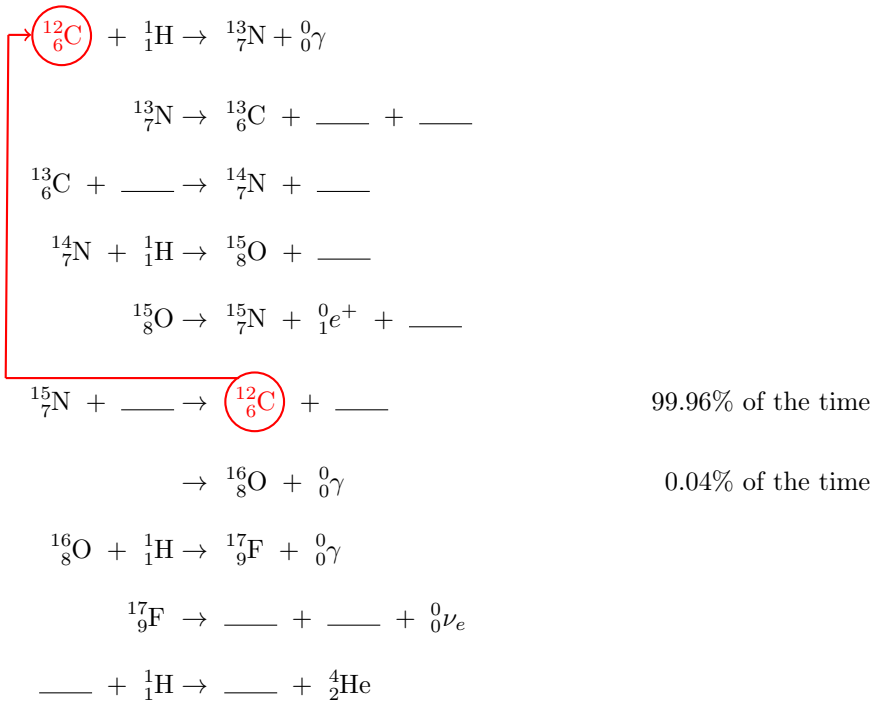
1. Can gravitational energy alone supply a star's luminosity?
   (a) A star with mass M and radius R has a uniform density ρ. What is its gravitational potential energy in terms of M and R?
   (b) The star shrinks in radius at a small but constant rate $dR/dt = -v$ where v is a positive number with units of velocity. At what rate dU/dt does the star's gravitational potential energy change?
   (c) Normally, the change in potential energy would be accompanied by a change in thermal energy. But suppose that the star stays at constant temperature (constant thermal energy) during this collapse and radiates the energy away that would normally add to its thermal energy. Suppose also that this radiation is the only radiation emitted by the star. What is the star's luminosity?
   (d) Suppose the Sun derived its luminosity in this fashion. At what speed would it need to shrink to produce the presently observed luminosity? How long in years would it continue to shine? How long in years would it take for the luminosity to double? Do you think this process can be ruled out as the source of the Sun's power?

2. **The CNO Bi-Cycle**: The complete CNO cycle of nuclear reactions is



   (a) Fill in the blanks in the table of reactions with the missing names of the reacting particles.
   (b) One part of the bi-cycle is indicated in the reaction table. Find another catalytic cycle among the reactions and label it like the first part.
   (c) What are the *overall* reactions associated with each of the two catalytic cycles? How does the energy released in each overall reaction compare with that released in the pp chain?

3. Suppose we have Z protons and we have to distribute them into two nuclei, one with Z_1 protons and the other with Z_2 protons, such that $Z = Z_1 + Z_2$.
   (a) What arrangements give the *maximum* and *minimum* Coulomb repulsion between the two nuclei?
   (b) What does this tell you about the types of fusion most likely to take place in stars?

