Phys 102 Astronomy Name ________________

Power From Fusion

The Energy of Fusion

The masses of subatomic particles are given in atomic mass units, amu's or u's where

$1\ u = 1.6605402 \times 10^{-27}\ kg.$

Do the following subtraction to find how much mass is "lost" when 4 hydrogen atoms fuse to one helium:[2]

m_H	=	1.007825 u	x 4	:	4.031300 u
m_{He}	=	4.002603 u	x 1	:	– 4.002603 u

mass "lost" in fusion = ______________ u

fraction of H mass "lost" in fusion $\left(\frac{m_{Lost}}{m_H}\right)$ = ______________ ←

"Bond. James Bond." Seems he knew something about fusion, eh?

Find the energy produced in each fusion reaction.

1. **Convert** this "lost" mass **from u/fusion to kg/fusion** using $1\ u = 1.6605 \times 10^{-27}\ kg$ (keep 5 sig figs)

Example: $\frac{0.028697\ u}{fusion}\left(\frac{1.6605\times10^{-27}\ kg}{1\ u}\right) = \frac{4.7653\times10^{-29}\ kg}{fusion}$ $\frac{kg}{fusion}$

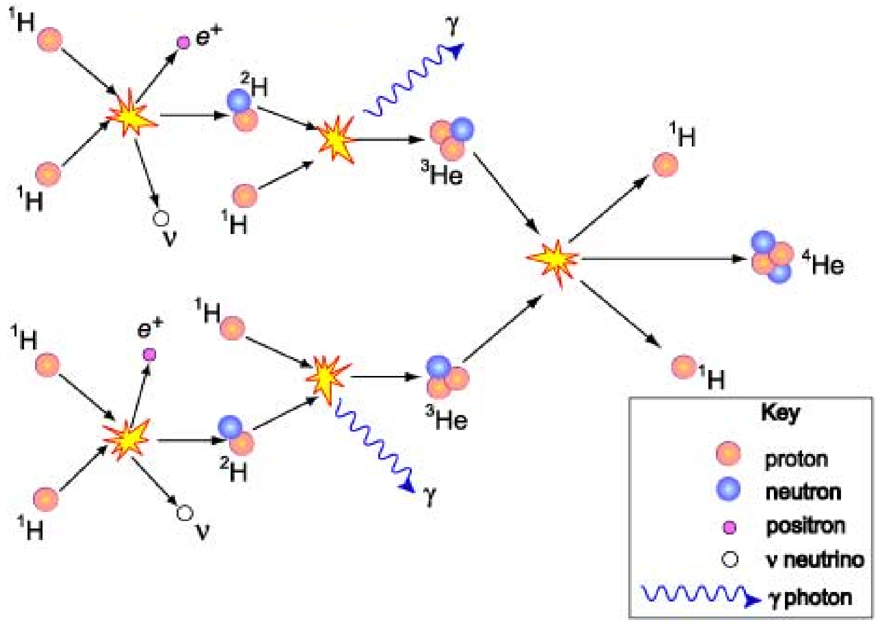
Use the conversion factor to multiply by one & get rid of unwanted units (u)!

2.[2] **Convert** from **mass/fusion** to **energy/fusion** (in Joules) using $E = mc^2$ and $c = 2.998 \times 10^8\ m/s$

$\frac{J}{fusion}$

3.[2] **Convert** the **energy/fusion** from **Joules** to **kilowatt-hour using** $1\ kWhr = 3.6 \times 10^6\ J$.

$\frac{kWhr}{fusion}$



The energy released by a single fusion reaction of 4 hydrogen atoms to one helium atom is:

______________ $\frac{kWhr}{fusion}$

How many pounds of H would we have to fuse to provide energy used in US households.

4. **Convert this** (1.190×10^{-18} kWhr/fusion) to **fusions/household** using 10,932 kWhr/household which the US Energy Information Administration gives as the 2014 average (www.eia.gov) (keep 4 sig figs)

$$\frac{10932 \text{ kWhr}}{\text{Household}}\left(\frac{\text{fusion}}{1.190 \times 10^{-18} \text{ kWhr}}\right) = \frac{9.189 \times 10^{21} \text{ fusions}}{\text{Household}}$$

Use the conversion factor to multiply by one & get rid of unwanted units (kWhr)!

Flip this factor to get fusions on top, then get rid of kWhr with the conversion factor

$\frac{\text{fusions}}{\text{household}}$

It should seem like a HUGE number!! BUT … how much hydrogen is this?

5.[2] Each fusion reaction uses 6.694×10^{-27} kg of H (that becomes He and energy). Find the total H that would have to be fused to supply an average households energy using your result in #4

$\frac{\text{kg of H}}{\text{household}}$

6.[2] **To supply 7,256,000 NY households**, how many **kg of hydrogen** would need to undergo fusion ?

$\frac{\text{kg of H}}{\text{NY State Households}}$

7.[2] How many **pounds of hydrogen** is this if 1 kg = 2.2 lb? What do you think of this number?

$\frac{\text{lb of H}}{\text{NY State}}$

What do you think of this number?[2]

THE ENERGY OF SOL … HOW MUCH H DOES SOL FUSE EACH SECOND?

Sol's luminosity is 3.827×10^{26} Watts or

$$L_{Sol} = 3.827 \times 10^{26} \frac{\text{Joules}}{\text{second}}$$

provided by the fusion of hydrogen into helium. On p. 1 (#2), you calculated that **Each fusion yields** an energy of

$$E_{fusion} = 4.283 \times 10^{-12} \frac{\text{Joules}}{\text{fusion}}$$

1. Use these to find the number of hydrogen **fusions per second** that provide Sol's **3.827×10^{26} J/sec** (keep 4 sig figs).

$$\frac{3.827 \times 10^{26}\ \text{J}}{\text{second}} \left(\frac{1\ \text{fusion}}{4.283 \times 10^{-12}\ \text{J}} \right) = \frac{8.935 \times 10^{37}\ \text{fusions}}{\text{second}}$$

Flip this factor to get fusions on top, then get rid of J with Sol's Luminosity

$\frac{\text{fusions}}{\text{second}}$

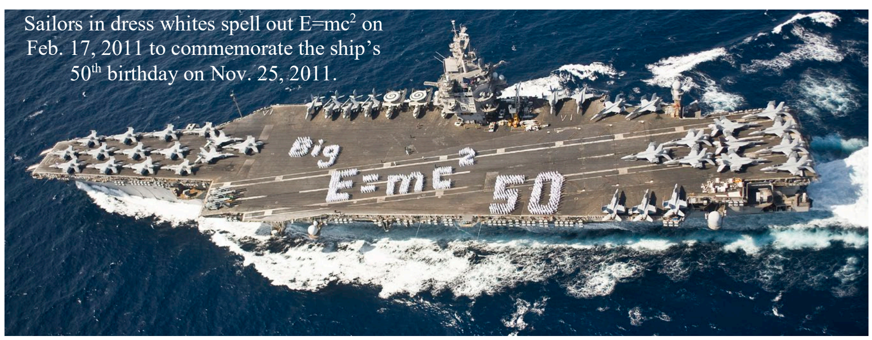
The total mass of H used in each fusion (to become He and energy) is

$$m_{fusion} = 6.694 \times 10^{-27} \frac{\text{kg of H}}{\text{fusion}}$$

2.[2] **Convert** your result from #1 (8.935×10^{37} fusions/sec) from **fusions/sec** to **kg/sec** using this.

$\frac{\text{kg of H}}{\text{second}}$

An aircraft carrier such as the USS Eneterprise (CVN-65) shown, weighs 94,781 metric tons (1 metric ton = 1 tonne = 1000 kg). How many of these ships would have to be fused each second to supply Sol's energy (IF they were pure hydrogen … not a great shipbuilding material, but hey, this is the ivory tower, eh?)?



Sailors in dress whites spell out $E=mc^2$ on Feb. 17, 2011 to commemorate the ship's 50th birthday on Nov. 25, 2011.

1.[2] Find the mass of the USS Enterprise in kg (keep 4 sig figs)

$\frac{\text{kg}}{\text{USS Enterprise}}$

2.[2] **Convert** the amount the sun fuses **from kg/sec** to **aircraft carriers/second** (USS Enterprise/sec)

$\frac{\text{USS Enterprises}}{\text{second}}$

3.[2] Compare this to the amount needed to supply New York State

Some star, eh?

THE ENERGY OF SOL … HOW MUCH H DOES SOL TURN FROM MATTER TO ENERGY EACH SECOND?

Sol's luminosity is 3.827×10^{26} Watts or

$$L_{Sol} = 3.827{\times}10^{26}\ \frac{\text{Joules}}{\text{second}}$$

provided by the fusion of hydrogen into helium. On p. 1 (#2), you calculated that **Each fusion yields** an energy of

$$E_{fusion} = 4.283{\times}10^{-12}\ \frac{\text{Joules}}{\text{fusion}}$$

The number of hydrogen **fusions per second** that provide Sol's **3.827×10^{26} J/sec** is

$$N_{fusions} = 8.935{\times}10^{37}\ \frac{\text{fusions}}{\text{second}}$$

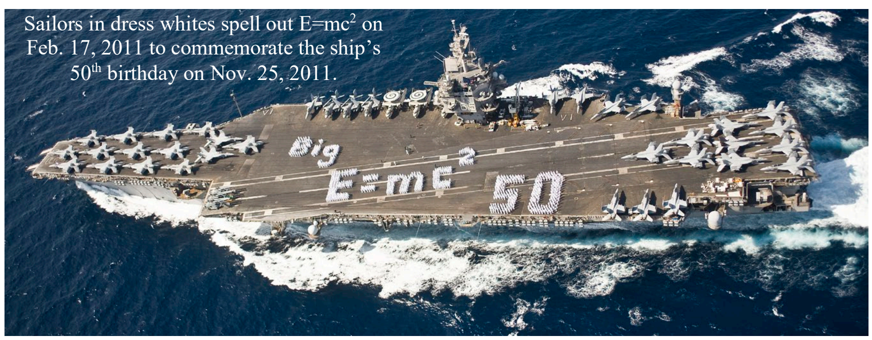
The mass of H transformed to energy in each fusion is

$$m_{\text{lost in fusion}} = 4.7653 \times 10^{-29}\ \frac{\text{kg of H}}{\text{fusion}}$$

1.[2]**Convert** your result from #1 (8.935×10^{37} fusions/sec) from **fusions/sec** to **kg/sec** using this.

$$\frac{8.935 \times 10^{37}\ \text{fusions}}{\text{second}}\left(\frac{6.694 \times 10^{-27}\ \text{kg}}{1\ \text{fusion}}\right) = \frac{5.981 \times 10^{11}\ \text{kg}}{\text{second}} \qquad \frac{\text{kg of H}}{\text{second}}$$

An aircraft carrier such as the USS Eneterprise (CVN-65) shown, weighs 94,781 metric tons (1 metric ton = 1 tonne = 1000 kg). How many of these ships would have to be fused each second to supply Sol's energy (IF they were pure hydrogen … not a great shipbuilding material, but hey, this is the ivory tower, eh?)?



Sailors in dress whites spell out $E=mc^2$ on Feb. 17, 2011 to commemorate the ship's 50th birthday on Nov. 25, 2011.

The mass of the USS Enterprise in kg (keep 4 sig figs)

$$m_{\text{USS Enterprise}} = 9.478 \times 10^{7}\ \frac{\text{kg}}{\text{USS Enterprise}}$$

1.[2] **Convert** the amount the sun convertst to energy **from kg/sec** to **aircraft carriers/second**

$$\frac{\text{USS Enterprises}}{\text{second}}$$

2.[2] What do you think of this much matter being converted entirely to energy EVERY SECOND??