# AP Environmental Science

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**C O N N E X I O N S**

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# Chapter 1

# FLOW OF ENERGY[1]

## 1.1 THE FLOW OF ENERGY

## 1.2 INTRODUCTION

**Energy** is the ability to do **work**. Work is done when a force is applied to an object over a distance. Any moving object has **kinetic energy** or energy of motion, and it thus can do work. Similarly, work has to be done on an object to change its kinetic energy. The kinetic energy of an object of mass $m$ and speed $v$is given by the relation $E = 1/2\text{mv}^2$.

Sometimes energy can be stored and used at a later time. For example, a compressed spring and water held back by a dam both have the potential to do work. They are said to possess **potential energy**. When the spring or water is released its potential energy is transformed into kinetic energy and other forms of energy such as heat. The energy associated to the gravitational force near the surface of the earth is potential energy. Other forms of energy are really combinations of kinetic and potential energy. Chemical energy, for example, is the electrical potential energy stored in atoms. Heat energy is a combination of the potential and kinetic energy of the particles in a substance.

## 1.3 FORMS OF ENERGY

**Mechanical energy** puts something in motion. It moves cars and lifts elevators. A machine uses mechanical energy to do work. The mechanical energy of a system is the sum of its kinetic and potential energy. Levers, which need a fulcrum to operate, are the simplest type of machine. Wheels, pulleys and inclined planes are the basic elements of most machines.

**Chemical energy** is the energy stored in molecules and chemical compounds, and is found in food, wood, coal, petroleum and other fuels. When the chemical bonds are broken, either by combustion or other chemical reactions, the stored chemical energy is released in the form of heat or light. For example, muscle cells contain glycogen. When the muscle does work the glycogen is broken down into glucose. When the chemical energy in the glucose is transferred to the muscle fibers some of the energy goes into the surroundings as heat.

**Electrical energy** is produced when unbalanced forces between electrons and protons in atoms create moving electrons called electric currents. For example, when we spin a copper wire through the poles of a magnet we induce the motion of electrons in the wire and produce electricity. Electricity can be used to perform work such as lighting a bulb, heating a cooking element on a stove or powering a motor. Note that electricity is a "secondary" source of energy. That means other sources of energy are needed to produce electricity.

[1]This content is available online at <http://cnx.org/content/m16468/1.3/>.

**Radiant energy** is carried by waves. Changes in the internal energy of particles cause the atoms to emit energy in the form of electromagnetic radiation which includes visible light, ultraviolet (UV) radiation, infrared (IR) radiation, microwaves, radio waves, gamma rays, and X-rays. Electromagnetic radiation from the sun, particularly light, is of utmost importance in environmental systems because biogeochemical cycles and virtually all other processes on earth are driven by them.

**Thermal energy** or **Heat energy** is related to the motion or vibration of molecules in a substance. When a thermal system changes, heat flows in or out of the system. Heat energy flows from hot bodies to cold ones. Heat flow, like work, is an energy transfer. When heat flows into a substance it may increase the kinetic energy of the particles and thus elevate its temperature. Heat flow may also change the arrangement of the particles making up a substance by increasing their potential energy. This is what happens to water when it reaches a temperature of $100^{o}C$. The molecules of water move further away from each other, thereby changing the state of the water from a liquid to a gas. During the phase transition the temperature of the water does not change.

**Nuclear Energy** is energy that comes from the binding of the protons and neutrons that make up the nucleus of the atoms. It can be released from atoms in two different ways: nuclear fusion or nuclear fission. In **nuclear fusion**, energy is released when atoms are combined or fused together. This is how the sun produces energy. In **nuclear fission**, energy is released when atoms are split apart. Nuclear fission is used in nuclear power plants to produce electricity. Uranium 235 is the fuel used in most nuclear power plants because it undergoes a chain reaction extremely rapidly, resulting in the fission of trillions of atoms within a fraction of a second.

## 1.4 SOURCES AND SINKS

The source of energy for many processes occurring on the earth's surface comes from the sun. Radiating solar energy heats the earth unevenly, creating air movements in the atmosphere. Therefore, the sun drives the winds, ocean currents and the water cycle. Sunlight energy is used by plants to create chemical energy through a process called photosynthesis, and this supports the life and growth of plants. In addition, dead plant material decays, and over millions of years is converted into fossil fuels (oil, coal, etc.).

Today, we make use of various sources of energy found on earth to produce electricity. Using machines, we convert the energies of wind, biomass, fossil fuels, water, heat trapped in the earth (geothermal), nuclear and solar energy into usable electricity. The above sources of energy differ in amount, availability, time required for their formation and usefulness. For example, the energy released by one gram of uranium during nuclear fission is much larger than that produced during the combustion of an equal mass of coal.

US ENERGY PRODUCTION (Quadrillion BTU)

| (Source: US DOE) | 1975 | 2000 |
|---|---|---|
| Coal | 14.989 (24.4%) | 22.663 (31.5%) |
| Natural Gas (dry) | 19.640 (32.0%) | 19.741 (27.5%) |
| Crude Oil | 17.729 (28.9%) | 12.383 (17.2%) |
| Nuclear | 1.900 (3.1%) | 8.009 (11.2%) |
| Hydroelectric | 3.155 (5.1%) | 2.841 (4.0%) |
| Natural Gas (plant liquid) | 2.374 (3.9%) | 2.607 (3.6%) |
| Geothermal | 0.070 (0.1%) | 0.319 (0.4%) |
| Other | 1.499 (2.5%) | 3.275 (4.6%) |
| TOTAL | 61.356 | 71.838 |

**Table 1.1**

(Source: US Department of Energy)

An **energy sink** is anything that collects a significant quantity of energy that is either lost or not considered transferable in the system under study. Sources and sinks have to be included in an energy budget when accounting for the energy flowing into and out of a system.

## 1.5 CONSERVATION OF ENERGY

Though energy can be converted from one form to another, energy cannot be created or destroyed. This principle is called the "law of conservation of energy." For example, in a motorcycle, the chemical potential energy of the fuel changes to kinetic energy. In a radio, electricity is converted into kinetic energy and wave energy (sound).

Machines can be used to convert energy from one form to another. Though ideal machines conserve the mechanical energy of a system, some of the energy always turns into heat when using a machine. For example, heat generated by friction is hard to collect and transform into another form of energy. In this situation, heat energy is usually considered unusable or lost.

## 1.6 ENERGY UNITS

In the International System of Units (SI), the unit of work or energy is the **Joule** (J). For very small amounts of energy, the erg (erg) is sometimes used. An **erg** is one ten millionth of a Joule:

$$1 \quad \text{Joule} \quad = \quad 10,000,000 \quad \text{ergs} \tag{1.1}$$

**Power** is the rate at which energy is used. The unit of power is the **Watt** (W), named after James Watt, who perfected the steam engine:

$$1 \quad \text{Watt} \quad = \quad 1 \quad \text{Joule/second} \tag{1.2}$$

Power is sometimes measured in **horsepower** (hp):

$$1 \quad \text{horsepower} \quad = \quad 746 \quad \text{Watts} \tag{1.3}$$

**Electrical energy** is generally expressed in **kilowatt-hours** (kWh):

$$1 \quad \text{kilowatt} - \text{hour} \quad = \quad 3,600,000 \quad \text{Joules} \tag{1.4}$$

**It is important to realize that a kilowatt-hour is a unit of energy not power. For example, an iron rated at $\mathbf{2000}$ $\mathbf{Watts}$ would consume $2x3.6x\mathbf{10}^6$ $J$ of energy in $1$ $\mathbf{hour}$ .**

**Heat energy is often measured in calories. One calorie (cal) is defined as the heat required to raise the temperature of $1$ $\mathbf{gram}$ of water from** 14.5 **to** 15.5 ºC:

$$1 \quad \text{calorie} \quad = \quad 4.189 \quad \text{Joules} \tag{1.5}$$

An old, but still used unit of heat is the **British Thermal Unit** (BTU). It is defined as the heat energy required to raise the energy temperature of 1 pound of water from 63 to 64$^\circ F$.

| Physical Quantity | Name | Symbol | SI Unit |
|---|---|---|---|
| Force | Newton | N | kg $\cdot\, m/s^2$ |
| Energy | Joule | J | kg $\cdot\, m^2/s^2$ |
| Power | Watt | W | kg $\cdot\, m^2/s^3$ |

**Table 1.2**

$1 \quad \mathit{BTU} \quad = \quad \mathit{1055} \quad \mathit{Joules}$

# Chapter 2

# CYCLING OF MATTER[1]

## 2.1 CYCLING OF MATTER

### 2.1.1 INTRODUCTION

The earth's biogeochemical systems involve complex, dynamic processes that depend upon many factors. The three main factors upon which life on the earth depends are:

1. The one-way flow of solar energy into the earth's systems. As **radiant energy**, it is used by plants for food production. As heat, it warms the planet and powers the weather system. Eventually, the energy is lost into space in the form of **infrared radiation**. Most of the energy needed to cycle matter through earth's systems comes from the sun.
2. The cycling of matter. Because there are only finite amounts of nutrients available on the earth, they must be recycled in order to ensure the continued existence of living organisms.
3. The force of gravity. This allows the earth to maintain the atmosphere encompassing its surface and provides the driving force for the downward movement of materials in processes involving the cycling of matter.

These factors are critical components to the functioning of the earth's systems, and their functions are necessarily interconnected. The main matter-cycling systems involve important nutrients such as water, carbon, nitrogen and phosphorus.

### 2.1.2 WATER CYCLE

The earth is sometimes known as the "water planet" because over 70 percent of its surface is covered by **water**. The physical characteristics of water influence the way life on earth exists. These characteristics include:

- Water is a liquid at room temperature, and remains as such over a relatively wide temperature range (0-100 ° C). This range overlaps the annual mean temperature of most biological environments.
- It takes a relatively large amount of energy to raise the temperature of water (i.e., it has a high heat capacity). For this reason, the vast oceans act as a buffer against sudden changes in the average global temperature.
- Water has a very high heat of vaporization. Water evaporation thus provides a good means for an organism to dissipate unwanted heat.
- Water is a good solvent for many compounds and provides a good medium for chemical reactions. This includes biologically important compounds and reactions.

[1]This content is available online at <http://cnx.org/content/m16470/1.3/>.

- Liquid water has a very high surface tension, the force holding the liquid surface together. This enables upward transport of water in plants and soil by capillary action.
- Solid water (ice) has a lower density than liquid water at the surface of the earth. As a result ice floats on the surface of rivers, lakes, and oceans after it forms, leaving liquid water below where fish and other organisms can continue to live. If ice were more dense than liquid water, it would sink, and bodies of water in cold climates might eventually freeze solid.

All living organisms require water for their continued existence. The water cycle (**hydrologic cycle**) is composed of the interconnections between water reservoirs in the environment and living organisms and the physical processes (e.g., evaporation and condensation) involved in its transport between those reservoirs. The oceans contain about 97 percent of the total water on the planet, which leaves about three percent as fresh water. Most of the fresh water is locked up in glacial and cap ice or buried deep in the earth where it is economically unfeasible to extract it. One estimate gives the amount of fresh water available for human use to be approximately 0.003 percent of the total amount of fresh water. However, this is actually a more than adequate supply, as long as the natural cycle of water is not severely disturbed by an outside force such as human activity.

There are several important processes that affect the transport of water in the water cycle. **Evaporation** is the process by which liquid water is converted to water vapor. The source of energy for this process is usually the sun. For example, the sun's radiation heats the surface water in a lake causing it to evaporate. The resulting water vapor is thus added to the atmosphere where it can be transported to another location. Two important effects of the evaporation are cooling and drying.

**Transpiration** is a process by which water evaporates from living plants. Water from the soil is absorbed by a plant's roots and transported to the leaves. There, some is lost as vapor to the atmosphere through small surface openings.

When water vapor in the atmosphere cools, it can transform into tiny droplets of liquid water. This process is called **condensation**, and it can occur as water vapor is transported into the cooler upper atmosphere. Dust and pollen in the atmosphere help to initiate the process by providing condensation centers. If the droplets remain small enough to be supported by air motions, they can group together to form a cloud. Condensation can also occur in the air near the ground as fog or on plant leaves as dew.

When condensed water droplets grow so large that the air can no longer support them against the pull of gravity, they fall to the earth. This is the process called **precipitation**.

If the water droplets fall as liquid, it is called rain. If the temperature of the surrounding air mass is cold enough to freeze the water droplets, the resultant precipitation can be called snow, sleet or hail, depending upon its morphology.

Water falling on the ground (e.g., as precipitation or irrigation), can move downslope over the surface (e.g., **surface runoff**) or penetrate the surface (e.g., **infiltration**). The amount of surface runoff and infiltration depends upon several factors: water infall rate, surface moisture, soil or rock texture, type and amount of surface cover (e.g., leaves and rooted plants), and surface topography. Surface runoff is the predominate process that occurs after precipitation, with most of the water flowing into streams and lakes. On a groundslope unprotected by vegetation, runoff can occur very rapidly and result in severe erosion.

Water that infiltrates the surface can move slowly downward through the layers of soil or porous rock in a process known as **percolation**. During this process, the water can dissolve minerals from the rock or soil as it passes through. The water collects in the pores of rocks as groundwater when it is stopped by an impermeable layer of rock. The upper limit of this **groundwater** is known as the **water table** and the region of water-logged rock is known as an **aquifer**. The groundwater may slowly flow downhill through rock pores until it exits the surface as a spring or seeps into a stream or lake.

Water is the essence of life. There would be no life as we know it without water. The vast oceans of water exert a powerful influence on the weather and climate. Water is also the agent by which the landforms are constantly reshaped. Therefore, the water cycle plays an important role in the balance of nature.

Human activity can disrupt the natural balance of the water cycle. The buildup of salts that results from irrigating with groundwater can cause soil infertility and irrigation can also deplete underground aquifers causing land subsidence or salt water intrusion from the ocean. The clearing of land for farming, construction, or mining can increase surface runoff and erosion, thereby decreasing infiltration. Increasing human populations and their concentration in certain geographic localities will continue to stress water systems. Careful thought is needed on local, regional and global scales regarding the use and management of water resources for wetlands, agriculture, industry and home.

### 2.1.3 CARBON CYCLE

Carbon is the basic building block of all organic materials, and therefore, of living organisms. However, the vast majority of carbon resides as inorganic minerals in crustal rocks. Other reservoirs of carbon include the oceans and atmosphere. Several physical processes affect carbon as it moves from one reservoir to another. The inter-relationships of carbon and the biosphere, atmosphere, oceans and crustal earth – and the processes affecting it – are described by the **carbon cycle**.

The carbon cycle is actually comprised of several inter-connected cycles. The overall effect is that carbon is constantly recycled in the dynamic processes taking place in the atmosphere, at the surface and in the crust of the earth. For example, the combustion of wood transfers **carbon dioxide** to the atmosphere. The carbon dioxide is taken in by plants and converted to nutrients for growth and sustenance. Animals eat the plants for food and exhale carbon dioxide into the atmosphere when they breathe.

Atmospheric carbon dioxide dissolves in the ocean where it eventually precipitates as carbonate in sediments. The ocean sediments are sub ducted by the actions of **plate tectonics**, melted and then returned to the surface during volcanic activity. Carbon dioxide gas is released into the atmosphere during volcanic eruptions. Some of the carbon atoms in your body today may long ago have resided in a dinosaur's body, or perhaps were once buried deep in the earth's crust as carbonate rock minerals.

The main carbon cycling processes involving living organisms are photosynthesis and respiration. These processes are actually reciprocal to one another with regard to the cycling of carbon: photosynthesis removes carbon dioxide from the atmosphere and respiration returns it. A significant disruption of one process can therefore affect the amount of carbon dioxide in the atmosphere.

During a process called **photosynthesis**, raw materials are used to manufacture sugar. Photosynthesis occurs in the presence of **chlorophyll**, a green plant pigment that helps the plant utilize the energy from sunlight to drive the process. Although the overall process involves a series of reactions, the net reaction can be represented by the following:

$$\underset{\text{(carbon dioxide)}}{6CO_2} + \underset{\text{(water)}}{6H_2O} + \underset{\text{(sunlight)}}{\text{Energy}} \rightarrow \underset{\text{(sugar)}}{C_6(H_2O)_6} + \underset{\text{(oxygen)}}{6O_2}$$

**Figure 2.1**

The sugar provides a source of energy for other plant processes and is also used for synthesizing materials necessary for plant growth and maintenance. The net effect with regard to carbon is that it is removed from the atmosphere and incorporated into the plant as organic materials.

The reciprocal process of photosynthesis is called respiration. The net result of this process is that sugar is broken down by oxygen into carbon dioxide and water. The net reaction is:

$$C_6(H_2O)_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$$

(sugar) (oxygen) (carbon dioxide) (water)

**Figure 2.2**

This process occurs not only in plants, but also in humans and animals. Unlike photosynthesis, respiration can occur during both the day and night. During respiration, carbon is removed from organic materials and expelled into the atmosphere as carbon dioxide.

Another process by which organic material is recycled is the decomposition of dead plants and animals. During this process, bacteria break down the complex organic compounds.

Carbon is released into the soil or water as inorganic material or into the atmosphere as gases. Decomposed plant material is sometimes buried and compressed between layers of sediments. After millions of years fossil fuels such coal and oil are formed. When fossil fuels are burned, the carbon is returned to the atmosphere as carbon dioxide.

The carbon cycle is very important to the existence of life on earth. The daily maintenance of living organisms depends on the ready availability of different forms of carbon. Fossil fuels provide an important source of energy for humans, as well as the raw materials used for manufacturing plastics and other industrially important organic compounds. The component processes of the carbon cycle have provided living things with the necessary sources of carbon for hundreds of millions of years. If not for the recycling processes, carbon might long ago have become completely sequestered in crustal rocks and sediments, and life would no longer exist.

Human activity threatens to disrupt the natural cycle of carbon. Two important ways by which humans have affected the carbon cycle, especially in recent history, are: 1) the release of carbon dioxide into the atmosphere during the burning of fossil fuels, and 2) the clearing of trees and other plants (deforestation) that absorb carbon dioxide from the atmosphere during photosynthesis. The net effect of these actions is to increase the concentration of carbon dioxide in the atmosphere. It is estimated that global atmospheric carbon dioxide is increasing by about 0.4% annually. Carbon dioxide is a **greenhouse gas** (i.e., it prevents infrared radiation from the earth's surface from escaping into space). The heat is instead absorbed by the atmosphere. Many scientists believe that the increased carbon dioxide concentration in the atmosphere is resulting in global warming.

This global warming may in turn cause significant changes in global weather, which could negatively affect all life on earth. However, increased photosynthesis (resulting from the increase in the concentration of carbon dioxide) may somewhat counteract the effects. Unfortunately, the issues of fossil fuel burning, deforestation and global warming are intertwined with economic and political considerations. Furthermore, though much studied, the processes are still not well-understood and their ramifications cannot be predicted with confidence.

### 2.1.4 NITROGEN CYCLE

The element Nitrogen is important to living organisms and is used in the production of **amino acids**, **proteins** and **nucleic acids** (**DNA, RNA**). Molecular nitrogen (N2) is the most abundant gas in the atmosphere. However, only a few single-cell organisms are able to utilize this nitrogen form directly. These include the bacteria species **Rhizobium**, which lives on the root nodules of legumes, and **cyanobacteria** (sometimes called blue-green algae), which are ubiquitous to water and soil environments. In order for multi-cellular organisms to use nitrogen, its molecular form (N2) must be converted to other compounds, e.g., nitrates or ammonia. This process is known as **nitrogen fixation**. Microbial organisms such as cyanobacteria carry out most of the earth's nitrogen fixation. The industrial manufacture of fertilizers, emissions from combustion engines and nitrogen burning in lightning account for a smaller fraction.

The **nitrogen cycle** is largely dependent on microbial processes. Bacteria fix nitrogen from the atmosphere in the form of **ammonia (NH3)** and convert the ammonia to **nitrate (NO3-)**.

Ammonia and nitrate are absorbed by plants through their roots. Humans and animals get their nitrogen supplies by eating plants or plant-eating animals. The nitrogen is returned to the cycle when bacteria decompose the waste or dead bodies of these higher organisms, and in the process, convert organic nitrogen into ammonia. In a process called **denitrification**, other bacteria convert ammonia and nitrate into molecular nitrogen and nitrous oxide (N2O). Molecular nitrogen is thus returned to the atmosphere to start the cycle over again.

Humans have disturbed the nitrogen cycle in recent history by activities involving increased fixation of nitrogen. Most of this increased nitrogen fixation results from the commercial production of fertilizers and the increased burning of fuels (which converts molecular nitrogen to nitric oxide, NO). The use of commercial fertilizers on agricultural lands increases the runoff of nitrates into aquatic environments.

This increased nitrogen runoff stimulates the rapid growth of algae. When the algae die, the water becomes depleted in oxygen and other organisms die. This process is known as **eutrophication**. The excessive use of fertilizers also stimulates the microbial **denitrification** of nitrate to **nitrous oxide**. Increased atmospheric levels of nitrous oxide are thought to contribute to global warming. Nitric oxide added to the atmosphere combines with water to form **nitric acid(HNO3)**, and when nitric acid dissolves in water droplets, it forms acid rain. Acid rain damages healthy trees, destroys aquatic systems and erodes building materials such as marble and limestone.

### 2.1.5 PHOSPHOROUS CYCLE

**Phosphorus** in earth systems is usually in the form of **phosphate (PO43-)**. In living organisms it is an essential constituent of cell membranes, nucleic acids and **ATP** (the carrier of energy for all life forms). It is also a component of bone and teeth in humans and animals. The **phosphorus cycle** is relatively simple compared to the other cycles of matter as fewer reservoirs and processes are involved. Phosphorus is not a nominal constituent of the atmosphere, existing there only in dust particles.

Most phosphorus occurs in crustal rocks or in ocean sediments. When phosphate-bearing rock is weathered, the phosphate is dissolved and ends up in rivers, lakes and soils. Plants take up phosphate from the soil, while animals ingest phosphorus by eating plants or plant-eating animals. Phosphate is returned to the soil via the decomposition of animal waste or plant and animal materials. This cycle repeats itself again and again. Some phosphorus is washed to the oceans where it eventually finds its way into the ocean-floor sediments.

The sediments become buried and form phosphate-bearing sedimentary rocks. When this rock is uplifted, exposed and weathered, the phosphate is again released for use by living organisms.

The movement of phosphorus from rock to living organisms is normally a very slow process, but some human activities speed up the process. Phosphate-bearing rock is often mined for use in the manufacture of fertilizers and detergents. This commercial production greatly accelerates the phosphorous cycle. In addition, runoff from agricultural land and the release of sewage into water systems can cause a local overload of phosphate. The increased availability of phosphate can cause overgrowth of algae. This reduces the oxygen level, causing eutrophication and the destruction of other aquatic species. Marine birds play a unique role in the phosphorous cycle. These birds take up phosphorous from ocean fish. Their droppings on land (**guano**) contain high levels of phosphorous and are sometimes mined for commercial use.

# Chapter 3

# THE SOLID EARTH[1]

## 3.1 THE SOLID EARTH

### 3.1.1 EARTH'S FORMATION AND STRUCTURE

The earth formed approximately 4.6 billion years ago from a nebular cloud of dust and gas that surrounded the sun. As the gas cooled, more solids formed. The dusty material accreted to the nebular midplane where it formed progressively larger clumps. Eventually, bodies of several kilometers in diameter formed; these are known as **planetesimals**. The largest planetesimals grew fastest, at the expense of the smaller ones. This process continued until an earth-sized planet had formed.

Early in its formation, the earth must have been completely molten. The main source of heat at that time was probably the decay of naturally-occurring radioactive elements. As the earth cooled, density differences between the forming minerals caused the interior to become differentiated into three concentric zones: the crust, mantle and core. The crust extends downward from the surface to an average depth of 35 km where the mantle begins. The mantle extends down to a depth of 2900 km where the core begins. The core extends down to the center of the earth, a depth of about 6400 km from the surface.

The **core** makes up 16 percent of the volume of the earth and about 31 percent of the mass. It can be divided into two regions: a solid inner core and a liquid outer core. The inner core is probably mostly metallic iron alloyed with a small amount of nickel, as its density is somewhat greater than that of pure metallic iron. The outer core is similar in composition, but probably also contains small amounts of lighter elements, such as sulfur and oxygen, because its density is slightly less than that of pure metallic iron. The presence of the lighter elements depresses the freezing point and is probably responsible for the outer core's liquid state.

The **mantle** is the largest layer in the earth, making up about 82 percent of the volume and 68 percent of the mass of the earth. The mantle is dominated by magnesium and iron-rich (mafic) minerals. Heat from the core of the earth is transported to the crustal region by large-scale convection in the mantle. Near the top of the mantle is a region of partially melted rock called the **asthenosphere**. Numerous small-scale convection currents occur here as hot **magma** (i.e., molten rock) rises and cooler magma sinks due to differences in density.

The **crust** is the thinnest layer in the earth, making up only 1 percent of the mass and 2 percent of the volume. Relative to the rest of the earth, the crust is rich in elements such as silicon, aluminum, calcium, sodium and potassium. Crustal materials are very diverse, consisting of more than 2000 minerals. The less dense crust floats upon the mantle in two forms: the **continental crust** and the **oceanic crust**. The oceanic crust, which contains more **mafic minerals** is thinner and denser than the continental crust which contains minerals richer in silicon and aluminum. The thick continental crust has deep buoyant roots that help to support the higher elevations above. The crust contains the mineral resources and the fossil fuels

[1]This content is available online at <http://cnx.org/content/m16682/1.2/>.