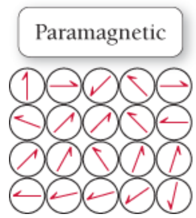
Pearson

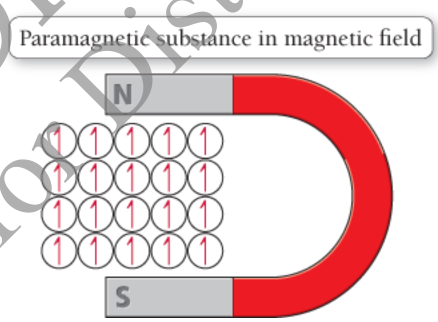
6.1: Oxygen: A Magnetic Liquid

Do you remember the first time you played with a magnet? As a child, I was in awe of the invisible force that allowed my magnet to attract objects at a distance or even through other substances. I once had a pair of magnets so strong that they interacted with one another on opposite sides of my palm. A substance that is attracted to a magnet is *paramagnetic*—it contains unpaired electrons (see Section 3.7).



A paramagnetic substance contains unpaired electrons. In the absence of an external magnetic field, the electrons are randomly oriented.

The spin of an unpaired electron generates a tiny magnetic field, just as the circular motion of electrical current running through a coil in an electromagnet generates a magnetic field. When a paramagnetic substance is brought near an external magnetic field, the orientation of the electrons' spin (within the substance) aligns, resulting in a magnetic interaction between the substance and the magnet. This occurs, for example, when you bring a paper clip close to a magnet. The paper clip is attracted to the magnet by the interaction between the magnetic field of the magnet and the magnetic field generated by the spin of the now aligned unpaired electrons in the paper clip.



When a paramagnetic substance is close to a magnetic field, its unpaired electrons orient, causing the substance to be attracted to the magnet.

Most common liquids, such as water or gasoline, are not magnetic—they are not attracted to a magnet. But there is one liquid that is magnetic: liquid oxygen, which forms when we cool gaseous oxygen below −183 °C (see chapter-opening image). What causes liquid oxygen to be magnetic?

We already know that oxygen is a diatomic molecule with the following Lewis structure:

$$:\ddot{O}::\ddot{O}:$$

Notice that, in this structure, the electrons are all paired. Yet we know liquid oxygen is magnetic; *therefore, we know it must contain unpaired electrons*. The Lewis model for chemical bonding, while very useful, fails to predict the correct magnetic properties for oxygen. In this chapter, we explore more advanced theories for chemical bonding: valence bond theory and molecular orbital theory. We will see that molecular orbital theory—the most sophisticated and accurate bonding theory—correctly predicts the magnetic properties of oxygen. When we apply molecular orbital theory to the O_2 molecule, it shows that O_2 contains two unpaired electrons. These unpaired electrons are responsible for the magnetic behavior of oxygen. We will also examine bonding models that apply to metals and semiconductors in this chapter.