Astronomy 100 Name(s):

Exercise 8: Solar processes

1. To compare the difference between chemical and nuclear energy, fill out the table below:

	Paper scrap 1	Paper scrap 2
Mass of paper scrap (g)		
Mass of paper scrap (kg)		
Energy (J) of total conversion of mass to energy ($E=mc^2$)		
Initial temperature of water (°C)		
Final temperature of water (°C)		
ΔT = Difference in temperature (°C)		
Energy (J) of burning* ($E=0.092 \times \Delta T$)		

*The formula is taken from the heat capacity equation: Energy = m C_p ΔT where m = mass of heated air in grams, C_p = specific heat of air = 0.240 J/g°C and assuming that air has a density of 0.0012 g/cm^3 and the calorimeter chamber has a volume of 320 cm^3.

2. a. Which of the calculated energies (which line in the table above) is chemical energy?

b. Which is nuclear energy?

c. Of nuclear and chemical conversions to (heat) energy, which process clearly produces more, and by approximately what **factor** (how many times more)?

Models are used to gain insight into otherwise difficult-to-picture processes, such as the **proton-proton cycle**, for which we will construct a model using Lego bricks.

A **proton** has a mass of 1 amu and a charge of +. Suppose you separate the two characteristics into two sub-particles, like this: a proton = a mass sub-particle and a charge subparticle plus a sub-particle which glues the two together. A **neutron** weighs about as much as a proton (without the charge). A **positron** ("positive electron") will have the + charge with hardly any mass. Invent a "glue" sub-particle called a **neutrino** which has no charge and hardly any mass.

So: proton = neutron + positron + neutrino

In terms of Lego bricks, then, to make one proton, you need three bricks:
a **1 × 8** brick (any color) representing the neutron
a **white 1 × 1** brick representing the positron
and a **blue 1 × 1** brick representing the neutrino.

3. Make two protons (also called **hydrogen nuclei**, for hopefully obvious reasons). From these two nuclei alone, make a **deuterium** nucleus, which is made of one proton and one neutron. What particles are left over? Save the pieces.

4. Make another proton. Using *only* this proton and the deuterium nucleus from the previous part, make a **helium-3** nucleus, which has two protons and one neutron. What particles are left over? Save the pieces.

5. Join forces with a neighbor so that you have two helium-3 nuclei and other leftover bits. Put the leftover bits aside. Using *only* the two helium-3 nuclei, make a **helium-4** nucleus (2 protons, 2 neutrons). From the leftover parts of *this* reaction, construct as many protons as you can. How many protons do you end up with?

6. To summarize: you started with 6 protons (in the various steps) and ended up

with ____ protons for a net usage of ____ protons. What particles did you end up with (include the leftover bits)?

7. Why is this called a proton-proton **cycle**? (I mean, why a cycle?)

There are a couple of ways to do the next part. You can do as Galileo Galilei and Thomas Harriot (co-discoverers of sunspots) did in the early 17^{th} century and look at the sun through a telescope (**PLEASE USE THE SOLAR FILTER**) and sketch what you see. Or, or more safely, you can go to:

http://boojum.as.arizona.edu/~jill/EPO/Sun/sunmain.html

then click on “Observe Today’s sunspots image” link to get an enlarged picture of the sun with the latitudes all neatly marked out. For a ridiculous amount of detail, go to:

http://www.astro.ucla.edu/~obs/images/cur_drw.jpg

but the NOAO site will suffice.

8. **Draw** the major sunspot groupings as accurately as you can on the solar disk below. Place the groupings at their correct **latitude**!

9. Go to the Solar Influences Data Analysis Center at

http://sidc.oma.be/index.php

then go to the “Sunspots” link on the left side and click the “Sunspots Index Graphics” entry. Click and examine the “Sunspot number since 1750” image.

a. Is sunspot number **periodic**? (In other words, do sunspot number minima and maxima repeat on a regular basis?) If yes, what is the length of the sunspot number period?

b. Predict if the number of sunspots increase or decrease or stay the same in the next few years. Then predict when we should reach the next sunspot **minimum**.

10. Click and examine the Maunder "Butterfly" diagram. This plot shows the **latitude** of the sunspots for each given year. Look at one **sunspot cycle** (immediately after a minimum to immediate before a minimum).

a. What happens to the **latitude** of sunspot appearance as the cycle progresses?

b. Astronomy textbooks claim that sunspots have lifetimes ranging from a few hours to a few months. Will any individual sunspot change latitude?

c. Are the latitudes of the sunspots on your sketch **consistent** or **inconsistent** with the Maunder Butterfly diagram and the part of the sunspot cycle we are in now?

11. Go to the SpaceWeather site at

http://www.spaceweather.com/glossary/sunspotnumber.html

and look at the historic sunspot record.

a. Read the text below the graph and explain how come sunspots are hard to count. Hint: what "correction" type of factors are in the formula to calculate sunspot number?

b. What happened to the number of sunspots between 1650 and 1700? Did this correspond to any dramatic events on Earth? Hint: What was the climate like at that time?