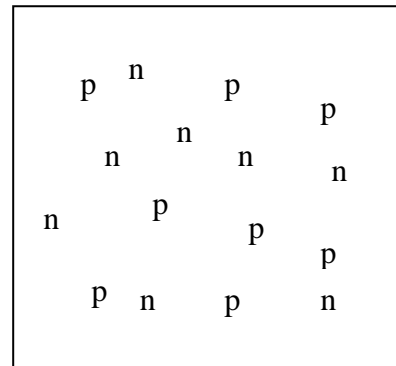


1. (3 pts.) **Simplicio thinks**, “Penzias and Wilson probably detected the radiation from lots of dust in the plane of the Milky Way Galaxy. The radiation is not from the Big Bang.” What evidence refutes Simplicio's incorrect statement?
2. (3 pts.) **Simplicio thinks**, “Penzias and Wilson probably detected the radiation from the evergreen trees nearby. Their radio antenna will receive signals even when not pointed directly at the trees, just as my satellite dish gets a signal even when not pointed directly at the satellite. The radiation is not from the Big Bang.” What evidence refutes Simplicio's incorrect statement?
3. **The Lives of the Helium Nuclei**. Write a short, short story about the life of a helium nucleus in the center of the sun. Helium can be made in several ways. Assume this helium nucleus was made in the most common way. Include (3 pts.) how it was born, (3 pts.) what it was before birth, and (3 pts.) what it may become when the sun dies.
4. The picture shows a sample of the universe 0.001 s after the big bang, when the expansion parameter was 6×10^{-12} . (Recall that the expansion parameter is distance/(present distance). The box was a cube 2×10^{-11} m on a side. There are 8 neutrons, 8 protons, and lots of light in the box.



- a. (5 pts.) The box expands with the universe. Draw its contents just before helium formed (at 3 minutes, when the expansion parameter is 2.3×10^{-9}). The number must be precise to 10%; for example, drawing 15 protons is OK if the actual number of protons is 16.
- b. (3 pts.) What is the temperature of the radiation in the box when helium formed?
- c. The box expands with the universe. (3 pts.) Draw its contents at the present time. Assume the box is not from some special place such as in a star, or in a galaxy.
- d. (3 pts.) How big is the box now?
- e. (0 pts.) What are the main ideas of this question? (There are main ideas about the formation of helium and about the expansion of the universe.)