Journal of Chemistry Science
ISSN: 3078-736X
DOI: https://doi.org/10.61784/jcs3001

CARBON ELEMENT AND SCIENTIFIC SPIRIT OF CHEMISTRY CORE ACCOMPLISHMENT

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Abstract: Carbon is a magical, unknown and awesome element. This paper tries to discuss and analyze the relevances between partial allotrope and nanostructure of carbon element and accomplishment of chemistry (which contains scientific exploration and innovation and creation con- sciousness, scientific attitude and social responsibility). Moreover, it expounds how to embody the accomplishment of chemistry and ideological and political guidance through the scientific knowledge related to carbon elements, and expects to experience the charm of scientific and techno-logical knowledge and discovery in the rich and colorful carbon element world through the deep understanding of the core accomplishment of chemistry.
Keywords: Carbon element; Allotropes; Scientific spirit; Accomplishment of chemistry

1 INTRODUCTION

Literacy is a way of thinking, behavior pattern, and emotional response that a person demonstrates through his or her standpoint and perspective on cognition of things, and his or her ideas and methods for solving problems. It reflects his or her values, moral values, and psychological qualities [1]. For each discipline, there are also its own literacy requirements, namely, disciplinary literacy, which is a comprehensive expression of knowledge, ability, and attitude based on the characteristics of the discipline. It is the disciplinarization and concretization of scientific literacy. For the discipline of chemistry and chemical engineering, disciplinary literacy is to cultivate and practice scientific literacy at the level of chemistry. Therefore, it is the deepening and development of disciplinary literacy. On the other hand, it must reflect and embody the characteristics of chemistry and chemical engineering, and is the concretization of disciplinary literacy and the embodiment of chemistry. Scientific inquiry and innovation and creation awareness, scientific attitude, and social responsibility are important aspects of chemistry and chemical engineering disciplinary literacy. We believe that scientific knowledge and scientific discoveries related to carbon are closely related to the scientific spirit of chemistry and chemical engineering disciplinary literacy.

So far, scientists have studied and reported at least 16 forms of carbon, including allotropes, crystals or nanostructures, of which 15 have been discovered in production practice or prepared in the laboratory. In biochemistry, carbon combines with other elements to form DNA, proteins and other types of biological macromolecules, becoming the most basic and common element that constitutes life on Earth. The colorful carbon element has more than just a place in chemistry, and its understanding process can almost perfectly reflect all aspects of the chemistry and chemical engineering literacy. This article attempts to explore and analyze some allotropes of carbon and their nanostructures, explain how to reflect the understanding of chemistry and chemical engineering literacy and ideological and political guidance through the study of carbon knowledge, and explore how to internalize chemistry and chemical engineering knowledge into learners' disciplinary literacy. In particular, it explains the scientific achievements related to carbon and the core literacy and ideological and political guidance values of scientists in scientific exploration and innovation and creation awareness, scientific attitude and social responsibility. At the same time, it is hoped that through a deep understanding of the core literacy of chemistry and chemical engineering, we can feel the charm of cutting-edge scientific knowledge and discoveries in the colorful world of carbon materials.

2 CARBON AND THE SCIENTIFIC EXPLORATION AND INNOVATION AWARENESS OF CHEMICAL AND CHEMICAL ENGINEERING LITERACY

Scientific inquiry and innovation drive require us to discover and raise valuable chemical questions, design feasible operation plans, explore the laws behind experimental information and data, and optimize and improve the experimental design on this basis; at the same time, this core literacy tells us that scientific research must respect facts and evidence, think independently, and have the innovative spirit of daring to question and criticize. Since the 1980s, scientists have been interested in obtaining new carbon structures and innovative thinking. Research work in the fields of fullerenes and graphene has won the Nobel Prize twice [2]. This has not only had a huge impact in related fields such as chemistry, physics, materials and information science, but also spawned a large number of industrial and technological applications. Based on these carbon nanostructures, scientists have synthesized many new derivatives and made new functional devices and related products.

The innovative spirit of science is to dare to challenge common sense and even authority. The discovery of some new pure carbon structures in recent years fully reflects the power of scientific inquiry and innovation consciousness, which is the core quality of chemistry. In 2011, scientists predicted the possibility of the existence of T -carbon through theoretical calculations. Based on the first principle study of density functional theory, it was found that the form of this carbon is extremely stable in terms of geometry, thermodynamics and kinetics, and the new allotrope of this carbon is named T -carbon. But for a long time, no one has observed and been able to synthesize it in the laboratory. T -carbon is a new three-dimensional carbon structure with the same space group as diamond. Its density is very small, about 2/3 of graphite and half of diamond. T -carbon also has a high hardness. Since T-carbon is a fluffy carbon material, there is a lot of space inside it for use. If it is used for energy storage materials, its hydrogen storage capacity is not less than 7.7% (mass fraction). Due to the above unique properties, T -carbon will have a wide range of potential applications in the fields of photocatalysis, adsorption, energy storage, aerospace materials, etc. Three years ago, Niu Chunming's research group at Xi'an Jiaotong University and a joint research team from Nanyang Technological University in Singapore successfully achieved the transition from sp^2 to sp^3 chemical bonds under conditions of extreme deviation from thermodynamic equilibrium by using a systematic experimental design of picosecond laser irradiation of multi-walled carbon nanotubes suspended in a methanol solution (Figure 1) . Detailed structural studies found that the new carbon material formed was completely consistent with the theoretically predicted T -carbon, proving that T -carbon was synthesized , thereby adding a new member to the carbon family.

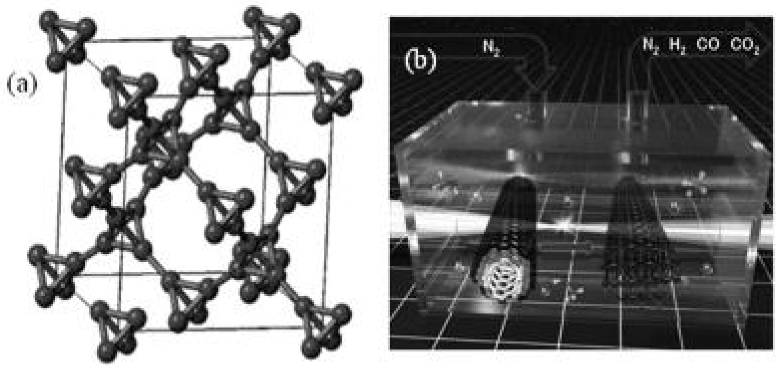

Figure 1 T-carbon Structure (a) and Its Picosecond Laser Irradiation Preparation of Multi-Walled Carbon Nanotubes Suspended in Methanol Solution (b)

In fact, long before chemists theoretically predicted T-carbon, they proposed through a large number of comparative studies that if each carbon atom in cubic diamond is replaced by a regular tetrahedral structural unit composed of 4 carbon atoms, a new three-dimensional cubic crystal structure of carbon will be formed. It is this scientific exploration and innovative consciousness that led to the birth of T-carbon, a new member of the carbon family.

The core role of chemistry and chemical engineering is to create new substances. Quasi-two-dimensional crystals were once considered by the academic community to be thermodynamically unstable, but it was precisely because of scientists' independent thinking and innovative spirit of daring to question and criticize that the preparation of graphene became possible. Unlike graphene, chemists believed from the beginning that it was possible to produce cyclic pure carbon molecules. Many scientists have tried to capture cyclic carbon and determine their molecular structure, but long-term work has been difficult to make progress. In August 2019, Science magazine published a result of a collaborative research between the Department of Chemistry at the University of Oxford and the IBM Zurich Laboratory [3], which synthesized the world's first cyclic molecule composed of pure carbon atoms, C_{18}. The 18 carbon atoms in C_{18} are connected by alternating single bonds and triple bonds. Chemists started with a triangular molecule composed of carbon and oxygen, and used an atomic force microscope or a scanning tuning microscope under high vacuum conditions to pass an electric current on the surface of a sodium chloride crystal to remove oxygen-containing groups (CO) to produce this C_{18} ring (Figure 2). Preliminary research on the properties of this ring carbon molecule shows that it has the function of a semiconductor and can become a potential molecular-level electronic component. In theoretical research on carbonaceous nano-ring molecules, the structures of C_{10} and C_{14} rings were predicted, and it was pointed out that they are more thermodynamically stable than C_{18} ring molecules. Scientists have prepared a new carbon allotrope, C_{18} ring, by precisely manipulating the atoms in the molecule, which is itself a profound manifestation of fearlessness of challenges, scientific exploration and innovation.

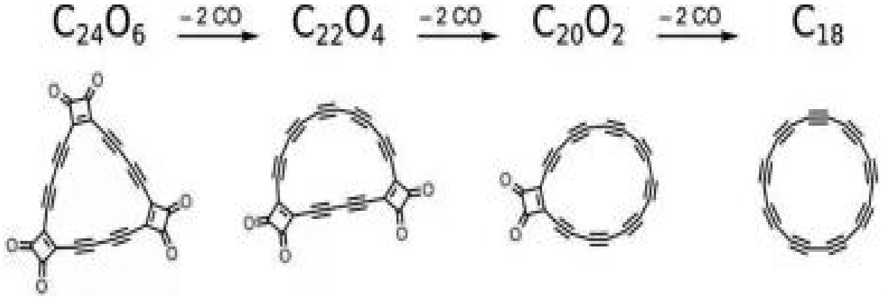

Figure 2 Deoxygenation Synthesis Process of C_{18} Ring Molecule

3 CARBON ELEMENT AND CHEMISTRY CORE LITERACY: SCIENTIFIC SPIRIT AND SOCIAL RESPONSIBILITY

Scientific spirit and social responsibility are the starting point and the end point of cultivating chemical and chemical engineering literacy. This literacy requires us to advocate truth, pay attention to social hot issues related to chemistry and chemical engineering; deeply understand the relationship between chemical and chemical science and engineering technology, society and the environment; be able to use chemical and chemical knowledge and thinking methods to actively participate in social decision-making and implementation of technical solutions related to chemical and chemical issues.

Gdyne is a new all-carbon nanostructure after fullerene, carbon nanotubes and graphene. It is an allotrope of a new carbon macroconjugated system with a two-dimensional planar network structure formed by the hybridization of sp and sp^2 (Figure 3a). It has a porous characteristic of 0.25 nm pore size, excellent mechanical and chemical properties, thermal stability, semiconductor properties, as well as catalytic and magnetic functions. It is the most stable artificially synthesized carbon allotrope. Due to its special electronic structure and excellent semiconductor properties similar to silicon, gyne is expected to be widely used in electronics, semiconductors and new energy fields. As early as 1968, chemist and materials scientist Baughman believed through theoretical calculations that the gyne structure can exist stably. Internationally renowned functional molecules and polymer research groups have begun related research, but have not been successful. In 2010, the team led by Li Yuliang, a scientist from the Institute of Chemistry of the Chinese Academy of Sciences, synthesized graphyne in situ on the surface of copper foil by chemical methods and successfully obtained a large-area (3.61 cm^2) graphyne film for the first time , and named it "graphyne" in Chinese. The successful synthesis of graphyne gave birth to a new member of the carbon material family and opened up a precedent for the artificial chemical synthesis of new carbon heteromorphs. graphyne also became the first "Chinese brand" all-carbon material with completely independent intellectual property rights in China, and is also one of the most promising nanomaterials. In addition to its scientific value, the major original research results achieved by Li Yuliang's team have earned honors for China's carbon material research and fully demonstrated its social responsibility and value commitment.

Fullerene is a general term for a series of spherical carbon atom clusters composed of pure carbon. They are conjugated olefins with closed hollow spherical or ellipsoidal structures composed of non-planar five-membered rings, six-membered rings, etc. (Figure 3b). Among them, the molecular structure of C_{60} is a spherical 32-hedron, which is a spherical hollow high-symmetry molecule with 30 carbon-carbon double bonds composed of 60 carbon atoms connected by 20 six-membered rings and 12 five-membered rings [2]. Coincidentally, the research team of Wang Chunru, a scientist at the Institute of Chemistry of the Chinese Academy of Sciences, has become the most powerful fullerene research team in the world, has made many internationally leading research results, and has the conditions to lead the application of fullerenes. Wang Chunru has focused on fullerene research for nearly 30 years, which is almost as long as the time when fullerene was discovered by humans. In his work, the medicinal value and non-toxic and side-effect-free properties of fullerenes were discovered and gradually studied in depth. A global search of fullerene biomedical authorized patents shows that Wang Chunru ranks first in the number of patents, making him one of the main pioneers in the industrialization of fullerenes in China [4]. In 2015, with his high sense of social responsibility and national sentiment, Wang Chunru and Beijing Funakang Biotechnology Co., Ltd. began to lay out the industrial development of fullerenes in the pharmaceutical field in China, and developed the fourth-generation metal fullerene preparation device using arc discharge method, avoiding the use of large amounts of helium in production (about 70% of the world's helium is produced in the United States) and not introducing impurities such as H, N and O. Through non-chromatographic separation and purification technology, the product purity can reach more than 99.9%. The entire purification process is simple to operate, not only with high yield, but also conducive to the high purity required by biomedicine. With his lofty scientific spirit, Wang Chunru's contribution to the fullerene-related industry will surely benefit human society with magical carbon materials.

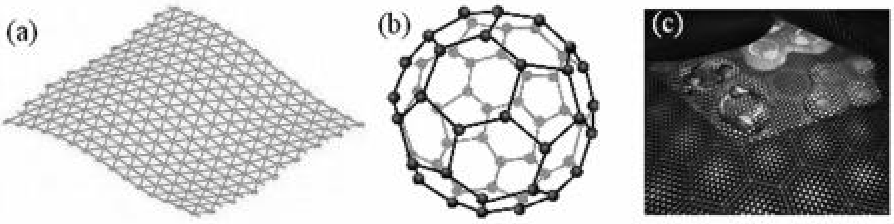

Figure 3 Structures of Graphyne (a) and Fullerene (b) and Magic Angle Double-Layer Graphene Model (c)

Graphene is known as the "king of new materials" and the "black gold" of the materials industry. Although since the Nobel Prize was awarded to the field of graphene research in 2010, graphene-related materials have been deployed as new strategic industries by many countries around the world, and China has 11 important graphene industrial parks or collaborative innovation centers, graphene-related products do not seem to enter the lives of the public as quickly as people imagine. In particular, basic research on graphene also seems to be calm. However, in the past two years, the four articles published in Nature by Cao Yuan, a young scholar born after 1995 in China, reported major original work that once again pushed the research on graphene to a climax. Scientists have long recognized that stacking two layers of graphene at an angle of 1.1° can form a two-dimensional moiré superlattice, and the speed of electrons in the lattice will be greatly reduced. In 2018, Cao Yuan, who is known as the driver of graphene, and others realized the preparation of magic angle double-layer graphene samples (model as shown in Figure 3c) for the first time, and observed the transition of graphene from metallic state to insulating state at about -270 °C. What is even more amazing is that if a certain amount of electrons are added to the insulating state, superconductivity will appear. As the saying goes, "Aspirations are not limited by age." Cao Yuan was also selected into the list of "30 Elites Under 30" in the science and technology field in China in 2018 released by Forbes China. In the same year, he was also awarded the title of "Top Ten Outstanding Chinese Youth in the United States in 2018." In May 2020, Cao Yuan et al. [5,6] published two related works on twisted bilayer-bilayer graphene and the use of nano-superconducting quantum interference instrument to characterize the angle non-uniformity problem in twisted bilayer graphene in Nature, pushing the field of twisted electronics to a peak. Recently, Cao Yuan et al. [7] published a report on the research results of "Identifying the entangled phase with broken rotational symmetry in magic-angle twisted bilayer graphene (TBG)" in Science. China's position in the field of graphene and carbon materials research is inseparable from the outstanding and significant original contributions of many young scholars like Cao Yuan who have scientific spirit, social responsibility and national mission.

In the major original work related to carbon materials, especially in the research on graphyne, fullerene and graphene, Chinese chemists and materials scientists have made outstanding contributions, reflecting the responsibility of Chinese scientists [8,9]. Their scientific spirit and sense of social responsibility set an example for chemists and chemical engineers. Of course, their contributions and successes are not achieved overnight, but the result of long-term adherence to the scientific spirit and strong social responsibility and national sentiment. Although this spirit and responsibility are not exclusive to the core literacy of the chemistry discipline, their success must be closely related to the cultivation of the early chemistry and chemical engineering discipline qualities.

4 CONCLUSION

The magical element carbon has given birth to a rich and colorful world of carbon nanostructures, carbon substances and materials, and even life. Human scientific discoveries and technological innovations related to carbon are far from over. Carbon itself, the scientists engaged in its research, and their work perfectly embody the chemistry and chemical engineering literacy, such as scientific inquiry and innovative creation consciousness, scientific attitude and social responsibility. This article discusses and deeply analyzes some allotropes and nanostructures of carbon, and explains how to embody the chemistry and chemical engineering literacy and ideological and political guidance value through scientific knowledge related to carbon. At the same time, it is expected that higher education recipients of chemistry and chemical engineering and related majors will feel the charm of cutting-edge scientific knowledge and discoveries in the colorful world of carbon through a deep understanding of the core literacy of chemistry and chemical engineering.

CONFLICT OF INTEREST

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Lin Chongde. Research on the core competencies of student development in the 21st century. Beijing: Beijing Normal University Press, 2016.
[2] Zheng Changlong. Major changes and analysis of the 2017 edition of the general high school chemistry curriculum standards. Chemical Education, 2018, 39(9): 41-47.
[3] Zhang J, Wang R, Zhu X, et al. Pseudo-topotactic conversion of carbon nanotubes to T-carbon nanowires under picosecond laser irradiation in methanol. Nature Communication, 2017, 8(1): 683.
[4] Kaiser K, Scriven LM, Schulz F, et al. An sp-hybridized molecular carbon allotrope, cyclo carbon. Science, 2019, 365(6459): 1299-1301.
[5] Cao Y, Fatemi V, Demir A, et al. Correlated insulator behav-iour at half-filling in magic-angle graphene superlattices. Nature, 2018, 556: 80-84.
[6] Cao Y, Fatemi V, Fang S, et al. Unconventional superconductivity in magic-angle graphene superlattices. Nature, 2018, 556: 43-50.
[7] Uri A, Grover S, Cao Y, et al. Mapping the twist-angle dis-order and Landau levels in magic-angle graphene. Nature, 2020, 581: 47-52.
[8] Cao Y, Rodan-Legrain D, Rubies-Bigorda O, et al. Tuna-ble correlated states and spin-polarized phases in twisted bi-layer-bilayer graphene. Nature, 2020, 583: 215-220.
[9] Cao Y, Rodan-Legrain D, Park JM, et al. Nematicity and competing orders in superconducting ma gic - angle graphene. Science, 2021, 372(6539): 264-271.