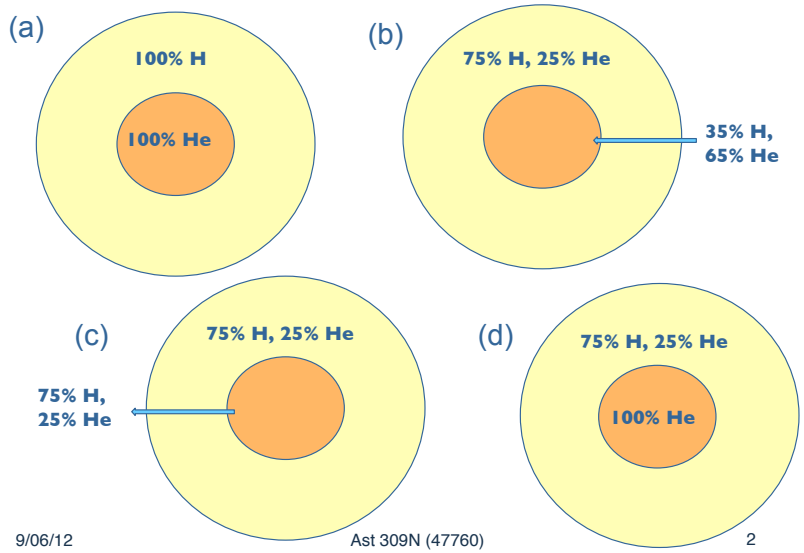
Index Card, Sep. 4

Organize into groups of 2 – 4 students. Write all names and EIDs at the top of the card. Have *one person* write the answers neatly and legibly!

We show below four possible arrangements of the elements H and He in the inner (core) and outer region of the Sun. Which diagram best represents:

1.the Sun when it first formed (before any H fusion reactions had taken place)
2.the Sun as it will be when the H is all used up and fusion has stopped occurring in its core
3. the Sun as it is today

State your choices, and briefly, your reasoning.



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Sun's life stage	(a)	(b)	(c)	(d)
newly formed	34%	10%	**49%**	7%
old Sun (end Main Sequence)	21%	15%	2%	**62%**
present-day Sun	2%	**46%**	44%	8%

Correct answer is in black, bold-face font.

How did the Sun reach its present state?

- The Sun began as a cloud of gas, contracting under gravity. It had the same composition throughout, a mixture of approximately 75% H, 25% He by mass.
- The contraction released energy that was ultimately converted to thermal energy, heating the central regions.
- When the center became hot and dense enough, H began fusing into He, supplying a new energy source. This fuel will last until all the H is converted into He, *in the core, the region that's hot enough for fusion*.
- This energy kept up the outward pressure to balance gravity's inward force, so the Sun achieved a long-term balance, with its present radius and luminosity.

Correct Explanations

- 1.(c) The newborn Sun: “75% H, 25% He from the early universe is what we would find in the Sun when it formed… the initial makeup of stars is 75% H, 25% He throughout.”
- 2.(d) “After all the hydrogen in the core has fused into helium, the core will be 100% He. However, hydrogen will still remain outside the core” [where no fusion occurred].
- 3.(b) “The Sun is about halfway through its life cycle, so halfway through the conversion (fusion) of H into He, so about half the initial H in the core has been used up.”

Misimpressions

- That H and He were spatially separated (in different layers) when the Sun formed – choice (a). The initial Sun had uniform composition. “Uniform” means *the same proportions* everywhere, 75/25 %, not “pure” regions composed of a single element. The He does not sink to the middle (see next point).
- That He created by fusion in the core will “rise to the surface,” increasing the proportion of He at the surface. In the Sun (and most stars), what’s made in the core **stays** in the core! There is a thick radiative zone between the core and the region where convection occurs. Unless there is a convective region, different layers don’t mix.

Confusions and Guesses

- 1(a). “He is denser, it would be in the center, and no reactions had taken place.” If the Sun started with arrangement (a), no reactions **would *ever*** take place! That’s because only the core is hot enough for H fusion, and the core is entirely He, in this scenario.
- Several groups chose (d) for the end of the Sun’s life, “because there’s no H left in the core.” But this argument applies equally to choice (a); indeed, a number of groups gave this reason for choosing option (a)!
- Some students seemed to think that H is converted to He at the surface. No, only the core is hot enough for fusion. (See next slide.)

Why Fusion Happens Only in the Core

- Both nuclei have positive charge, so they repel each other.
- For fusion to occur, the nuclei must have enough kinetic energy to overcome this repulsion
- High kinetic energy means high temperature (and pressure)
- When the nuclei get close enough, the strong nuclear force overcomes the repulsion and fuses the nuclei together