# SMNA 2022 - Lecture 8B-mini - Sampling Nuclear Reaction Rates in Low Mass Stellar Models

*We are going to walk through how to sample nuclear reaction rates in models of low mass stars. We will work to focus on core He-burning in a low mass star model exploring various ways of modifying nuclear reaction rates.*

This exercise is based on the ApJ article **Properties of Carbon-Oxygen White Dwarfs From Monte Carlo Stellar Models** which can be found online.

### Learning objectives

- How to modify a single rate using rate multipliers.
- How to provide user defined reaction rates.
- How to verify user provided reaciton rates.
- Determine the impact of modifying helium burning reaction rates in low mass stars.

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## Task 0 - Getting Started

1. Download the work directory 8B-mini.zip!
2. Ensure that you can compile and run work directory:

```
cd pgstar
 ./mk && ./rn
```

This example will be evolving a 3 $M_\odot$ star using a simplified network starting from core H depletion! Note the first model will take a few hundred retries to converge. That is okay!

## Task 1 - Modifying reaction rates using rate factors

One of the first methods for modfying reaction rates is to utilize `special_rate_factors`.

This allows the user to apply a multiplicative factor to a specific reaction rate.

1. Search the `star_job.defaults` for the relavant flags to utilize.
2. Set the special rate factor for the triple$-\alpha$ reaction rate. Note: `MESA` naming scheme is `r_` `isos_in_entrance_channel` `to` `exit_channel_isos.` So, `r_he4_he4_he4_to_c12` corresponds to triple alpha. The complete list lives in `data/rates_data/reactions.list`. Choose a value from [0,2] for the factor.
3. Evolve your model to core He depletion.
4. Record the `center_c12` in the spread sheet including the rate factor used. Spreadsheet here.

# Task 2 - Modifying reaction rates user-defined reaction rates

It is often the case that you might measure or produce your own nuclear reaction rate and want to determine the impact your new rate has on stellar models. This section of the lab will focus on the steps to do this.

1. Search the `star_job.defaults` for the relavant flags to utilize.
2. Set rate table and cache directory locations.
3. Locate the `r_he4_he4_he4_to_c12.txt` in your directory and apply the correct header to the rate as explained in the instructions.
4. Be sure to add `r_he4_he4_he4_to_c12` to your rates list and to comment out the special rate factor options.
5. Rerun your model and record your value for `center_c12` in the Task 2 sheet of the google spreadsheet here.

The source of our rate is found here.

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Ok, so how do you *know* that your rate was properly used and applied to your stellar model?

When you run `MESA` using the default rates it will store the results in a cache directory located at `~/MESA_DIR/data/rates_data/cache/`. Moreover, `MESA` provides a `show_rates` tool that allows you to read these binary files in the cache and show what rate it used.

1. Navigate to `~/MESA_DIR/rates/test` and run the `show_rates` tool on the cache file corresponding to the default `r_he4_he4_he4_to_c12` rate. This default rate is from the NACRE compilation. Save the output of `show_rates` to a text file.

2. Repeat this for the binary file produced in your *local* cache directory as part of Task 2. Save the output of this file to a text file. This is the Fynbo 2005 rate.
3. Open the `compare_rates.ipynb` Jupyter Notebook to produce a quick plot showing these two rates as a function of T8. Feel free to use your own plotting tool for this step!
4. Do the rates look the same? They shouldn't! Discuss with your neighbors.

# Task 3 (Optional) - Applying custom rates to a Test Suite

Explore the `test_suite` cases that come with `MESA`. Choose one as your basis.

1. Copy your selected test_suite case and compile it. Make sure it runs outside of the MESA directory.
2. Apply one of the methods for modifying reaction rates discussed above.
3. Explore how it changes the results of the test_suite and those implications.