

ENERGY I

NON-NUCLEAR ENERGY

WHAT IS ENERGY?

First, energy is a *quality*, not a substance. A bowling ball, for example, can have energy, but the ball itself is not energy.

Energy of motion: kinetic energy

Let us first think about a bowling ball rolling toward the pins. We know that the rolling ball has energy because the ball can knock down the pins. This type of energy, energy by virtue of motion, is called *kinetic* energy.

Kinetic energy depends upon mass

Experience indicates that the kinetic energy of an object is proportional to its mass. Doubling the mass, all other factors being equal, will double the kinetic energy. A 6000 pound truck at 30 miles per hour will have twice the kinetic energy of a 3000 pound car at 30 miles per hour.

Kinetic energy depends upon the square of the velocity

Experience also indicates that the kinetic energy of an object is proportional to the square of its velocity. Doubling the velocity, all other factors being equal, will increase the kinetic energy by a factor of four. At 60 miles per hour your car will have four times the kinetic energy that it has at 30 miles per hour. Putting these considerations together indicates that a 6000 pound truck at 60 miles per hour will have eight times the kinetic energy of a 3000 pound car at 30 miles per hour.

Energy of position: potential energy

Let's now think about a bowling ball and your foot. If I gently set the bowling ball on your foot and then let go, no harm will be done. If, however, I hold the bowling ball above my head and then let it fall on your foot your toes will be knocked out of place. The placed ball will have no kinetic energy when it touches your foot, but the dropped ball will have a lot of kinetic energy when it hits. It appears that the position of the ball when released is important. The higher the ball above the surface of the earth when released the more kinetic energy the ball will have when it hits your foot. This source, or potential, for greater kinetic energy is energy by virtue of position, or *potential* energy. In contrast, energy by virtue of motion, or *kinetic* energy, is

the form of energy that actually does the work.

Mechanical energy

All of the examples so far have been examples of *mechanical* energy. Later we will consider other kinds of energy.

One more example of mechanical energy

The bowling ball, the car, and the truck have provided familiar examples of *mechanical energy*, the energy of position or motion of everyday sized objects. A screen door with a spring also provides a familiar example of potential and kinetic energy. As the screen door is pushed open, potential energy is stored in the spring. As the screen door swings shut that potential energy is converted to the kinetic energy of the moving door.

ENERGY IN NATURE

Both potential and kinetic energy are present in natural phenomena. Consider, for example, a waterfall.

The energy of falling water

At the top of the falls the water has potential energy. At the bottom of the falls some of the potential energy of the water has been converted to kinetic energy, the energy of motion of the falling water. The significance of this conversion of potential energy to kinetic energy is this. When a water wheel is placed in the stream of falling water some of the water's kinetic energy will force the wheel to turn, and the motion of the wheel can then be used to run the machines of a factory. It is no coincidence that the early factory towns were mill towns. Nowadays the energy of falling water is most often used to rotate turbines connected to electric generators. The generators produce electrical energy (which we will consider later), and the electrical energy is used to turn the electric motors of the factories. Since electrical energy can be transported over wires the factories need no longer be built next to the waterfalls.

The energy of the wind

Moving air, or *wind*, is another source of energy that occurs in nature. The motion produced by the wind pushing against the sails of a windmill has long been used to grind grain or pump water. More recently, however, the energy of the wind, like the energy of falling water, is being used to rotate turbines connected to electric generators.

MORE FORMS OF ENERGY

Other forms of energy include sound energy, electrical energy, chemical energy, light energy (electromagnetic energy), heat energy (thermal energy), and nuclear energy

Sound energy

Our perception of sound starts with the in-and-out motion of our ear drum. Since sound involves motion, sound is a form of mechanical energy. The push that moves our ear drum is provided by the air that pushes against our ear drum, just as it pushes against the rest of our body. It is only the ear, however, that can detect tiny changes in this push and initiate the events that lead to the sensation that we call sound.

Most sounds, including speech, involve complex motions of the ear drum, but some, such as a constant tone played on the violin, involve a more simple motion. A constant tone played on the violin (or any other musical instrument capable of playing a single tone) produces a regular pulsating motion that is conveyed to the air around the instrument, and propagated through the air to our ear. The *pitch* of the tone is determined by the rate of pulsation of the air, which is called the *frequency* of the note. The typical tuning tone of the violin is 440 in-and-outs per second, or a frequency of 440 cycles per second.

The reason that different instruments playing the same tone sound different is that no instrument emits a pure frequency, and the mixture of harmonic frequencies is different for different instruments.

Electrical energy

So far we have considered the mechanical energy, potential and kinetic, of familiar individual objects (bowling balls, cars, trucks) or familiar collections of particles: water, a collection of water molecules; and air, a mixture of about 78% nitrogen molecules and 21% oxygen molecules.

We now consider the energy of a much smaller and very light particle that is a constituent of every atom of every substance. This particle is called an electron.

The electron

The electron has a distinguishing feature, which is called its charge, and, by convention the charge of an electron is designated negative. In most materials the electrons are confined to individual atoms, where they are

present in such number as to exactly balance the opposite, or positive, charge of the rest of the atom. Materials in which electrons are confined are called *insulators*.

In other materials, however, some of the electrons are unrestrained, and these materials are called *conductors*. Metals are generally good conductors, the best being silver and copper.

It turns out that conduction electrons, like water, can be pumped up to a higher level of potential energy. A device that does this is called an electric generator. It is also true that some of the kinetic energy of falling electrons can be converted to energy of motion. Such a device is called an electric motor. In order to understand how electric generators and electric motors work, we need to understand the concept of a field.

A field

We understand that a bowling ball at chest height, say, experiences a pull toward the ground. Careful experimentation would reveal that the pull is less the higher the ball is held. Imagine that such experiments are done over the entire surface of the earth, from ground level to thousands of miles into the air. The record of the results, a record of the strength and direction of the pull at each point, is called a *field*. Since all the pulls, or *forces*, measured in these experiments are the result of gravitational attraction, this particular field is called a *gravitational field*. Part of Sir Isaac Newton's genius was to realize that every massive body produces a gravitational field, and that it is the attractive force between the earth and the moon that keeps the moon from flying off in a straight line, and that it is the attractive force between the sun and the planets that confines the planets to their orbits. Newton also correctly deduced that the force of mutual attraction was proportional to the product of the masses of the attracting bodies, and inversely proportional to the square of their distance of separation.

A magnetic field

As we know, a magnet can exert an attractive force on certain materials. This magnetic attraction, both size and direction, can be mapped just as the earth's gravitational attraction can be mapped. The resulting map in the case of magnetic attraction is called a *magnetic field*. The earth, we know, has both a gravitational field and a magnetic field. When we use a compass we are sampling the earth's magnetic field. One of my uncles was involved in the first mapping of the earth's magnetic field.

Electric generators

It was Sir Michael Faraday who demonstrated that the free electrons in a wire that experiences a changing magnetic field will be pushed from one end of the wire toward the other end of the wire. That is, a changing magnetic field will induce a flow of electrons in a wire. This phenomenon is the basis of the electric generator. In the hydroelectric generation of electricity the waterfall rotates magnets thus producing a changing magnetic field that draws electrons from one end of a wire and pushes them to the other to create a difference in potential energy between the electrons at the two ends of the wire. In this way some the kinetic energy of falling water is converted to the potential energy of electrons.

If the two ends of the wire are now connected through, say, a light bulb, the bulb will light as the electrons flow from the high potential energy end of the wire (the high voltage end of the wire) through the light bulb to the low potential energy end of the wire (the low voltage end of the wire). If an electric motor is substituted for the light bulb, the shaft of the motor will turn.

Electric motors

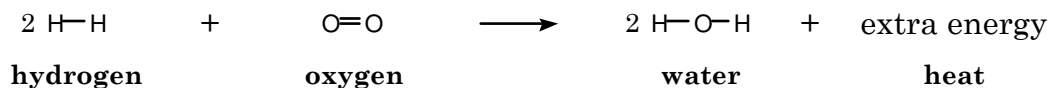
An electric motor is the converse of an electric generator. In an electric motor electrons of high potential energy flow through a wire to create a magnetic field, and that induced magnetic field forces another magnet, connected to the drive shaft of the motor, to turn.

Chemical energy

Many substance can be “burned” to produce energy.

The burning of hydrogen

The push given to the space shuttle by the reaction of hydrogen with oxygen to form water indicates that simple chemical substances can undergo changes that produce energy.



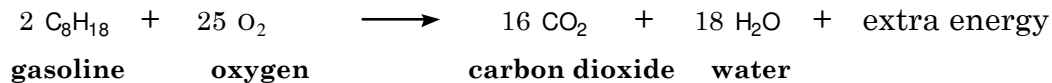
Thus it appears that four hydrogen atoms and two oxygen atoms as two hydrogen molecules and one oxygen molecule is a state of higher potential energy than the same six atoms as two molecules of water. When the chemical change represented above takes place there is extra energy left over, and the reaction is said to be *exothermic*. The implication is clear:

chemicals contain potential energy, some more than others, and this type of potential energy is called *chemical* energy.

In the representation above, the “extra” or “left over” energy is indicated as heat. We will talk later about heat as a form of energy.

The burning of gasoline

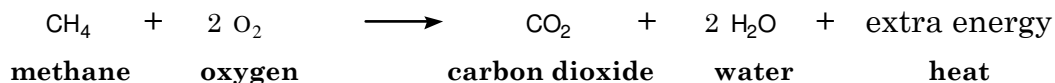
Another example of the transformation of chemical energy into mechanical energy is the burning of gasoline in an internal combustion engine, such as the engine of your car.



The reason this reaction is useful is that there is a large amount of energy left over after the chemical change has taken place. Some of that extra energy is used to push the car forward, but the rest ends up as heat.

The burning of methane

A third example of the release of chemical energy is the burning of natural gas, mostly methane, in your furnace.



In this application the point is to heat your house, and, since your furnace is an “external combustion engine”, all of the extra energy is produced as heat.

A “high efficiency” furnace

In older furnaces the water is produced as water *vapor*, which is allowed to go up the chimney along with the hot flue gases. Remembering that our wet skin is cooled by the evaporation of water we can understand that a high efficiency furnace achieves its goal by condensing the water vapor produced by combustion, thereby recapturing the heat absorbed by evaporation, and adding it to the heat sent to the house. It is for this reason that a high efficiency furnace is also called a condensing furnace. You can recognize a condensing furnace by the presence of a pipe to the floor drain and the absence of a flue to the roof.

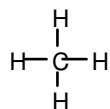
Petroleum and natural gas as sources of chemical energy

As we have seen, the burning of methane, the major component of natural gas, and the burning of gasoline, obtained from petroleum, liberate large amounts of chemical energy. Natural gas and petroleum (“rock oil” or just “oil”) are sources of many other pure substances and mixtures of substances that are allowed to react with oxygen (or “burned”) so as to release chemical energy.

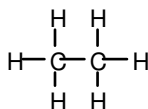
The components of natural gas and petroleum

The molecules of natural gas and petroleum have a common structural feature. Their molecules contain one or more carbon atoms, and twice that number of hydrogen atoms, plus two. Since the only elements that these substances contain are hydrogen and carbon, these substances are called *hydrocarbons*. When hydrocarbons are pure, complete combustion will produce only water and carbon dioxide. It is for this reason that natural gas is called a “clean” fuel.

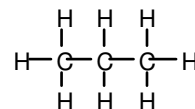
The connectivities of the atoms of some of the simplest hydrocarbons are indicated here.



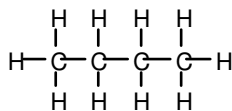
methane



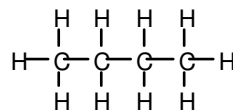
ethane



propane



butane



pentane

Methane and ethane are gases; propane and butane can be liquefied under pressure, and pentane is just barely a liquid at room temperature and atmospheric pressure.

Some of the mixtures in which hydrocarbons are present include *natural gas* (mostly methane and some ethane), *compressed natural gas*, or “CNG” (again mostly methane and some ethane), propane (both as a gas and as a liquid), and *liquefied petroleum gas* or “LPG” (mostly liquefied propane and butane).

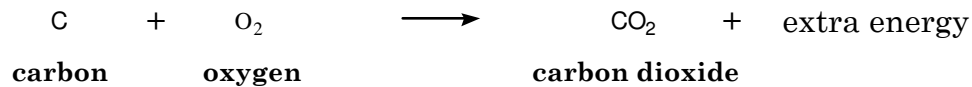
Gasoline contains hydrocarbons of carbon number 5 to 12 (mostly 6 to 8), *kerosene* mostly hydrocarbons of carbon number 12 and 13, and *fuel oils* hydrocarbons of carbon number 14 and higher.

The importance of natural gas and petroleum

Two reasons combine to make natural gas and petroleum important contributors to our way of life. The first and most important is that they occur in nature. The second is that their reaction with oxygen is highly exothermic. Relative to hydrocarbons, the products of their oxidation, water and carbon dioxide, are much lower in potential energy.

The burning of coal

As we all know, coal will burn.



Although we have represented coal in this equation as carbon, coal also contains hydrogen, sulfur, and nitrogen. Anthracite coal, a hard, shiny, black rock, can contain more than 90% carbon by weight, perhaps 3% hydrogen by weight, and about 1% sulfur. It burns with a pale blue flame, and produces very little smoke. Bituminous coal, or soft coal, contains somewhat less carbon, somewhat more hydrogen, and about 1.5% sulfur.

Burning coal, therefore, produces carbon dioxide, as indicated, and also water and the oxides of sulfur and nitrogen. The oxides of sulfur produce one of the acids of “acid rain”.

At this time most coal is burned in boilers to produce steam at high pressures and temperatures. The steam is run to turbines, which are connected to generators that produce electricity. In some cases the lower pressure and lower temperature steam that exits the turbines is used for commercial heating, “steam heat”. This combined production of electricity for power and steam for heating is called *cogeneration*.

Light energy

How do we know that light is energy? Because light can make electrons move. This famous phenomenon is called the photoelectric effect, the ability of light to push an electron. This time it was the genius of Albert Einstein that provided the insight. The photoelectric phenomenon works in this way. A difference in electric potential is set up between a piece of metal in which the conduction electrons are relatively loosely held, and a wire at a lower potential. The point of the experiment is to get an electron to jump from the piece of metal at the higher potential to the wire at a lower potential. It's sort of like getting a bowling ball to fall off a cliff, except that the bowling ball will not just roll off the edge; it has to be pushed. That is where the light comes

in. The electrons won't "fall" from the higher potential piece of metal to the lower potential wire unless light is shined on the piece of metal! And it has to be special light, light of a certain color. The light has to be blue enough. If the light is not blue enough, it doesn't matter how bright the light; it can't push the electrons off. If, however, the faint light is just blue enough an electron will just barely be pushed off. And if the just-blue-enough light is a little brighter, several electrons can be pushed off. Finally, if the light is even more blue than just-blue-enough the electrons will be given a harder shove.

Here is Einstein's explanation. Light is a form of energy. But not all light is equally energetic. Some colors of light are more energetic than others. Blue light, for example, is more energetic than red light. But the most surprising part of the story is that light is *granular*, not uniform. Light energy comes in bits, called *quanta*. It takes a specific amount of energy to push the electron off the piece of metal, and the quantum must be big enough (blue enough) to do the job by itself. Two smaller quanta (not blue enough) do not work. If the quantum is larger than the minimum necessary (more blue than required), the pushed-off electron gets to keep the extra energy as part of the kinetic energy it gains by falling to the wire at a lower potential.

The particle nature of light

The view of light just presented considers light to be a particle. The light particles, or *photons*, are not like the particles that we experience in everyday life. Light particles consist entirely of energy, they exist only in motion, and they move very fast -- at the speed of light. The light from the sun travels the 93 million miles to the earth in only 8 minutes; it would take about 15 years for sound to travel the same distance through air. No wonder we see the lightning flash before we hear the thunder.

The wave nature of light

Other experiments reveal the wave nature of light. The most famous of these are the "two slit" experiments. In these experiments a beam of light is passed either through a single slit, or through a pair of slits next to one another. One would expect that the two slit result would look like a pair of single slit results, one superimposed upon the other. That is not the case. There is produced instead an *interference pattern*, just exactly the result one would expect if light were a wave. Huygens, in fact, did the original experiments of this type so as to demonstrate the wave nature of light.

Waves

Before we continue our consideration of light we need to talk a little more about waves.

A wave is a disturbance in a medium. A sound wave is, typically, a disturbance in air. As we said above, the source of the sound creates an in-and-out (longitudinal) disturbance in the air, and this in-and-out motion is propagated in all directions. The propagation moves from the source of the sound to our ear, but overall the air stays in place, just moving in-and-out a little bit. Scrolling signs work analogously. The state of being lit moves; the light bulbs don't move.

Water waves are also a disturbance in a medium, but this time the disturbance is an up-and-down (transverse) motion. Again, the disturbance propagates, but the water does not. A cork will bob on the water, but it will not travel with the wave.

Light waves

If light is a disturbance in a medium, what is the medium? When light travels from the sun to the earth, what is the medium? Since the space between the sun and the earth is essentially empty, we know there is no medium. How can light have a wave nature without a medium? It appears that the wave nature of light is expressed not with matter but with two *fields*, one electric and one magnetic. The fields vary back and forth with time, which is to say they have a frequency, which qualifies them to be called waves. Their oscillation is perpendicular to the direction of transmission (they are transverse waves), and the fields are perpendicular to one another. Light in transit, then, is an oscillating electromagnetic field. When light interacts with matter, the field gives up its energy to an electron. As we said before, light can make electrons move; it does so by virtue of its changing electric and magnetic fields.

Wavelength and frequency

If we stand at the seashore and watch the waves we notice that the successive waves are separated in time. If a wave breaks every ten seconds or so, we would say that these water waves have a frequency of 1/10 of a wave per second. When we spoke of sound waves, we mentioned that the tuning note of the violin has a frequency of 440 oscillations, or cycles, per second. The frequency of the ocean waves is quite low, and this corresponds to a large distance between successive ups and downs; ocean waves have a long wave length. In contrast, the distance between successive in-and-outs of a sound wave of a frequency of 440 cycles per second is much shorter. This distance is, in fact, twice the length of the A string of the violin, about 66 cm.

Wavelength, frequency, energy, and color of light

We have mentioned that light has energy and color and frequency and, by implication, wavelength. These are actually all different ways of saying the same thing. Blue light is higher in energy and in frequency, and shorter in wavelength than red light. When you know either the color, the frequency, or the wavelength of the light in a vacuum you know the energy of the light. When we said that light was “not blue enough”, we were saying, in effect, that the light quanta, or photons, did not have enough energy to dislodge the electron.

The electromagnetic spectrum

Newton demonstrated, and we know, that “white” light is composed of all the colors of the rainbow. When white light is passed through a prism the colors are spread out to reveal the visible spectrum. The entire spectrum, however, the *electromagnetic spectrum*, extends beyond the visible in both directions. It extends into the ultraviolet (more energetic light) and into the infrared (less energetic light). Beyond the ultraviolet are the highly energetic x-rays and γ -rays. Beneath the infrared are the microwaves and radio waves.

The electromagnetic spectrum and energy

X-ray and γ -ray photons are sufficiently energetic to pop an electron out of anything, which is why we should avoid exposing our body to these types of radiation. Ultraviolet radiation is not quite so energetic, and so the damage it does to our body is less, and is more easily repaired.

Infrared, microwave and radio wave photons are quite weakly energetic, and are essentially harmless. An infrared photon can cause a molecule to wiggle, a microwave photon can cause a molecule to rock, but a radio wave photon does not disturb most molecules at all; it just passes right through. This is why we can hear the radio in most buildings and underground. Radio wave photons can, however, wiggle conduction electrons in a metal.

Is light a particle, or is light a wave?

As we have seen, light sometimes acts as a particle, and light sometimes acts as a wave. When light interacts with matter it acts more like a particle, but when it is traveling light acts more like a wave. There is no need to decide what light “is”. Light follows its own rules, and those rules lead to what appears to us to be a dual nature. A dual nature such as this is at odds with our everyday experience, which is why we are surprised and puzzled.

The wave/particle duality

Our understanding now is that any particle can show a wave nature under the right circumstances, and this was first shown for electrons in a famous experiment by Davisson and Germer. When they scattered (reflected) electrons from a nickel surface they found, to their surprise, that the scattered electrons produced a diffraction pattern. Apparently the layers of nickel atoms appeared as “slits” to the electrons. Nowadays this effect is used in reverse: electron diffraction is used to determine distances between atoms.

Heat energy

Heat is a quality, not a substance. It is a form of motion, as indicated by observations and experiments reported by Benjamin Thompson in 1798. These are some of his words.

“It frequently happens that in the ordinary affairs and occupations of life opportunities present themselves of contemplation of some of the most curious operations of nature; and very interesting philosophical experiments might often be made, almost without trouble or expense ...

“Being engaged, lately, in superintending the boring of cannon ... I was struck with the very considerable degree of heat which a brass gun acquires, in a short time, in being bored ...

“The more I meditated on these phenomena the more they appeared to me to be curious and interesting. A thorough investigating of them seemed even to bid fair to give a farther insight into the hidden nature of heat; and to enable us to form some reasonable conjectures respecting the existence, or non-existence, of an igneous fluid: a subject on which the opinions of philosophers have, in all ages, been much divided.”

He then describes experiments in which he measures the heat produced by boring.

“This cylinder being designed for the express purpose of generating heat by friction, by having a blunt borer forced against its solid bottom at the same time that it should be turned round its axis by the force of horses ...”

He then repeats the experiment, but this time with the cylinder and borer supported in a box containing 2 1/4 gallons of water.

“The cylinder, revolving at the rate of about thirty-two times in a minute, has been in motion but a short time when I perceived, by putting my hand into the water and touching the outside of the cylinder, that heat was generated; and it was not long before the water which surrounded the cylinder began to be sensibly warm.”

After one hour the temperature of the water was 107° F; after two hours, 178° F.

“At two hours twenty minutes it was 200° F, and at two hours thirty minutes it actually boiled!

“It would be difficult to describe the surprise and astonishment expressed in the countenances of the bystanders on seeing so large a quantity of cold water heated and actually made to boil without any fire.”

“By meditating on the results of all these experiments we are naturally brought to that great question which has so often been the subject of speculation among philosophers; namely: What is heat? is there any such thing as an igneous fluid? Is there anything that can with propriety be called caloric?”

“And in reasoning on this subject we must not forget to consider that most remarkable circumstance, that the source of the heat generated by friction, in these experiments, appeared evidently to be inexhaustible.

“...and it appears to me to be extremely difficult, if not quite impossible, to form any distinct idea of anything, capable of being excited and communicated, in the manner the heat was excited and communicated in these, except it be motion”.

What is moving? The molecules, and the atoms within the molecules of which all matter is composed. Heat is the mechanical energy of atoms and molecules. At a low temperature, when the material is solid, relatively little heat energy is present. At a higher temperature, when the material is a liquid, there will be more atomic and molecular motion and the heat content will be greater. At a still higher temperature, when the material is a gas, there will be much more atomic and molecular motion, and the heat content will be greater still.

Coherent and random motion

Consider again the falling bowling ball just before it hits the ground. The bowling ball has kinetic energy by virtue of its motion toward the ground. This type of motion is called *coherent* motion because this motion is the same for all molecules. Coherent motion can push something; coherent motion can do work, as we will say later.

The bowling ball also has thermal energy by virtue of its temperature. This kinetic energy of thermal motion, however, is *random*, and different for every molecule. Thermal energy can sometimes do work, as we shall see, but only

under special circumstances.

Heat and temperature

We can say that temperature is that measure by which we distinguish between something we call hot, and another thing that we call cold. If we put something hot in contact with something cold, heat is what is transferred from the hotter body to the colder body that brings them to the same temperature. We could say that temperature is a measure of the quality of thermal energy. Something “hotter” can export some of its heat to something “colder”. Temperature is a measure of the degree of heat that is present.

Thermometers

A thermometer is well named: a “thermo meter” measures the degree of thermal energy. The most common scale of thermal energy takes the temperature of a mixture of ice and water to be the zero degree point of the scale. A reference state such as this is chosen because *when both ice and water are present, the temperature will remain constant*. Additional heat will merely melt more ice, and removal of heat will just cause more water to freeze.

The second reference point on this scale is the temperature of boiling water, which is taken to be the 100 degree point. This reference point is again a good choice because adding more heat will just boil more water away without any increase in temperature until the water is gone. The interval between these two temperatures is divided into 100 equal steps, and the resulting scale is called the centigrade, or Celsius, scale. In some parts of the world these two reference points are represented as 32 degrees and 212 degrees; this is the Fahrenheit scale.

Lower temperatures

As we know, it is possible for something to be colder than a mixture of ice and water. A question, therefore, naturally arises: just how cold can something get? Experience shows that the volume of a gas becomes less the colder the gas. You could check this by taking a balloon outdoors in the winter.

Careful experiments indicate that the volume of a gas should approach zero at -273 degrees on the Celsius scale.

Absolute zero

Since it is hard to imagine a negative volume, perhaps -273 Celsius is as cold

as it can get, or the absolutely lowest temperature possible, the absolute zero of temperature. Taking -273 , then, as the zero point, the temperature of a mixture of ice and water will be $+273$ degrees, and that of boiling water will be $+373$ degrees. This scale is called the absolute temperature scale, or Kelvin scale. There are no negative temperatures with this scale.

Thermal energy and absolute zero

If heat is energy, the absolute zero of temperature must also be the temperature at which a substance has no thermal energy. A moment's thought will indicate that it is impossible to achieve the absolute zero of temperature as heat will flow only from a hotter body to a cooler body, and nothing can have a temperature less than absolute zero. It is possible to get very close, within a millionth of a degree of zero (and only for a moment for a tiny sample), but not absolutely to zero.

Zero-point energy

While there is no thermal energy at absolute zero there can be "zero-point" energy. This zero-point energy comes in half quanta. Since, apparently, only whole quanta can be transferred, this residual energy cannot be lost, which is another way of saying that it is not thermal energy. You can't "cool it away".

Summary of Energy I; non-nuclear energy

- Energy is a *quality*, not a substance.
- Kinetic energy: energy by virtue of *motion*; depends upon mass and the square of the velocity
- Potential energy: energy by virtue of *position*
- Mechanical energy: kinetic and potential energy of everyday objects
- Energy in nature: falling water; moving air
- Sound energy: sound waves; longitudinal waves; frequency
- Electrical energy: electrons; insulators; conductors; fields; electric generators; electric motors
- Chemical energy: hydrogen; gasoline; natural gas; petroleum; coal
- Light energy: particle nature of light; wave nature of light; transverse waves; wavelength, frequency, energy, and color; electromagnetic spectrum
- Heat energy: random kinetic energy of atoms and molecules; temperature; absolute zero