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Urea: Its Characteristics, Synthesis and Applications

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Abstract

Urea is also known as the "food of the food". Because it is considered as the most affordable and effective inorganic source of nitrogen for agricultural use. So, it has an important role in satisfying the rising global demand of food for human as well as animals. In 1828, German Scientist Friedrich Wöhler discovered that urea can be synthesised from inorganic materials. Later, Bosch–Meiser gave the most efficient process to produce urea. Currently Bosch–Meiser urea process is widely used in the industries for large scale production of urea. Here we discuss in brief about Urea, it's discovery, characteristics, method of production and important applications.

Introduction

Urea is also referred as carbamide/ Carbonyldiamide as it consists two amino groups connected by a functional carbonyl group. It is an important inorganic source of nitrogen that could be used by farmers. There are various types of Nitrogen-based fertilizers available in the market, like DAP (Diammonium Phosphate- contains 18% nitrogen), Ammonium Nitrate (34% nitrogen) and Calcium Nitrate (20% nitrogen). Urea has the advantage that it contains 46% of nitrogen. Also, urea completely dissolves in the water which is important feature that make it easily available fo absorption for the plants.

Urea is hygroscopic in nature, easily soluble in the water and hence requires good quality of packaging. If it used in excess amount in farming process, it results into increased ammonia concentrations in the soil, causes acidification of soil and loss in the quality of soil fertility. German chemists Carl Bosch and Wilhelm Meiser in 1922 gave the method to produce urea on large scale, known as Bosch–Meiser urea process. The process includes several steps like Ammonia synthesis, Carbamate formation, Conversion of Ammonia Carbamate into Urea**,** Purification, and Granulation. Apart from agriculture, urea also used as raw material in various fields like Chemical, Pharmaceutical and automotive industries.

Discovery of urea

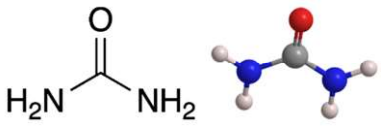
As Urea is naturally produced in Animals and Human body, excreted by kidney as part of natural cyclic process that helps to throw waste and toxic materials out of the body. It was discovered by French chemist Hilaire-Marin Rouelle in human urine in 1773.

In 1828, German Scientist Friedrich Wöhler discovered that urea can be synthesised from inorganic materials, which is an essential milestone in chemistry and agriculture. It is diamide of carbonic acid with chemical formula $CO(NH_2)_2$, where shows polar bond in the molecule, it forms hydrogen bonds between two urea molecules.

Characteristics of urea

Urea is a weak base, with a pKb of 13.9. It is a weak alkaline, which forms salts if combined with strong acids. It contains diamide of carbonic acid with chemical formula $CO(NH_2)_2$, where two amino groups ($–NH_2$) connected by a carbonyl functional group (–C=O), that's why it is also known as Carbonyldiamide. It is a colourless, odourless, solid, highly soluble in water, and practically non-toxic, with melting point of 133 to 135^{0}C. The urea molecule is planar when in a solid crystal because of sp2 hybridization of the N orbitals.

Urea is a highly concentrated, solid, containing 46.0% Nitrogen. It is completely soluble in water hence Nitrogen is easily available to crops. On the other hands it is highly hygroscopic in nature that absorbs moisture from the atmosphere and can create lumps if stored inappropriately.



Structure of Urea

Manufacturing of Urea

There are various methods used for production of urea, where industrial methods are 'Bazarov reaction' and the 'Bosch–Meiser urea process'. Bosch–Meiser urea process is used widely in the industries. It was named after its discoverers Carl Bosch and Wilhelm Meiser in 1922. The process of manufacturing of Urea as Bosch–Meiser urea process is a simple series of chemical reactions. There are three key steps involved in the production of Urea.

a) Synthesis of Ammonia

Synthesis of ammonia is the first step of urea manufacturing. It involves the reaction of nitrogen and hydrogen gas to produce ammonia gas, also known as Haber process. It releases carbon dioxide as byproduct and heat, that's so an exothermic reaction. The reaction involves the combination of nitrogen gas (N_2) and hydrogen gas (H_2) to produce ammonia gas (NH_3).

$$N_2 + 3H_2 \xrightarrow[300atm]{\blacktriangle} 2NH_3$$

In this reaction, nitrogen gas (N_2) and hydrogen gas (H_2) are combined in the presence of a catalyst to form ammonia gas (NH_3). The most commonly used catalyst is iron-based i.e., iron with Calcium oxide, Potassium Oxide, etc. which speed up the reaction and provides more yield of ammonia. The catalyst is typically suspended in the reactor and is consistently circulated to maximum contact with the reactants. The reaction occurs at high temperatures, typically between 190 and 260°C, and high pressures 300 atm.

b) Carbamate formation

The fresh liquid ammonia with gaseous carbon dioxide CO_2, at high temperature and pressure shows exothermic reaction and forms Ammonium Carbamate known as Baker's ammonia. The reaction occurs at temperatures typically between 180 and 200 °C, and high pressures of 110 atm.

$$2NH_{3(liq)} + CO_{2(g)} \rightleftharpoons NH_4CO_2NH_{2(liq)}$$

c) Conversion of Ammonia Carbamate into Urea

This is a slower endothermic decomposition reaction of ammonium carbamate into urea and water takes place between 160 to 180^0C and 140 to 175atm pressure.

Granules of Urea

$$NH_4CO_2NH_2 \rightleftharpoons CO(NH_2)_2 + H_2O$$

d) Purification

To remove impurities in urea it is purified after synthesis. The purification involves a combination of physical and chemical methods like Crystallization, Filtration and Distillation to remove impurities from the urea solution. Firstly, cooling the urea solution and then filtering out the urea crystals from the remaining solution is a purification method. The crystals of urea are then washed and dried to remove impurities.

e) **Granulation**:

Granulated urea is easier to handle and transport than powder, as it is less dusty and less prone to caking and moisture absorption. This is the final step of urea manufacturing. It involves grinding the purified urea crystals into a fine powder and converting the powder into pellets or granules. And then its ready for packaging and then supply to the market.

Applications

Urea is used in various sectors of life, some of the important applications are as follows. Agriculture Sector: Urea is a vital component in nitrogen fertilisers. It is widely used in agriculture to improve crop yields.

Chemical Industry: Used as a raw material for production of various chemicals, including pharmaceutical drugs, polymers, resins and adhesives. It is also used in the production of Melamine.

Urea can be used as raw material in manufacturing urea nitrate, a highly explosive material used in construction and industrial work.

Automotive Industry: Urea is used in the automotive industry as a diesel engine exhaust fluid (DEF) component. DEF is used to reduce emissions from diesel engines, and using urea in DEF helps reduce nitrogen oxides in the exhaust gases, which are harmful to the environment.

De-icing: Urea used as de-icing agent. It is simply applied on the runways of airplane, roads and walkways that must be kept free from corrosion and icing. (De-icing is the process of removing snow, ice or frost from a surface.)

Conclusion

Urea is a diamide of carbonic acid with chemical formula $CO(NH_2)_2$ Urea is an important and widely used fertiliser as it completely dissolves in water, so Nitrogen is easily available to the crops. On the other hands it is used as industrial raw material to manufacture various types of chemicals.

The Urea manufacturing process involves chemicals such as Ammonia and Carbon Dioxide. The process includes several steps like Ammonia synthesis, Carbamate formation, Conversion of Ammonia Carbamate into Urea, Purification, and Granulation.

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