Name: ____ **Date:** ________________________

Our Amazing, Powerful Sun Worksheet Answer Key

This worksheet will step you through how to calculate the: (1) Power of the Sun and (2) lifetime of the Sun.

1. Power of the Sun

The Stefan Boltzman Law allows us to relate the temperature of a planetary object (like the Sun) to its energy output and is given by:

$$P = 4\pi r^2 \sigma T^4$$

where P is the energy rate output of the object, T is it's temperature, r is it's radius, and σ is the Stefan Boltzman constant ($5.670\ x\ 10^{-8} W\ m^{-2} K^{-4}$). If the temperature and radius of the Sun are approximately $5800\ K$ (hot!!) and $6.995\ x\ 10^8\ m$, respectively, calculate the rate of energy output of the Sun in Watts.

Solution:

Using the Stefan Boltzman law, we can plug in all the information given in the problem statement:

$$\boldsymbol{P = 4\pi(6.995x10^8\ m)^2\ (5.670\ x\ 10^{-8}\ W\ m^{-2}\ K^{-4})(5800\ K)^4}$$

$$\boldsymbol{P = 3.95\ X\ 10^{26}\ W}$$

2. The Lifetime of the Sun

We learned that the energy emitted from the Sun is formed through nuclear fusion. Specifically, four hydrogen atoms are transformed into one helium atom. From the Periodic Table of Elements, one helium atom has less mass than four hydrogen atoms. We can assume that the Sun will "die" when it runs out of energy.

Upon fusion to helium, about 0.7% of the original mass is lost. Therefore, we can express the total energy, E, of the Sun as $E = 0.007\ mc^2$, where c is the speed of light ($c = 299{,}792{,}458\ m\ s^{-1}$) and M is the mass in the sun that is capable of going through fusion. If the total mass of the Sun is $2x10^{30}$ kg and only the hottest center (about 10%) can actually undergo nuclear reactions, calculate the total Energy of the Sun.

Solution:

First we'll solve for the amount of Sun's mass that can undergo nuclear reaction:

$$M = 0.1(2x10^{30}kg) = 2x10^{29}kg$$

Then we'll solve for the total energy using Einstein's famous formula:

$$E = 0.007Mc^2 = 0.007(2x10^{29}kg)(299,792,458\ m\ s^{-1})^2$$

$$E = 1.26\ x\ 10^{44} Joules$$

Now that we know the total available energy that can undergo a reaction, we will assume that the Sun will "die" when it runs out of this energy. Put into mathematical form, this means:

$$lifetime = \frac{total\ available\ E}{rate\ of\ E\ output}$$

Solve for the lifetime (in years) of the Sun. Note that $1\ Watt = 1\ Joule\ s^{-1}$.

Solution:

$$lifetime = \frac{1.26\ x\ 10^{44}\ J}{3.96x10^{26}\ W}\left(\frac{1\ hr}{3600\ s}\right)\left(\frac{1\ day}{24\ hr}\right)\left(\frac{1\ year}{365\ days}\right) = 10,113,058,041\ years$$

Therefore, the lifetime of the Sun is approximately 10 billion years!!