Measuring Stellar Reaction Rates with Bubble Chamber

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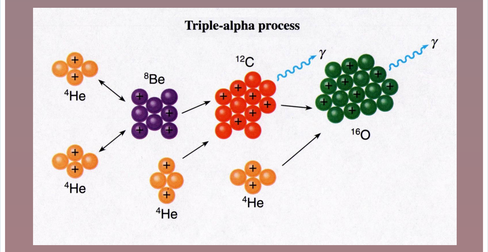
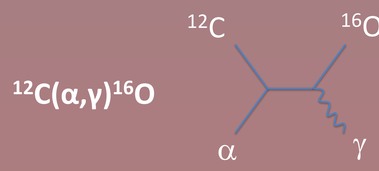
Motivations

Learn more about the helium-carbon fusion reaction:

- Helium burning is an important process in stellar nucleosynthesis (star T = 200,000,000 K)

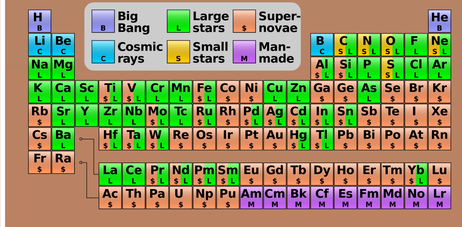


- The process we are investigating is the fusion of helium and carbon into oxygen

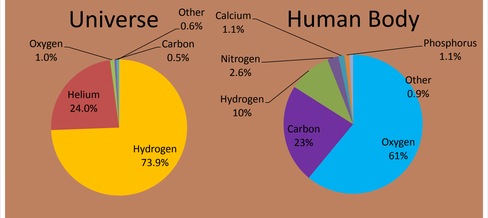


Why is the $^{12}C(\alpha,\gamma)^{16}O$ Reaction Important?

- Affects the synthesis of most of the elements of the periodic table



- Sets the $N(^{12}C)/N(^{16}O)$ (≈0.4) ratio in the universe



- Determines the minimum mass a star requires to become a supernova

Our Investigation

What is our experiment?

$^{12}C(\alpha,\gamma)^{16}O$ is very difficult to measure in the laboratory. We plan to obtain the rate for the helium-carbon fusion reaction by measuring the inverse process:

- The photo-disintegration of oxygen into helium and carbon

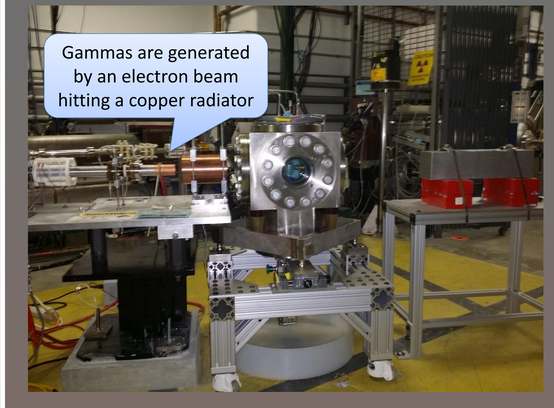
$$^{16}O(\gamma,\alpha)^{12}C$$

beam target signal

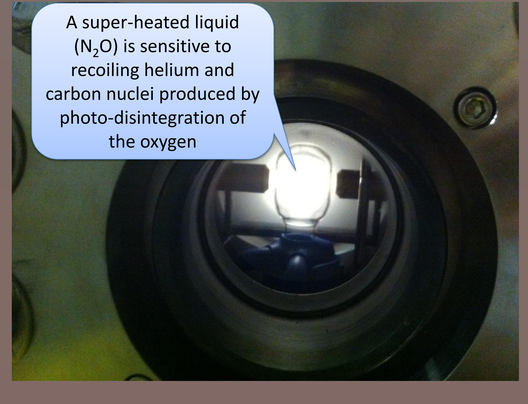
$$\gamma + {}^{16}O \rightarrow {}^{12}C + \alpha$$

- This measurement is achieved by using a novel bubble-chamber technique

1. Produce Gammas



2. Gammas Collide with the Target



How does the Chamber Work?

1 Cell is cooled then filled with room temperature gas

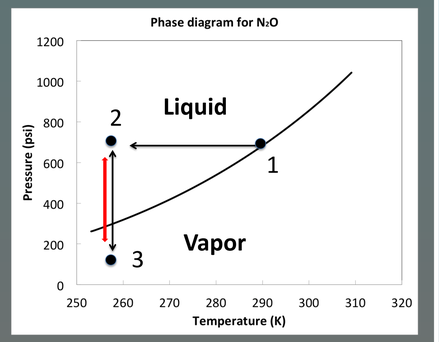
2 Gas is cooled and condenses into liquid

3 Once cell is completely filled with liquid, pressure is reduced creating a superheated liquid

3 Nuclear reactions induce bubble nucleation

2 Camera detects bubble; system re-pressurizes

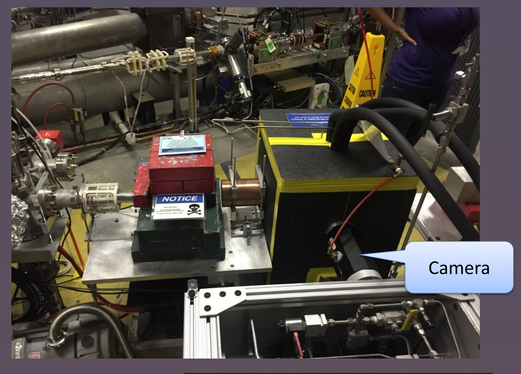
3 System depressurizes; ready for another cycle

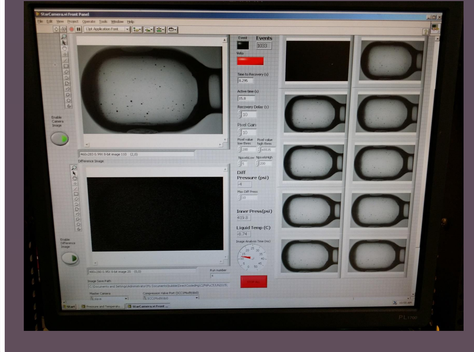


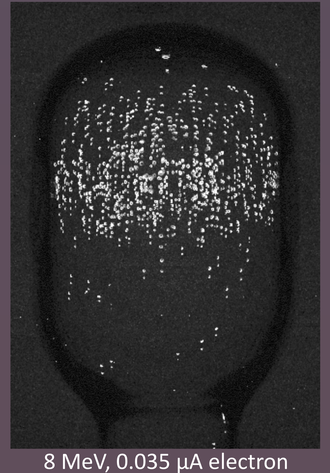
T = -10˚C (263 K , 14˚F); P = 20 atm (294 psi)

Our Data

- The recoiled helium and carbon nuclei will heat up small parts of the unstable liquid causing it to vaporize. We capture this bubble event with a 100 Hz digital camera







8 MeV, 0.035 μA electron beam

Next Step

Goal <±10%

Currently, reaction rate error is large (±35%)

- Test the Bubble Chamber during the Summer of 2016
- Improve systematic uncertainties of our set up
- Move camera further back to allow for more radiation shielding
- Study acoustic signal to distinguish any background events (the helium-carbon bubbles have very distinct sound)

Summary

- Helium-carbon fusion to form oxygen is a very important reaction → it is considered to be the key reaction in the helium burning of stars
- For our purposes, it is much easier to measure the time reversal reaction (the disintegration of oxygen into helium and carbon when bombarded with gamma rays)
- At Jefferson Lab, we use our electron beam to generate gammas by colliding them into a copper radiator
- These gammas hit oxygen nuclei in laughing gas (N_2O) inside of the bubble chamber
- The helium and carbon nuclei from the breakup of oxygen heat up small parts of the unstable liquid vaporizing it
- This event generates a small bubble which we capture using a high speed digital camera

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