Name

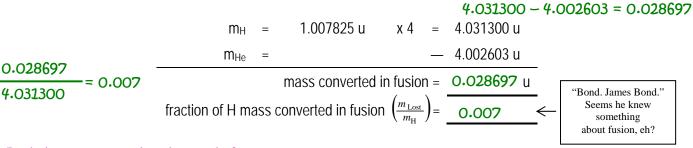
# POWER FROM FUSION

## THE ENERGY OF FUSION

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

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

The masses of the hydrogen nuclei that go into the reaction and the helium nuclei that result from it are:



#### Find the energy produced in each fusion reaction.

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

$$\frac{0.028697 \text{ u}}{\text{fusion}} \left( \frac{1.6605 \times 10^{-27} \text{ kg}}{1 \text{ u}} \right) = \frac{4.76514 \times 10^{-29} \text{ kg}}{\text{fusion}} \qquad \frac{\text{kg}}{\text{fusion}} \text{ converted}$$

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

Compare this to the energy used in US households.

1. Convert the energy from a single fusion from Joules to kilowatt-hours, 1 kWhr =  $3.6 \times 10^6$  J.

$$\frac{4.283 \times 10^{-12} \text{ J}}{\text{fusion}} \left( \frac{1 \text{ kWhr}}{3.6 \times 10^6 \text{ J}} \right) = \frac{1.190 \times 10^{-18} \text{ kWhr}}{\text{fusion}} \qquad \qquad \frac{\text{kWhr}}{\text{fusion}}$$

2. According to the Department of Energy, in 2005 (http://www.eia.doe.gov/) the average residential customer uses 11,040 kWhr. Calculate **how many fusion reactions** per customer it takes to produce this:

$$\frac{11040 \text{ kWhr}}{\text{Customer}} \left( \frac{\text{fusion}}{1.190 \times 10^{-18} \text{ kWhr}} \right) = \frac{9.277 \times 10^{21} \text{ fusions}}{\text{Customer}} \qquad \frac{\text{fusions}}{\text{customer}}$$

It should seem like a HUGE number!! BUT ... how much hydrogen is this? Fusion uses 4.0313 u/fusion or  $6.694 \times 10^{-27}$  kg/fusion ... so what mass of hydrogen does the average residential customer require?

$$\frac{9.277 \times 10^{21} \text{ fusions}}{\text{Customer}} \left( \frac{6.694 \times 10^{-27} \text{ kg}}{\text{fusion}} \right) = \frac{6.210 \times 10^{-5} \text{ kg}}{\text{Customer}} \qquad \frac{\text{kg of H}}{\text{customer}}$$

For the 7 million NY households counted in the 2000 census, **how many kilograms of hydrogen** would need to undergo fusion to supply the annual residential power consumption?

$$\frac{6.210 \times 10^{-5} \text{ kg}}{\text{Customer}} \left( \frac{7,000,000 \text{ Customers}}{\text{NY State}} \right) = \frac{434.7 \text{ kg}}{\text{NY State}} \qquad \qquad \frac{\text{kg of H}}{\text{NY households}}$$

What do you think of this number?

Key

#### THE ENERGY OF SOL

Sol's luminosity is 3.827x 10<sup>26</sup> Watts or

$$L_{Sol}$$
 = 3.827×10<sup>26</sup>  $\frac{Joules}{second}$ 

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

Calculate the number of hydrogen fusions per second that provide the luminosity of Sol (keep 4 sig figs).

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

The mass of H used to make He and energy each fusion is

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

what mass of hydrogen must be converted (in kg/sec) to He and energy by Sol each second?

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

A Nimitz Class aircraft carrier such as the USS Nimitz shown, weighs 98,556.67 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?)?

1. Find the mass of an aircraft carrier in kg (keep 4 significant figures)

1 ACC = 98,556.67 tonnes x 
$$\frac{1,000 \text{ kg}}{\text{tonne}}$$
 = 9.856 x 10<sup>7</sup> kg  $\frac{\text{kg}}{\text{ACC}}$ 

2. Convert the kg/second the sun fuses to aircraft carriers per second

$$\frac{5.981 \times 10^{11} \text{ kg}}{\text{second}} \left( \frac{1 \text{ ACC}}{9.856 \times 10^7 \text{ kg}} \right) = \frac{6069 \text{ ACC}}{\text{second}} \qquad \frac{\text{ACC}}{\text{second}}$$

The sun fuses 6069 Aircraft Carrier masses of hydrogen to helium every second ... and fusing 435 kg would supply NY State for a year!!! Some star, eh?