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|  | **Where Do Chemical Elements Come From?  By Carolyn Ruth** |
| 1 | In 1054, Chinese astronomers recorded what they called a “guest star” in the constellation of Taurus, the Bull. This star had never been seen before, and it became brighter than any star in the sky. In the American Southwest, a culture rich in astronomical tradition called the Anasazi also witnessed this brilliant new star. Easily visible in broad daylight, the observers could read by it at night. Today, we know the Chinese and Anasazi were witnessing a huge star explosion, called a supernova. |
| 2 | What these observers did not know is that during the explosion, the star not only emitted huge amounts of light—more light than a billion suns—but also released chemicals in space. Inside the star were most of the first 26 elements in the periodic table, from simple elements, such as helium and carbon, to more complex ones, such as manganese and iron; and the giant explosion sprayed them in space. During the explosion, other elements were created as well, and after the explosion, the chemicals in space combined with each other to form ions and molecules. |
| 3 | These elements travel in space and ultimately end up in planets like Earth, bring part of everything we see around us and ourselves. The carbon in our cells, the oxygen in the air, the silicon in rocks, and just about every element, were all forged inside ancient stars before being strewn across the universe when the stars exploded. |
| 4 | During the past century, scientists have been studying how chemical elements form in stars and in outer space. Like genealogist-experts who study the origins of people and families- these scientists can track down where most chemical elements came from and how they descended from each other. And, similar to forming a family tree, studying the links between the chemical elements has brought-and keeps bringing – many surprises and interesting discoveries. |
|  | 1. What is a supernova? |
|  | 1. What are the two things that stars emit/release during the explosion? |
|  | 1. Where were elements formed according to paragraph 3? |
|  | **Stellar Ovens** |
| 1 | A young star is composed primarily of hydrogen, the simplest chemical element. This hydrogen ultimately leads to all known elements. First, the two constituents of each hydrogen atom-its proton and electron- are separated. The high pressure inside the star can literally squeeze together two protons, and sometimes, a proton will capture an electron to become a neutron. |
| 2 | When two protons and two neutrons band together, they form the nucleus of helium, which is the second element in the periodic table. Then, when two nuclei of helium fuse with each other, they form the nucleus of another element, beryllium. In turn, the fusion of beryllium with helium produces a carbon nucleus; the fusion of carbon and helium nuclei leads to an oxygen nucleus, and so on. This way, through successive fusion reactions, the nuclei of most elements lighter than iron can be formed. Scientists call this process nucleosynthesis. |
| 3 | In stars, these fusion reactions cannot form elements heavier than iron. Up until the formation of iron nuclei, these reactions release energy, keeping the star alive. But nuclear reactions that form elements heavier than iron do not release energy; instead, they consume energy. If such reactions happened, they would basically use the star’s energy, which would cause it to collapse. |
| 4 | Not all stars form iron, though. Some stars explode before creating that many elements. In stars less massive than the sun, the reaction converting hydrogen into helium is the only one that takes place. In stars more massive than the sun but less massive than about either solar masses, further reactions that convert helium to carbon and oxygen take place in successive stages before such stars explode. Only in very massive stars (that are more massive than eight solar masses), the chain reaction continues to produce elements up to iron. |
| 5 | A star is a balancing act between two huge forces. On the one hand, there is the crushing forces of the star’s own gravity trying to squeeze the stellar material into the smallest and tightest ball possible. On the other hand, there is tremendous heat and pressure from the nuclear reactions at the star’s center trying to push all of that material outward. |
| 6 | The iron nucleus is the most stable nucleus in nature and is resists fusing into any heavier nuclei. When the central core of a very massive star becomes pure iron nuclei, there core can no longer support the crushing forces of gravity resulting from all of the matter above the core, and the core collapses under its own weight. |
| 7 | The collapse of the core happens so fast that it makes an enormous shock waves that blow the outer part of the star into space- a supernova. It is during the few seconds of the collapse that the very special conditions of pressure and temperature exist in the supernova that allow for the formation of elements heavier than iron. The newly created elements are ejected into the interstellar dust and gas surrounding the star. |
| 8 | “The amount of elements released through a supernova is truly phenomenal,” says Stan Woosley, professor of astronomy and astrophysics at the university of California at Santa Crus. “For examples, SN1987A, a supernova seen in 1987, ejected 25,000 Earth masses of iron alone.” |
|  | 1. What is a young star primarily composed of? |
|  | 1. Use the information in paragraph 2 to fill in the blanks with what element forms next?  A. 2 Protons+ 2 Neutrons=  |  | | --- | |  |   B. Helium nucleus + Helium nucleus=   |  | | --- | |  |   C. Beryllium + Helium=   |  | | --- | |  |   D. Carbon + Helium=   |  | | --- | |  | |
|  | 1. True or False:  Nuclear reactions that form elements heavier than iron do not release energy; instead, they consume energy. |
|  | 1. From paragraph 6, in your own words describe what happens when a star cannot support the crushing forces of gravity? |
|  | 1. What are the two special conditions that exist in the supernova that allow for the formation of elements heavier than iron? |
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|  | 1. How many Earth masses of iron did the supernova observed in 1987 eject? |
|  | **How stars make elements heavier than iron** |
| 1 | Elements that are heavier than iron can be assembled within stars through the capture of neutrons- a mechanism called the “s” process. The process starts when an iron nucleus captures neutrons, thus creating a nuclei. These nuclei can be either stable, that is, they do not change, or radioactive, meaning that they transform, or decay, into another element after a certain amount of time, which can be as short as a fraction of a second and as long as a few million years. |
| 2 | Also, the newly formed nuclei can be different versions of a given element. These different versions of an element are called isotopes. They all contain the same number of protons in their nucleus but have different numbers of neutrons. Some isotopes are radioactive, while others are stable and never change. |
| 3 | For examples nickel can appear in the form of 23 different isotopes. They all have 28 protons, but each isotope contains between 20 and 50 neutrons. Of these 23 isotopes, only five are stable, while the others are radioactive. |
|  | 1. When does the “s” process start? |
|  | 1. What are isotopes? |
|  | 1. How many protons does an isotope of nickel have? How many neutrons can an isotope of nickel have? (this should be a range) |
|  | **Our Stellar Origins** |
| 1 | When a supernova spews its newly made elements into space, the elements become part of an enormous cloud of gas and dust, called an interstellar cloud. The gas is made of 90% hydrogen, 9% helium, and 1% heavier atoms. The dust contains silicates (compounds made of silicon), carbon, iron, water ice, methane (CH4), ammonia (NH3), and some organic molecules, such as formaldehyde (H2CO). |
| 2 | Such clouds are found so often between stars in our galaxy that astronomers think that all stars and planets have formed from them. Except for hydrogen, which appeared when the universe formed through the Big Bang explosion, all of the elements on Earth have been cooked for billions of years in stars and then released in the universe through supernova explosions. The nitrogen in our DNA, the calcium in our teeth, the iron in our blood, and the caron in our apple pies were all made in the interior of stars. The gold in jewels, tungsten in lightbulbs, and silver in cookware were all produced during stellar explosions. We ourselves are made of “star stuff.” |
|  | 1. What is an interstellar cloud? |
|  | 1. What are the gasses and their percentages in the interstellar cloud? |
|  | 1. What are silicates? |
|  | 1. How have all the elements on Earth (except for hydrogen) formed? |
|  | 1. What are we made of? |
|  | Wrap-it up |
|  | 1. What is the main idea of the reading? |
|  | 1. What are 3 pieces of evidence that support your main idea? |
|  | 1. What are two things you learned from this reading? |
|  | Selected references  Cowen, R. Bang. The Cataclysmic Death of Stars. National Geographic, March 2007, pp 78–95.  Pendick, D. Archival Search Spots Supernova. Astronomy, Jan 2009, p 18.  Pendick, D. Watching Echoes of a Supernova, Astronomy, Jan 2009, p 26.  Soderberg, A. X-rays Mark the Spot. Sky & Telescope, Nov 2008, pp 26–31.  Carolyn Ruth is an adjunct professor of chemistry at Mercyhurst College, Erie, Pa. Her most recent ChemMatters article, “Letting Off Steam,” appeared in the April 2009 issue. |