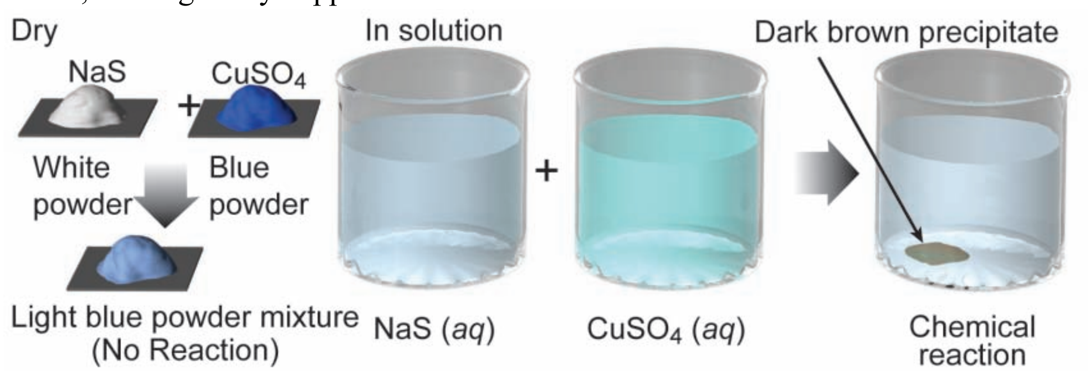
4.3 Chemical Reactions in the Lab

Many reactions occur in solution

Many reactions occur between chemicals dissolved in water. This includes all of the reactions that sustain life in your body. Why are solutions so important in reactions?

The answer is not complicated. Reactions can only occur if *molecules can move around and touch each other*. For example, sodium sulfide (NaS) is a white powdery mineral salt. Copper sulfate ($CuSO_4$) is a bright blue powder. If you mix the two chemicals as powder, nothing really happens.



The result is quite different if you dissolve the powdered chemicals in water and then mix the solutions. The copper sulfate is a bright blue solution. The sodium sulfide is a colorless solution. When you mix the two, a deep brown, almost black sludge forms and settles at the bottom. If the quantities are right, the blue color may almost disappear.

Aqueous solutions

A solution with water as the solvent is called an **aqueous** solution. Aqueous solutions are so important that chemists consider being dissolved in water to be almost a fourth state of matter! In writing reactions we use the symbols *(s)*, *(l)*, *(g)* and *(aq)* to show what state of matter the reactants and products are in.

(s)	indicates a solid
(l)	indicates a liquid
(g)	indicates a gas
(aq)	indicates a substance dissolved in water

Precipitates

The brown sludge is an example of a *precipitate*. A **precipitate** is a compound that is not soluble in water. Precipitates are evidence that a chemical reaction has occurred. In this reaction the insoluble compound is copper sulfide (CuS).Aqueous means dissolved in water.

Chemistry terms

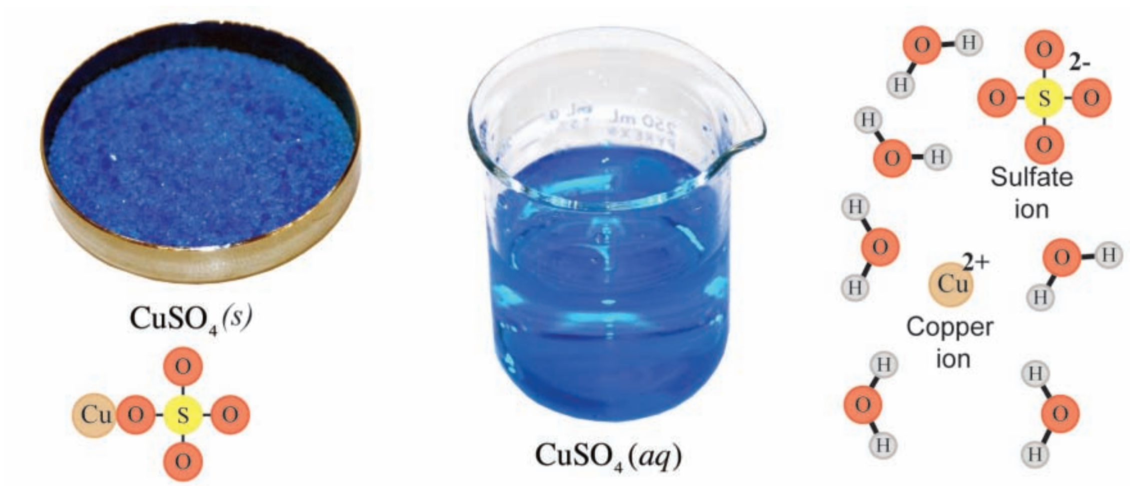
aqueous - dissolved in water- indicated by *(aq).*

precipitate - an insoluble compound that forms in a chemical reaction in aqueous solution.

Oxidation and reduction

Salts are ionic compounds that dissolve to form ions

In the next few chapters, you will see how electrons in atoms are directly responsible for chemical properties. For example, when sugar is dissolved in water, the molecules become separated, but remain whole. This is not true for *salts* such as copper sulfate ($CuSO_4$). **Salts** are ionic compounds which form *ions* when dissolved in water. If you could look at the molecular level, you would find that in aqueous solution, copper sulfate dissociates into copper ions (Cu^{2+}) and sulfate ions (SO_4^{2-}). This happens because each single copper atom transfers two electrons to the sulfate ion.



Oxidation is losing electron(s)

Pure zinc is a relatively soft, grey metal. Copper is also a soft metal but is reddish-gold in color. When zinc metal is placed in a solution of copper sulfate, the zinc slowly disappears! The zinc disappears because it is being oxidized. In chemistry, **oxidation** means losing an electron and becoming more positive. The zinc metal atoms become Zn^{2+} ions and go into the solution.

Reduction is gaining electron(s)

Zinc has to give up two electrons to become Zn^{2+} so where do these electrons go? They go to the copper ions. Cu^{2+} ions accept the two electrons to become copper (Cu) atoms. Copper atoms are no longer soluble in water, so they drop out of the solution as copper metal. The reddish-brown sludge that appears in the test tube is pure copper metal. In chemistry, **reduction** is the process of gaining electrons and becoming more negative. The copper ion (Cu^{2+}) accepts two electrons and loses its positive charge to become copper metal.

Chemistry terms

salt - an ionic compound that dissolves in water to produce ions.

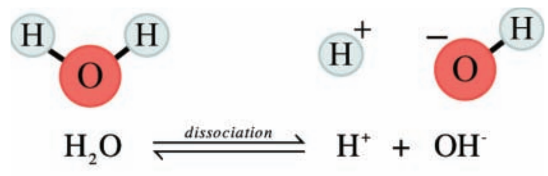
oxidation - a chemical reaction that increases the charge of an atom or ion by giving up electrons.

reduction - a chemical reaction that decreases the charge of an atom or ion by accepting electrons.

Acids and bases

The dissociation of water

When pure water is carefully examined, we find that on average, one out of every 550 million water molecules is *dissociated,* or separated, into a hydrogen (H^+) ion and a hydroxide (OH^-) ion.



The dissociation reaction is written with the double arrow to show that the ions can re-combine to make a normal water molecule. In equilibrium, the constant dissociation and recombination leaves (on average) one out of 550 million molecules broken apart into into H^+ and OH^-.

Properties of acids

An **acid** is a compound that dissolves in water to make a solution that contains *more* H^+ ions than there are in pure water. Some properties of acids are listed below:

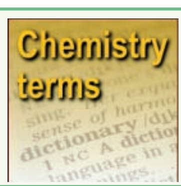
- Acids create the sour taste in food, like lemons;
- Acids react with metals to produce hydrogen gas (H_2);
- Acids can corrode metals and burn skin through chemical action.

When hydrochloric acid (HCl) dissolves in water it ionizes into hydrogen (H^+) and chlorine (Cl^-) ions. The fact that the H^+ ion is created is what makes HCl an acid.

Properties of bases

A **base** is a compound that dissolves in water to make a solution with more OH^- ions than there are in pure water. Some of the extra OH^- combines with H^+ to make water again, so another way to think about bases is that they reduce the concentration of H^+ ions. Some properties of bases are listed below:

- Bases create a bitter taste;
- Bases have a slippery feel, like soap;
- Bases can neutralize acids.



acid - a chemical that dissolves in water to create more H^+ ions than there are in pure water.

base - a chemical that dissolves in water to create less H^+ ions than there are in pure water (or equivalently, more OH^- ions).

Acid / base reactions

Acids and bases react to form salts and water

When acids and bases are combined in aqueous solution they react to make water and salt. In fact, the chemical definition of *salt* is any compound formed from the positive ion from a base and the negative ion from an acid. For example, hydrochloric acid (HCl) is a common laboratory acid, also found in your stomach where it helps break down food. Sodium hydroxide (NaOH) is a common base. Sodium hydroxide is found in drain cleaners and industrial processes.

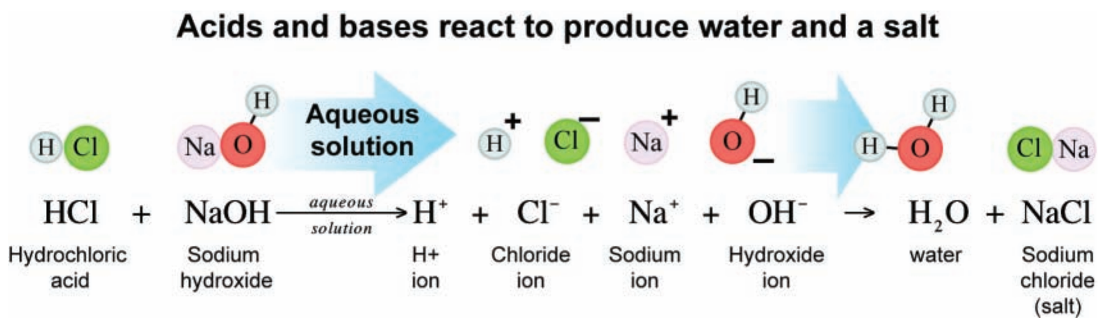


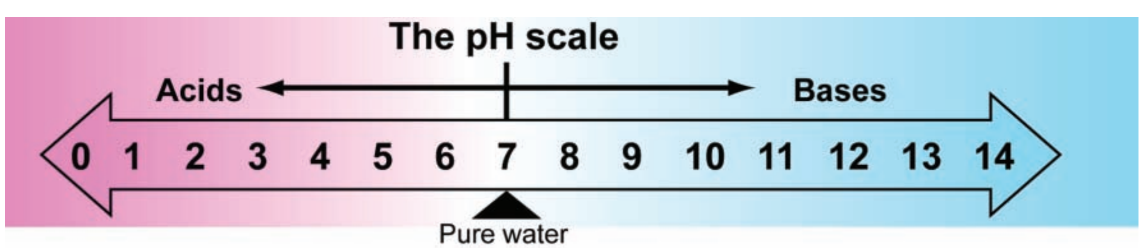
Table salt (NaCl) is formed by the positive sodium ion from sodium hydroxide (a base) and the negative chloride ion from hydrochloric acid.

Acids are important because of the H^+ ion

The H^+ ion is very important in chemistry. The main reason is that H^+ is a single bare nucleus, *with no electrons*. Earlier in the chapter we said that chemical bonds come from the interactions of electrons, in the outer part of the atom. This is true with one big exception - the H^+ ion. Since H^+ is chemically powerful, and it is *always* present in water, acids play a crucial role in chemistry. Many reactions that occur in aqueous solutions are sensitive to the concentration of H^+ ions, including nearly all the reactions in your body.

The pH scale

Because acids and bases are so important, they have a special measurement - the *pH scale*. The **pH scale** tells you whether a solution is acidic or basic. A pH less than 7 indicates an acid. An acid has higher concentration of H+ than pure water. A pH greater than 7 indicates a base. A base has H+ concentration less than pure water.



Chemistry terms

pH scale - a measurement of the H+ ion concentration that tells whether a solution is acid or base. Pure water has a pH of 7. Solutions with pH <7 are acidic. Solutions with pH >7 are basic.