

NCN

NCN CHEMISTRY NEWS

EDITION 1/2011

Microphotography of Cyanamide F1000 in polarized light



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EDITORIAL

Dear reader,



In the International Year of Chemistry 2011 we would like to dedicate this newsletter to the core business of AlzChem, NCN chemistry, a business that enjoys a long and rich tradition. The term „NCN chemistry“ stands for products that have a nitrogen-carbon-nitrogen bond. At AlzChem this ranges from the commercial scale production of calcium cyanamide and cyanamide through to the manufacture of derivative products such as dicyandiamide, a broad range of other guanidine compounds and numerous specialty products.

Over 100 years ago calcium cyanamide was the first product manufactured by the historic Bayerische Stickstoffwerke (see below) and at the beginning was used „only“ as a fertilizer for agriculture.

Over time this basic chemical provided the foundation for the development of an intensive value-added product chain that turned the former SKW Trostberg AG into a company which was known throughout the world, and led to this chemistry being permanently established in the ChemDelta Bavaria.

The resulting upstream integration of the product range and broad portfolio of products now live on in the AlzChem Group, where they are proving their advantages not only in economically turbulent times.

The river Alz as a lifeline not only provided the electricity in the past but now has also lent its name to the company AlzChem.

HISTORICAL PERSPECTIVES

The beginnings of our company stretch back over 100 years, and are based on the discoveries of the chemists and later founders of the company Adolph Frank and Nikodem Caro. Their ingenious finding of using calcium carbide to fix atmospheric nitrogen was developed further until it was ready for industrial-scale production. Calcium carbide production requires a great deal of electrical power due to the high temperatures involved. Flowing out of lake Chiemsee, the Alz river has a very steep incline, making it ideal for the operation of hydro power stations. This is why they decided in 1908 to begin electricity-intensive carbide/calcium cyanamide production along the Alz, founding the Bayerische Stickstoffwerke. As high-voltage technology was still in its infant stages, it was more economical at the time to transport the raw materials to the electricity rather than to feed the electricity over long distances to the factories.

Dr. Nikodem Caro was born in Łódź on May 23, 1871. He studied chemistry in Charlottenburg and received his doctorate from the university of Rostock. He died in Zurich on June 27, 1935.

Dr. Adolph Frank was born on January 20, 1834. He studied pharmacy and science at the university of Berlin. He began to take an interest in the use of potash salts as fertilizers at a very early stage. He died in Zurich on May 30, 1916. His son, Dr. Albert Frank, followed in his father's footsteps and together with Caro headed the production of calcium cyanamide in the Bavarian Chemical Triangle until 1938.

BASICS/BACKGROUND

Cyanamide and its salts

Based on its expertise and the long tradition of calcium carbide and calcium cyanamide production AlzChem continues to be the leading manufacturer of cyanamide and its derivatives. Cyanamide is manufactured on a commercial scale at the Trostberg site from calcium carbide and nitrogen with subsequent hydrolysis (a simplified overview of the process is shown in Figure 1).

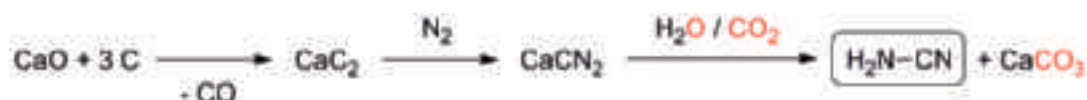


Figure 1: Individual production stages in the manufacture of cyanamide.

Cyanamide can also be obtained in the form of various metal salts. Alongside the outstanding importance of calcium cyanamide, other compounds play a rather subordinate role, although some of them are used in special applications. Moreover, the cyanamide anion can act as a complex ligand. The next sections explain the most important substances in more detail.

Cyanamide is capable of forming two sodium compounds depending on the reaction stoichiometry – monosodium cyanamide (NaHNCN) and disodium cyanamide (Na_2CN_2) – whereby only the monosodium salt has aroused much interest. Even if in most cases the direct use of Cyanamide L500 and sodium hydroxide is possible, the isolated intermediate can be advantageous in particular cases with regard to the reaction control (e.g. water-free systems).

Heavy metal cyanamides are easiest to access by reacting the appropriate soluble metal precursors with cyanamide in an aqueous solution. This results in products with a microcrystalline structure, and

Systematic and continual research means that we are able to offer this molecule with its broad range of different uses in the most diverse forms.

For example, a 50% solution (brand name Cy L500) can be obtained in water in technical and highly pure quality. In addition, we are able to offer our customers solid cyanamide in pure form (Cy F1000 – shown on the cover picture).



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Did you know...

...that some plants, such as the *hairy vetch* and the *native tufted vetch*, themselves produce cyanamide? The cyanamide content of the plants is up to 0.35%. It is supposed that the plants use the cyanamide they produce as a herbicide to suppress the growth of rival plants around them. Scientists are investigating the precise biosynthesis of cyanamide, but they have not yet found the full explanation.

some of these products have an intensive coloring (see Figure 2). Hence they can also be used as pigments.



colorless	cadmium, mercury, zinc cyanamide
yellow	silver, lead cyanamide
green	nickel cyanamide
reddish brown	cobalt cyanamide
jet black	copper cyanamide

Figure 2: Coloring of various metal cyanamides.

In inorganic salts the cyanamide ion exhibits a linear, symmetrical structure, correspondingly $[\text{N}=\text{C}=\text{N}]^{2-}$. With its 16 valence electrons it is isoelectronic to CO_2 , CNO^- , NCO^- , NCS^- , NO_2^+ and N_3^- . In particular the example of low water solubility and low thermal stability shows clearly the relationship to azides.

For example, some of the cyanamides from silver(I), thallium(I), mercury(I) and copper(II) decompose violently at elevated temperatures.

For a long time lead cyanamide was of technological importance as an active anti-corrosion pigment that acts as an alkaline passivator. Due to its toxicity it was sometimes replaced by the less harmful zinc cyanamide. The latter is also used as a primer for paint application.

The jet black copper cyanamide is only suitable to a limited extent as a pigment due to its lower thermal stability. However, its fungicide effect (e.g. wood protection) may be of interest either as a pure substance or as the corresponding methylol compound.



APPLICATIONS

Cyanamide as an amidinating reagent

As reported in Newsletter 01/2010, cyanamide can be used as an amidinating reagent for practically every amine. For example, glycine or sarcosine are converted with cyanamide into the corresponding guanidine compounds guanidinoacetic acid (GAA, brand name CreAmino®) and creatine (brand name Creapure®).

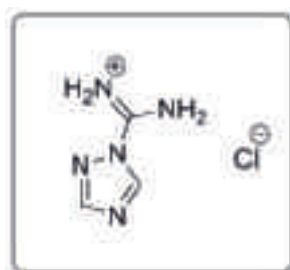


If cyanamide proves to be too unreactive for a reaction then AlzChem also offers suitable solutions for this, e.g. in the form of the derivative chloroformamide hydrochloride. This reagent is obtained

in a simple reaction from the basic substance cyanamide and hydrogen chloride (Figure 3), and exhibits a higher reactivity in amidination reactions than cyanamide. Another outstanding reagent for producing guanidine compounds is amidinotriazole (see box), which is accessible from cyanamide and triazole.

Introducing a leaving group (in this case the heterocycle) enormously increases the reactivity of cyanamide in relation to the amidinating properties. Moreover, formamide acetate (accessible by

reducing cyanamide using hydrogen, Fig. 4) and chloroformamidinium hydrochloride represent valuable N=C=N building blocks that are used in synthesizing heterocyclic compounds such as pyrimidine or imidazole and their related structures (Figures 4 and 5). Particularly interesting here is the mechanism of the reaction of chloroformamidinium hydrochloride with molecules such as those shown in Fig. 4. First an amidination of the amine group of the heterocycle occurs. The subsequent ring-closure reaction via liberation of ethanol results in the interesting 2-aminopyrimidine structures.



1-Amidinotriazole hydrochloride

Did you know

...that AlzChem not only offers the specialty product formamidinium as an acetate but is also able to manufacture the corresponding hydrochloride and hydrogen sulfate? This enables the needs of the customers to be met in line with their requirements for the planned reaction.

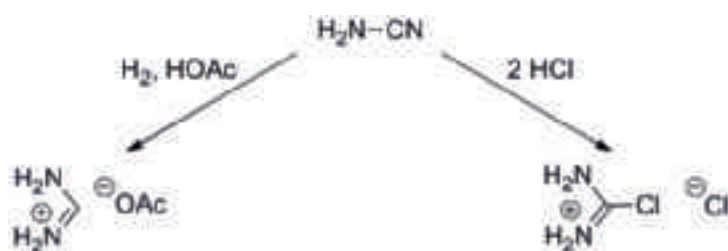


Figure 3: Synthesis of formamidinium acetate and chloroformamidinium hydrochloride.

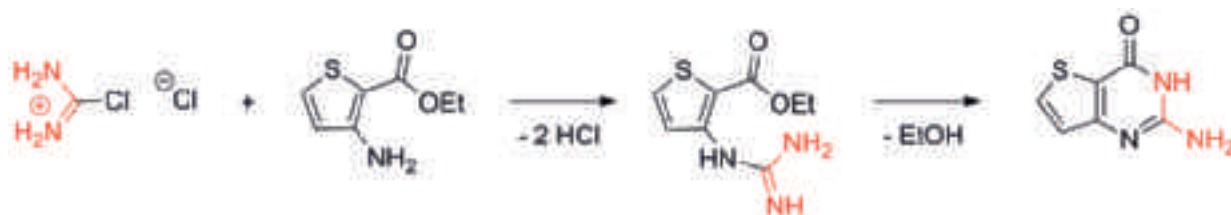


Figure 4: Chloroformamidinium hydrochloride in chemical synthesis.

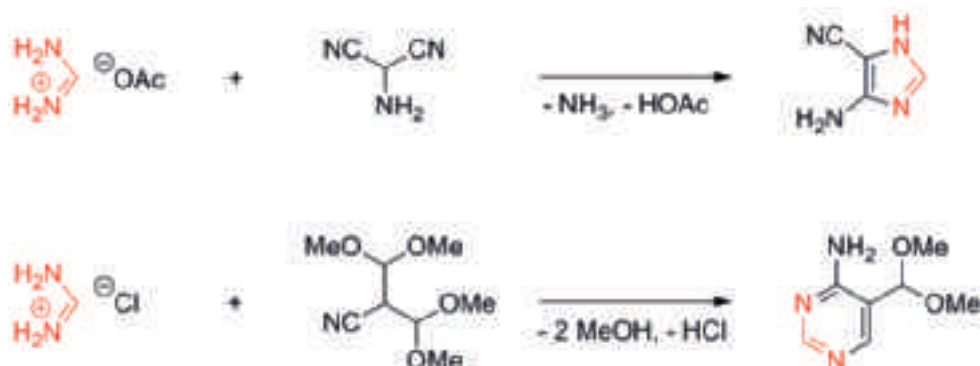
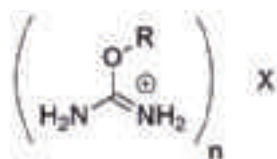


Figure 5: Applications of formamidinium acetate and formamidinium chloride in heterocyclic synthesis.

APPLICATIONS

O-Alkylisoureas

The classic NCN product portfolio of AlzChem is being expanded to include O-alkylisoureas. Selecting the alkyl substituents and monovalent or bivalent anions yields numerous different variations. At present the following derivatives are available:



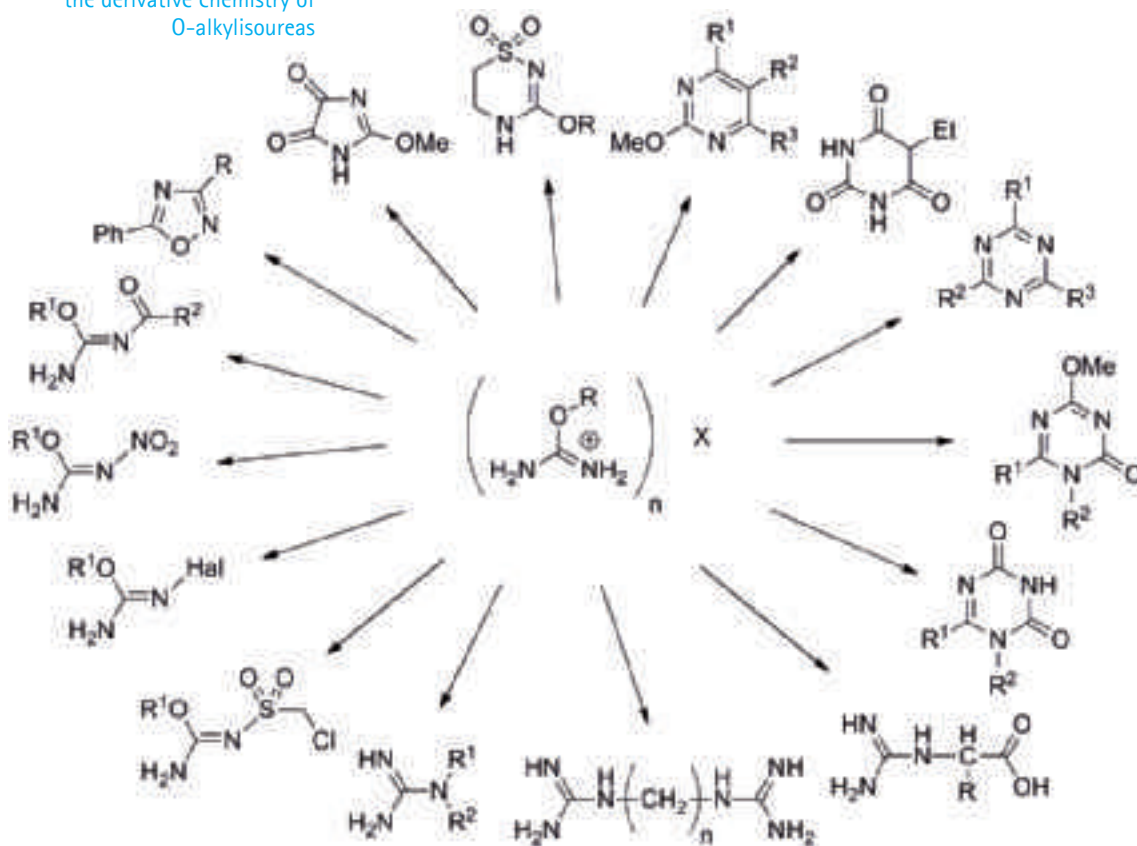
R	methyl	ethyl	isopropyl
X	Ac ⁻	HSO ₄ ⁻	SO ₄ ²⁻
n	1	1	2

As a result of the ambivalent reactivity of these NCN building blocks, numerous applications in organic synthesis emerge (Figure 6). Here three basic fields of the derivative chemistry of O-alkylisoureas may be distinguished:

- substituted isoureas
- heterocycles
- guanidines

The first field, the conversion of O-alkylisoureas into N-substituted isoureas, isobiurets and thioisobiurets, results in building blocks which themselves in turn exhibit a diverse derivative chemistry. Often ring systems with special substitution patterns can be obtained that are accessible only with great difficulty by other methods. Due to the structural relationship both to guanidine and to amidines particular importance lies in the field of direct heterocyclic synthesis, especially of the pyrimidine ring system. Ring-closure reactions with β -dicarbonyl compounds are a good example of this. But it is also possible to construct numerous variations of the s-triazine.

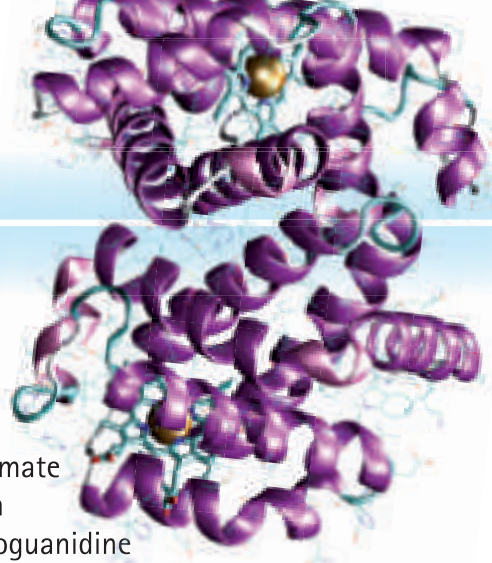
Figure 6: Examples of the derivative chemistry of O-alkylisoureas



Finally, O-alkylisoureas are excellently suited for synthesizing guanidine derivatives that are very difficult, if at all possible, to access directly from cyanamide.

In contrast to the likewise suitable isothiurea analogues only the corresponding alcohol is released during the guanylation reaction, rather than the very malodorous mercaptans, which makes the work much more pleasant.

Guanidines



The compounds mentioned overleaf serve for building heterocycles and diverse and various guanidine compounds. As part of the NCN chemistry that is deeply-rooted in the company, AlzChem offers numerous guanidines for the most diverse applications. Because of their structure, guanidines are among the strongest organic bases (pKs approx. 13.5), whose strength matches that of alkali hydroxides.

One reason for this is the outstanding resonance stabilization of the guanidinium cation. Therefore unsubstituted guanidines are sold mostly as salts. However, AlzChem offers free guanidine as a 50% methanol solution. Apart from the well-known DCD (dicyandiamide; 1-cyanoguanidine), which is used primarily as a hardener for epoxy resins, the unsubstituted guanidine can be

obtained using, for example, chloride, nitrate, formate, sulphamate and thiocyanate as a counter-ion (Figure 7). Because DCD and nitroguanidine (see below) have electron-withdrawing groups, these two substances do not react basically and are stable as free guanidines.

The guanidines have diverse applications: Guanidinium nitrate and nitroguanidine are used as propellants, e.g. for airbags; highly pure guanidinium hydrochloride and the corresponding thiocyanate are used in biochemistry for cleaning proteins. In additionally alkyl- or amino-substituted guanidines can also be manufactured (Figure 8). More complex compounds such as biguanide or phenylguanidine round out the AlzChem Group's palette of open-chain guanidine compounds.

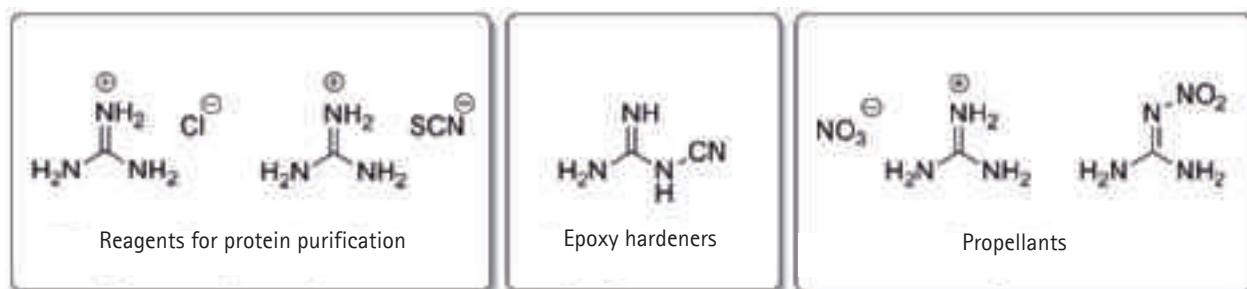


Figure 7: Blockbusters of the AlzChem Group

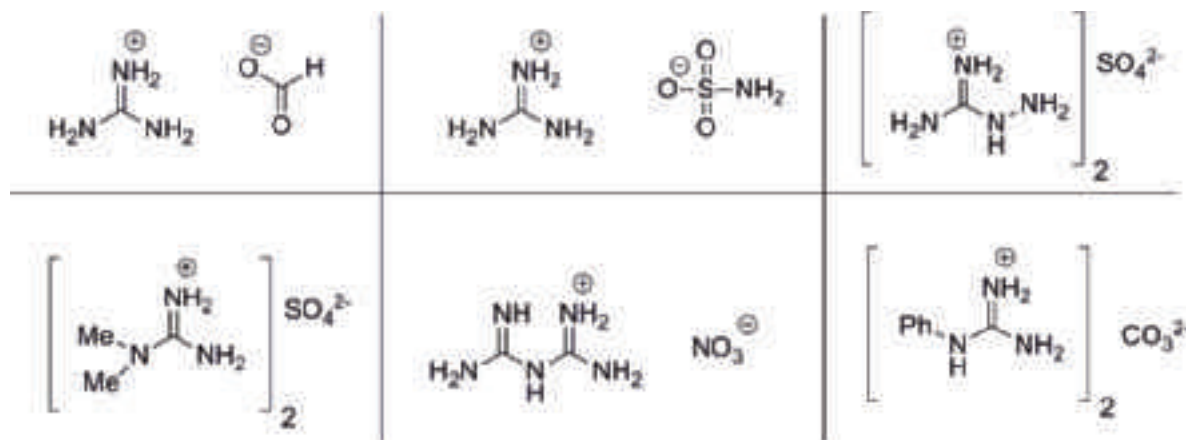


Figure 8: Special guanidines of the AlzChem Group



Cyanamide and its derivatives:

Cyanamide L500	CAS (420-04-2)
Cyanamide F1000	CAS (420-04-2)
Monosodium cyanamide	CAS (17292-62-5)
1-Amidino-1,2,4-triazole hydrochloride	CAS (19503-26-5)
Formamidine acetate	CAS (3473-63-0)
Chloroformidine hydrochloride	CAS (29671-92-9)
O-Methylisourea hydrogen sulfate	CAS (29427-58-5)
O-Methylisourea sulfate (2:1)	CAS (52328-05-9)
O-Methylisourea acetate	CAS (77164-02-4)
O-Ethylisourea hydrogen sulfate	CAS (68303-38-8)
O-Isopropylisourea monohydrochloride	CAS (28811-41-8)
N-Methoxycarbonyl-O-methylisourea	CAS (40943-37-1)

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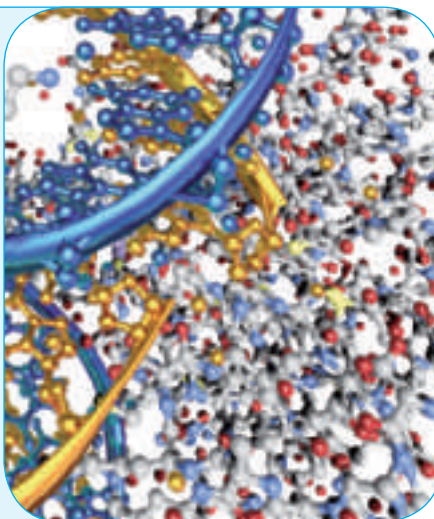
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Guanidines:

Guanidine hydrochloride	CAS (50-01-1)
Guanidine thiocyanate	CAS (593-84-0)
Dicyandiamide	CAS (461-58-5)
Guanidine nitrate	CAS (506-93-4)
Nitroguanidine	CAS (556-88-7)
Guanidine formate	CAS (63656-95-1)
Guanidine sulfamate	CAS (50979-18-5)
Aminoguanidine sulfate	CAS (996-19-0)
N,N-Dimethylguanidine sulfate	CAS (598-65-2)
Biguanide nitrate	CAS (22817-07-8)
Phenylguanidine carbonate	CAS (6291-89-0)



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