

DEMONSTRATION 2

Notes for the Instructor

PURPOSE

To illustrate that conductivity of material can be increased by adding electrons to an empty band or, in this case, removing electrons from a filled one.

METHOD

Bromine will be used to oxidize a sample of graphite. This oxidative process removes electrons from the highest filled energy band of the carbon atoms, thus creating a partially filled band. In addition, the bromide ions produced fill in the spaces between the graphite sheets, forcing them further apart. This process causes individual graphite particles to swell, which increases the pressure inside the tube holding the graphite. The increased pressure improves the electrical contact between the particles, reduces resistance and thereby further increases conductivity. The process may be followed by comparing the relative brightness of a small light bulb placed in the circuit.

MATERIALS

2 graphite rods

Teflon tubing-approximately 3 inches long

evaporating dish

1-2 grams of graphite powder (Decolorizing Carbon-Nordit works)

ring stands and clamps

10% (by volume) Br₂ in methyl alcohol (elemental bromine may be used with caution)

6-V battery or power supply*

1-2 light bulb*

wires and alligator clips*

multimeter and leads*

* The physics department should have these materials.

PROCEDURE

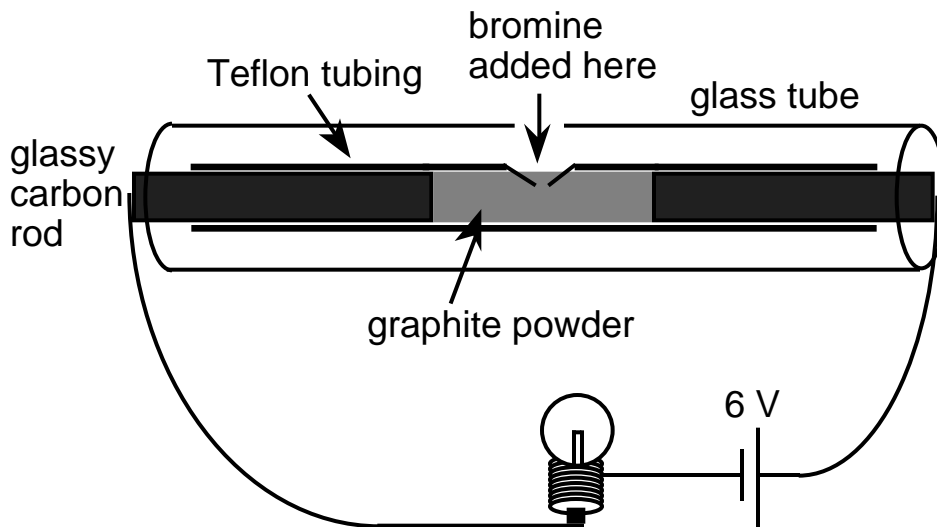


Figure 1. The conductivity apparatus for demonstrating the intercalation of bromine into graphite.

1. Place several grams of graphite powder between two graphite rods in a Teflon tube, as shown in the figure above. It helps to lubricate the rods with glycerin before inserting them. It is also recommended that the hole in the tubing be made after the powder and rods have been inserted. A small cork bore works well for making the hole.

2. Apply sufficient pressure to the rods so that the resistance between the two rods is less than 100 ohms. Clamp the apparatus in a horizontal position and place a beaker beneath it. If you wish to demonstrate the increased conductivity using a small light bulb, connect the apparatus in series with a power-supply and the bulb. The voltage should be adjusted so that the bulb just faintly glows or is dark, indicating that the carbon has a fairly high resistance. If you want to follow the resistance change with a multimeter, simply attach the meter in series with the apparatus. It will be necessary to project the image of the meter using a video camera if an entire class is to observe the changes. If you have access to a large demonstration meter it should also work well without the need to project it.

3. Place several drops of the bromine solution into the hole in the tubing. After several seconds the light will begin to glow and the meter will record a significant lowering of resistance. **CAUTION: If elemental liquid bromine is used, the demonstration should be performed in a fume hood, and the demonstrator should wear gloves, as the reagent is volatile, corrosive, and highly toxic.**

FOLLOW-UP QUESTIONS

Either prior to, during, or after the demonstration the following points should be emphasized.

1. What makes a material a good conductor of electricity? **(1) the presence of an energy band with delocalized orbitals that is (2) only partially filled with electrons.**
2. What is the band occupancy of the graphite? **It has a valance band that is filled and the next highest energy band that is relatively empty. The two bands are, however, close in energy. which accounts for the conductivity the graphite initially possesses.**
3. What is oxidation? **The loss of electrons.**
4. During the demonstration, what evidence is there that a chemical reaction took place? **The change in conductivity. Some students may wonder if the change was simply because either the bromine itself or the solvent in the solution enhanced the conductivity. Therefore some explanation or demonstration of the conductivities of these substances is probably required.**
5. Describe the nature of this chemical reaction. **Given its location in the periodic table bromine is expected to act as a reasonably strong oxidizing agent, which is exactly what occurs in this reaction. The carbon atoms are being oxidized and the bromine atoms are being reduced.**
6. How does this increase the conductivity of the carbon? **The loss of electrons results in the previously filled valence band now being only partially filled. The orbitals not used for carbon-carbon sigma bonding form a band that has been previously discussed in Investigation 1 in this unit. Therefore, carbon now fulfills the requirements for conductivity to a greater extent than it did.**

7. What happens to the bromide ions that are produced? **The bromide ions fill in the spaces (intercalate) between the layers of the two-dimensional network arrangement that constitutes the graphite structure. This causes the graphite layers to be pushed apart and individual graphite particles to exert greater pressure on each other. This increases the pressure inside the tube and further increases the conductivity. This increase in conductivity may be demonstrated by inserting another graphite rod into the hole in the tubing and pushing down. The change in resistance/conductivity is readily detected by the meter. See the figure below.**

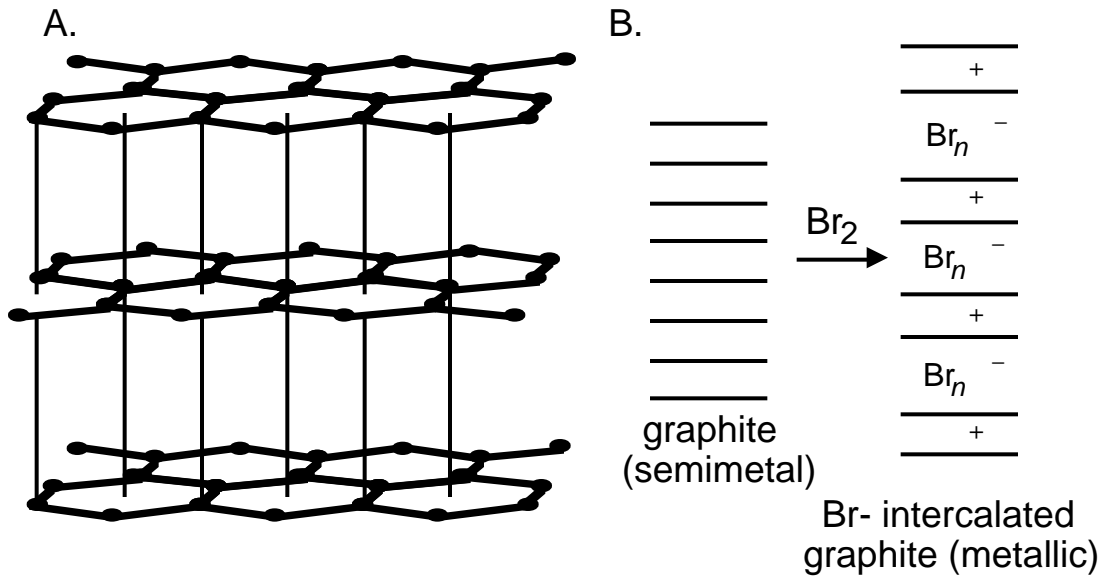


Figure 2 A: The layered structure of graphite. B: The bromine inserted between the layers of graphite and increasing the pressure thus increasing the conductivity.