Chapter 7: Chemical Energy

Goals of Period 7

Section 7.1: To describe atoms, chemical elements and compounds
Section 7.2: To discuss the electromagnetic force and physical changes
Section 7.3: To illustrate chemical changes, reactions, and equations
Section 7.4: To discuss energy and chemical reactions
Section 7.5: To give examples of exothermic reactions
Section 7.6: To give examples of endothermic reactions

Chemical reactions are one of the primary sources of energy in the United States today. The principal process is the combustion of substances known as fossil fuels that have been stored in the earth over many millions of years. Fossil fuels in common use are natural gas, petroleum products and coal.

7.1 Atomic Structure, Elements and Compounds

Atomic Structure

The structure of an atom was discussed briefly in Physics 103. A tiny, dense nucleus contains more than 99.9% of the mass of the atom. This nucleus consists of protons and neutrons bound together. Surrounding this tiny nucleus is a cloud of electrons. The size of the atom is really the size of this electron cloud.

Electrons and protons have electrical charges exactly equal in magnitude but opposite in sign. Therefore, the electromagnetic force between a proton and an electron is attractive, while two protons or two electrons repel each other electrically. In a neutral atom the number of negatively-charged electrons in the atomic cloud is equal to the number of positively-charged protons in the nucleus of the atom.

The diameter of a typical atom, such as carbon, is about 100,000 (10^5) times larger than that of the tiny nucleus inside it. Suppose our classroom represents a carbon atom (the electron cloud of the carbon atom). On this scale, the nucleus would be about 0.1 mm in diameter. The period on a printed page is about 0.3 mm across, while the smallest dot you can make with a sharp pencil is about 0.1 mm across. This dot would represent the size of the nucleus of a room-sized atom. Yet 99.9% of the mass of the atom would be inside this dot.

Chemical Elements

Atoms usually come together, due to the electromagnetic force, to form molecules. Matter exists because the electromagnetic force that binds protons and electrons for form atoms also binds individual atoms together to form molecules. A substance consisting of only one type of atom, such as two oxygen atoms O_2, is an ***element***.

The identity of an element is determined by the number of protons in its atomic nucleus. For example, a nucleus with 20 protons is an atom of calcium, an element found in bones. Chemical symbols are used to represent the chemical elements. Calcium has the symbol Ca.

Elements can display different properties within one state of matter. Carbon, for example, can exist as two quite different solids – as hard diamonds or as soft graphite. Both materials are composed of only of carbon atoms, however the carbon atoms of diamonds are arranged into a rigid crystal while the carbon atoms of graphite can move more freely. The difference in these structures is the difference in the strength of the electromagnetic force holding together the carbon atoms together. The electromagnetic force is responsible for holding atoms together in all substances.

Abundance of Chemical Elements

Hydrogen (H) and helium (He) are the most abundant elements in the universe. Table 7.1 lists the names and symbols of the most commonly occurring elements in the earth's crust and its atmosphere. Not included is the material of the earth's core, which is believed to be mainly iron, or the material of the fluid mantle beneath the crust that surrounds the core, which is believed to consist mainly of iron, calcium, magnesium, silicon, and oxygen. In Table 7.1, note that the first two elements, oxygen and silicon, comprise 75.2% of the mass of the earth's crust and its atmosphere. The first ten elements listed make up 99.2% of the mass of the earth's crust and atmosphere.

Table 7.1 Abundance of Elements in the Earth and its Atmosphere

Symbol	Element	Number of protons (Z)	Percent of total Mass	Percent of total atoms
O	Oxygen	8	49.4	55.1
Si	Silicon	14	25.8	16.3
Al	Aluminum	13	7.5	5.0
Fe	Iron	26	4.7	1.5
Ca	Calcium	20	3.4	1.5
Na	Sodium	11	2.6	2.0
K	Potassium	19	2.4	1.1
Mg	Magnesium	12	1.9	1.4
H	Hydrogen	1	0.9	15.4
Ti	Titanium	22	0.6	0.2
Cl	Chlorine	17	0.2	
P	Phosphorus	15	0.12	
Mn	Manganese	25	0.10	
C	Carbon	6	0.08	
S	Sulfur	16	0.06	
Ar	Argon	18	0.04	
B	Nitrogen	7	0.03	
Rb	Rubidium	37	0.03	
Sr	Strontium	38	0.03	
F	Fluorine	9	0.03	

Chemical Compounds

Atoms of elements can combine to form molecules or ions. ***Molecules*** are electrically neutral combinations of atoms because they have equal numbers of positive charges (protons) and negative charges (electrons). Two hydrogen atoms combine to form one molecule of hydrogen gas, H_2. Two hydrogen atoms and one oxygen atom form one molecule of water, H_2O. One carbon atom combines with two oxygen atoms to form carbon dioxide, CO_2. A substance composed of molecules all of one kind is a chemical ***compound***. Compounds are formed from elements by chemical processes.

Most materials in nature do not consist of a single type of molecule. A piece of wood contains many different types of molecules. Even distilled water, which has been evaporated and condensed to remove impurities, contains small amounts of ions and molecules other than H_2O molecules. Many substances are such mixtures of molecules, and not elements or a single compound.

7.2 The Electromagnetic Force and Physical Changes

In chapter 5 we discussed states of matter. In solids, the electromagnetic force binds molecules together so tightly that the molecules can only vibrate about an equilibrium position. In liquids, the molecules are still close together and strongly attracted to each other, but they can freely slide past one another. Their average vibrations are faster than in the solid state. In a gas, the molecules move so fast and are so far apart that they fly around relatively freely, experiencing intermolecular forces only when they colliding with each other.

Like matter composed of a single type of atom, compounds and substances can exist in any of the states of matter. Substances consisting of molecules of H_2, H_2O, and CO_2 can exist as solids, liquids, or gases. Differences in the way the electromagnetic force holds together the molecules of a substance result in differences in structures. For example, liquid water flows more freely than a liquid with higher viscosity, such as honey. Solid wood, diamonds, and plastics exhibit different properties as the result of differing electromagnetic force among their molecules.

Phase changes between states of matter usually involve taking in or giving off energy. For example, energy must be added to liquid water to change it to water vapor and energy must be removed from liquid water to freeze it into solid ice.

A change of phase is one example of a ***physical change*** of a substance. Magnetizing a piece of iron also involves a physical change in the orientation of the magnetic domains of the iron. In both cases, properties of the water or iron have changed, but the water molecules and the iron atoms are unchanged. Frozen water still consists of molecules with 2 hydrogen atoms and one oxygen atom (H_2O) and magnetized iron consists of atoms of Fe. A physical change of a substance involves no change to the chemical composition of that substance.

7.3 Chemical Changes, Equations, and Reactions

When matter undergoes a physical change, the properties of the substance may change, but there is no change to the identity of the molecules making up the substance. However, when a substance undergoes a ***chemical change***, the atoms of chemical elements and molecules are rearranged to form new molecules. For example, a chemical change occurs when molecules of hydrogen and oxygen gas combine to form water or iron combines with oxygen in the presence of water to form iron oxide (rust). The formation of water and iron oxide are examples of ***chemical reactions***.

Chemical equations are used to describe chemical reactions. Equations show the substances that react and the substances produced in the reaction. It is a fact of nature that matter is not created or destroyed in chemical reactions. This conservation of matter is the basis for constructing chemical equations.

Chemical Reactions with Molecules

A familiar example of a chemical formula is the expression for water, H_2O. This expression means that every molecule of water consists of two atoms of the element hydrogen H and one atom of the element oxygen O. However the oxygen that we breathe (air consists of approximately 20% oxygen and 80% nitrogen) and the oxygen that is commonly used in chemical combustion consists of two atoms of oxygen bonded to form an oxygen molecule, O_2. Hydrogen also usually exists as a molecule, H_2. Therefore, the correct chemical equation for combining hydrogen and oxygen to form water is

(Equation 7.1)

$$2H_2 + O_2 \rightarrow 2H_2O$$

On the left side of Equation 7.1, $2H_2 + 0_2$ are the reactants and $2H_2O$ on the right side of the equation is the product. This chemical equation is balanced. A balanced equation has the same number of atoms of each element in the formulas on each side of the arrow.

Equation 7.1 states that two molecules of hydrogen combine with one molecule of oxygen to yield two molecules of water. Notice that in this balanced chemical equation the number of hydrogen atoms (4) is the same on each side of the equation. The same is true for the number of oxygen atoms (2) on the left and right sides of the equation. The coefficient 2 in front of the H_2O on the right side of the equation says that there are two molecules of water and the number of atoms in the chemical compound is multiplied by the coefficient 2.

Concept Check 7.1

Which of the equations given below are correctly balanced and which are unbalanced?

a) $C + O_2 \rightarrow CO_2$

b) $CH_2 + 2O_2 \rightarrow CO_2 + 2H_2O$

c) $CH_4 + O_2 \rightarrow CO_2 + H_2O$

d) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

(Example 7.1)

In the more complex chemical equation

$$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$$

how many atoms of carbon C, hydrogen H, and oxygen O are on the left side of the arrow? How many atoms of carbon C, hydrogen H, and oxygen O are on the right side of the arrow? Is this a balanced equation?

On the left side there are 8 carbon atoms, 20 hydrogen atoms, and 26 oxygen atoms. On the right side there are 8 carbon atoms, 20 hydrogen atoms, and 26 oxygen atoms. The equation is balanced.

Chemical Reactions with Ions

Ions are atoms or combinations of atoms that have a net positive charge because they have lost one or more electrons or a net negative charge because they have gained electrons. When writing chemical equations to represent reactions with positively or negatively charged ions, the total electrical charge of the ions must be balanced. For example, one water molecule can dissociate into a positively-charge hydrogen ion H^+ and a negatively-charged hydroxide ion OH^- ion as shown in Equation 7.2.

(Equation 7.2)

$$\mathbf{H_2O \rightarrow \quad {}^{+} + OH^-}$$

The one positive and one negative charge of the reactants cancel, making the right side

atoms of each element and the total electrical charge on each side of the equation.

(Example 7.1)

NaCl (table salt) is dissolved in water, the sodium chloride and water molecules dissociate into ions. Write a balanced equation for this reaction.

$$NaCl + H_2O \rightarrow Na^+ + Cl^- + H^+ + OH^-$$

balanced by the charge of the two negative ions.

In class we will use make a battery by using negatively charged ions to produce a flow

In summary, chemical reactions involve chemical changes. Chemists define chemical change in the following way. In a chemical change

one or more substances are partially used up,

2) one or more new substances are formed, and

3) energy is absorbed or released.

Energy may be absorbed or released during physical or chemical changes. Both chemical reactions and physical changes can involve a change in the entropy of the system. It is often the case that processes taking place in the world around us involve simultaneous chemical reactions and physical changes.

7.4 Energy and Chemical Reactions

Chemical bonds are defined as the forces that hold groups of atoms together so that they function as a unit. A chemical bond results from attractive electromagnetic forces. To break a chemical bond, energy must be added to overcome these attractive forces. In most cases, energy is given off when atoms combine to form chemical compounds. This energy is called the ***binding energy***. When hydrogen and oxygen molecules combine to form water, energy is given off. Equation 7.1 may be written as

(Equation 7.3)

$$2H_2 + O_2 \quad \rightarrow \quad 2H_2O + \text{energy}$$

In some cases, energy is added to bind the atoms together. Reactions also frequently involve the breaking of previously formed bonds and the making of new ones.

Endothermic and Exothermic Reactions

Chemical reactions also involve interchanges of energy between chemical energy and energy in other forms. A chemical reaction that continues to supply energy, often heat, is an ***exothermic*** reaction. A chemical reaction that continues only if energy continues to be supplied to the reactants is known as an ***endothermic*** reaction. It is the net effect of the changes in bond energy that determines whether a reaction is endothermic or exothermic.

Some exothermic reactions and some endothermic reactions occur spontaneously, while other reactions do not. A piece of iron exposed to oxygen in the presence of water will form iron oxide (rust) spontaneously. Whether a reaction occurs spontaneously depends in part on entropy and the second law of thermodynamics. An exothermic chemical reaction that also increases entropy will definitely occur spontaneously, but perhaps very slowly. When one atom of carbon and two atoms of oxygen combine to form one molecule of carbon dioxide, energy is given off. The carbon dioxide molecule has more binding energy than the oxygen molecule. The structure of the more tightly bound carbon dioxide molecule has more disorder and, thus, greater entropy. This exothermic reaction results in increased entropy and occurs spontaneously. Even though an endothermic chemical reaction increases in entropy, it will not occur spontaneously. Energy must be continuously added to the reactants to produce an endothermic reaction.

The total amount of energy released by an exothermic reaction (or taken in by an endothermic reaction) depends on the amounts of the reactants present and on which products are formed. The temperature affects the ***rate*** of energy conversion, that is, the power, but not the total amount of energy converted. If an exothermic reaction starts by breaking bonds, then energy must be supplied to initiate the reaction. This energy is called an ***activation*** energy.

(Example 7.4)

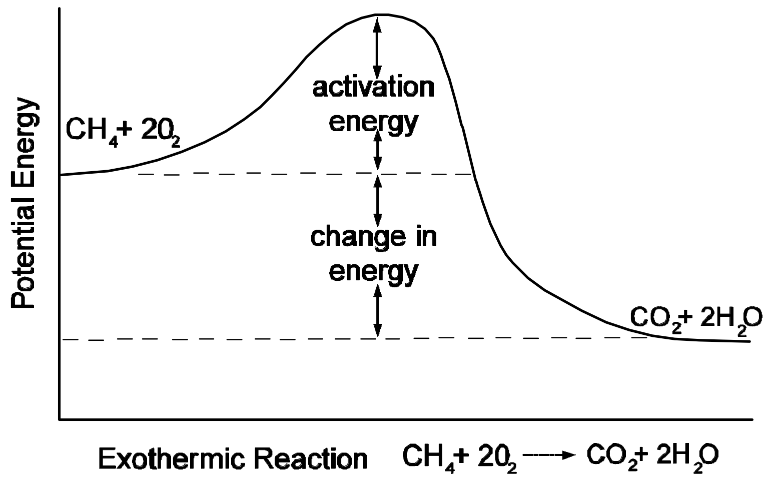
Shown below is the reaction for the combustion of methane gas in air (oxygen). Is this reaction endothermic or exothermic?

(Equation 7.4)

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{energy (heat)}$$

Since heat is given off, the reaction is exothermic. In this case, the potential energy of the bonds of the reactants, $CH_4 + 2O_2$ is larger than the potential energy of the product, $CO_2 + 2H_2O$. The energy given off is the change in energy shown in Figure 7.1

Figure 7.1 An Exothermic Reaction



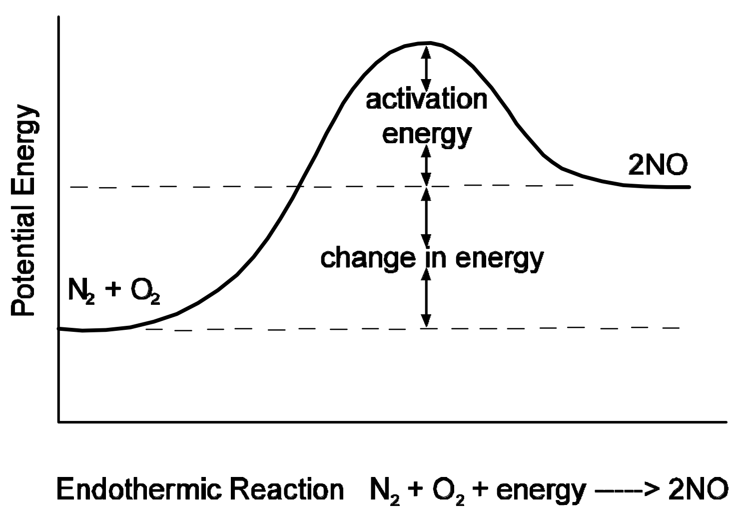
(Example 7.5)

Shown below is the reaction for the formation of nitrous oxide from nitrogen and oxygen. Is this reaction endothermic or exothermic?

$$N_2 + O_2 + \text{energy (heat)} \rightarrow 2NO$$

Since heat must be continuously added to the reactants, the reaction is endothermic. In this case, the potential energy of the bonds of the reactants, $N_2 + O_2$ is smaller than the potential energy of the product, 2NO. The energy added is the change in energy shown in Figure 7.2

Figure 7.2 An Endothermic Reaction



We will discuss the reactions shown in Examples 7.4 and 7.5 when we consider the consequences of using chemical energy.

(Example 7.6)

A chemical reaction involves both the making and breaking of chemical bonds. In a certain reaction, the energy involved in breaking existing chemical bonds is 25 joules. Thirty joules of energy are released when the new chemical bonds are made. Is this reaction endothermic or exothermic?

Since more energy is released (30 J) than is taken in (25 J), the reaction is exothermic and releases 5 joules of energy.

Concept Check 7.2

a) The energy involved in breaking existing chemical bonds of a substance is 40 J. When new chemical bonds are formed, 15 J of energy are released. Is this reaction endothermic or exothermic?

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b) Another reaction requires 25 J of energy to break existing chemical bonds and releases 45 J of energy when new chemical bonds are formed. Is this reaction endothermic or exothermic?

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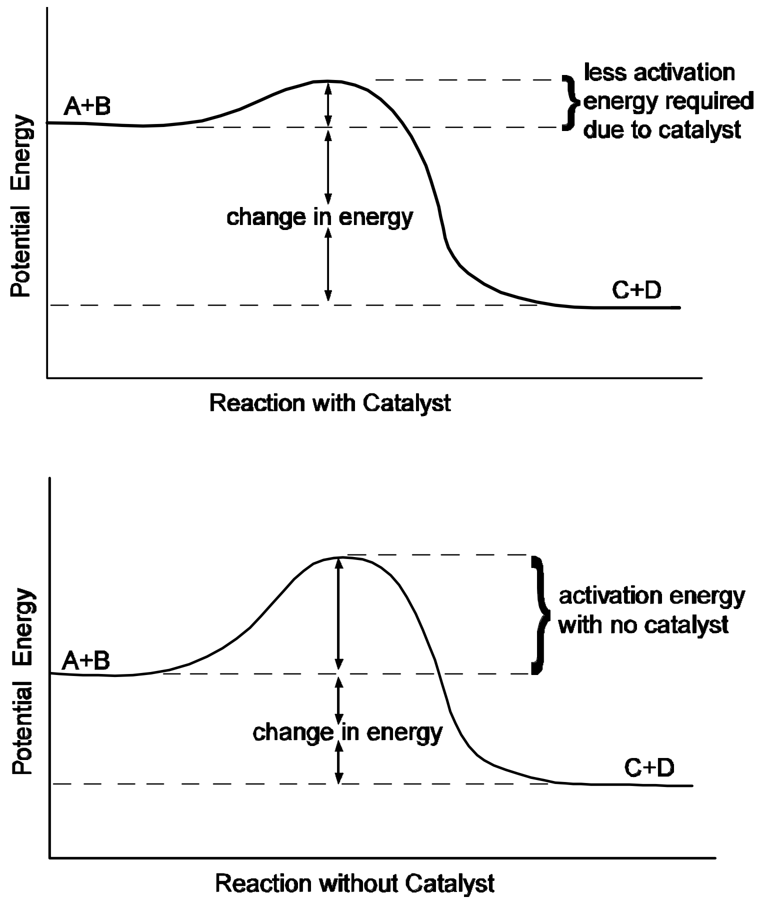
Reaction Rates and Catalysts

The rate at which a reaction proceeds depends on the temperature of the reactants. Thus for combustion to occur, it is often necessary to supply thermal energy initially, but the thermal energy produced by the reaction is then sufficient to maintain the temperature of the reactants necessary for combustion. An alternative to raising the temperature of the reactants is to place the reactants in the presence of a ***catalyst***. A catalyst is a substance that aids a chemical reaction but is not used up or changed by the reaction. The catalyst changes the rate at which the reaction proceeds, not the eventual outcome. Figure 7.3 on the next page shows that less activation energy is required to initiate a reaction when a catalyst is used.

A good example of a catalytic process is the enzyme process in which the human body converts food into energy. As food is oxidized (burned) in the human body, the heat that is given off raises the body temperature to 98.6 ^{o}F. This is a great deal lower than the temperature of burning paper (around 459 ^{o}F). The reason that the oxidation of food takes place at a lower temperature in living things than in non-living things is the presence of proteins called enzymes, which act as catalysts. Enzymes lower the temperature at which the chemical reactions take place. The catalysts change the reaction rate and allow the temperature of the human body to remain roughly constant.

Figure 7.3 Reaction Rates and Catalysts



7.5 Examples of Exothermic Reactions

The Conversion of Chemical Energy to Thermal Energy

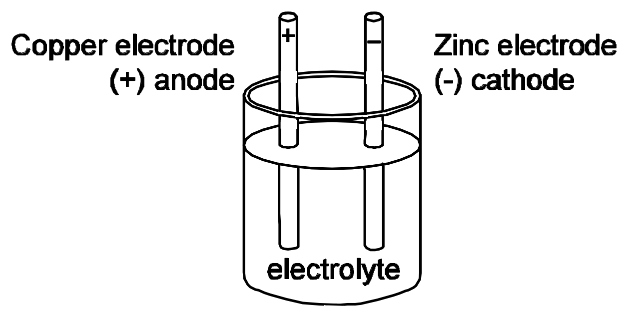
Chemical energy can be converted to many other forms of energy in exothermic reactions. One common conversion of chemical energy is into thermal energy. Combustion of natural gas and the derivatives of crude oil are one of the world's principal sources of thermal energy.

The Conversion of Chemical Energy to Other Forms of Energy

When a reaction is exothermic, the energy conversion may be from chemical energy to any one of several other forms of energy. Depending upon the conditions under which the reactants interact, chemical energy can be changed into thermal, electrical, radiant, or many other types of energy. For example, chemical energy can be converted to electrical energy in a battery.

The necessary components of a battery are two plates made of different materials called ***electrodes***, which are immersed in a conducting solution called an electrolyte. ***Electrolytes*** are generally an acid, base or salt often dissolved in water. In the water, the molecules of the substance are more or less completely dissociated into positively and negatively charged ions. (Recall that an ion is an atom or combination of atoms that has gained or lost one or more electrons.) It is the availability of these ions to carry the current that enables such a solution to conduct electricity. Both positively and negatively charged ions move. The chemical reaction that takes place causes negative charge to migrate toward one plate, the cathode, which becomes negatively charged, while positive charge migrates toward the other plate, the anode, which becomes positively charged. When the cathode and anode are connected to an external circuit, the voltage from the buildup of accumulated separated charge causes a current to flow. The chemical energy in the battery has been converted into electrical energy.

Figure 7.4 A Battery



Battery

Batteries are referred to either as primary or secondary batteries. Batteries that can be discharged and then recharged to their original state are called secondary or storage batteries. The necessary condition for such a battery is that the charging process be the reverse of the discharge process. Batteries that are constructed such that there is a chemical change that cannot be reversed (e.g. one of the products goes off into the air and is lost) are known as primary batteries.

The Conversion of Chemical Energy to Radiant Energy

The process of the conversion of chemical energy directly into radiant energy is known as ***chemiluminescence***. One of the most familiar examples of this phenomenon occurs in the firefly. In a firefly reaction, a light-emitting substance called luciferin is oxidized with the aid of an enzyme, luciferase, which acts as a catalyst. The reaction does not release appreciable amounts of thermal energy; essentially only radiant energy is released.

7.6 Examples of Endothermic Reactions

In endothermic chemical reactions there is a conversion of some other form of energy into chemical energy. An endothermic reaction that is basic to all life is photosynthesis. In the process of photosynthesis, visible radiant energy is converted into a form of chemical energy that can be stored by the plant in which the process is taking place. Energy from the sun is absorbed by membranes called chloroplasts, which contain chlorophyll molecules. The absorbed energy allows an endothermic reaction involving water and carbon dioxide to take place. This reaction produces oxygen and various types of sugars. Photosynthesis can take place in bacteria as well as plants and algae. The chemical process uses enzymes, organic catalysts, to break apart the water molecule forming oxygen and hydrogen molecules. The oxygen is released and the hydrogen is combined with the carbon dioxide to make the sugars.

Every time we move our bodies, we are converting stored chemical energy to mechanical energy. We obtain our chemical energy from food, which comes either directly or indirectly from green plants. Thus we can see the importance of the chemical process of photosynthesis.

Energy from the sun stored in plants millions of years ago led to the formation of coal. Similarly, oil and natural gas deposits are traced back to the energy from the sun stored in prehistoric organic matter. Because the energy source is the sun, oil, natural gas and coal are in some sense renewable, but the time scale, millions of years, is too long for human use.

The Conversion of Radiant Energy to Chemical Energy

In class we will see examples of photochromic glass. The light transmittance of this glass varies from 45% when the glass has darkened to 85% when the glass has faded. The chemical reaction that takes place to darken the glass is triggered by light in the near ultraviolet. It is similar to the reaction that takes place when light strikes the emulsion of a photographic film.

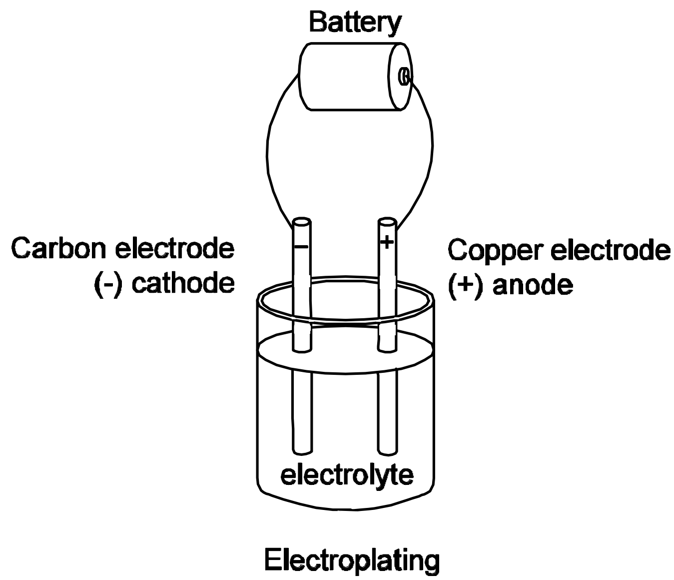
The Conversion of Electrical Energy to Chemical Energy

An excellent example of the conversion of electrical energy into chemical energy occurs in the process of recharging a secondary battery. Another endothermic reaction in which electrical energy is converted into chemical energy is the process of ***electrolysis***, the decomposition of a chemical compound by the action of an electric current. In class we will demonstrate electrolysis of water. In this process, electrical energy is used to dissociate water into hydrogen and oxygen. It is clear that energy is required to separate water into its component parts because when we recombine oxygen and hydrogen to form water, energy is released. The energy per molecule will be the same for both processes, as indicated by the law of conservation of energy. Any compound that will conduct electricity in solution can be decomposed in this manner.

Almost all of the aluminum so widely used in our daily lives is obtained by electrolysis of the aluminum-bearing ore bauxite. Prior to the application of this technique to the extraction of aluminum from bauxite, aluminum could only be obtained in small amounts by costly chemical techniques and was merely a laboratory curiosity. Electrolysis of bauxite is very energy intensive. For example, to make one six-pack of aluminum beverage cans requires around 1 kilowatt-hour of electrical energy. One can certainly appreciate the need for recycling!

Electroplating makes use of basically the same process as electrolysis. In copper plating, for example, the article to be plated is used as one of the terminals, the negative cathode, and a piece of pure copper is used as the other terminal, the positive anode. The two metals are placed in a solution of copper sulfate (the electrolyte). The electrolyte contains the substance to be plated, in this case copper. When the terminals are connected to a source of electricity, a current flows. This current causes some of the copper to dissolve and go into the solution as positive copper ions. These ions are attracted to the negative electrode where they are plated out on the electrode, which is the item to be plated. This process can continue, if desired, until the copper anode is completely dissolved.

Figure 7.5 Electroplating



Fuel Cells

If a reaction is endothermic, then the reverse reaction is exothermic. Consider the reverse of electrolysis of water. If hydrogen and oxygen are combined in the presence of a source of thermal energy to initiate the reaction, they form water in an explosive exothermic reaction. But it is also possible to recombine hydrogen and oxygen in a process that is the reverse process of the electrolysis of water. That is, it is possible to produce electricity rather than thermal energy in the chemical reaction of recombination. Devices in which the reactants are continually supplied to produce electrical energy in an electrochemical reaction are known as ***fuel cells***. Thus a device that converts hydrogen and oxygen continuously into electrical energy and water is called a hydrogen-oxygen fuel cell.

There are several types of fuel cells. Instead of hydrogen, the fuel might be propane, butane, carbon monoxide or zinc, to name only a few. In contrast to a secondary battery, which must be recharged when it stops converting chemical to electrical energy, a fuel cell is able to provide a continuous conversion of chemical to electrical energy as long as its source of fuel is not exhausted.

Concept Check 7.3

a) Two chemicals at room temperature are mixed in a beaker. When the chemicals react, the beaker feels cold. Is this reaction endothermic or exothermic?

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b) A match is used to light a candle. Is the reaction of the candle burning an endothermic or exothermic reaction?

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Period 7 Summary

7.1: Atomic nuclei consist of positively charged protons and neutral neutrons. The tiny nucleus contains 99.9% of the mass of the atom. The nucleus is surrounded by a cloud of negatively charged electrons.

Elements consist of atoms. The number of protons in the atomic nucleus determines the identity of the element.

Elements can combine into molecules or electrically charged ions.

A compound consists of atoms or molecules all of the same kind

Matter consisting of different compounds is a substance.

7.2: The electromagnetic force holds atoms together into molecules to form matter.

Matter can exist in the solid, liquid, or gaseous state. A phase change from one state of matter to another, such as solid ice melting into liquid water, usually involves a change in energy.

A phase change is an example of a physical change. In a physical change, no change in chemical composition occurs.

7.3: In a chemical change, one or more substances are partially used up, one or more new substances are formed, and energy is absorbed or released.

Chemical equations represent chemical reactions. Equations must be balanced, with the same number of atoms of each element on each side of the arrow.

Ions are electrically charged atoms or molecules. In a balanced chemical equation involving ions, the total electric charge on each side of the equation must be equal.

7.4: Exothermic reactions continually give off energy (often as heat)
Examples: combustion, batteries, or fuel cells

Endothermic reactions continually require energy input to occur.
Examples: recharging batteries, electroplating, photosynthesis

Period 7 Summary, Continued

Activation energy is the minimum energy needed to start a chemical reaction.

All reactions require activation energy. In some cases the thermal energy of the reactants is sufficient. In other cases, energy must be added.

Catalysts change the rates of chemical reactions by reducing the activation energy needed. Catalysts are not used up in the reaction and do not change the outcome of the reaction.

7.5: Batteries and fuel cells are examples of exothermic reactions. In a battery, negative charge moves toward the cathode, and positive charge moves toward the anode. When the cathode and anode are connected to an external circuit, the voltage from the accumulated separated charge causes a current to flow.

In a fuel cell, H_2 and O_2 gases are combined to form H_2O with a release of energy.

7.6: Electrolysis of water is an example of an endothermic reaction. In electrolysis, water molecules are separated into H_2 and O_2 gases. A source of energy (an electric current) is required.

Period 7 Exercises

E.1 When in our classroom demonstration ammonium nitrate was dissolved in water, the temperature of the water decreased. This shows that

a) an exothermic reaction occurred.
b) an endothermic reaction occurred.
c) the reaction used a catalyst.
d) the ammonium nitrate was colder than the water.
e) None of the above is correct.

E.2 An exothermic reaction, such as that between carbon and oxygen, will not always begin when the chemicals are mixed. The molecules can be made to react by

a) pumping the air out of the container.
b) performing the reaction in the dark.
c) lowering the specific heat of the oxygen.
d) lowering the specific heat of the carbon.
e) increasing the temperature.

E.3 A certain chemical reaction involves both the making and breaking of chemical bonds. The energy involved in breaking existing chemical bonds is 15 joules. Ten joules of energy are released when new chemical bonds are made. This reaction is

a) exothermic and releases 5 joules of energy.
b) exothermic and takes in 5 joules of energy.
c) endothermic and releases 5 joules of energy.
d) endothermic and takes in 5 joules of energy.
e) endothermic and releases 25 joules of energy.

E.4 Photosynthesis is a process by which plants

a) move toward the source of sunlight.
b) make carbon dioxide.
c) make water.
d) convert light into chemical energy.
e) convert chemical energy into light.

E.5 If you charge a battery such as the ones used in automobiles, you are

a) filling each cell with water.
b) violating the law of conservation of energy.
c) causing the same chemical reaction to take place that normally takes place in the battery when it is producing an electric current.
d) reversing the chemical reaction which normally takes place in the battery when it is producing an electric current.

E.6 A catalyst

a) is a type of plant.
b) is used up in a chemical reaction.
c) aids some chemical reactions.
d) will be broken up into hydrogen and oxygen when subjected to electrolysis.
e) is a type of phase change.

E.7 To construct a chemical electric cell (battery) one needs

a) two dissimilar electrodes and fuel oil.
b) two identical metal electrodes and an electrolyte.
c) one metal alloyed electrode and an electrolyte.
d) two dissimilar electrodes and an electrolyte.

E.8 Iron can combine with oxygen in two ways: rust slowly at room temperature or burn rapidly if heated in an atmosphere of pure oxygen. Assume that the amounts of iron and oxygen that combine are the same in both reactions and that the same end product is produced. The energy released

a) is greater when iron rusts slowly than when it burns rapidly.
b) is greater when iron burns rapidly than when it rusts slowly.
c) is the same in either reaction.
d) can be changed by adding a catalyst.

E.9 A fuel cell is a device that converts

a) electrical energy to mechanical energy.
b) electrical energy to chemical energy.
c) chemical energy to electrical energy.
d) radiant energy to mechanical energy.

Period 7 Review Questions

R.1 What is an exothermic reaction? Give examples of exothermic reactions.

R.2 What is an endothermic reaction? Give examples of endothermic reactions. How can endothermic reactions occur in nature?

R.3 What is a catalyst? Give examples of chemical processes that require catalysts.

R.4 In class we made a battery using tap water as the electrolyte. Why was it possible to use tap water as the electrolyte?

R.5 What is a fuel cell? Could a fuel cell be used to power a car? What are some of the advantages of fuel cells? Are there any disadvantages for using fuel cells to power a car?