Chapter 1
Science and Technology of Energy

Breathing Fire

Scientists seek to discover previously unknown facts about nature and technologists find ways to use those discoveries. There are many definitions of technology but one that is short and easy to remember is — *Technology is the application of scientific discoveries to the needs and desires of people*. Because technology reflects what people consider to be important needs or desires, a study of the technologies used by different groups of people provides insight and awareness of different cultures. One of the central technologies to any culture is the way it uses energy.

Why Do I Need to Know This?

In this chapter, you learn about the science of energy and then about how technologies apply that scientific knowledge to the basic needs of heating, cooking, and lighting. Because the level of technology is so different between rich and poor countries, comparison of these technologies will increase your awareness of how different are the lives of many people from your own. The knowledge obtained in this chapter will be used to understand issues related to air pollution and choices of alternative sources of energy discussed in later chapters.

1 Heating, Cooking, and Smoke

Learning Objectives

1. Identify the percentage of households world-wide that burn solid fuel for cooking and heating. [1.1.1]
2. Identify five types of solid fuel burned for cooking and heating in many countries. [1.1.2]
3. Identify the amount of air pollution that is attributed to wood smoke in Washington State. [1.1.3]
4. Identify an example of a problem caused by the difference in perception of the problem of air pollution from burning solid fuels between poor and affluent countries. [1.1.4]

In countries that use advanced technologies, most people cook and heat their homes using natural gas, liquid propane, fuel oil, coal, or uranium. The energy is produced in devices that protect the homeowner from direct exposure to smoke, gasses, or additional radiation. This is not the case for about half of the people on earth.

The World Health Organization (WHO) informs us that ninety percent of rural households and fifty percent of all households use solid fuels such as wood, charcoal, animal dung, or crop residue for cooking and heating. (Desai, Mehta and Smith 2004) [Link] This is commonly done using little or no technology to burn the fuel efficiently or to protect the people from inhaling smoke as shown in Figure 1.1. (Brown and Nichols 2011) [Link]

Figure 1.1. Half of all households in the world burn solid fuels for cooking and heating.

Women and young children are affected the most by acute respiratory infections and lung cancer due to their exposure to smoke inside the home. Indoor air pollution from the use of solid fuels accounts for 2.6% of all ill-health in the world and nearly all of it is in poor regions. This translates into 1.6 million deaths per year, most of which are women and children who spend more time indoors near cooking fires. (Desai, Mehta and Smith 2004).

In countries that use more advanced technologies to produce energy like the United States, smoke from burning fuels is diverted outside the home. Consequently, few Americans associate indoor smoke with burning fuel for cooking and heating. This lack of global awareness can lead to misunderstandings.

…few air pollution studies in developed countries have focused on ALRI (Acute Lower Respiratory Illness), either through a lack of interest, or because there were too few cases to be statistically significant. Ironically, therefore, when exposure-response information from developed countries is applied to situations in developing countries, ALRI is often omitted. (Desai, Mehta and Smith 2004)

Smoke from burning solid fuels can be an issue in some areas of the USA where wood is burned for heating or aesthetic purposes. This is even a problem in affluent, environmentally conscious areas like

Washington State. The American Lung Association of Washington reports that ten percent of the air pollution in Washington State comes from wood smoke. (Wood Smoke Pollution 2007)

Key Takeaways

About 50% of households in the world burn solid fuel for cooking and heating. [1.1.1]

Solid fuels used for cooking and heating include wood, charcoal, animal dung, and crop residue. [1.1.2]

Smoke from burning wood in Washington state contributes 10% of their air pollution. [1.1.3]

When exposure-response information regarding indoor air pollution that is gathered from developed countries is applied to situations in developing countries, ALRI (Acute Lower Respiratory Infection) is often omitted because it isn't a problem in developed countries. [1.1.4]

2 Physics and Chemistry of Energy

Learning Objectives

1. Identify the difference between heat and temperature. [1.2.1]
2. Identify the relationship between wavelength and visibility of light. [1.2.2]
3. Identify the meaning of each letter in Einstein's famous energy equation. [1.2.3]
4. Identify the relationship between the number of protons and electrons in a neutral atom and in an ion. [1.2.4]
5. Describe how electrons arrange themselves around a nucleus and how that determines the chemical behavior of the atom. [1.2.5]
6. Identify the relationship between pH scale, acids, and bases. [1.2.6]
7. Identify the five most common gasses in the earth's atmosphere and their relative abundance. [1.2.7]
8. Describe the source of energy in the sun and how that energy gets to the earth. [1.2.8]

To understand energy and its use, you must have a basic understanding of several areas of science. In this section, we review the basic science concepts used in technologies that are related to energy. This may be a review for some of you and entirely new information for others. If you haven’t taken a course in chemistry, physics, earth science, or biology this section may show you why it is valuable to know more about these subjects and to encourage you to further your education in these areas.

The Physics of Energy

Energy can take many forms and they can be grouped into two major categories; stored energy and motion energy. The forms you need to know about for this unit are:

Motion

- Heat: The rapid random motion and vibration of atoms is known as heat. The measurement of the average amount of motion and vibration is the temperature.
- Light: Light consists of tiny bundles of energy called photons that have some of the same properties as waves in water such as wavelength. A certain range of wavelengths of light can be perceived by the human eye and is called visible light. Light with wavelengths that are too long for us to perceive are called infrared and light with wavelengths that are too short for us to perceive are called ultraviolet. Photons of light with shorter wavelengths have more energy than photons of light with longer wavelengths. (Freundenrich n.d.) [Link]

Stored

- Chemical energy: Matter is made up from units called atoms that consist of a positively charged nucleus at the center that contains almost all of the atom's mass with negatively charged electrons outside the nucleus. Atoms can be combined into groups called molecules. Some molecules contain more energy than others. If energy is released from these molecules by breaking them apart and recombining them into molecules with less energy we call this chemical energy.
- Nuclear Energy: In 1905 Albert Einstein explained that matter itself can be thought of as extremely concentrated, stored energy (Bellis 2011) [Link] Under the right circumstances, the nuclei of very small atoms can combine or the nuclei of very large atoms can split and the resulting atoms have less total mass. The missing mass is a small fraction of the mass of the atoms but because it is extremely concentrated, the combining or splitting of nuclei produces about a million times more energy per atom than chemical energy. In Einstein's famous formula, $E=mC^2$, the E stands for energy, m stands for the missing mass, and C stands for the speed of light

Chemistry of Atoms and Molecules

Chemistry deals with the properties of atoms and molecules where molecules are combinations of atoms.

Here are some basic concepts that we will use later:

- The nucleus of an atom consists mainly of two types of particles; a positively charged proton and an uncharged neutron. These two particles are approximately the same mass which is far greater than the mass of an electron. The fundamental nature of the atom is determined by the number of protons in the nucleus. For example; Hydrogen has only one proton, Helium has two, Lithium has three, up to Uranium which has 92 which is the largest atom found in nature.
- In general, an atom has as many negatively charged electrons as it does positively charged protons in the nucleus for a net charge of zero. If it doesn't, the atom has a net positive or negative charge and is called an ion**.**
- Chemical reactions between atoms involve the electrons that surround the nuclei.
- Although electrons are negative and repel each other, they have spin and tend to form pairs with opposite spins and then to form layers of pairs like an onion around the nuclei.
- The number of negative electrons that surround the nucleus is determined by the number of positive protons in its nucleus.

If we look at the way the electrons arrange themselves around nuclei with increasing number of protons, we find that they form layers.

- The innermost layer can have one or two electrons.
- The next two layers can accommodate up to eight more electrons each
- The next two layers can each accommodate eighteen electrons
- The last two layers are a bit more complicated but can hold thirty-two electrons

For example, if we consider Lithium which has three protons in its nucleus, it will have three electrons. Two of them will form the first layer leaving one electron by itself in the next layer. If we consider Sodium which has eleven positive protons in its nucleus, it will have eleven electrons nearby. Two will form the first layer, and eight will form the second layer—leaving one electron in the outermost layer.

- If the outer layer of electrons of an atom is full, there is little interaction between this type of atom and other atoms. Atoms with full outer shells are Helium (two electrons), Neon (10), Argon (18), Krypton (36), Xenon (54), and Radon (86). This group is known as inert gasses.

- In contrast to the inert gasses, atoms like Hydrogen, Lithium, and Sodium each have only one electron in the outermost layer. The single unpaired electron in their outmost layer pairs easily with the electrons in outer layers of other atoms to form a complete shell, as shown in Figure 1.2. This type of combination is called a covalent bond. (Clark 2000) [Link]

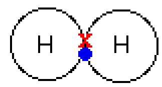

Figure 1.2. Atoms can share outer electrons to make a complete shell

For example, if you put two hydrogen atoms near each other, the electrons will pair up and spend some of their time around each nucleus. This pair has less energy than the individual atoms and so combining two hydrogen atoms into a hydrogen molecule releases energy.

We represent molecules as combinations of atoms with a letter for the type of atom and a subscript to tell us how many atoms there are in the molecule. For example, a molecule consisting of two hydrogen atoms is represented as H_2.

Oxygen has eight protons in the nucleus and eight electrons. Two of the electrons are in the inner layer and six in the outer layer. Oxygen is two electrons short of a full layer so it will share two electrons with another atom to complete an outer shell. If two Oxygen atoms combine to share electrons and form a molecule, we have O_2.

Similarly, Nitrogen with seven electrons has five in its outer layer which is three short of a full layer. Two nitrogen atoms can combine to share three electrons and form N_2. Carbon has six positive protons in its nucleus and six negative electrons surrounding it. It has two electrons in the inner layer and four in the outer layer. Carbon atoms can combine with other carbon atoms to share up to four electrons.

In general, oxygen and carbon atoms combine readily with hydrogen to form molecules. Oxygen, which needs to share two electrons to complete its outer layer, will combine with two electrons from hydrogen atoms to produce H_2O (water), as shown in Figure 1.3.

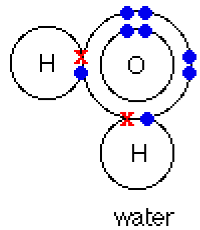

Figure 1.3. Molecule of water creates complete outer shells by sharing electrons.

Carbon has four outer electrons and a complete shell needs eight. Carbon can combine with many other atoms to create a variety of molecules. For example, it can share its four outer electrons with two oxygen atoms to form CO_2 (carbon dioxide) or with four hydrogen atoms to form CH_4 (methane).

Chemistry of Acids and Bases

In a sample of pure water (H_2O), some of the molecules of water will separate into two charged ions—a single hydrogen (H) and a combination of oxygen and hydrogen called a hydroxyl group (OH). The electrons that are shared by a molecule of H_2O tend to stay with the OH resulting in a net negative charge that is indicated by a minus sign (OH^-). The single hydrogen just has its positive nucleus that is represented with a plus sign (H^+). The number of H^+ and OH^- ions is the same so the net charge is neutral.

If you dissolve molecules in water and they break apart into ions where one of them is a H^+ ion, it is called an acid. For example, if you dissolve hydrogen chloride (HCl) in water, it separates into hydrogen (H^+) and chlorine (Cl^-) ions. In this solution, there are more H^+ ions than OH^- ions so it is an acid called hydrochloric acid. A scale called the pH scale is used to indicate the balance of H^+ to OH^-. If the ions are present in equal numbers, the solution is neutral with a pH of 7. If the numbers of H^+ ions outnumber the OH^- ions the pH is less than 7. If the molecules that dissolve in water separate into parts that contribute OH^- ions more than H^+ ions it is called a base or alkaline and the solution has pH values above 7.

Earth Science

The earth's atmosphere is a mixture of gasses that is relatively constant except for water vapor and carbon dioxide. The amount of water in the air varies from almost zero above the cold polar deserts to about 4% near the hot, wet equator. The water molecules are mixed with the other gasses and we don't see them unless the air is cooled and they come together to form droplets of liquid water that we see as clouds or fog. If we consider the gasses that make up "dry" air—air without water vapor—the percentages are shown in the following table (see Figure 1.4). The percentage of carbon dioxide is also variable depending on burning of fossil fuels and the temperature of the oceans. The cause of the recent increase in this percentage is commonly attributed to the release of CO_2 from burning fossil fuels.

Name	Atom or Molecule	Percentage
Nitrogen	N_2	78.0842
Oxygen	O_2	20.9463
Argon	Ar	0.9342
Carbon Dioxide	CO_2	0.0350
Methane	CH_4	0.0002
Other	He, Ne, Kr, H, CH_4, O_3	0.0001

Figure 1.4. Nitrogen and Oxygen make up 99% of the dry air

There is almost six hundred times more oxygen in the atmosphere than carbon dioxide. If a plant produces enough oxygen during its lifetime to oxidize its remains when it dies, this would imply that are hundreds of times more fossil plant remains trapped in the earth's crust than have been burned to date. However, relatively little of it would be concentrated and easily extracted from the earth.

Nuclear Physics

In the sun, the nuclei of hydrogen atoms are squeezed together under tremendous gravitational forces to fuse into helium nuclei. Each helium nucleus is slightly less massive than the sum of the masses of the two hydrogen nuclei that combined to make it. The missing mass is converted into heat and light. This process is known as nuclear fusion. As a result of the tremendous release of nuclear energy, some of the particles in the sun are so hot and are traveling so fast that they escape the sun's gravity and radiate outward toward the planets. These particles are known as the solar wind. The light energy also radiates outward and a small fraction of it is intercepted by the earth. This light comes in a variety of wavelengths including visible, infrared and ultraviolet.

Key Takeaways

Heat is the energy of motion of the atoms. The atoms move at different speeds. The temperature represents the average energy of the atoms. [1.2.1]

Photons of light have wave properties. The human eye can perceive a narrow range of wavelengths. Photons with wavelengths longer than the human eye can see are called infrared while shorter wavelengths are ultraviolet. [1.2.2]

The formula is $E=mC^2$. The E stands for energy, m is the mass that is converted to energy and C is the speed of light. [1.2.3]

In a neutral atom the number of positive protons is the same as negative electrons. If this is not the case, the atom has a net charge and is called a positive or negative ion depending on which type of charge is surplus. [1.2.4]

Where atoms have more than one electron, they tend to pair up and form layers around the nucleus. The electrons in the outermost layer have the most effect on nearby atoms. Atoms with the same number of electrons in the outermost layer have similar chemical behaviors. Atoms with incomplete layers may join with other atoms to create complete layers which is called covalent bonding. [1.2.5]

A few water molecules spontaneously break up into equal numbers of ions of H^+ and OH^-. The pH scale indicates this balance and the number 7 on the pH scale indicates a balance. If another chemical is dissolved in the water that contributes extra H^+ ions the pH number is less than 7 and it is called an acid. If the chemical that is dissolved contributes extra t OH^- ions, the pH is above 7 and it is a base which is also called alkaline. [1.2.6]

The "dry" gasses in the earth's atmosphere are mostly Nitrogen (78%) and Oxygen (21%). The remaining 1% is mostly Argon (0.93%), Carbon Dioxide (0.035%) and Methane (0.0002%). The amount of water dissolved in the air varies from almost zero to 4%. [1.2.7]

The sun's energy comes from conversion of mass into energy when two hydrogen atoms fuse into a helium atom that has less total mass. The energy is emitted from the sun as photons of light and individual particles that can travel to the earth. [1.2.8]

3 Biology and Earth Science of Fuels

Learning Objectives

1. Identify the relationship between sunlight, photosynthesis, hydrocarbons, and oxygen. [1.3.1]
2. Identify the differences between cellulose and dextrose. [1.3.2]
3. Identify forms of oxidation. [1.3.3]
4. Identify the grades of coal and how the grades relate to the carbon and sulfur content. [1.3.4]
5. Identify the difference between the processes thought to produce coal and petroleum. [1.3.5]
6. Identify the difference between fossil fuels and other forms of fuels derived from photosynthesis. [1.3.6]

Trees absorb light energy from the sun and use it to reorganize low-energy molecules into higher energy molecules that are used to store the sun's energy. The plants take in carbon dioxide (CO_2) and water (H_2O) from the Earth's atmosphere. They separate the carbon and hydrogen from the oxygen and combine the carbon and hydrogen into molecules called hydrocarbons which refers to any combination of carbon and hydrogen atoms. The oxygen (O_2) is released into the atmosphere. The energy from the nuclear fusion that took place in the sun is stored in these molecules. This process is called photosynthesis. (What is Photosynthesis? n.d.)

Plants convert carbon dioxide (CO_2) and water (H_2O) into several types of hydrocarbons such as cellulose ($C_6H_{10}O_5$) and dextrose ($C_6H_{12}O_6$). Even though these molecules are similar the differences are important. Dextrose is a type of sugar that humans can digest and use directly as a source of food energy. Cellulose forms the fibrous or woody portion of a plant and humans cannot digest it but it can be burned as fuel. Cattle can digest cellulose partially but their dung still contains enough undigested cellulose to burn once the dung is dried.

Charcoal is the remains of wood that has been heated in the absence of oxygen to break down most of the hydrocarbons. The hydrogen and oxygen become gasses and are removed leaving a black, porous residue that is mostly carbon. Charcoal is lighter weight than wood and burns with less smoke. Most of the people in the world burn cellulose from wood, charcoal, dried animal dung, or crop waste such as rice stalks.

When a tree dies and falls to the ground, the hydrocarbons start to break down and recombine with the oxygen in the atmosphere, which is called oxidation. If this happens slowly, we say it is rotting. If the right conditions exist, the hydrocarbons combine with oxygen rapidly. The heat and light are released much faster and we call it fire. The process of oxidation combines oxygen with hydrogen and carbon to create molecules of water and carbon dioxide. A plant produces enough oxygen during its lifetime to consume itself by oxidation when it dies by rotting or by fire.

However, if a tree dies and is covered up by more dying trees or other vegetation before it oxidizes, its hydrocarbons retain their energy. If this process goes on for very long periods, thick layers of plant material can be trapped that represent a reservoir of stored energy. This is the process that is thought to have produced peat bogs where the process is relatively recent as shown in Figure 1.5.

Figure 1.5. Blocks of peat cut from a peat bog

If this process continues and the buried plant material is compressed and heated underground over millions of years it can turn into coal as shown in Figure 1.6. Coal is mostly carbon but it can contain other elements such as sulfur and silica.

Figure 1.6. Coal mining from a surface pit

Coal is found in layers underground. In some areas, the edge of the layer is exposed and the coal can be removed by simply digging it out along the edge. Once the easily accessible coal is used up, the remaining coal can be made accessible by removing the layers of rock and soil above the layer of coal which is called strip mining. Alternatively, vertical shafts can be dug through the overlying rock and then branches dug in the layer of coal which is called deep mining.

Recall that coal is the fossil remains of ancient plants where the coal is mostly carbon. Some layers of coal have higher concentrations of carbon than others. The cleanest burning coal that produces the most heat per pound is the type with the highest concentration of carbon (92-98%) which is called anthracite. A lesser quality coal with more plant material left in it and with less heat per pound is bituminous (60-80% carbon). Bituminous coal is the grade used most in electric power plants. Two lower quality coals, sub-bituminous and lignite have even less carbon.

If sunlight falls on the ocean, small plants floating near the surface use photosynthesis to convert sunlight into hydrocarbons. When these plants die, some of them sink and are covered with mud thereby separating them from the oxygen in the atmosphere. When this process goes on for millions of years, large quantities of hydrocarbons can be deposited on the bottom of a body of water. If these deposits are subsequently buried and then heated deep within the earth, their hydrocarbons turn into petroleum and natural gas. Petroleum and natural gas can travel through porous rock and might be trapped beneath a layer of non-porous rock forming a reservoir, as shown in Figure 1.7. (Blue Ridge Group Inc. n.d.)

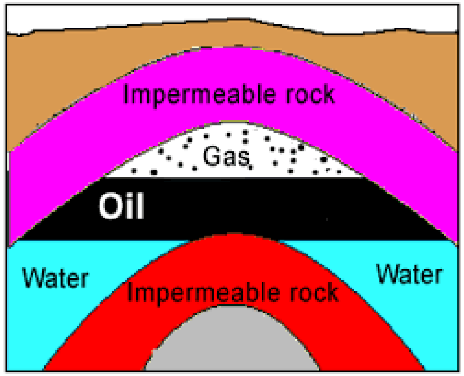

Figure 1.7. Oil and gas trapped below layer of rock

Coal, petroleum, and natural gas are thought to be the product of a process that traps carbon and hydrocarbons for very long periods of time. Fossils are the remains or traces of ancient plants or animals. Because these sources of energy are derived from the remains of ancient plants, these forms of stored energy are known as fossil fuels. Fossil fuels are a more concentrated form of energy than recently living plant material.

Key Takeaways

Plants absorb the sun's energy from its sunlight and by the process called photosynthesis combine molecules of water and carbon dioxide into molecules of carbon and hydrogen called hydrocarbons. The process releases oxygen to the atmosphere. [1.3.1]

Cellulose and dextrose are both created by photosynthesis. Dextrose is sugar than can be digested by humans. Cellulose is the woody or stem material that some insects and animals can digest. The energy of cellulose can be released by burning it. [1.3.2]

Oxidation is the recombination of oxygen with the carbon and hydrogen in hydrocarbon molecules to create molecules of water and carbon dioxide. [1.3.3]

Coal comes in grades that reflect the percentage of pure carbon in the coal. The highest is anthracite (92-98%) followed by bituminous (60-80%). Two lower carbon grades are sub-bituminous and lignite. [1.3.4]

Coal is thought to be created when plants fall to the ground and are covered up before they rot or burn. Thick layers are compressed and buried and eventually turn into seams of concentrated carbon. Petroleum is thought to be created by tiny marine plants and animals whose bodies contain hydrocarbons. When those plants and animals die and sink below the water, they can become trapped in deposits below ground where time and pressure convert them to petroleum and natural gas. [1.3.5]

Ancient remains of plants and animals are called fossils. If the remains are hydrocarbons and may be used as fuel, they are called fossil fuels. Cellulose from recently living plants such as wood, charcoal, animal dung, and crop waste may be also used as fuel. [1.3.6]

4 Science and Technology of Combustion

Learning Objectives

1. Describe the ideal process of burning a hydrocarbon fuel including inputs and outputs. [1.4.1]
2. Identify the technologies used to control combustion to reduce its harmful effects while maximizing its benefits. [1.4.2]
3. Identify the harmful products of burning real fuels using atmospheric gasses. [1.4.3]
4. Identify the environmental impacts of burning solid fuels for heating and cooking. [1.4.4]

If plant material is exposed to oxygen it will oxidize slowly because the hydrogen and carbon in the hydrocarbons are bound to each other and only a few at a time are available to combine with the oxygen in the air. If the hydrocarbons are heated enough to break them apart, the process can happen much more quickly. The heat from the oxidation process can be used to break up more hydrocarbons. The result is a self-sustaining process we call fire.

Science of Combustion

In addition to the carbon dioxide and water that is produced by burning the hydrocarbons, other gasses and impurities in the fuel are emitted that can pollute the air. To control the air pollution that results from burning solid fuels, it helps to understand what happens when something burns. A fire needs a fuel source, a source of oxygen, and heat. Before the molecules that comprise the fuel source can combine with oxygen, they have to be broken up into separate atoms. Recall that heat is random motion or vibration of atoms. If we add enough heat to the fuel and oxygen, the motion of their atoms becomes great enough to break apart the molecules so the carbon and hydrogen atoms are free to make new molecules with the oxygen. They recombine to form molecules of CO_2 and H_2O. The chemical energy that was stored in the fuel is released. Some of this energy can be used to heat more fuel to make the fire self-sustaining and the rest is given off as light or remains in the CO_2 and H_2O in the form of heat.

Consider what happens when you light a candle. First, you have to supply heat to start the process with a match or lighter. The solid wax melts and then some of it vaporizes into individual carbon and hydrogen atoms. If there is enough oxygen to burn all the available fuel, it emits a blue light. If there isn't enough oxygen, the fuel is hot enough to emit colored light until it comes in contact with enough oxygen to complete the combustion process, as shown in Figure 1. The invisible CO_2 and H_2O gasses rise above the flame. Some of the heat from this process melts more wax and the process continues until you remove the oxygen, the heat, or the fuel. (Harris n.d.)

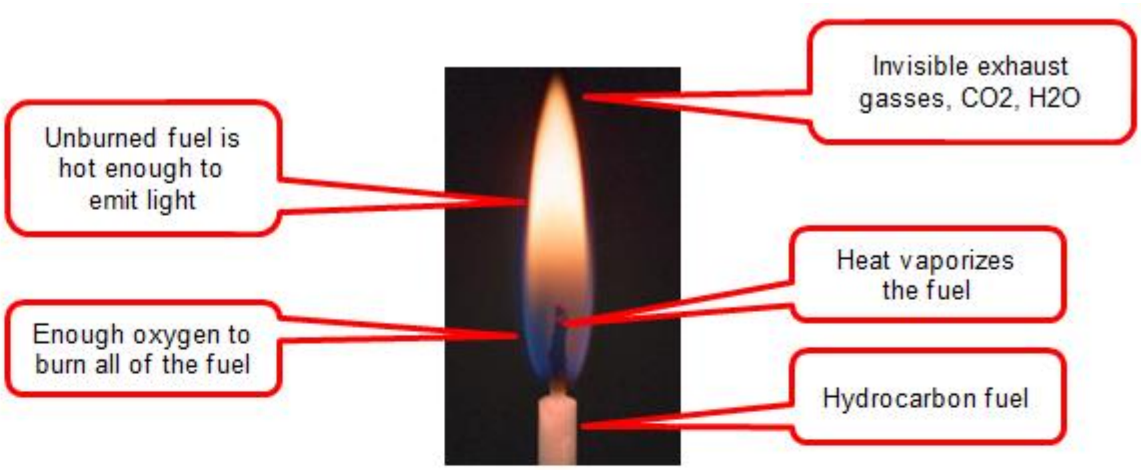

Figure 1.8. Process of combustion

An ideal fire combines the carbon and hydrogen from a pure fuel source with oxygen from the atmosphere in the right proportions and mixes them thoroughly while they are separated into individual atoms so that all of the fuel is oxidized—combined with oxygen. In practice, this rarely happens unless the fire is carefully controlled. Here are some problems that occur when most solid fuels are burned:

In most cases, the fuel is not completely broken down or doesn't encounter enough oxygen while it is hot enough to combine with it. One of the results of this partial oxidation is carbon monoxide (CO). Unlike CO_2, carbon monoxide still has two unpaired electrons and it can behave similarly to oxygen in chemical reactions.

Impurities in the fuel can be oxidized into chemicals that harm human lung tissue.

Impurities in the fuel become airborne particles that cause allergic reactions or irritate eyes and lungs.

Technology of Combustion

Simply burning solid fuel in an open fire pit does not make efficient use of the fuel and exposes people to harmful smoke. People have invented a variety of technologies over the centuries to improve the lives of those people who burn solid fuels for heat and cooking.

Fireplace

One of the technologies that helps people burn solid fuels inside their homes for heat and cooking is the combination of a firebox and chimney. The idea behind a fireplace is simple but building a firebox and chimney that is safe and works properly is not as simple as it seems. Recall that a fire needs fuel, oxygen, and heat. A good fireplace design provides these elements plus it provides a way of disposing of the smoke.

Firebox: The firebox must be made of materials that can protect the home from catching fire.

It may have a door and adjustable vents to control the flow of air. The firebox might have a an adjustable baffle or moveable wall or ceiling that can force the hot gasses to travel a longer route to give them more time in the firebox to complete the burning process.

Chimney: The molecules in the hot gasses from a fire are moving faster because of the heat energy. They bounce off of each other at high speed thereby increasing the distance between molecules and lowering the total weight of a given volume of air. Because the hot air weighs less than surrounding cool air it is buoyant and rises (hot air rises). If this hot air rises through a chimney, the entire column of hot air is rising and the effect is increased. By using a chimney, the smoke can be removed from the home. The gasses rising up the chimney must remain hot enough to remain buoyant until they leave the top of the chimney so a fair amount of heat can escape the house through the chimney. If the gasses cool down too much in the chimney, soot can collect where it can catch fire to create an unwanted chimney fire. The chimney must be made of materials that will protect the rest of the house from catching fire.

Combustion air: Some of the gasses in the smoke were drawn from inside the home. This produces a lower pressure inside the home which draws air from the outside. New fireplace installations in advanced countries require installation of a separate pipe that provides outside air directly into the firebox so the home is not cooled by drafts at doors and windows. (Todd 2003)

Cooking: Open fireplaces can be used for cooking. Hooks for pots can be mounted that swing the pot above the fire or food may be placed on a spit above the fire.

Stoves

Most fireplaces that use stone and brick are built into the wall of a house. Consequently, at least one side of the hot firebox is facing outdoors. An alternative to a fireplace is a steel or cast iron stove that stands completely within the living space. The iron firebox gets hot and transfers heat into the room on all sides. The smoke and gasses are transported from the stove through a metal pipe that leads outdoors or into a traditional chimney. Stoves have doors and vents that allow the user to seal the firebox and control the flow of air to provide greater control of the rate of burning and make more efficient use of the fuel. The top of the stove may be used for cooking and compartments within the stove may be used for baking.

Furnaces

Fireplaces and stoves only heat the room they are in. Many older houses in affluent countries would have a fireplace in each bedroom and the main parlor and a stove in the kitchen. The function of heating the home from a central location was accomplished by a furnace. A furnace is similar to a stove, except that it has a heat exchanger that is designed to heat air that can be circulated in the building to provide clean, safe heat. A heat exchanger is a set of tubes that are placed in the hot exhaust gasses of the fire. The heat passes through the metal tubes and heats the air inside. Early furnaces, such as the one shown in Figure 1.x, used the natural buoyancy of warm air to circulate the air in the house. The warm air would rise through the supply pipes and the cold air would sink through return pathways in the floors and walls. The furnace was in the basement where the cold air would return due to its lack of buoyancy. In many cities in Europe and the U.S., coal was delivered into the basement from the street and then shoveled by hand into the furnace to heat the house. A furnace is a more effective method of heating a multi-room house than individual fireplaces or stoves but a separate method of cooking is needed.

Figure 1.9. Early furnaces used the buoyancy of hot air to circulate heated air

Harmful products of combustion

In an ideal situation, the fuel would consist of pure hydrocarbon molecules, the oxidation would be complete using only oxygen, and the only products would be carbon dioxide and water vapor. The technology of applying these scientific principles to the real world has to deal with fuels that are not pure hydrocarbons and combustion processes that use atmospheric gasses. The devices that apply the science of combustion to the needs of people for heating, cooking, and lighting must minimize the undesirable side-effects.

Incomplete Oxidation

If the mixture of fuel and oxygen is not carefully controlled by the appropriate technology, it is likely that some of the fuel will not completely oxidize. Incomplete oxidation of hydrocarbons in the fuel can create molecules that are poisonous such as Carbon monoxide (CO) or cancer-causing such as formaldehyde (H_2CO). Carbon monoxide is particularly dangerous to humans because it has two electrons in its outer shell just like an oxygen atom and combines with the red blood cells in lungs like oxygen but our cells don't remove it, rendering the affected red blood cells useless for transporting oxygen from our lungs to our bodies. Carbon monoxide and formaldehyde emissions are greatly reduced by controlling the mixture of fuel and air in a closed firebox to assure that enough oxygen is mixed with the fuel. Tall chimneys are used to release the gasses high in the air so that by the time they reach humans the concentration is much lower.

If the carbon passes through the hot part of the flame before it can be oxidized into CO_2, particles of unburned carbon—soot—exist in the smoke. The soot can collect in the chimney where it can catch fire at a later time and burn down the house, killing its occupants, if the chimney is not constructed properly. The soot can be inhaled where it irritates the lung tissues that respond by producing more fluids which causes breathing problems. Soot is reduced by pulverizing solid fuels like coal to aid in complete combustion and by routing the gasses within a stove through a second chamber that is kept hot enough to allow for additional combustion.

Impurities in the Fuel

Sulfur is an element that is usually present in solid fuels, particularly coal. The sulfur can combine with oxygen during the burning process to form sulfur dioxide (SO_2) which then combines with water (H_2O) in the atmosphere to form sulfuric acid (H_2SO_4). Sulfuric acid dissolves in water where it contributes two H^+ ions to create an acid that can kill living tissue in the eyes and lungs. The amount of sulfur in coal varies significantly from one type of coal to another.

- Anthracite coal is the most desirable coal because it has a high carbon content (more than 85%) but only a half-percent (0.5%) sulfur by weight. Anthracite is seldom burned for heating and cooking because it is rare and expensive.
- Bituminous coal has less carbon content (60-80%) and its sulfur content is the highest of all the coal categories ranging from 0.6% to 4.0% sulfur by weight. (Kallander and Milici 1996)
- Sub-bituminous coal is lower in carbon content than bituminous coal at 42-52% but it is also lower in sulfur content (about 1%).
- Lignite has the lowest carbon content of the coals (less than 42%) but its sulfur content is also low at about 1%. (Reciepts and Quality of Coal Delivered for the Electric Power Industry 2006)

A simple, affordable method of removing sulfur dioxide from home fires is not available at this time but the sulfur content of wood is much less than coal (about 0.1%).

Solid fuels contain silica and calcium that can be oxidized in the fire and mix with the exhaust gasses as fly ash. The silica combines with oxygen to form silicon dioxide (SiO_2) as sharp crystals like tiny flakes of granite that can cut delicate lung tissue. The calcium combines with oxygen to form calcium oxide (CaO). Calcium oxide combines with water in lung tissues to form Calcium Hydroxide ($Ca(OH)_2$) which dissolves into $CaOH^+$ and OH^-. Because it contributes extra OH^- ions to the solution, it is a base (alkaline) solution that can dissolve tissue and cause a burning sensation.

Environmental Impact of Burning Solid Fuels

Where fossil fuels are not available, most people burn wood, charcoal, crop waste, or animal dung.

Deforestation

The rate at which trees grow and convert sunlight into cellulose is not fast enough to keep up with rapidly increasing populations. If a village or city uses wood, the trees in the area are usually cut down faster than they can grow back and the countryside near these population centers is deforested. If there are other sources of cellulose such as sugar cane waste, charcoal can be made without cutting down trees. In Haiti, 98% of the country is deforested. Students from M.I.T. are working on a project to convert sugar cane waste into charcoal to replace wood as the source. (McClintock 2006) Loss of forests in hilly landscapes results in soil erosion that reduces the fertility of the soil that results in lower crop yields.

Animal Habitat

Cutting down trees for use as fuel changes the habitat that can cause the extinction of animals that depend upon it. For example, the city of Goma in the Democratic Republic of Congo has 500,000 people who use wood or charcoal for cooking. The area around Goma is deforested and fuel must be transported from ever-increasing distances by bicycle. The only wood that is left nearby is found in the Virunga national park where it is illegal to cut trees but they are cut in large numbers and partially burned to form charcoal. As a result, the habitat for the mountain gorillas in the park is disappearing. (Lovgren 2001)

Smog

Technologies of fireplaces, stoves, and chimneys can remove the products of combustion from the home and put them into the atmosphere where they become diluted. When the number of people burning solid fuels is small in a given area, this method is sufficient because the environment can absorb a certain amount of these materials. When the population increases and more people are burning fuels in the same area, it can become more than the environment can absorb and the environment changes. London is an example of a city that has naturally occurring fog due to its location near ocean currents that are warmer than the air but the fog is made much worse by smoke from coal. By the 1100s, most of the trees near London had been cut down and burned for fuel but a large deposit of bituminous coal was discovered nearby and they started burning coal. The soot and fly ash from the coal provided condensation sites for more water droplets to form in the air making the fog worse and trapping the fly ash and other gasses in the water droplets where they could be breathed into people's lungs. In 1879, London had a fog that lasted from November to March and in 1905 this combination of smoke and fog was called smog. (Voeux 2001) In 1952, London had a four-day fog that was so toxic to breath that approximately 4,000 people died from respiratory illness. British parliament subsequently passed the Clean Air Act in 1956 which reduced ash and soot emitted from burning coal. (Urbinato 1994)

Acid Rain

If the temperature of the fire is hot enough, some of the atmospheric nitrogen will oxidize to create Nitrous Oxide (N_2O). The nitrous oxide reacts with water in the atmosphere to form nitric acid (HNO_3). If the fuel contains sulfur, sulfur dioxide is also created that turns into sulfuric acid. The sulfur and nitrogen oxides from burning hydrocarbon fuels can dissolve in rain water and separate into ions that have more H^+ ions than OH^- ions lowering the pH of the water below 7 making it acidic. This acid rain can dissolve limestone which is a common building stone and marble from which many ancient sculptures are made. The acidic rain can kill fish and plants in streams fed by the rainwater.

Climate

Water vapor and carbon dioxide are transparent to visible light but less transparent to infrared light (this is also a property of glass). When visible light from the sun heats the surface of the earth, some of that heat is emitted as infrared light and radiated into space. Water vapor and carbon dioxide can act like the glass in a greenhouse to allow heat in as visible light but block its exit as infrared light raising the amount of heat on earth. This process is named after the glass-enclosed buildings used in northern climates and is known as the greenhouse effect. The amount of water vapor in the atmosphere is about fifty times greater than the percentage of carbon dioxide (about 2% compared to .035%) but the amount of carbon dioxide in the atmosphere has increased since burning fossil fuels became more common. Many people are concerned that increases in CO_2 levels will increase the earth's temperature due to the greenhouse effect.

Key Takeaways

- In an ideal situation, the fuel would consist only of molecules of carbon and hydrogen. They would mix with the right amount of oxygen and produce heat, light, carbon dioxide and water vapor. [1.4.1]
- The amount of air mixed with the fuel can be controlled by using an enclosure (stove) with air vents to obtain complete combustion and minimize production of carbon monoxide and formaldehyde. The exhaust gasses can be routed outdoors using a chimney. A fireplace has less control of the air mixture but the chimney still routes most of the gasses outdoors. A furnace separates the combustion gasses from the air that is heated and circulated in the house.

[1.4.2]

- Real fuels contain unwanted elements such as sulfur, silica, and calcium that end up in the exhaust gasses. Atmospheric gasses are mostly nitrogen that can be oxidized to form nitrous oxide. The sulfur and nitrous oxide and combine with rain water and produce acid rain. The silica and calcium form fly ash that causes lung problems. Unburned carbon becomes soot that can catch fire in the chimney or cause fogs. [1.4.3]
- Cutting wood for fuel can cause deforestation and loss of animal habitat. Sulfur and nitrogen oxides can cause acid rain, and increased amounts of greenhouse gasses like carbon dioxide might cause an increase in global temperatures. [1.4.4]

5 Burning Petroleum for Lighting, Heating, and Cooking

Learning Objectives

1. Identify the first four alkanes and the number of carbon atoms in each. [1.5.1]
2. Identify the characteristic that makes an hydrocarbon molecule an alcohol. [1.5.2]
3. Identify the advantages of kerosene over other forms of lighting fuel. [1.5.3]
4. Identify the difference between natural gas, LP, and fuel oil and the relative size of the hydrocarbon molecules. [1.5.4]
5. Identify the environmental impact of burning liquid fuels. [1.5.5]

A major advance in indoor lighting came with the use of petroleum for lighting. To understand the use of petroleum, you need to know more about the chemistry of carbon.

Chemistry of Petroleum Fuels

Recall that the carbon atom has four electrons in the outer layer that can form covalent bonds with other atoms. Carbon is a wonderfully versatile atom that can connect in long chains, rings, or crystals. There is a branch of chemistry devoted to carbon molecules named organic chemistry. In order to discuss liquid fuels, you need to know a few more basic organic chemistry concepts.

One of the terms you already know is hydrocarbon which refers to the molecules that are made up of hydrogen and carbon. There is a family of hydrocarbons that have the same shape. If the hydrocarbon molecule is a straight chain of carbon atoms with hydrogen atoms attached, it is an alkane. The simplest alkane is a molecule with one carbon atom. Because carbon has four outer electrons to share and hydrogen atoms have one, this molecule is CH_4. Its common name is methane. Notice the ending of the name is –ane which tips you off that this molecule is a member of the alkane family.

If the chain has two carbon atoms, its common name is ethane, C_2H_6. Notice that one of the covalent bonds connects the two carbon atoms and the others connect to hydrogen atoms. The next two alkanes have familiar names—propane and butane. Refer to Figure 1.10.

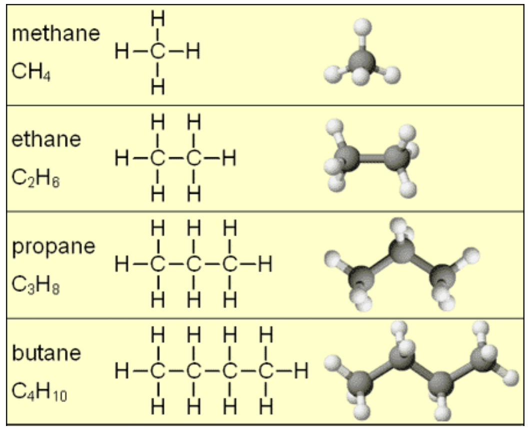

Figure 1.10. The first four alkanes

These two molecules are gases at normal temperature and pressure but under about 100 pounds of pressure per square inch (psi), propane will turn into a liquid. Because it is a longer molecule, butane requires less pressure to turn it into a liquid—about 17 psi at 70 degrees F. Propane and butane in liquid form are known as liquefied petroleum gas (LP). When you buy a tank of LP Gas for your barbeque grill, it is mostly propane and butane. The names of the first four alkanes are historical in origin. A simple saying such as "**M**ary **E**ats **P**eanut **B**utter" helps to remember their order from methane to butane.

Longer chains in the alkane group use Greek prefixes such as pentane (C_5H_{12}), hexane (C_6H_{14}), heptane (C_7H_{16}), octane (C_8H_{18}), nonane (C_9H_{20}), and decane ($C_{10}H_{22}$).

The gas that comes out of a natural gas well is mostly methane with significant amounts of ethane, propane, butane, pentane, carbon dioxide, nitrogen, helium, hydrogen sulfide (H_2S), mercury, and water. This mixture goes to a processing plant that extracts the smaller alkanes so that the natural gas that is sold to homes for cooking and heating is about 90% methane. Methane is also found in coal deposits and is produced by bacteria that are digesting carbohydrates.

The term alcohol does not refer to one specific molecule. The term refers to a family of hydrocarbon molecules that have one characteristic in common. If one of the hydrogen atoms is replaced by an oxygen-hydrogen pair, it is an alcohol. For example, if you take one of the alkanes, like methane, and replace one of its hydrogen atoms with the oxygen-hydrogen pair, you have methanol (CH_3OH). Methanol is produced by combining carbon monoxide and hydrogen; $CO + 2\ H_2 = CH_3OH$. If methanol is consumed by humans it can cause intoxication but it also attacks the optic nerve causing blindness.

If you have an ethane molecule with the OH group, it is ethanol (C_2H_5OH). Ethanol can be produced biologically when yeast organisms metabolize sugars like dextrose; $C_6H_{12}O_6 = 2\ C_2H_5OH + 2\ CO_2$. The ethanol will kill the yeast when it reaches a concentration of about 15% so higher concentrations are achieved by boiling the mixture and condensing the alcohol from the vapors in a process called distillation. To prevent humans from drinking ethanol that is intended for use as fuel, it is often mixed with methanol or gasoline to make it poisonous. If an OH group is added to propane, you have propanol (C_3H_7OH) that is also known as rubbing alcohol.

Petroleum Fuels for Lighting

Solid fuels like wood and coal are inherently difficult to burn completely because the solid fuel must be heated enough to break it apart into a gas in order to mix well with the oxygen molecules in the atmosphere. They are also likely to contain other materials that can cause respiratory problems when inhaled that are carried into the air as smoke. The problem is partially addressed by removing the smoke from the interior of the dwelling. This solution isn't available if you want to use the fuel to create light. Individual lamps cannot be vented to the outdoors easily. Alternatives to wood and coal are necessary to provide light.

Light from a fireplace is not sufficient for most purposes. Burning fuel for lighting is desirable in order to extend working and social hours into the night. Lamps and candles were commonly used for this purpose. Oil from animal fat was more available but produces undesirable amounts of smoke.

Beeswax burned with little smoke and is still used to make candles but the supply is limited by the amount that bees can produce.

Oil from whale blubber also burned cleanly and was the chief product of the whaling industry. The slaughter of whales for oil led to a dramatic decline in the whale population. In the mid-1800s, about 15,000 whales were killed per year for lamp oil and they were getting harder to find. The price of whale oil sold went from $.30 per gallon to over $2.00 per gallon.

Camphene is a liquid lamp fuel that was available in the mid-1800s that is a mixture of alcohol, turpentine, and camphor. It is a cheap fuel that burns cleanly but it evaporates easily which makes it dangerous to use due to the risk of explosion and fire.

Coal oil can be made from coal by heating low-quality coal in the absence of air and then cooling the gasses until they condense into a liquid. Coal oil was used in lamps but still produced undesirable amounts of smoke. It was also used for street lighting. Cities had plants that converted coal into town gas which was used for street lighting.

Kerosene is less flammable than camphene and burns with little smoke if the airflow is controlled by a glass chimney, as shown in Figure 1.11.

Figure 1.11. Kerosene lamp

Kerosene is a range of alkanes that have between 12 and 15 carbon atoms and are liquids at room temperature and pressure. In 1855 an organic chemist named Benjamin Stillman evaluated the oil that was contaminating the streams near Oil Creek, Pennsylvania. He found that it could be refined inexpensively to separate it into clear oil suitable for lamps and into heavier greases that could be used as lubricants for the machines of the industrial age. In 1859, Edwin Drake applied drilling technology that was previously used for finding salt to the recovery of oil and produced the first oil well at Titusville, PA.

The term for the oil that comes from the ground is petroleum which is derived from petra for rock and oleum for oil so it literally means rock oil. It is a mix of hydrocarbons that can be separated by heating and distilling. If you heat petroleum to about 500^{o}F, the alkanes with carbon chains that are 12 to 15 carbons long boil out of the mix and are drawn off and cooled into a liquid that makes an excellent lamp oil called kerosene. The name is derived from the Greek word keros for wax. Kerosene that was refined from Pennsylvania rock oil sold for about $0.10 per gallon and was widely popular. Kerosene replaced other lamp oils and was the primary use for petroleum in the 1800s. A cheap source of kerosene for use as lamp oil meant that people could extend their activities into the night and the demand for kerosene grew rapidly. The demand for kerosene around the world meant great wealth for those who could find petroleum, refine it and then get it to customers. The growth of the petroleum companies was driven by the desire for kerosene lamp oil—not gasoline which would come later.

The development of the petroleum industry demonstrates how this technology brought disparate cultures into contact with each other and set the stage for our current state of world affairs. This story is told in detail in the book, *The Prize* by Daniel Yergin which has also been made into a television series for the Public Broadcasting System.

Heating and Cooking with Petroleum and Natural Gas Fuels

The gas that comes out of a well is mostly methane with significant amounts of ethane, propane, butane, pentane, carbon dioxide, nitrogen, helium, hydrogen sulfide (H_2S), mercury, and water. This mixture goes to a processing plant that separates the methane and ethane from the other components so that the natural gas that is sold to homes for cooking and heating is a mixture of mostly methane and some ethane. The propane and butane is collected and pressurized and sold as a liquid fuel.

When natural gas and LP gas became widely available, coal furnaces were fitted with a gas burner and the home owner no longer had to shovel coal or ashes. The technology for burning natural gas and LP gas is very similar but because LP gas consists of large molecules and is supplied at different pressure, the control devices are slightly different. Later improvements in furnaces included electric fans that force the air through the building without relying on gravity for circulation. The most advanced designs of modern furnaces transfer more than 90% of the heat from the fuel into the home.

Instead of transferring heat from the exhaust gasses into another stream of air, hot water heating systems pass the hot exhaust gasses around a set of tubes that contain water. The heated water is pumped through pipes in the building and releases its heat to the room via another heat exchanger called a radiator that consists of water pipes with fins attached to help transfer the heat to the air in the room.

Fuel oil consists of longer chains of carbon with 20 to 70 carbon atoms. It is a thick liquid at room temperature. These liquids are heated and sprayed under pressure into a firebox where they are oxidized. Fuel oil can be used in a furnace to heat buildings and homes.

If natural gas is available, it is useful for cooking because it provides a controllable heat quickly. It burns with little smoke. If the air flow in the burners is not adjusted properly, some of the carbon might not be oxidized and carbon monoxide can be emitted. The proper mixture of gas and air creates a blue flame.

Environmental Impact of Burning Liquid and Gas Fuels

Fuel oil has more impurities such as sulfur than LP or natural gas. Liquid petroleum and natural gas have most of the impurities removed at a refinery before they are sold.

Burning natural gas, which consists mostly of methane, or LP does not form formaldehyde. Furnaces that burn natural gas or fuel oil can produce carbon monoxide and the heat exchanger that separates the exhaust gases from the air that circulates in the home should be checked for cracks that might allow CO to mix with home air. Carbon monoxide alarms are available that warn of harmful concentrations in the home.

If the burners are adjusted properly, soot is not produced and there is no fly ash.

Because petroleum and natural gas are fossil fuels, burning them releases carbon dioxide into the atmosphere that raises it concentration. This might contribute to a greenhouse effect that might affect global temperatures. The refineries that remove the impurities from natural gas can have a negative impact on the local environment if those impurities are released near the refinery.

Key Takeaways

- The first four alkanes are methane, ethane, propane, and butane with 1,2,3, and 4 carbons respectively. [1.5.1]
- If one of the hydrogen atoms in a hydrocarbon is replaced with an OH molecule, it is an alcohol. [1.5.2]
- Kerosene is refined from petroleum which is cheaper than beeswax and whale oil. It is less volatile than camphene and less likely to explode and it burns cleaner than coal oil. [1.5.3]
- Natural gas is mostly methane which has only one carbon atom per molecule. LP gas is a mixture of propane and butane with three or four carbon atoms per molecule. LP is a liquid under pressure at normal temperatures. Fuel oil has a viscous liquid at normal temperatures and pressure and has 20 to 70 carbon atoms per molecule. [1.5.4]
- Burning liquid fuels has less environmental impact than solid fuels. Fuel oil can have some sulfur but the others do not and they do not have fly ash. They all produce carbon dioxide which could contribute to a global greenhouse effect. [1.5.5]

Key Terms

Acid

solution of water plus other molecules that separate into ions where there is a surplus of H+ ions

Acid rain

rainwater that has a pH lower than 7 that indicates a surplus of H+ ions

Alcohol

a hydrocarbon with an OH group

Alkaline

solution of water plus other molecules that separate into ions where there is a surplus of OH- ions (see base)

Alkane

group of hydrocarbons that have the same general shape of a chain of carbons held together by single covalent bonds and the other available bonds occupied by hydrogen atoms

Anthracite

high quality coal that is usually more than 90% carbon

Atoms

smallest unit of an element with a positively charged nucleus and layers of electrons around it

Baffle

a barrier inside a firebox to keep burning gasses in the box longer to allow for more complete combustion

Base

solution of water plus other molecules that separate into ions where there is a surplus of OH- ions (see alkaline)

Bituminous

coal with 60-80% carbon

Butane

an alkane with four carbon and ten hydrogen atoms- C_4H_{10}

Camphene

lamp fuel consisting of alcohol, turpentine, and camphor

Carbon monoxide (CO)

molecule of one carbon and one oxygen

Cellulose

woody portion of a plant

Chemical energy

energy stored in the bonds between atoms

Chimney

an enclosed vertical space used to trap hot gasses and create an upward draft

Coal

buried plant material that has been compressed until it is mostly carbon

Coal oil

liquid fuel made from coal

Combustion air

atmospheric air used to burn fuel

Covalent bond

attraction between atoms that are sharing electrons

Deep mining

method of retrieving desired minerals by digging vertical shafts

Deforest

remove the trees faster than they can grow back

Dextrose

a hydrocarbon created by plants that stores energy in a form that can be used as food by humans

Distillation

boiling a liquid that is a mixture and collecting the lighter parts of the mixture that turn into a gas first

Ethane

an alkane with two carbon and six hydrogen atoms, C2H6

Fire

the rapid, self-sustaining oxidation of fuel that produces heat and light

Firebox

enclosure in which a fire can be controlled

Fly ash

minerals from the fuel that occur in exhaust gasses, typically silicon dioxide and calcium oxide

Formaldehyde

molecule of H_2CO

Fossil fuel

fuel from ancient plants or animals

Fuel oil

liquid fuel refined from petroleum of 20 to 70 carbon atoms

Furnace

a firebox with a heat exchanger that heats air without polluting it

Greenhouse effect

passes visible light but not infrared thereby trapping heat

Heat

rapid motion or vibration of atoms and molecules

Heat exchanger

a set of connected tubes that allows the heat from exhaust gasses to be transferred into another flow of air without contaminating it

Hydrocarbons

combinations of carbon and hydrogen atoms

Hydroxyl group

combination of one oxygen and one hydrogen

Inert gasses

atoms whose outermost layers are full and that do not react readily with other atoms

Infrared

wavelengths of light that are too long to be perceived by humans

Ion

an atom or molecule that has an imbalance of charge

Kerosene

liquid fuel made from petroleum

Light

tiny bundles of energy that also have wave properties

Lignite

form of coal with less than 42% carbon

Liquefied petroleum gas (LP gas)

Mix of propane and butane that is pressurized into a liquid

Methane

an alkane with only one carbon and four hydrogen atoms, CH_4

Molecules

groups of atoms

Natural gas

at the well it is a mixture of gasses but after refining it is mostly methane with some ethane

Nuclear energy

energy derived from the conversion of mass into energy when light nuclei are fused or large nuclei are split

Nuclear fusion

combining of two light nuclei

Organic chemistry

study of the behavior of carbon molecules

Oxidation

combining atoms with oxygen

Peat

layer of partially decayed plant matter useable as fuel

Petroleum

oil from rocks

pH scale

used to indicate the degree of imbalance of H+ and OH- ions

Photons

small bundles of light energy

Photosynthesis

process of converting light energy into stored chemical energy

Propane

an alkane with three carbon and eight hydrogen atoms, C_3H_8

Propanol

alcohol made from propane, C_3H_7OH

Radiator

tubes that transfer heat into a room

Rotting

slow oxidation

Smog

combination of smoke and fog, later just a name for visible air pollution

Solar wind

particles emanating from the sun

Soot

unburned carbon

Strip mining

method of retrieving coal by removing the layer of rock above it

Sub-bituminous

type of coal with less carbon than bituminous coal

Temperature

measure of the average motion of atoms and molecules

Town gas

gas made from coal used for street lighting

Ultraviolet

light with wavelengths that are too short to be perceived by humans

Visible light

light with wavelengths that humans can perceive

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