

## Chapter 2

Topic: Atoms, bonding

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### Main concepts:

- Atoms are the smallest unit of an element.
- Atoms bonded together make up molecules.
- Atoms are composed of sub-atomic particles: protons (positive charge), electrons (negative charge), and neutrons (no charge). Protons and neutrons have mass. Electrons have negligible mass.
- An atom in its normal state has just as many electrons as protons.
- The outer “shell” of an atom is the valence “shell,” which is involved in bonding.
- The valence “shell” can hold a given number of electrons. The number of electrons needed to fill the outer shell tells us how many bonds any one atom can make.
- An atom that has one electron less or one more than its usual number is an ion. If it is missing one electron, it has a positive charge. If it has gained an electron, it has a negative charge.
- The elements most common in biological molecules that make up organisms are “CHNOPS”: Carbon, Hydrogen, Nitrogen, Oxygen, Phosphorous, Sulfur.
- Three types of bonds hold atoms together within molecules: ionic, covalent, and polar covalent.
- Ionic bonds are electrostatic attractions between ions of opposite charge.
- Covalent bonds involve two atoms sharing electrons between them (co=together, valent=valence shell).
- Polar covalent bonds also involve sharing electrons between two atoms, but the electrons are shared unequally. This kind of bond produces a polar molecule.
- Hydrogen bonds are bonds between a hydrogen in one polar molecule and the negatively charged end of another polar molecule. Hydrogen bonds allow two molecules to link together temporarily.
- Water molecules are made up of two hydrogen atoms and one oxygen atom, held together by polar covalent bonds. The polarity of the water molecule is what gives water its unique properties. These properties are important to living systems.
- Water is the closest thing to a universal solvent that there is. Solids made up of polar molecules or ionically bonded atoms tend to dissolve in water.
- Molecules that are mostly non-polar, such as fats, tend to repel water.
- The pH of a solution is a number that describes the proportion of **hydrogen ions** to **hydroxide ions** in a water solution. A pH of 7 is neutral. Low pH is acidic. High pH is basic (alkaline). The term **neutralize** refers to the fact that when an acid is mixed with a base in the right proportions, a chemical reaction occurs that creates a neutral (pH 7) solution.
- The **functional groups** on molecules (see table on page 38 for examples) determine whether a molecule is acidic, basic, or neutral. They also determine how molecules interact with each other.
- Water moderates temperature in an environment. Water has a high freezing point and high boiling point compared with many other liquids. Water’s ability to absorb heat is one reason that temperatures are more mild in coastal areas than they are in the middle of a continent.
- Unlike most other substances, water is less dense when it is frozen than when it is liquid. This is why water expands when it freezes. The fact that ice floats is important to aquatic organisms.
- In chemistry, the word **organic** refers to molecules that are made up of carbon and hydrogen. **Inorganic** refers to carbon dioxide (which has no hydrogen) and all non-carbon-based molecules. (The term “organically grown” or “organic” on food labels refers to agricultural practices.)

### Common misconceptions:

- Students often confuse the terms “atom,” “molecule,” and “cell,” either thinking they are all the same thing, or simply forgetting which makes up which.
  - Students often find it hard to think of substances on the molecular scale, and tend to think of materials as continuous rather than made up of particles.
  - Students may misunderstand scale, and think that molecules are bigger than or about the same size as cells (which are made up of thousands of molecules). Students may also think that atoms and molecules can be seen under a microscope.
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- Some students confuse the nucleus of the atom with the nucleus of the cell, and believe that atoms can divide like cells can. This may also cause some students to conclude that atoms are alive.
- “In between molecules there’s air.” “Matter exists between atoms.” All material is made of molecules, including air. Between air molecules there’s only empty space.
- “Hydrogen bonds are what make hydrogen atoms stick to each other.” Hydrogen bonds are bonds *between* molecules, not *within* molecules.
- “Heat makes atoms/molecules bigger.” This is caused by confusions about density or the effects of heat on a gas. Students hear that molecules of a gas “expand” with heat. The molecules themselves do not expand. Rather, the distance between them increases (if the container can expand) and the molecules move more rapidly.
- Students confuse neutralization (which occurs when acids and bases are mixed) with the attraction between oppositely-charged ions.
- Students often believe that when substances dissolve in water, the covalent bonds in a molecule are broken, when in fact molecules stay intact (though the hydrogen bonds *between* molecules are broken). They may also believe that dissolved substances “disappear” or “melt” in water.
- Students often have difficulty remembering that low pH is acidic and high pH is basic, often believing that the term “high pH” refers to any strong chemical, or that “basic” is the same as “neutral.”
- Students may believe that “pH” is a substance that is dissolved in water, and that the pH scale is a measure of this substance.
- Students may think of water as a continuous substance rather than a compound made up of many water molecules. They may believe that there is water between the water molecules, which they see as particles dissolved in the water.

## Chapter study guide:

- Define **atom**. List the three types of particles that make up atoms, and state what electrical charge each carries.
  - Define **element** and **atomic number**.
  - Define **isotope**. Describe how isotopes are used in PET scans.
  - Define **electron shell**. What is the relationships between these shells and bonding?
  - Describe the difference between an atom that is *inert* versus an atom that is *reactive*.
  - Define **chemical bonds** as the term is defined in the reading.
  - Define **ion**. Describe the difference between an ion with a positive charge and an ion with a negative charge. Describe how **ionic bonds** form between ions. Note that ionic bonds do not create distinctive molecules, but instead form a lattice of atoms. Ionic bonds are strong, but can be broken by a polar solvent such as water (as we will see later).
  - Define **covalent bonds**. Describe what happens when hydrogen atoms form covalent bonds with each other to form hydrogen molecules. Note that covalent bonds link atoms into distinct molecules. Covalent bonds are strong, and are not easily broken.
  - Define **polar** in the sense it is used in this chapter. Describe how two atoms may join to form a **polar covalent bond**. Describe how this differs from both an ionic bond and a covalent bond (the website “How to Atoms and Molecules Interact,” listed below, will help illustrate the differences).
  - List the number of covalent bonds each of these atoms can form: hydrogen, carbon, nitrogen, oxygen, phosphorus, sulfur.
  - Define **free radical**. Explain why free radicals are damaging to human health. Give some examples. Define **antioxidant**. Give some examples, and explain why these chemicals are important for human health.
  - Define **hydrogen bond**. Describe how these bonds form between molecules (not within molecules), and explain why these bonds are found between polar molecules.
  - Explain why the polar nature of the water molecule makes water such a good solvent.
  - Define **hydrophobic** and **hydrophilic**. List some examples of hydrophobic and hydrophilic substances.
  - Define **adhesion** and **cohesion**. Explain how hydrogen bonding gives water the properties of cohesion and adhesion. Explain how cohesion and adhesion cause surface tension in water, and how they cause water to climb to the top of a tall tree.
  - Draw a hydrogen ion and a hydroxide ion. Indicate which ion has a positive charge and which has a negative charge. Use the terms “hydroxide ion” and “hydrogen ion” to explain why some substances are acidic, some are basic, and some are neutral.
  - Explain what a **buffer** is, and why buffers are important to living things.
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# Notes

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- Explain why water has the ability to absorb heat, and why water's ability to absorb heat is important to living things.
- Define **density**. Explain why ice is less dense than water.

## Useful websites:

- "All About Atoms" <http://education.jlab.org/atomtour/listofparticles.html> is an elementary review of the basic units that make up an atom.
  - "How do Atoms and Molecules Interact?" <http://w3.dwm.ks.edu.tw/bio/activelearner/02/ch2intro.html> has several animations that will help make the main types of bonds more clear.
  - "A Closer Look at Water" <http://programs.northlandcollege.edu/biology/Biology1111/animations/hydrogenbonds.html> shows hydrogen bonding between water molecules. You'll want the sound on for the second part of this one.
  - "pH: the Power of Hydrogen" <http://www.johnkyrk.com/pH.html> includes an animated pH scale that will show you the pH of common substances. When you open the page, look for a tiny green navigation arrow near the bottom left-hand corner.
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