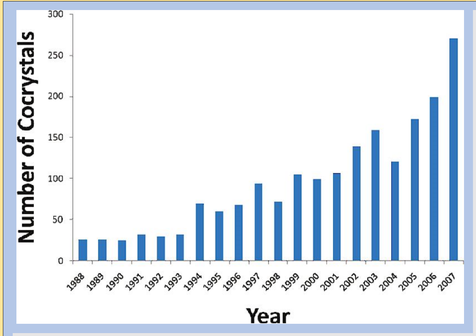
THE USE OF COCRYSTALLIZATION OF CL-20 AND HMX IN UNITED STATES MILITARY EXPLOSIVES

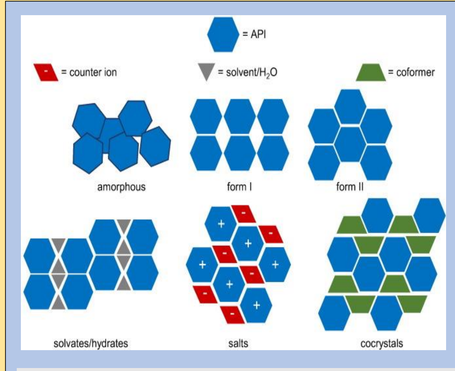
Zachary Sebastian and Edward Ganter

History of Cocrystallization



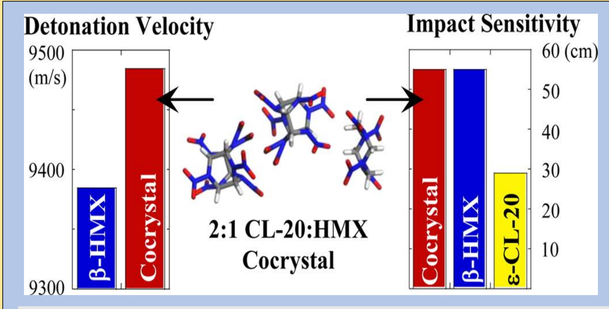
Cocrystallization is the process of combining two or more compounds together to make a unique cocrystal that differs from a normal mixture of the original compounds. Cocrystals were originally discovered in 1844 by Friedrich Wöhler. When X-ray diffraction was invented in the 1920's researchers were able to see the molecular structure of compounds and identify what made cocrystals different from the normal mixtures of two or more compounds. Cocrystals are useful because they are able to take the advantageous properties from different compounds and combine them. Cocrystals have primarily been used in the Pharmaceutical industry, but recently have started being applied in other fields such as explosive manufacturing.

Science Behind Cocrystallization



Cocrystals can be created a few different ways. They can be made by combining aqueous mixtures of two or more substances and drying them out leaving behind the cocrystals. They can also be created by sending the solids straight from solid to gas forms, growth from the melt, slurries mixtures of the two compounds, or by grinding them together in a ballmill. The molar ratios between the compounds used also plays a role in determining the properties of the final cocrystal. The reason cocrystals behave differently from normal mixtures of the compounds is because of different hydrogen bonding and intramolecular forces present in the cocrystals caused by the cocrystallization process. It is important for researchers to understand the chemistry behind cocrystallization because with all the different possible combinations of cocrystallization techniques, trying to create a desired cocrystal can be extremely difficult if only relying on blind trial and error.

Cocrystal of HMX and Cl-20



The cocrystal of HMX (1,3,5,7-tetranitro-1,3,5,7-tetrazacyclooctane), and CL-20 (2,4,6,8,10,12-hexanitro-2,4,6,8,10,12-hexaazaisowurtzitane) is a combination of two explosives that was created to have more powerful explosions while maintaining a low chance of accidentally exploding. HMX is a traditional explosive used by the United States military. It has a relatively high impact sensitivity meaning it can survive more applied force without exploding. The downside of HMX is that it is not very powerful. CL-20 on the other hand is one of the most powerful explosives ever discovered, but is very sensitive to force and can explode by accident very easily. The cocrystal combines CL-20 and HMX in a 2:1 molar ratio. It has a detonation velocity, a way to express explosive force, that is an average of HMX and Cl-20's. The cocrystal, however maintains an impact sensitivity nearly identical to HMX's. This combination means that it only sacrifices a little explosive power for a big increase in safety.

Decreasing Accidental Explosions

One major catastrophe that happens occasionally for American soldiers is accidental explosions. These explosions ca take the lives of US soldiers, and can be caused by a bullet or a crash with enough magnitude to set a bomb off. These accidental explosions occur because the chemicals that make up modern explosives like RDX and TNT are very sensitive. If enough energy is absorbed by the explosive or if enough force is exerted on the explosive, the chemicals that make up the explosive will react, causing the bomb to detonate. With a new cocrystal of HMX and Cl-20, these accidental explosions will happen less frequently because the cocrystal is not as sensitive to energy exerted on it as the currently used modern explosives. If shot by a bullet, or dropped accidentally, explosives containing this new cocrystal will be much less likely to go off and injure, or kill, the soldiers handling them. This new explosive is an advancement from modern explosives like RDX because is less likely to accidentally detonate, and is more powerful than the modern explosives the military utilizes today.

Environmental Advantages

There are several advantages to a new cocrystal of HMX and Cl-20 over older, out-of-date explosives such as RDX and TNT. The main environmental advantage of a cocrystal of HMX and Cl-20 is that it would leave behind very little residue that is harmful to the environment. With explosives like RDX, a large amount of acetic acid is left behind after the explosion occurs. Acetic acid is a weak acid that is very detrimental because it can damage the skin and eyes of civilians and animals, and can cause damage to internal organs if ingested. RDX has also been known to release toxins into the atmosphere that can cause sickness and nausea in humans and animals. If RDX was replaced by an HMX and Cl-20 cocrystal, there would be fewer highly toxic chemicals like acetic acid lying around in the environment. With lower quantities of toxic chemicals the environment would be safer to inhabit.

Sustainability and Ethics

If an engineering or scientific advancement is to be sustainable, it has to benefit civilians in society and improve the current state of society and the environment. It also has to leave behind no negative impact o future generations of people. A cocrystal of HMX and Cl-20 will be sustainable because it will help save the lives of many soldiers on the battlefield from accidental explosions. It will also be less of a danger to the lives of innocent civilians in the range of one of these explosions. Another benefit is that it will improve the quality of the environment, which will keep civilians and organisms from developing sicknesses from the dangerous chemicals used in traditional explosives. The cocrystal will keep the environment more safe and stable for future generations.