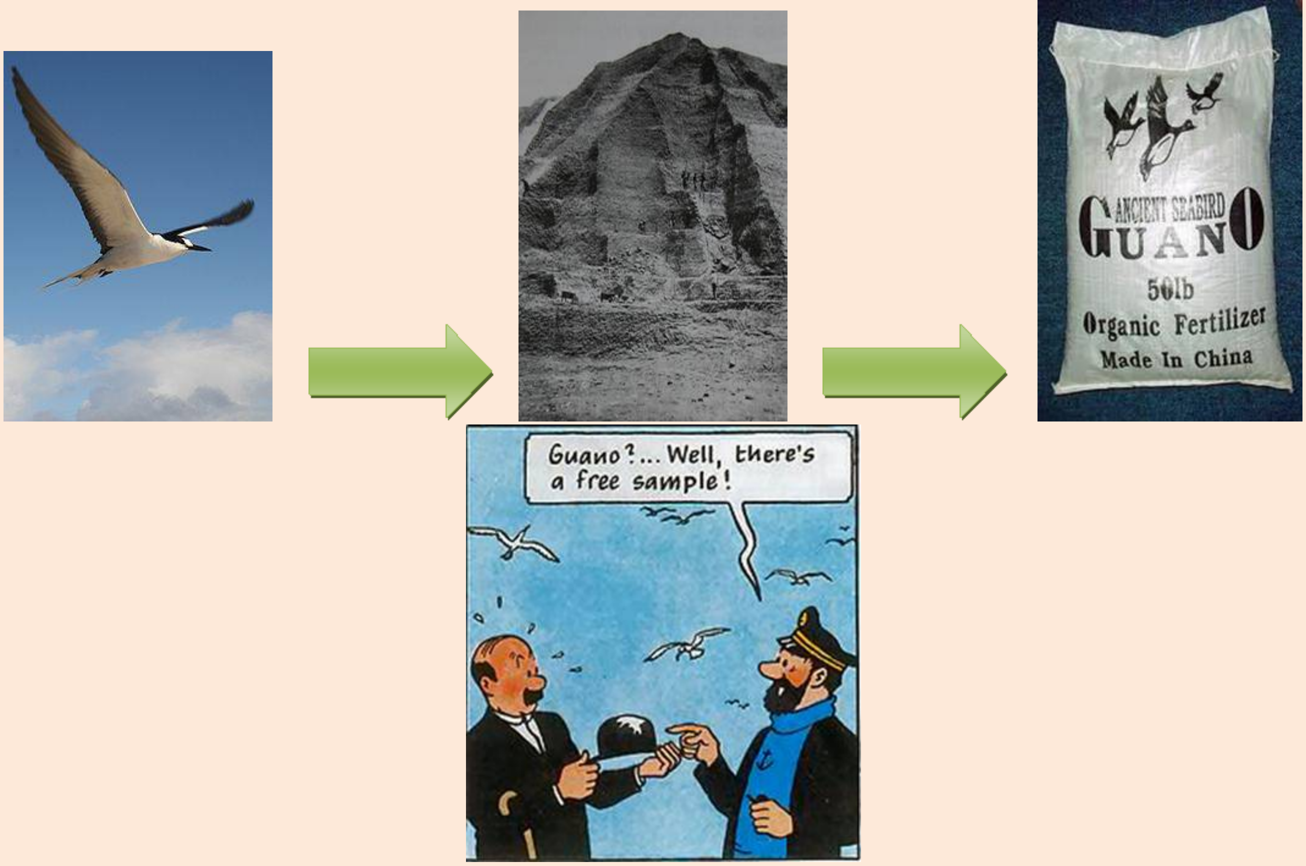


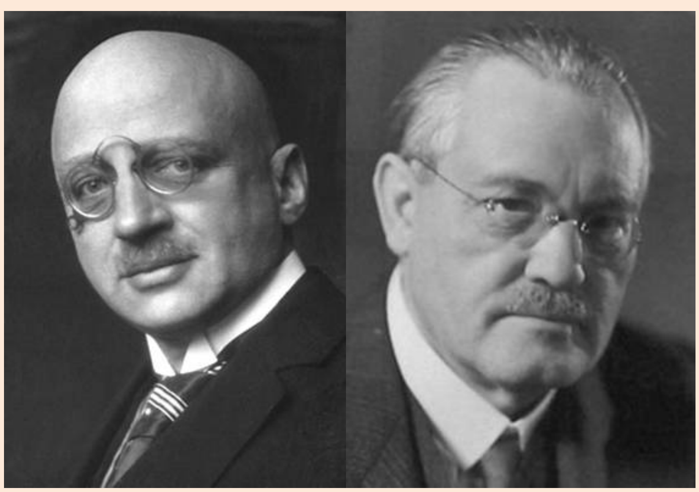
Fig: Guano is simply deposits of bird droppings

Independence from mineral dependency

Even though our atmosphere consists 78% nitrogen, atmospheric nitrogen is nutritionally unavailable to plants or animals because nitrogen molecules are held together by strong triple bonds. The demand and the desire to fix nitrogen to make explosives, as well as fertilizers, led to the development of chemical processes to produce ammonia. During 1910s Fritz Haber and Carl Bosch developed the first practical process to synthesis ammonia from atmospheric nitrogen. Prior to the discovery of the Haber process, ammonia had been difficult to produce on an industrial scale, and related industries were completely dependent on ammonia minerals.

Haber equation: $N_2\,(g) + 3\,H_2(g) \rightarrow 2NH_3(g)$

It is estimated that half of the protein within human beings is made of nitrogen that was originally fixed by this process; the remainder was produced by nitrogen fixing bacteria and archaea.



Picture: Fritz Haber and Carl Bosch

Ammonia in fertilizer

Half of the protein required to feed the world's population is acquired from plant sources, and nitrogen content in fertilizers directly influences a plant's ability to produce protein. Plants require nitrogen to produce this protein. Ammonia is the only viable source of nitrogen for producing large amounts of protein. The nitrogen content of fertilizers improves both the quantity and quality of protein-containing crops. In addition to food production, nitrogen fertilizers are currently used to produce the plants for ethanol fuel. Approximately 83% (as of 2004) of ammonia is used as fertilizers either as its salts, solutions or anhydrously.

While ammonia can be applied directly to the soil as a liquid or reacted with CO_2 to produce urea ($(NH_2)_2CO$) fertilizer, a large percentage is converted to nitric acid (HNO_3) by the Ostwald Process which uses platinum gauze as a catalyst. The nitric acid is then used to produce a variety of nitrate fertilizers including ammonium nitrate (NH_4NO_3), potassium nitrate (KNO_3), and calcium nitrate ($Ca(NO_3)_2$). Ammonia is also used to produce ammonium phosphate (NH_4PO_4), and ammonium sulfate ($(NH_4)_2SO_4$), which can also be used as fertilizers.

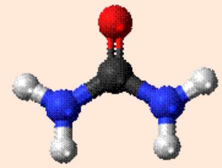


Fig: Urea

Precursor to nitrogenous compounds

Acids

Nitric acid (HNO_3) is a highly toxic and corrosive acid which is produced by using ammonia (NH_3), air and water as feedstock. It is estimated that 80% of the nitric acid produced worldwide is used as an intermediate in the production of nitrogenous fertilizers where about 65% is used to make ammonia nitrate, and the remaining 20% used in the explosive, plastics and chemical industries. These alternative uses of nitric acid include:

- Silver and gold separation
- Military munitions
- Photoengraving
- Acidulation of phosphate rock
- Steel and brass pickling
- Production of nitrobenzene, dinitrotoluenes, and other chemical intermediates, which can be utilized in the manufacture of explosives

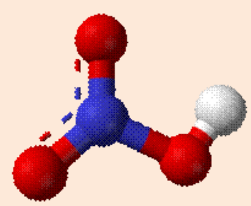


Fig: Nitric acid

Explosives

The Nitro-Explosives are substances that have been nitrated. The manufacture of the various nitro-explosives has made great advances during late years, and the various forms of nitro-compounds are gradually replacing the older forms of explosives, both for blasting purposes and also for propulsive agents, under the form of smokeless powders. The nitro-explosives belong to the so-called High Explosives, and may be defined as any chemical compound possessed of explosive properties, or capable of combining with metals to form an explosive compound, which is produced by the chemical action of nitric acid, either alone or mixed with sulphuric acid, upon any carbonaceous substance, whether such compound is mechanically mixed with other substances or not.

Fig: Mortar shell filled with TNT, TNT

Ammonia in refrigeration

Due to its interesting thermo-dynamic properties ammonia has been used for decades in industrial style refrigeration. Apart from its toxic properties in case of an accidental release, it is considered to be efficient, economical and environmentally friendly because it does not deplete the ozone layer or contribute to global warming, which is not the case for most other refrigerants.

Ammonia was first used as a refrigerant in the 1850s in France and was applied in the United States in the 1860s for artificial ice production. The first patents for ammonia refrigeration machines were filed in the 1870s. By the 1900s, ammonia refrigeration machines were being commercially installed in block ice, food processing, and chemical production facilities. By the 1920s, ammonia refrigeration was being applied to ice rinks. During the 1930s, air conditioning markets began to develop, first for industrial applications and then for human comfort. The use of smaller units for domestic refrigerators increased substantially between 1920 and 1930.

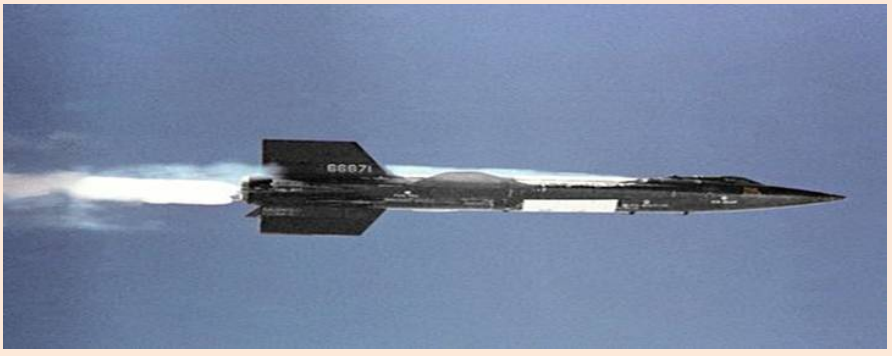
Recently, air conditioning provided by ammonia refrigeration systems has found applications on college campuses and office parks, small scale buildings such as convenience stores, and larger office buildings. These applications have been achieved by using water chillers, ice thermal storage units, and district cooling systems. In Europe, where regulatory regimes have encouraged new applications, ammonia refrigeration systems are used safely for air conditioning in hospitals, public buildings, airports, and hotels. Ammonia refrigeration provides air conditioning for the International Space Station and Biosphere II.

Possible carrier of hydrogen

The use of ammonia as a fuel for internal combustion engines has been around at least since the year 1935. A more extensive use of ammonia as a fuel was undertaken on vehicles in Belgium in 1942.

Ammonia has a high octane rating (about 120 versus gasoline at 86-93). So it does not need an octane enhancer and can be used in high compression engines. However, it has a relatively low energy density per gallon – about half of gasoline. The fuel mileage of ammonia is about half of gasoline's mileage.

Liquid ammonia also fuelled the Reaction Motors XLR99 rocket engine that powered the X-15 hypersonic research aircraft.



Ammonia and fuel cells

Hydrogen fuel cells take in hydrogen (H_2) and oxygen (O_2), produce electricity to power the motor vehicle and emit water (H_2O). Hydrogen is the most abundant element in the universe but it is relatively rare in its elemental (H_2) form on earth. Although hydrogen has high energy density by weight, it is the lightest of all elements and requires large volumes to power a motor vehicle. So, elemental hydrogen is difficult to store and transport. Hydrogen volumes can be reduced by compressing it as either compressed hydrogen or liquid hydrogen. However, the pressures required to do either of these are substantial and create a potential safety hazard.

Ammonia is sometimes called the "other hydrogen" due to its structure of three hydrogen molecules and one nitrogen molecule. The ability of ammonia gas to become a liquid at low pressures means that it is a good "carrier" of hydrogen. Liquid ammonia contains more hydrogen by volume than compressed hydrogen or liquid hydrogen. For example, ammonia is over 50% more energy dense per gallon than liquid hydrogen. So ammonia can be stored and distributed easier than elemental hydrogen. Fueling stations are much easier to convert to dispensing ammonia than elemental hydrogen. Ammonia could be stored onboard a motor vehicle where the elemental hydrogen and nitrogen are separated just before the hydrogen is fed into the fuel cell.

Role in biological world:

The nitrogen cycle is the process by which nitrogen is converted between its various chemical forms. This transformation can be carried out through both biological and physical processes.

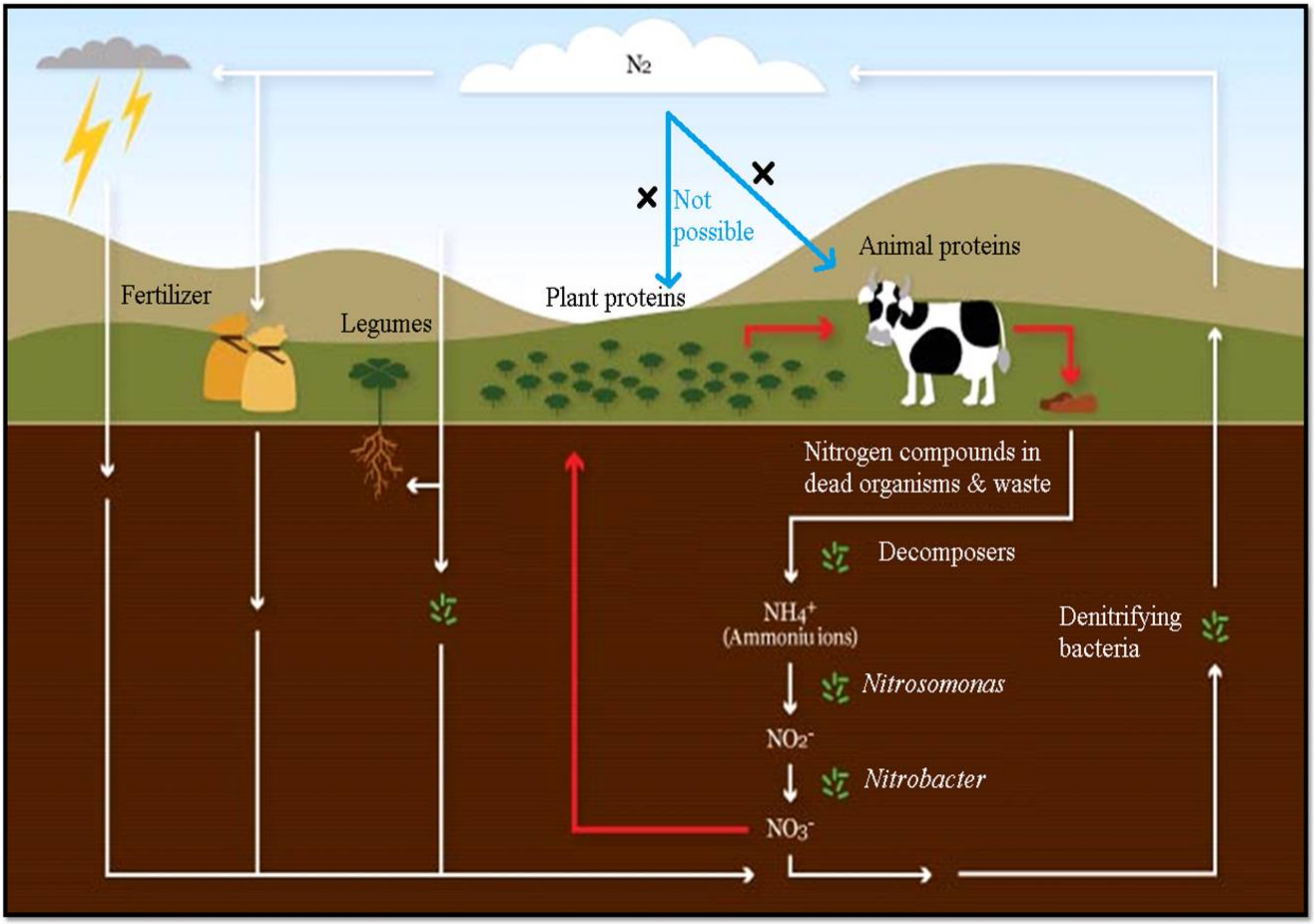


Fig: Nitrogen (N_2) cycle in which ammonia is recycled in one or another form

Reference:

- Encyclopedia Britannia
- Wikipedia

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