

A possible role for space diamonds in origin of life

Posible influencia de los diamantes cósmicos en el origen de la vida

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Abstract

The possibility of forming many widespread carbon compounds based upon detonation nanodiamonds has been shown from thermodynamic data. These reactions may play a key role in the origins of life and the formation of atmospheres of giant planets within our solar system.

Key words: detonation, diamonds, properties, reactivity, origin of life.

Resumen

Con datos de termodinámica el trabajo muestra la posibilidad de formación de varios compuestos de carbono basados en los nanodiamante de detonación. Estas reacciones pueden jugar un papel importante en los orígenes de la vida y la formación de atmósferas de planetas gigantes dentro de nuestro sistema solar.

Palabras clave: detonación, diamantes, propiedades, reactividad, origen de la vida.

GREINER *et al* (1988) noticed the similarity between detonation nanodiamonds (DND) with the diamonds of a meteoric origin. Assuming that diamonds in space are formed in space explosions of supernovae (HENBEST 1980), in the peripheral area of red giant stars (CLEGGETT-HALEIM *et al* 2001) and in shock collisions of carbon meteorites (FISENKO *et al* 1987) (ALAMANDOLA *et al* 1992, 1993) considers that the carbon content of interstellar clouds contain up to 20% nanodiamonds.

The detonation nanodiamonds differ from the other types of diamonds in their shape (figure 1).

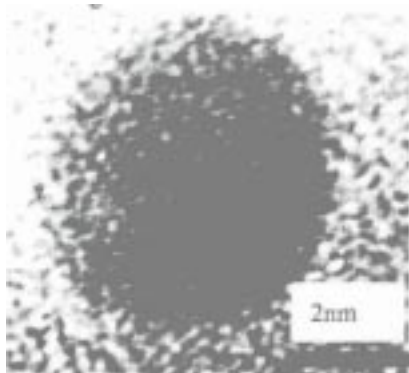
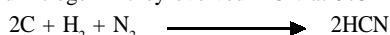


Figure 1. Particle of detonation nanodiamonds

Particle shape of DND is connected with the unusual formation mechanism through liquid carbon phase. They have a narrow average size of particles about 4-6 nm, which consist of hollow spheres (VERESHCHAGIN *et al* 2001) and resemble a solid diamond foam. They have a tetragonal crystal structure (VERESHCHAGIN *et al* 2003) and a very high enthalpy of formation +3,425 MJ/kg (diamonds under a standard condition of +0,158 MJ/kg). For the same reason DND have an unusual high reactivity for carbon dioxide (adsorption up to 753 K) and for a mixture of hydrogen and nitrogen – they evolved HCN at 573 K (VERESHCHAGIN 2001):



On the basis of these data, it is possible to suggest the following model of carbon transformations in space (VERESHCHAGIN 2002).

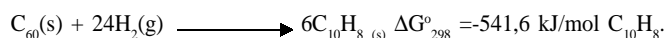
Detonation nanodiamonds reactions with hydrogen. During the explosion of a star enriched with carbon, nanodiamonds should be formed through a liquid phase in the environment of hydrogen and helium. Liquid carbon 'nanodroplets' containing dissolved hydrogen and helium will crystallize. The process of crystallization of the diamond droplets will start from the surface. Due to the difference of density of liquid and crystal diamond (3.22 g/cm³ against 3.515 g/cm³ of crystal) often such a crystalli-

zation process forms voids (spaces) inside the particles. These voids will be filled with hydrogen and helium at high pressure as the gasses come out of solution. It is established, that the diamonds formed in space have the critical size 2.9...3 nm (BADZIAG *et al.* 1990); (ANISICHKIN *et al.* 1988). In that case the internal diameter of a cavity is about 1.54 nanometers, and the thickness of walls - will be not less than 0.78 nm (or approximately 5 lengths of bond C-C) (assuming, the density of star diamond to be equal to the density of the DND – 3.05 g/cm³). These are abnormally high values for the curvature of the DND surface resulting in their high reactivity. The hydrogen contained inside at very high pressure (by our estimations for DND up to 20 MPa) can diffuse on the particles' surface and be desorbed as methane molecules. This will lead to the reduction of thickness of the walls of diamond particles. The thinning of the walls of the nanospheres due to the formation of carbon compounds is unlikely to result in the actual formation of C₆₀ since the high internal pressure will burst the thinning sphere at some point and release the compounds - and reduce the internal pressure. A limiting case of this transformation is the formation of the one-layer closed structure (like fullerenes) with a carbon transition from sp³ to sp² hybridised state. Subsequent hydrogenation by high-energy protons causes transformation into flat polycyclic fragments such as molecules of naphthalene. The thermodynamic probability of such reaction is great enough, as standard enthalpy formations of fullerenes C₆₀ is equal to +2346 ± 12 kJ/mol (Diky *et al.* 2000) and nanodiamonds + 41,1 kJ/mol. To estimate the possibility of such a transformation we shall make the following assumptions.



In view of these assumptions, we obtained a value of minus 3692,8 kJ/mol C₆₀ for standard Gibbs energy change. Therefore nanodiamonds *can*, in principle, form fullerenes.

From a thermodynamic viewpoint, the formation of naphthalene structures from DND, and the fullerenes are also possible. However, the velocity of these processes can be insignificant at the low temperatures of the interstellar space. Perhaps the high kinetic energy of colliding particles may compensate for the low temperature of the surrounding space and allow the reactions to take place more quickly:

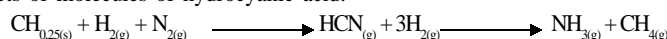


Again thermodynamic considerations predict that subsequent hydrogenation of aromatic cyclic structures up to methane is possible, but, it is likely only to take place with the participation of the atomic hydrogen or through a complex mechanism:

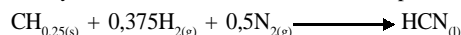


Heating particles of DND at temperatures higher than 1473 K under the influence of colliding with high-energy space particles must result in the graphitization of the DND.

Detonation nanodiamonds reactions with nitrogen and hydrogen. As DND are capable of reacting with N₂ and H₂ under soft conditions (VERESHCHAGIN *et al* 1996) as shown by the presence in the reaction products of molecules of hydrocyanic acid:



Thus it is necessary to note, that the mechanism of hydrocyanic acid formation should include some other stages. From the point of view of thermodynamics the HCN formation in the process

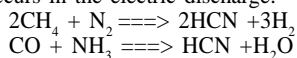


is impossible for thermodynamic reasons as Gibbs potential is positive + 70 kJ/mol HCN. From a thermodynamic viewpoint the formation of hydrocyanic acid is more likely via nitrils, cyanogens, dicyanogen or

dicyanoacetylene. Taking into consideration the data received that further elucidate the formation of hydrocyanic acid from DND under the laboratory conditions, one can assume, that N_2 is first chemisorbed with the dissociation into atoms on the DND surface followed by the formation of nitryl groups, which are subsequently hydrogenated with H_2 (probably as well as by atomic hydrogen) to produce hydrocyanic acid.

The curvature of the surface is extremely high due to the nanosize of diamonds and the latter favours the dissociation of the adsorbed diatomic molecules of hydrogen into atoms.

The observed formation of a hydrocyanic acid under soft conditions provides additional data for the consideration of the initial stages of the genesis of carbon compounds in the Universe. So, according to the classic theory of the life origin on the Earth (MILLER 1953), the formation of HCN occurs in the electric discharge:



Considering the data regarding the formation of hydrocyanic acid under mild conditions provides a new perspective on this theory.

Further, the structure of the atmospheres of giant-planets in our Solar system can include ammonia and methane in a molar ratio approximately 1:1 (table 1) (one must take into account the composition of aerosols).

Table 1. The structure of the gas atmospheres of planets-giants of Solar system

Planet	Composition of atmosphere [http://nssdc.gsfc.nasa.gov/planetary]
Jupiter	H_2 - 89.8%; He - 10.2% impurities (ppm): CH_4 - 3000; NH_3 - 260; HD - 28; C_2H_6 - 5.8; H_2O - ~4 Aerosols: solid NH_3 , H_2O , NH_4HS
Saturn	H_2 - 96.3%; He - 3.25% impurities (ppm): CH_4 - 4500; NH_3 - 125; HD - 110; C_2H_6 - 7 Aerosols: solid NH_3 , H_2O , NH_4HS
Neptune	H_2 - 80.0%; He - 19.0%; CH_4 1.5% impurities (ppm): HD - ~192; C_2H_6 - ~1.5 Aerosols: solids NH_3 , H_2O , NH_4HS , CH_4 (?)
Uranus	H_2 - 82.5%; He - 15.2%; CH_4 - ~2.3% impurities (ppm): HD - ~148 Aerosols: solids NH_3 , H_2O , NH_4HS , CH_4 (?)

Precisely the same parity between these compounds is observed under the reduction of a hydrocyanic acid with hydrogen $HCN + 3H_2 = CH_4 + NH_3$. In view of these data it is possible to hypothesise that in the first stage of formation of giant-planets of the solar system there was hydrocyanic acid which was subsequently converted to ammonia and methane (VERESHCHAGIN 2003). The HCN was originally formed from ultradisperse carbon, hydrogen and nitrogen.

Therefore, the products of the carbon stars explosion may contain a plenty of the various carbon substances formed in the reactions of a primary carbon, – hollow diamond nanoparticles and the products of their hydrogenation: fullerenes, polycyclic structures, hydrocyanic acid, ammonia, methane. Besides, the DND at temperatures higher than 1273 K are capable to be graphitized.

Thus, detonation nanodiamonds may be hypothesised as the primary state of carbon in the Universe.

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Special section: Microscale Science Sección especial: Ciencia en microescala

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Determination of the hardness of water by a microscaled EDTA titration

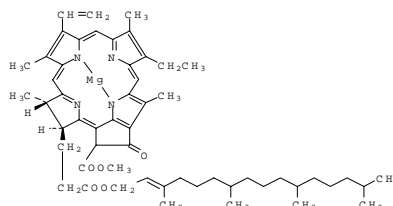
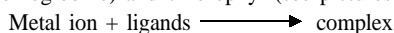
INTRODUCTION

Most of the water that we drink contains positive ions (cations) and negative ions (anions). The most common cations in water are Na^+ , Ca^{2+} and Mg^{2+} . These ions are the substituents of most of the earth's rocks, and during solubility they will always be found in rivers, lakes, and the ocean.

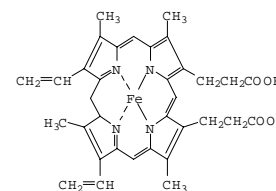
When water contains these two ions it is called "hard water", and without these ions the term is "soft water" (e.g., rain water).

How is the "hardness" of water determined?

To determine the **amounts** of Ca^{2+} and Mg^{2+} (hardness) in water, a known technique called "complexometric titration" is used. **Complexes** are compounds that are produced when an ion metal reacts with molecules or ions (ligands) that have a tendency to "contribute" electrons. An example of two well known complexes in our everyday life are hem (hemoglobine) and chlorophyl (see pictures below).



Chlorophyl



hem

One of the most powerful ligands which is used to form complexes with many kinds of ion metals is EDTA (ethylene diamine tetra acetic acid).