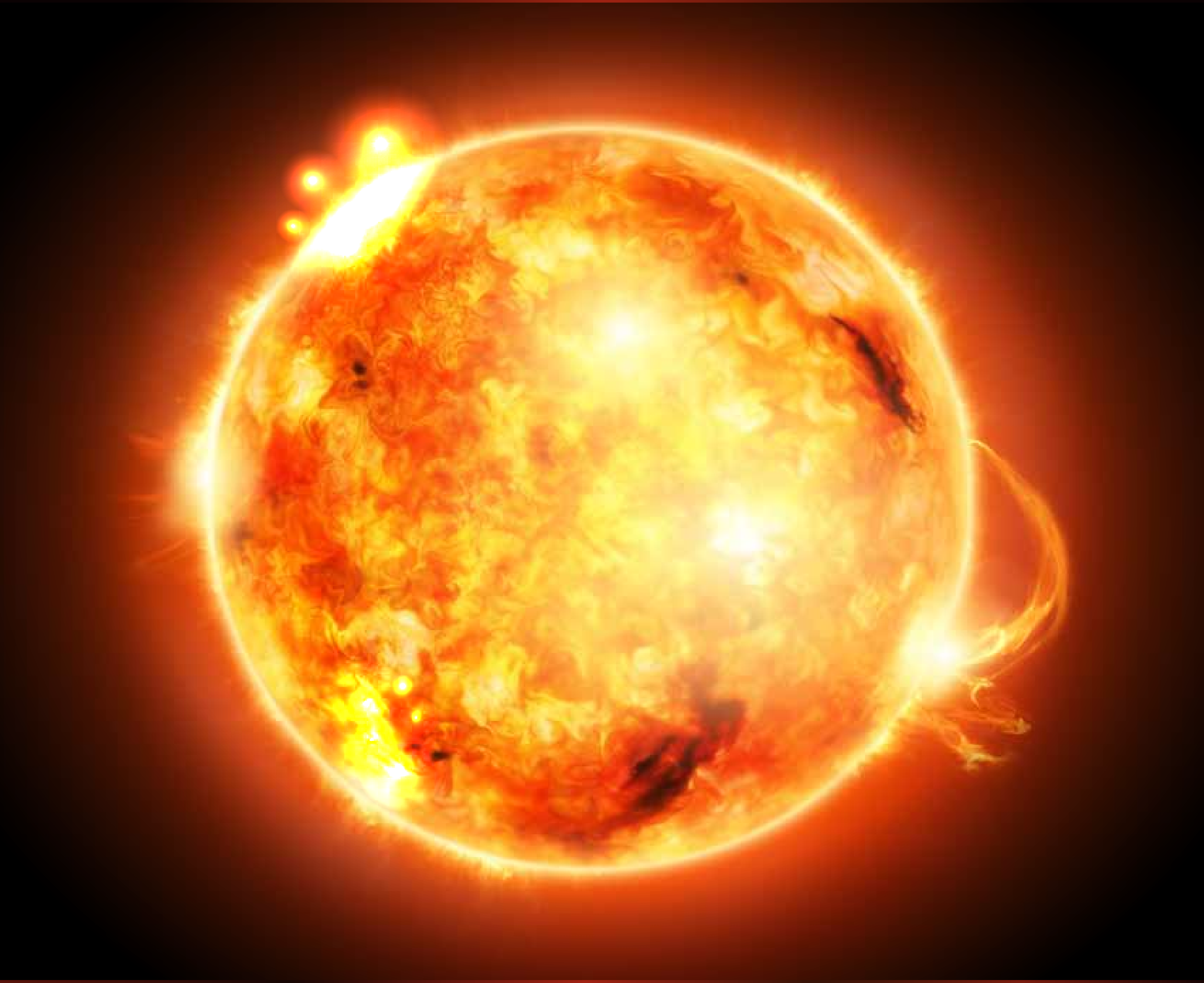
SUNSTRUCK

EDUCATOR GUIDE



MICHIGAN Science CENTER

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THE SUN

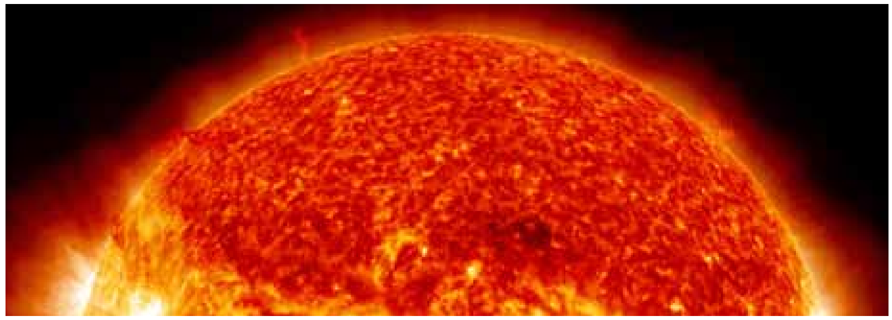


PHOTO COURTESY OF NASA.GOV

The Sun is humanity's star. It is classified as a G2V star (see stellar classification) along the main sequence. The Sun was once considered to be a fairly dim star compared to most other stars in the universe. Recent discoveries have shown, however, that there are many more red dwarf stars than expected. This makes our star brighter than about 85% of all stars. This shouldn't be taken to mean it is close to the brightest stars out there. In fact, the brightest (and most massive) known star, R136a1, is over 8 billion times brighter than our Sun. Even though this star is so incredibly bright, humans can't even see it with the unaided eye. The Sun, on the other hand, is so bright in our sky that it can quickly do irreversible damage to the human eye. This is a good demonstration of the difference between apparent magnitude and absolute magnitude.

The areas of the Sun can be broken up into five broad categories; the atmosphere, the photosphere, the convective zone, the radiative zone, and the core. The atmosphere is broken up into sub regions like most of the categories of the Sun. The atmosphere varies wildly in temperature, from about 4,100 Kelvin near the surface of the Sun, to close to 1 million Kelvin in the corona. The photosphere is the visible surface of the sun. We have monitored this portion of the Sun for sunspots, cooler darker regions on the surface, for hundreds of years. Sunspots remain one of the most accurate ways of monitoring solar activity. The convective zone is just what it sounds, the layer where convection currents develop. This layer of the Sun works very similar to how water moves in a pot as it is being heated at the bottom before it boils. The hot water at the bottom is less dense, rises, cools, becomes more dense than the hot water below it, and falls back down. The radiative zone differs from the convective zone in that material in the radiative zone is hot and dense enough that convection currents don't really develop. Instead, the primary method of energy transfer is through thermal radiation, like heating one end of a metal pipe so that eventually the heat will travel down and make the other end of the pipe hot as well. Finally the core, is the only region of the Sun where nuclear fusion is taking place. This means that the core is the source of energy for the rest of the Solar System.

PHOTO COURTESY OF NASA.GOV

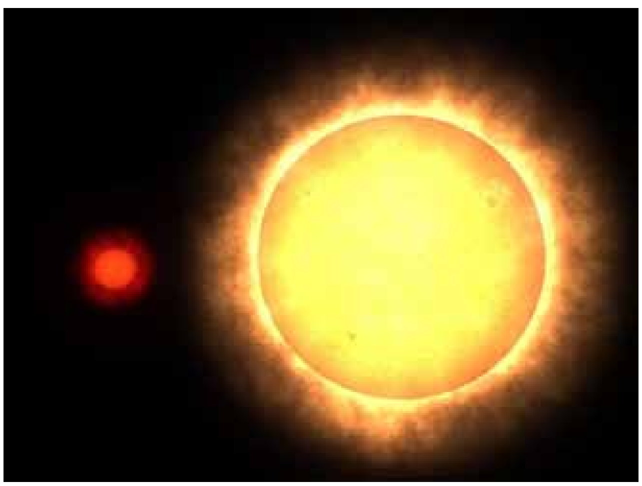
STELLAR BIRTH

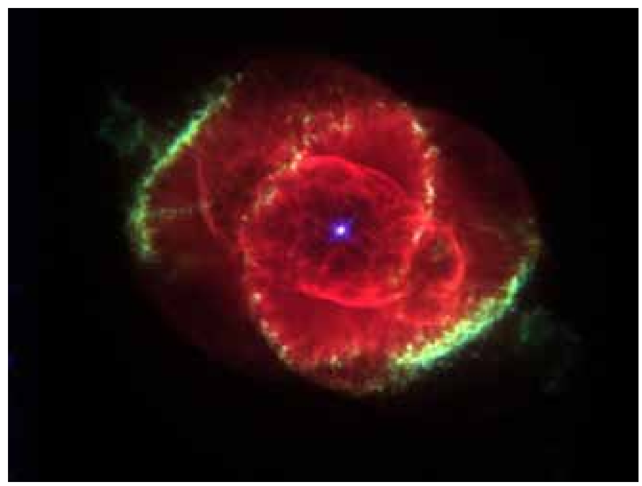
The birth of a star begins when large clouds of gas (typically about 100 light years, or 590 trillion miles across) begin to collapse. There are stable clouds of gas in the universe, balancing the inward pressure of gravity with the outward pressure of the gas. If something, like a nearby supernova, knocks these forces out of balance, then the collapse begins. As the cloud collapses, clumps of material form together and the pressure in the middle of these clumps begins to build. As the pressure builds, the temperature begins to rise. These clumps continue to fall inward and eventually begin to meet up with other clumps, gaining mass and temperature. The heat inside of this mass is not from a nuclear reaction as in stars, it is the transition of gravitational potential energy to thermal energy as the gas falls inward. These types of warm balls of gas are called protostars. This collapsing phase of the birth of the star will take several million years. Eventually, the pressure inside the protostar will become so great that it will begin crushing hydrogen into helium. This nuclear reaction (usually a proton-proton chain reaction for stars the size of our Sun, and the CNO cycle for larger stars, although no star uses just one cycle exclusively) gives off a tremendous amount of energy. This new source of outbound energy blasts any extra dust away from itself. This dust will later form the planets that will orbit this new star.

STELLAR DEATH

Eventually every star will run out of hydrogen in its core and a collapse begins. What happens next is largely dependent on the star's size.

Stars smaller than our Sun live for an incredibly long time. Recent models suggest they may live for 6-12 trillion years, which is around 500 times longer than the entire universe is thought to have been in existence. Because of this, the death of a low mass star has yet to be observed, but it is thought that it would be similar to the death of our sun, but on a much grander time scale.





PHOTOS COURTESY OF NASA.GOV

Stars that are about the size of our Sun are initially unable to reach temperatures high enough to fuse the helium in its core. As the core collapses, it gives off heat to the layers of hydrogen outside the core, and the dense helium core compresses the nearby layers. This causes the layers near the core to begin fusing hydrogen into helium again, but at a faster rate than before. The helium being created continues to be deposited into the core and the rate of hydrogen fusion will continue to speed up. This rapid fusion of hydrogen causes the star to expand and shine brighter than ever before, becoming a red giant. After enough helium has been deposited, the pressure will be enough to begin fusing the helium core. For stars like our Sun, this will begin with a runaway reaction which pushes all the outer layers away, revealing a small core of burning helium known as a white dwarf. The outer layers will slowly drift away, forming a nebula.

STELLAR DEATH...Continued

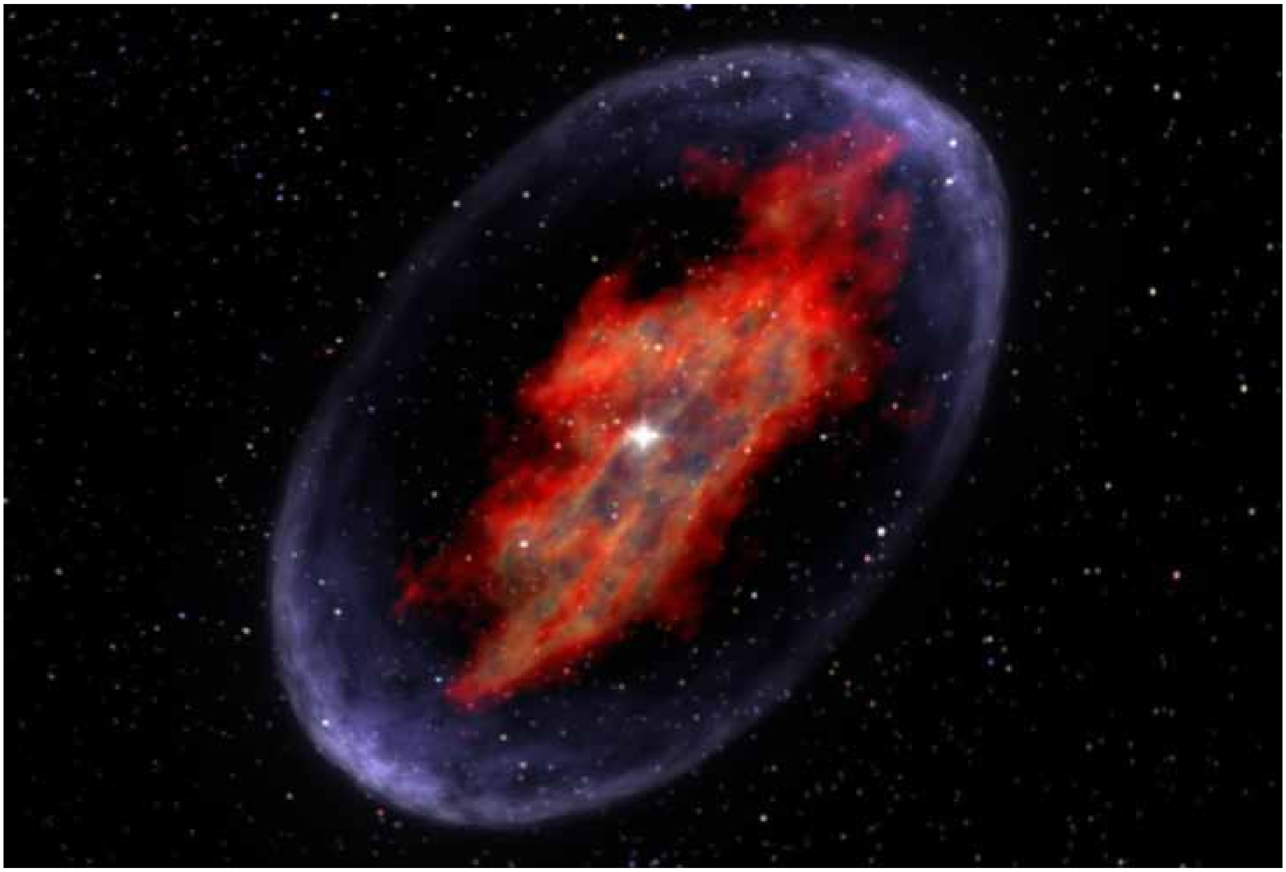


PHOTO COURTESY OF NASA.GOV

Stars larger than our Sun will be able to reach internal temperatures high enough to fuse helium without the need for a large scale collapse. The largest of these stars will continue to fuse material all the way to iron. Other stars will stop the process at other, lower mass elements depending on their size, but no star will reach past iron in its life span. This is because iron is the first element that uses more energy than it creates in its fusion. This will cause the star to collapse in on itself and form, depending on the mass of the core, either a neutron star or a black hole. The rapid collapse of the star begins a sudden change in energy state causing a supernova.

ABSOLUTE MAGNITUDE

The absolute magnitude of an object is the true brightness of the object. This is an idea that needs to be defined since the brightness of an object is going to differ for any change in distance. Absolute magnitude is defined to be the apparent magnitude of the object for an observer that is exactly 10.0 parsecs (32.6 light years or 190 trillion miles) away. With this definition, two things can be compared for true brightness regardless of how far away they are from the observer or from each other.

Object	Absolute Magnitude
R136a1	-12.6
Deneb	-8.38
Rigel	-7.84
Polaris	-3.6
Vega	0.58
Sirius	1.4
Sun	4.83

APPARENT MAGNITUDE

The apparent magnitude of an object is the brightness as it appears to an observer on Earth. How bright an object appears to an observer is dependent on two things; how bright the object really is, but also how far that object is from the observer. A light source will appear 4 times more dim if it is twice as far away. In dealing with the apparent magnitude of an object, we ignore how far it is, and simply ask how bright it appears in our sky. The apparent magnitude scale is a logarithmic scale, where going down one value represents an object 2.5 times brighter. This means the lower the number, the brighter the object. On a dark, clear night, human eyes can see down to an apparent magnitude of around 6 or 7 before needing the aid of binoculars or telescopes.

Object	Max Apparent Magnitude
Sun	-26.74
Full Moon	-12.92
Venus	-4.89
Sirius	-1.47
Saturn	-0.49
Andromeda Galaxy	3.44
Limit of Human Vision	6.5

STELLAR
CLASSIFICATION

Stars are classified based on their absolute magnitude and their temperature. Most stars are classified on the Morgan-Keenan system using the letters OBAFGKM. O type stars are the hottest and M type stars are the coolest. There are stars that do not fall within these types, but the majority of stars are somewhere between O and M on the Morgan-Keenan system. Once a star has been assigned a letter, it is assigned a number from 0-9 to subdivide stars of that class. Stars with the number 0 are the hottest of that class of stars, and stars with a 9 are the coolest for that class. Finally the star is assigned a roman numeral based on its absolute magnitude. Class 0 is the brightest of stars, class III is a regular giant star, class V is our sun, and class VIII are brown dwarfs. This is how we classify our sun as a G2V type star.

MAIN
SEQUENCE

Main sequence is a term heard a lot when talking about stars. Hertzsprung-Russel diagrams are plots of a star's color against the star's brightness (seen to the right). When plotted in this way, it becomes clear that most stars lie on a line with a downward slope. This line is called the main sequence. Stars spend the majority of their lives along this line. While they are on it, they are called main sequence stars. Though there are many stars not on the main sequence, the percentage of total stars not on the main sequence is very small. This is because once a star leaves the main sequence, it begins the series of events, that will ultimately lead to the destruction of that star. Stars not on the main sequence include red giants, supergiants, and white dwarfs.

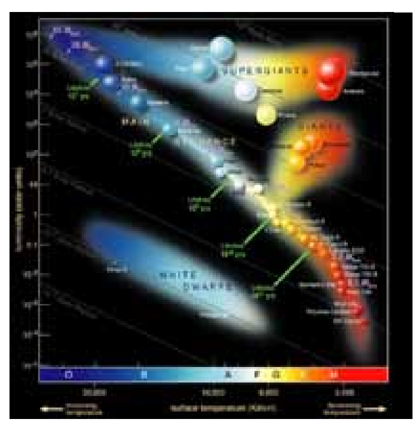


IMAGE SOURCE: WIKIMEDIA.ORG

$${}^{6}_{12}C + {}^{1}_{1}H \rightarrow {}^{7}_{13}N$$

$${}^{7}_{13}N \rightarrow {}^{6}_{13}C + \text{Positron}$$

$${}^{6}_{13}C + {}^{1}_{1}H \rightarrow {}^{7}_{14}N$$

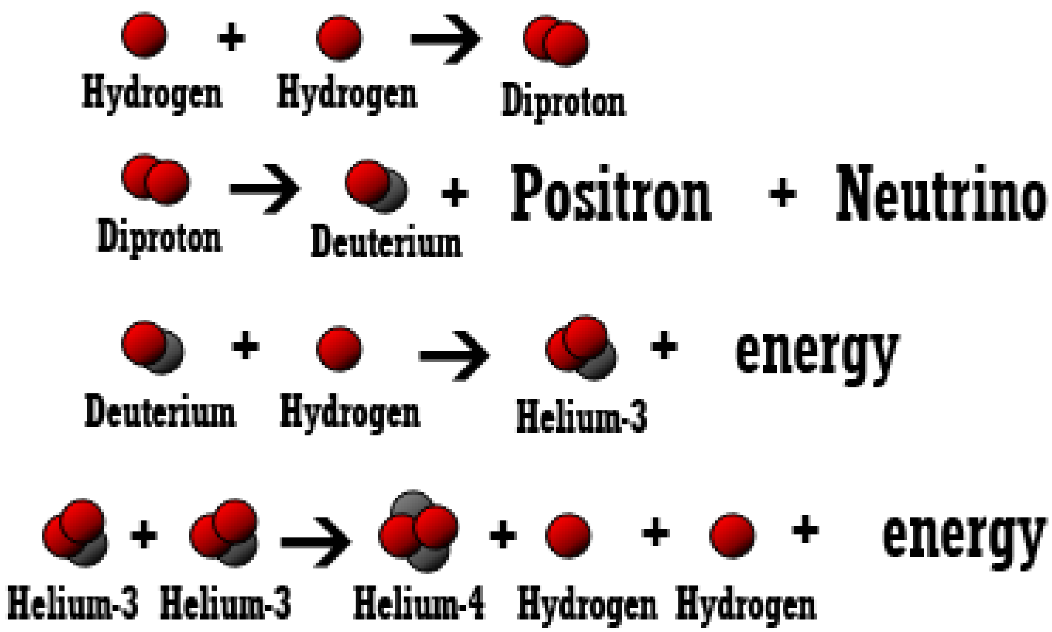
$${}^{7}_{14}N + {}^{1}_{1}H \rightarrow {}^{8}_{15}O$$

$${}^{8}_{15}O \rightarrow {}^{7}_{15}N + \text{Positron}$$

$${}^{7}_{15}N + {}^{1}_{1}H \rightarrow {}^{6}_{12}C + \text{Alpha Particle (Helium Nucleus)}$$

CNO CYCLE

In stars more massive than about 1.3 solar masses, the CNO cycle is the primary method of fusion inside the star. CNO stands for carbon, nitrogen, and oxygen, as these are used during the transition phases of reaching a stable helium-4 atom. The CNO cycle begins with a carbon-12 atom being fused with a hydrogen atom into an unstable nitrogen-13 atom. This nitrogen-13 atom will degenerate into a carbon-13 atom and a positron. The new carbon-13 atom will fuse with another hydrogen atom to form nitrogen-14. Nitrogen-14 is a stable isotope and will eventually find another hydrogen atom to fuse with, forming a very unstable oxygen-15 atom. This oxygen-15 atom will degenerate into a nitrogen-15 atom and a positron. In one final step the nitrogen-15 atom will fuse with one more hydrogen atom, fire off an alpha particle (the nucleus of a helium atom) and become the carbon-12 atom which began the cycle, ready to begin all over again. In this way, the star has used carbon, nitrogen, and oxygen to combine four hydrogen atoms into one helium atom. It needs to use four, because two of the protons will become the neutrons needed by helium-4 after the creation of the positrons. This process, as well as the proton-proton chain reaction, is difficult to follow when read as a block of text, and is usually easier to visualize with charts like the one above.



PROTON-PROTON CHAIN REACTION

In stars the size of our Sun, the proton-proton chain reaction is the primary method of fusion inside the star. Initially, when two hydrogen atoms fuse, the new helium atom has two protons and no neutrons. This is a very unstable form of helium called a diproton and it will degenerate into heavy hydrogen, also called deuterium, and a positron. It can also degenerate back into two separate hydrogen atoms but that doesn't move the reaction forward, so we are only interested in the case of deuterium. Deuterium is one proton and one neutron instead of a lone proton like most hydrogen. The neutron found in this new atom came from one of the protons ridding itself of its positive charge. The new deuterium atom can now fuse with another hydrogen atom to form a helium-3 atom. There are several ways to get to the final stable helium-4 atom. One way is to combine the two helium-3 atoms into one helium-4 atom and two hydrogen atoms ready to be recycled into the process. This process, as well as the CNO cycle, is difficult to follow when read as a block of text, and is usually easier to visualize with charts like the one above.

SUNSTRUCK

ACTIVITIES

NAME: ______________________________

SOLAR
Oven Activity

Nearly all the energy here on Earth finds its origin in the Sun. Even fossil fuels were once living organisms that used energy from the Sun to sustain life. Wind is also driven by the Sun. The Sun heats the air during the day, which changes the pressure in various areas and causes the air to flow. In fact, it is very difficult to find any energy sources here on our planet that can't be traced back to the sun eventually. This activity will use some of that solar energy on a warm sunny day to cook some food.

MATERIALS

One empty pizza box per group

Plastic wrap

Aluminum foil

Thermometers

One ruler or stick per group (to prop open the box)

Paper plates

Scotch tape

Enough s'mores material for your class

SET UP

Setup for this activity is relatively simple. Just make sure to have all the supplies pre-sorted for the groups so they are easier to hand out. The tricky part of this activity is to find a nice hot sunny day and a place to leave your solar ovens where they will be undisturbed. They will take about an hour to cook depending on the day, so the ideal place is right outside the classroom windows where you teach a lesson and observe them at the same time.

STUDENT PROCEDURE

Step 1

Cut a flap out of the top of the pizza box leaving about two inches around the edges.

Step 2

Open the flap and cover it with aluminum foil. Tape the foil into place. Cover the remaining interior of the pizza box with aluminum foil and tape it as well.

STUDENT PROCEDURE

Step 3

Cover the hole in the top of the box (made by the open flap) with plastic wrap and tape it into place.

Step 4

Go outside and place the marshmallows on a paper plate inside the oven. Place a thermometer inside the oven as well. Mark the initial temperature of your thermometer.

Step 5

Prop open the flap of your oven using your ruler or stick so that it is reflecting as much light as possible into the plastic screen of your oven.

Step 6

Mark the temperature of your thermometer every 10 minutes.

Step 7

After recording temperatures for 50 minutes, make a s’more and eat your results.

NAME: ______________________________

SOLAR
Oven Activity - Answer Sheet

TIME OF MEASUREMENT	TEMPERATURE OF OVEN
Initial	

1. What is the purpose of the aluminum foil on your solar oven?

2. What is the purpose of the plastic wrap on your solar oven?

3. When was the biggest change in temperature of your oven? Why do you think it changed so much during that particular time period?

4. How could you improve the design of your solar oven?

KEY

SOLAR
Oven Activity - Answer Sheet

TIME OF MEASUREMENT	TEMPERATURE OF OVEN
Initial	Answers Vary
10 Minutes	Answers Vary
20 Minutes	Answers Vary
30 Minutes	Answers Vary
40 Minutes	Answers Vary
50 Minutes	Answers Vary

1. What is the purpose of the aluminum foil on your solar oven?

   To reflect extra light into the oven and bounce as much of it onto the marshmallows as possible.

2. What is the purpose of the plastic wrap on your solar oven?

   Visible light can pass through transparent materials, but infrared (heat) has a much tougher time. The plastic wrap lets more light in, but doesn't let heat out. (This is also why cars get so hot under the summertime sun)

3. When was the biggest change in temperature of your oven? Why do you think it changed so much during that particular time period?

   The biggest change in temperature is most likely the first change as it begins to heat up. It will typically slow down as the oven approaches its maximum possible temperature under the current conditions. Although if a decision is made to move the oven mid-cook, or if a cloud passes the sun, it may be a different value. Any rational explanation is acceptable.

4. How could you improve the design of your solar oven?

   Lots of various answers would be acceptable, including: use extra reflectors to get more light in, try spray-painting the inside black, make the oven compartment smaller and more concentrated, any proof of thought.

NAME: ______________________________

SOLAR WATER
Purifier Activity

Knowing how to distill water is a life skill that may become necessary in an emergency situation. There are several methods of distilling water each with their own benefits and drawbacks. The drawback to a solar water purifier is that it takes a good deal of time, but the benefit is that once set up, it will distill water all on its own with no need to keep a fire going to boil it. In this activity we will build a small solar water purifier.

MATERIALS

One large bowl per group (clear bowls if you want the students to have a good view)

One small bowl per group (the heavier the better)

One cup per group to retrieve “contaminated” water

Plastic wrap

One small bowl per group (the heavier the better)

Weights (small rocks or pennies)

Salt

Scotch tape

Green food coloring

SET UP

Before class, mix together a batch of “contaminated” water by mixing in half a cup of salt per gallon of water, then add some green food coloring until it has a nice sewage look. Set aside one large bowl and one small bowl per group. Inside of the large bowl, place the weights. Have a station where students can retrieve “contaminated” water, the plastic wrap, and tape when needed.

If you have created the “contaminated” water as directed above, you can allow students to taste the before water if they would like. Do not let them drink more than a couple sips, as saltwater causes you to dehydrate and a full glass will likely lead to nausea.

If you would like to speed up the process, angling a mirror or aluminum foil so that it reflects extra sunlight into the bowl will cause the temperatures to rise more quickly, beginning condensation earlier.

STUDENT PROCEDURE

Step 1

Remove the weights from the large bowl, place the small bowl directly in the center of the large bowl.

Step 2

Carefully fill the large bowl with the “contaminated” water making sure that no water gets into the small bowl. Once the water level is close to the height of the small bowl, stop filling. If the small bowl begins to float, remove some water so that the small bowl remains on the bottom of the large bowl.

Step 3

Cover the bowl tightly with the plastic wrap. Depending on the size of your bowl, you may need to tape more than one strip together. Make sure the plastic wrap is nice and tight, if it struggles to keep hold of the bowl, you may need to tape it in place with a few strips of tape.

Step 4

Place a few weights directly over the small bowl so that the plastic wrap droops lowest directly over the small bowl.

Step 5

Place your purifier in direct sunlight and wait. It will take a few hours, so you may need to check back the next day.

Step 6

When finished, open the purifier. The water in the small bowl should be nice and clear and safe to drink.

*Note: if this water came from a source suspected of harmful bacteria, you would still need to boil the water after distilling it to make it safe for consumption.

NAME: ______________________________

SOLAR WATER
Purifier Activity - Answer Sheet

1. What is the purpose of the weights on top of the plastic wrap?

2. Did the bowl need to be clear? What about the plastic wrap? What type of material would make this purifier work more quickly?

3. Would this method work if it were cold outside? Why or why not?

4. How could you improve the design of your solar water purifier?

5. Using the terms evaporate, condensate, and precipitate, explain what is happening inside of the purifier.

KEY

SOLAR WATER
Purifier Activity - Answer Sheet

1. What is the purpose of the weights on top of the plastic wrap?

The weights cause the plastic wrap to bow in the center, making the distilled water only drip into the cup, instead of all over the place.

2. Did the bowl need to be clear? What about the plastic wrap? What type of material would make this purifier work more quickly?

Neither needs to be clear, they are clear just so we can watch. Materials that work best are materials that retain heat, such as black barrels and dark colored material in place of the plastic wrap.

3. Would this method work if it were cold outside? Why or why not?

This method does not work very well when it's cold because the inside of the bowl has to get warm enough to cause the water to evaporate quickly. If it is cold, placing a similar device over a fire can speed up the process.

4. How could you improve the design of your solar water purifier?

Any answer showing a logical attempt at improvement is good. (You could follow this activity up by using some of their ideas and seeing if there is any improve on the speed or amount of water distilled). One way to improve it (as noted above) is to angle mirrors or tin foil into the bowls to collect more sunlight.

5. Using the terms evaporate, condensate, and precipitate, explain what is happening inside of the purifier.

The bowl lets light inside, but traps heat. As the bowl heats up, the water begins to evaporate. Eventually the water will begin to condense on the plastic wrap, and once enough water is on the plastic wrap, it will begin precipitating into the smaller bowl.

NAME: ______________________________

SOLAR
Balloon Activity

This activity will demonstrate one method of gathering energy from the sun. This can segue into a conversation about other solar energy methods such as wind (which is driven by the sun) and photovoltaic cells. This activity also helps demonstrate the concept of density and air pressure.

MATERIALS

Solar balloon (cheap and available online or in science equipment stores)

String

A warm sunny day

SET UP

The only set up for this activity is to make sure you have all the materials listed above and that the students know they will be going outside during today's class.

STUDENT PROCEDURE

Step 1

Have students make a line with their arms outstretched in front of them.

Step 2

Drape the solar balloon over their arms so they are all helping to hold it off the ground.

Step 3

Use the string to tie off one end of the balloon, and open the other end to allow air to fill the balloon. Make sure to leave enough string so that the balloon can go high into the air while still being tethered to something.

Step 4

Once air has filled the balloon, tie off the other end as well and move to a nice sunny spot.

Step 5

Watch the balloon rise into the air. Make sure you have tethered the balloon to the ground or that a responsible student is holding onto the string.

NAME: ______________________________

SOLAR
Balloon Activity - Answer Sheet

1. Why is the balloon black? Why not make it a more fun color, like blue?

2. How long did it take this balloon to rise? Why did it take that long?

3. How is this balloon, which is just filled with regular air, able to float?

4. If the air outside of the balloon suddenly got much hotter, what would happen to the balloon?

5. What if the air outside of the balloon suddenly got much colder?

KEY

SOLAR

Balloon Activity - Answer Sheet

1. Why is the balloon black? Why not make it a more fun color, like blue?

   Black absorbs all the wavelengths of light, so it heats up more quickly. Other colors, like blue, would not work nearly as well at lifting the weight of the balloon, and if the air inside couldn't get hot enough, may not lift the balloon at all.

2. How long did it take this balloon to rise? Why did it take that long?

   This will depend somewhat on the amount of sunlight on your particular day, but the balloon rarely rises immediately. Usually you have to wait a short time for the air inside the balloon to be significantly warmer than the surrounding air.

3. How is this balloon, which is just filled with regular air, able to float?

   At the beginning, the air inside the balloon is the same density as all the air around it, but as the air inside the balloon warms up, it becomes less dense. The less dense air inside the balloon rises until it hits equilibrium again.

4. If the air outside of the balloon suddenly got much hotter, what would happen to the balloon?

   If the air outside the balloon suddenly became very hot (assuming it's not hot enough to melt the balloon), the density of the air outside the balloon would match or be less dense than the air inside the balloon, therefore the balloon would no longer rise and (if the air outside was less dense then the air inside) would begin to sink. Eventually, assuming the sun was still shining, the air inside the balloon would warm up past the temperature outside again, and would again begin to float.

5. What if the air outside of the balloon suddenly got much colder?

   Using the same rationale as above, if suddenly the air outside the balloon was much colder, then the air outside would be even more dense than before, causing the hot air inside the balloon to rise even faster and even more frantically, trying to find its equilibrium point.

ASTRONOMY

Help From The Web

Here are some helpful astronomy related websites with additional information for your classroom.

www.stellarium.org

Free, easy to use, planetarium software for your windows/mac/linux based computer. Includes a search function to locate anything in the sky.

www.sky-map.org

An interactive map of the evening sky. Mouse over objects to get information about them.

www.fourmilab.ch/yoursky/

An interactive map of the evening sky that can zoom into individual constellations.

www.skymaps.com

Download printable star maps for your classroom. Carry the maps outside with you while stargazing for help out in the field.

http://spaceplace.nasa.gov/menu/parents-and-educators/

A variety of free resources on space and science related activities provided for teachers by NASA.