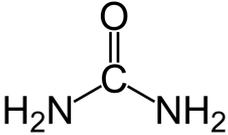
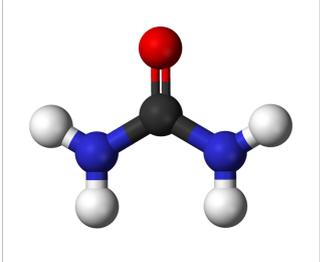
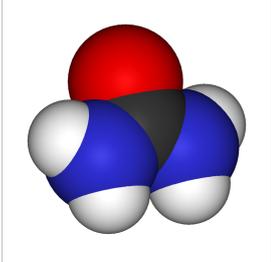


Urea

Urea	
	
	
Identifiers	
CAS number	57-13-6 ^[1] ✓
PubChem	1176 ^[2] ✓
ChemSpider	1143 ^[3] ✓
RTECS number	YR6250000
SMILES	
Properties	
Molecular formula	CH ₄ N ₂ O
Molar mass	60.06 g mol ⁻¹
Appearance	White solid
Density	1.32 g/cm ³
Melting point	132.7–135 °C
Solubility in water	108 g/100 ml (20 °C) 167 g/100 ml (40 °C) 251 g/100 ml (60 °C) 400 g/100 ml (80 °C) 733 g/100 ml (100 °C)
Basicity (p <i>K</i> _b)	p <i>K</i> _{BH⁺} = 0.18 ^[4]
Structure	
Dipole moment	4.56 D
Hazards	
MSDS	JT Baker ^[5]
EU Index	Not listed
Flash point	Non-flammable
Related compounds	

Related ureas	Thiourea Hydroxycarbamide
Related compounds	Carbamide peroxide Urea phosphate
✓ (what is this?) (verify) ^[6] Except where noted otherwise, data are given for materials in their standard state (at 25 °C, 100 kPa)	
Infobox references	

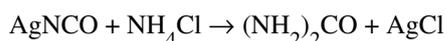
Urea or **carbamide** is an organic compound with the chemical formula $(\text{NH}_2)_2\text{CO}$. The molecule has two amine ($-\text{NH}_2$) groups joined by a carbonyl ($\text{C}=\text{O}$) functional group.

Urea serves an important role in the metabolism of nitrogen-containing compounds by animals and is the main nitrogen-containing substance in the urine of mammals. It is solid, colourless, and odorless (although the ammonia which it gives off in the presence of water, including water vapor in the air, has a strong odor). It is highly soluble in water and non-toxic. Dissolved in water it is neither acidic nor alkaline. The body uses it in many processes, most notably in the kidneys as a concentrated salt. Urea is widely used in fertilizers as a convenient source of nitrogen. Urea is also an important raw material for the chemical industry. The synthesis of this organic compound by Friedrich Wöhler in 1828 from an inorganic precursor was an important milestone in the development of organic chemistry, as it showed for the first time that a molecule found in living organisms could be synthesized in the lab without biological starting materials.

The terms **urea** and **carbamide** are also used for a class of chemical compounds sharing the same functional group $\text{RR}'\text{N}-\text{CO}-\text{NRR}'$, namely a carbonyl group attached to two organic amine residues. Example include carbamide peroxide, allantoin, and hydantoin. Ureas are closely related to biurets and related in structure to amides, carbamates, diimides, carbodiimides, and thiocarbamides.

History

Urea was first discovered in urine in 1773 by the French chemist Hilaire Rouelle. In 1828, the German chemist Friedrich Wöhler obtained urea by treating silver cyanate with ammonium chloride in a failed attempt to prepare ammonium cyanate:^[7]

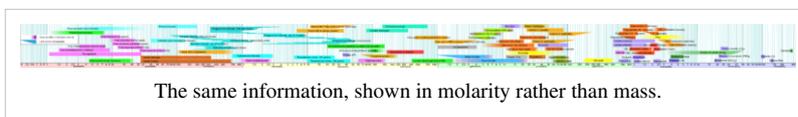
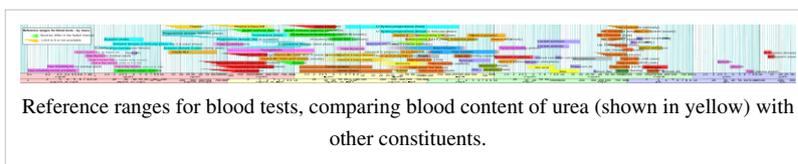


This was the first time an organic compound was artificially synthesized from inorganic starting materials, without the involvement of living organisms. The results of this experiment implicitly discredited vitalism: the theory that the chemicals of living organisms are fundamentally different from inanimate matter. This insight was important for the development of organic chemistry. His discovery prompted Wöhler to write triumphantly to Berzelius: "I must tell you that I can make urea without the use of kidneys, either man or dog. Ammonium cyanate is urea." For this discovery, Wöhler is considered by many the father of organic chemistry.

Physiology

Urea is synthesized in the body of many organisms as part of the urea cycle, either from the oxidation of amino acids or from ammonia. In this cycle, amino groups donated by ammonia and L-aspartate are converted to urea, while L-ornithine, citrulline, L-argininosuccinate, and L-arginine act as intermediates. Urea production occurs in the liver and is regulated by N-acetylglutamate. Urea is found dissolved in blood (in the reference range of 2.5 to 7.5 mmol/liter) and is excreted by the kidney as a component of urine. In addition, a small amount of urea is excreted (along with sodium chloride and water) in sweat.

Amino acids from ingested food which are not used for the synthesis of proteins and other biological substances are oxidized by the body, yielding urea and carbon dioxide, as an alternative source of energy.^[8] The oxidation pathway starts with the removal of the amino group by a transaminase, the amino group is then fed into the urea cycle.



Ammonia (NH_3) is another common byproduct of the metabolism of nitrogenous compounds. Ammonia is smaller, more volatile and more mobile than urea. If allowed to accumulate, ammonia would raise the pH in cells to toxic levels. Therefore many organisms convert ammonia to urea, even though this synthesis has a net energy cost. Being practically neutral and highly soluble in water, urea is a safe vehicle for the body to transport and excrete excess nitrogen.

In water, the amine groups undergo slow displacement by water molecules, producing ammonia and carbonate anion. For this reason, old, stale urine has a stronger odor than fresh urine.

In humans

The handling of urea by the kidneys is a vital part of human metabolism. Besides its role as carrier of waste nitrogen, urea also plays a role in the countercurrent exchange system of the nephrons, that allows for reabsorption of water and critical ions from the excreted urine. Urea is reabsorbed in the inner medullary collecting ducts of the nephrons,^[9] thus raising the osmolarity in the medullary interstitium surrounding the thin ascending limb of the loop of Henle, which in turn causes water to be reabsorbed. By action of the urea transporter 2, some of this reabsorbed urea will eventually flow back into the thin ascending limb of the tubule, through the collecting ducts, and into the excreted urine.

This mechanism, which is controlled by the antidiuretic hormone, allows the body to create hyperosmotic urine, that has a higher concentration of dissolved substances than the blood plasma. This mechanism is important to prevent the loss of water, to maintain blood pressure, and to maintain a suitable concentration of sodium ions in the blood plasma.

In other species

In aquatic organisms the most common form of nitrogen waste is ammonia, while land-dwelling organisms convert the toxic ammonia to either urea or uric acid. Urea is found in the urine of mammals and amphibians, as well as some fish. Birds and saurian reptiles have a different form of nitrogen metabolism, that requires less water and leads to nitrogen being excreted in the form of uric acid. It is noteworthy that tadpoles excrete ammonia but shift to urea production during metamorphosis. Despite the generalization above, the urea pathway has been documented not only in mammals and amphibians but in many other organisms as well, including birds, invertebrates, insects, plants, yeast, fungi, and even microorganisms.

Uses

Agriculture

More than 90% of world production of urea is destined for use as a nitrogen-release fertilizer. Urea has the highest nitrogen content of all solid nitrogenous fertilizers in common use (Therefore, it has the lowest transportation costs per unit of nitrogen nutrient).

Many soil bacteria possess the enzyme, urease, which catalyzes the conversion of the urea molecule to two ammonia molecules and one carbon dioxide molecule, thus urea fertilizers are very rapidly transformed to the ammonium form in soils. Among soil bacteria known to carry urease, some ammonia-oxidizing bacteria (AOB), such as species of *Nitrosomonas* are also able to assimilate the carbon dioxide released by the reaction to make biomass via the Calvin Cycle, and harvest energy by oxidizing ammonia (the other product of urease) to nitrite, a process termed nitrification^[10]. Nitrite-oxidizing bacteria, especially, *Nitrobacter*, oxidize nitrite to nitrate, which is extremely mobile in soils and is a major cause of water pollution from agriculture. Ammonia and nitrate are readily absorbed by plants, and are the dominant sources of nitrogen for plant growth. Urea is also used in many multi-component solid fertilizer formulations. Urea is highly soluble in water and is, therefore, also very suitable for use in fertilizer solutions (in combination with ammonium nitrate: UAN), e.g., in 'foliar feed' fertilizers. For fertilizer use, granules are preferred over prills because of their narrower particle size distribution which is an advantage for mechanical application.

The most common impurity of synthetic urea is biuret, which impairs plant growth.

Urea is usually spread at rates of between 40 and 300 kg/ha but rates vary. Smaller applications incur lower losses due to leaching. During summer, urea is often spread just before, or during rain to minimize losses from volatilization (process wherein nitrogen is lost to the atmosphere as ammonia gas). Urea is not compatible with other fertilizers.

Because of the high nitrogen concentration in urea, it is very important to achieve an even spread. The application equipment must be correctly calibrated and properly used. Drilling must not occur on contact with or close to seed, due to the risk of germination damage. Urea dissolves in water for application as a spray or through irrigation systems.

In grain and cotton crops, urea is often applied at the time of the last cultivation before planting. In high rainfall areas and on sandy soils (where nitrogen can be lost through leaching) and where good in-season rainfall is expected, urea can be side- or top-dressed during the growing season. Top-dressing is also popular on pasture and forage crops. In cultivating sugarcane, urea is side-dressed after planting, and applied to each ratoon crop.

In irrigated crops, urea can be applied dry to the soil, or dissolved and applied through the irrigation water. Urea will dissolve in its own weight in water, but it becomes increasingly difficult to dissolve as the concentration increases. Dissolving urea in water is endothermic, causing the temperature of the solution to fall when urea dissolves.

As a practical guide, when preparing urea solutions for fertigation (injection into irrigation lines), dissolve no more than 30 kg urea per 100 L water.

In foliar sprays, urea concentrations of 0.5% – 2.0% are often used in horticultural crops. Low-biuret grades of urea are often indicated.

Urea absorbs moisture from the atmosphere and therefore is typically stored either in closed/sealed bags on pallets, or, if stored in bulk, under cover with a tarpaulin. As with most solid fertilizers, storage in a cool, dry, well-ventilated area is recommended.

Chemical industry

Urea is a raw material for the manufacture of many important chemical compounds, such as

- Various plastics, especially the urea-formaldehyde resins.
- Various adhesives, such as urea-formaldehyde or the urea-melamine-formaldehyde used in marine plywood.
- Potassium cyanate, another industrial feedstock.
- Urea nitrate, an explosive.

Automobile systems

Urea is used in SNCR and SCR reactions to reduce the NO_x pollutants in exhaust gases from combustion from diesel, dual fuel, and lean-burn natural gas engines. The BlueTec system, for example, injects water-based urea solution into the exhaust system. The ammonia produced by the hydrolysis of the urea reacts with the nitrogen oxide emissions and is converted into nitrogen and water within the catalytic converter.

Other commercial uses

- A stabilizer in nitrocellulose explosives.
- A component of animal feed, providing a relatively cheap source of nitrogen to promote growth.
- A non-corroding alternative to rock salt for road de-icing, and the resurfacing of snowboarding halfpipes and terrain parks.
- A flavor-enhancing additive for cigarettes.
- A main ingredient in hair removers such as Nair or Veet.
- A browning agent in factory-produced pretzels.
- An ingredient in some skin cream^[11], Moisturizer, hair conditioners, .
- A reactant in some ready-to-use cold compresses for first-aid use, due to the endothermic reaction it creates when mixed with water.
- A cloud seeding agent, along with other salts.
- A flame-proofing agent, commonly used in dry chemical fire extinguisher charges such as the urea-potassium bicarbonate mixture.
- An ingredient in many tooth whitening products.
- An ingredient in dish soap.
- Along with ammonium phosphate, as a yeast nutrient, for fermentation of sugars into ethanol.
- A nutrient used by plankton in ocean nourishment experiments for geoengineering purposes.
- As an additive to extend the working temperature and open time of hide glue.
- As a solubility-enhancing and moisture-retaining additive to dye baths for textile dyeing or printing.

Laboratory uses

Urea in concentrations up to 10 M is a powerful protein denaturant as it disrupts the noncovalent bonds in the proteins. This property can be exploited to increase the solubility of some proteins. A mixture of urea and choline chloride is used as a deep eutectic solvent, a type of ionic liquid.

Urea can in principle serve as a hydrogen source for subsequent power generation in fuel cells. Urea present in urine/wastewater can be used directly (though bacteria normally quickly degrade urea.) Producing hydrogen by electrolysis of urea solution occurs at a lower voltage (0.37v) and thus consumes less energy than the electrolysis of water (1.2v).^[12]

Medical use

Urea is used in topical dermatological products to promote rehydration of the skin. If covered by an occlusive dressing, 40% urea preparations may also be used for nonsurgical debridement of nails. This drug is also used as an earwax removal aid.

Certain types of instant cold packs (or ice packs) contain water and separated urea crystals. Rupturing the internal water bag starts an endothermic reaction and allows the pack to be used to reduce swelling.

Like saline, urea injection is used to perform abortions.

Urea is the main component of an alternative medicinal treatment referred to as urine therapy.

The blood urea nitrogen (BUN) test is a measure of the amount of nitrogen in the blood that comes from urea. It is used as a marker of renal function.

Urea labeled with carbon-14 or carbon-13 is used in the urea breath test, which is used to detect the presence of the bacteria *Helicobacter pylori* (*H. pylori*) in the stomach and duodenum of humans, associated with peptic ulcers. The test detects the characteristic enzyme urease, produced by *H. pylori*, by a reaction that produces ammonia from urea. This increases the pH (reduces acidity) of the stomach environment around the bacteria. Similar bacteria species to *H. pylori* can be identified by the same test in animals such as apes, dogs, and cats (including big cats).

Analysis

Urea is readily quantified by a number of different methods, such as the diacetyl monoxime colorimetric method, and the Berthelot reaction (after initial conversion of urea to ammonia via urease). These methods are amenable to high throughput instrumentation, such as automated flow injection analyzers^[13] and 96-well micro-plate spectrophotometers^[14].

Terrorism

Ahmed Ressam, the al-Qaeda Millennium Bomber, used urea as one of the components in the explosives that he prepared to bomb Los Angeles International Airport on New Year's Eve 1999/2000; the explosives could have produced a blast 40x greater than that of a devastating car bomb.^{[15] [16]}

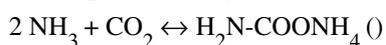
Synthetic production

Urea is produced on a scale of some 100,000,000 tons per year worldwide.^[17]

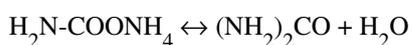
Industrial methods

For use in industry, urea is produced from synthetic ammonia and carbon dioxide. Large quantities of carbon dioxide are produced during the manufacture of ammonia from coal or from hydrocarbons such as natural gas and petroleum-derived raw materials. Such point sources of CO₂ facilitate direct synthesis of urea.

The basic process, developed in 1922, is also called the Bosch-Meiser urea process after its discoverers. The various urea processes are characterized by the conditions under which urea formation takes place and the way in which unconverted reactants are further processed. The process consists of two main equilibrium reactions, with incomplete conversion of the reactants. The first is an exothermic reaction of liquid ammonia with dry ice to form ammonium carbamate (H₂N-COONH₄).^[18]:



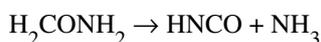
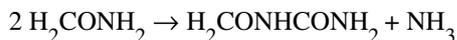
The second is an endothermic decomposition of ammonium carbamate into urea and water:



Both reactions combined are exothermic.^[17]

Unconverted reactants can be used for the manufacture of other products, for example ammonium nitrate or sulfate, or they can be recycled for complete conversion to urea in a total-recycle process.

Urea can be produced as prills, granules, pellets, crystals, and solutions. Solid urea is marketed as prills or granules. The advantage of prills is that, in general, they can be produced more cheaply than granules. Properties such as impact strength, crushing strength, and free-flowing behaviour are, in particular, important in product handling, storage, and bulk transportation. Typical impurities in the production are biuret and isocyanic acid:



The biuret content is a serious concern because it is often toxic to the very plants that are to be fertilized. Urea is classified on the basis of its biuret content.

Laboratory processes

Ureas in the more general sense can be accessed in the laboratory by reaction of phosgene with primary or secondary amines, proceeding through an isocyanate intermediate. Non-symmetric ureas can be accessed by reaction of primary or secondary amines with an isocyanate.

Chemical properties

Molecular and crystal structure

The urea molecule is planar. In solid urea, the oxygen center is engaged in two N-H-O hydrogen bonds. The resulting dense and energetically favourable hydrogen-bond network is probably established at the cost of efficient molecular packing: The structure is quite open, the ribbons forming tunnels with square cross-section. The carbon in urea is described as sp^2 hybridized, the C-N bonds have significant double bond character, and the carbonyl oxygen is basic compared to, say, formaldehyde. Urea's high aqueous solubility reflects its ability to engage in extensive hydrogen bonding with water.

By virtue of its tendency to form a porous frameworks, urea has the ability to trap many organic compounds. In these so-called clathrates, the organic "guest" molecules are held in channels formed by interpenetrating helices comprising of hydrogen-bonded urea molecules. This behaviour can be used to separate mixtures, e.g. in the production of aviation fuel and lubricating oils, and in the separation of paraffins.

As the helices are interconnected, all helices in a crystal must have the same molecular handedness. This is determined when the crystal is nucleated and can thus be forced by seeding. The resulting crystals have been used to separate racemic mixtures.

Reactions

Urea reacts with alcohols to form urethanes. Urea reacts with malonic esters to make barbituric acids.

Safety

Urea can be irritating to skin, eyes, and the respiratory tract. Repeated or prolonged contact with urea in fertilizer form on the skin may cause dermatitis.

High concentrations in the blood can be damaging. Ingestion of low concentrations of urea, such as are found in typical human urine, are not dangerous with additional water ingestion within a reasonable time-frame. Many animals (e.g., dogs) have a much more concentrated urine and it contains a higher urea amount than normal human urine; this can prove dangerous as a source of liquids for consumption in a life-threatening situation (such as in a desert).

Urea can cause algal blooms to produce toxins, and its presence in the runoff from fertilized land may play a role in the increase of toxic blooms.^[19]

The substance decomposes on heating above melting point, producing toxic gases, and reacts violently with strong oxidants, nitrites, inorganic chlorides, chlorites and perchlorates, causing fire and explosion.

External links

- MSDS sheet on urea ^[20]
- Use of urea in hand dyeing ^[21]

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