Forms of Crystalline Carbon

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How annoying! Just as you start to write in your notebook, your pencil lead breaks. Actually, pencil “leads” aren’t made of lead at all. They are made of a form of carbon called graphite. How carbon atoms are arranged in graphite explains why it’s suitable for writing—and also why it breaks so easily.

Q: Graphite is one of several forms of carbon. How can a single element exist in different forms?
A: Carbon can exist in different forms because atoms of carbon can combine in different ways.

What Are the Forms of Carbon?

Graphite is one of three forms of crystalline, or crystal-forming, carbon. Carbon also exists in an amorphous, or “shapeless,” form in substances such as coal and charcoal. Different forms of the same element are called allotropes. Besides graphite, the other allotropes of crystalline carbon are diamond and fullerenes. All three forms exist as crystals rather than molecules. In a crystal, many atoms are bonded together in a repeating pattern that may contains thousands of atoms. The arrangement of atoms in the crystal differs for each form of carbon and explains why the different forms have different properties.

Q: How do you think the properties of diamond might differ from the properties of graphite?
A: Diamond is clear whereas graphite is black. Diamond is also very hard, so it doesn’t break easily. Graphite, in contrast, is soft and breaks very easily.
Diamond

Diamond is a form of carbon in which each carbon atom is covalently bonded to four other carbon atoms. This forms a strong, rigid, three-dimensional structure (see Figure 1.1). Diamond is the hardest natural substance, and no other natural substance can scratch it. This property makes diamonds useful for cutting and grinding tools as well as for rings and other jewelry (see Figure 1.2).
Graphite

Graphite is a form of crystalline carbon in which each carbon atom is covalently bonded to three other carbon atoms. The carbon atoms are arranged in layers, with strong bonds within each layer but only weak bonds between layers (see Figure 1.3). The weak bonds between layers allow the layers to slide over one another, so graphite is relatively soft and slippery. This makes it useful as a lubricant.

Q: Why do graphite’s properties make it useful for pencil “leads”?
A: Being slippery, graphite slides easily over paper when you write. Being soft, it rubs off on the paper, allowing you to leave marks. Graphite’s softness also allows you to sharpen it easily. (Imagine trying to sharpen a diamond!)

Fullerene

A fullerene (also called a Bucky ball) is a form of carbon in which carbon atoms are arranged in a hollow sphere resembling a soccer ball (see Figure 1.4). Each sphere contains 60 carbon atoms, and each carbon atom is bonded to three others by single covalent bonds. The bonds are relatively weak, so fullerenes can dissolve and form solutions. Fullerenes were first discovered in 1985 and have been found in soot and meteorites. Possible commercial uses of fullerenes are under investigation.

Summary

- Different forms, or allotropes, of carbon are diamond, graphite, and fullerenes.
- In diamond, each carbon atom is bonded to four other carbon atoms, forming a rigid structure that makes diamond very hard.
- In graphite, each carbon atom is bonded to three other carbon atoms, and the atoms forms layers that are only weakly bonded together. This makes graphite soft and slippery.
- In a fullerene, carbon atoms are bonded to three other atoms in a soccer ball pattern. The bonds are weak, so fullerenes can dissolve and form solutions.

Review

1. Describe the bonds between carbon atoms in diamond.
2. How does the arrangement of atoms in diamond and graphite affect their properties?
3. What substance is represented by the chemical formula \( \text{C}_{60} \)?

**Explore More**

Watch the video about forms of crystalline carbon. Then answer the questions below.

1. What are crystals? What are the crystalline forms of carbon?
2. Describe the unit cell of a diamond crystal.
3. Relate pencil marks on paper to the structure of graphite.
4. In a Buckyball, what repeating shapes do carbon atoms form?

**References**
