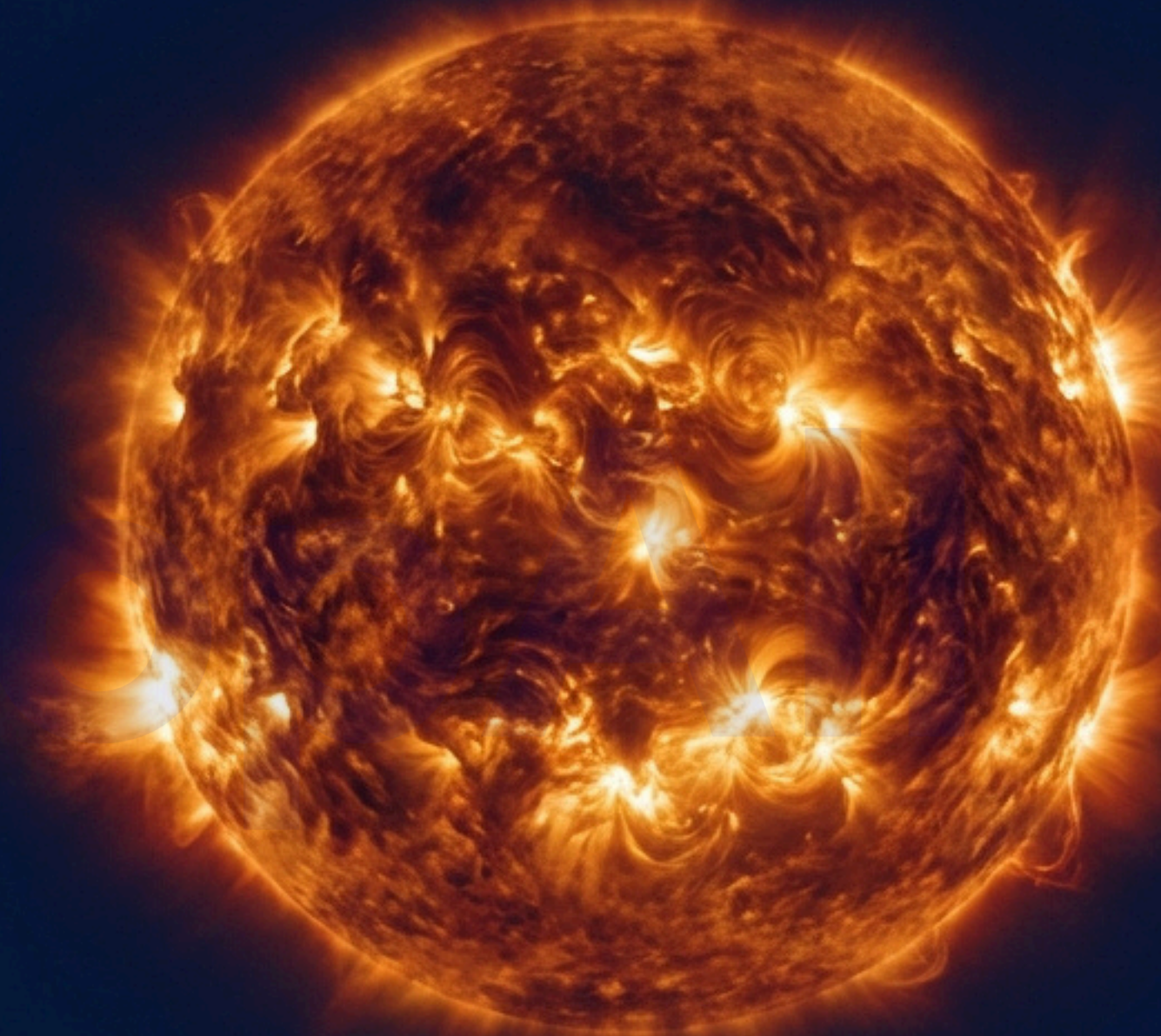


How the Sun Makes Its Energy

The Physics of Nuclear Fusion and Stellar Power

At the heart of our solar system lies a massive thermonuclear reactor. Understanding how stars generate their immense power requires looking at the smallest building blocks of matter: the nucleus.



What Fusion Means



The Principle

When two light nuclei fuse to form a larger nucleus, pure energy is released.

The Physics

The fused, larger nucleus is more tightly bound. Less total mass is required to hold the system together, creating a mass defect.

The Catalyst

Requires immense kinetic energy to overcome the repulsive Coulomb barrier between positively charged particles.

Three Example Fusion Reactions

	Reactants	Products	Energy Yield
Eq. 13.13(a)	$[1\text{H}] + [1\text{H}]$	$[2\text{H}] + e^+ + \nu$	0.42 MeV
Eq. 13.13(b)	$[2\text{H}] + [2\text{H}]$	$[3\text{He}] + n$	3.27 MeV
Eq. 13.13(c)	$[2\text{H}] + [2\text{H}]$	$[3\text{H}] + [1\text{H}]$	4.03 MeV



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$$E=mc^2$$



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Key Highlights

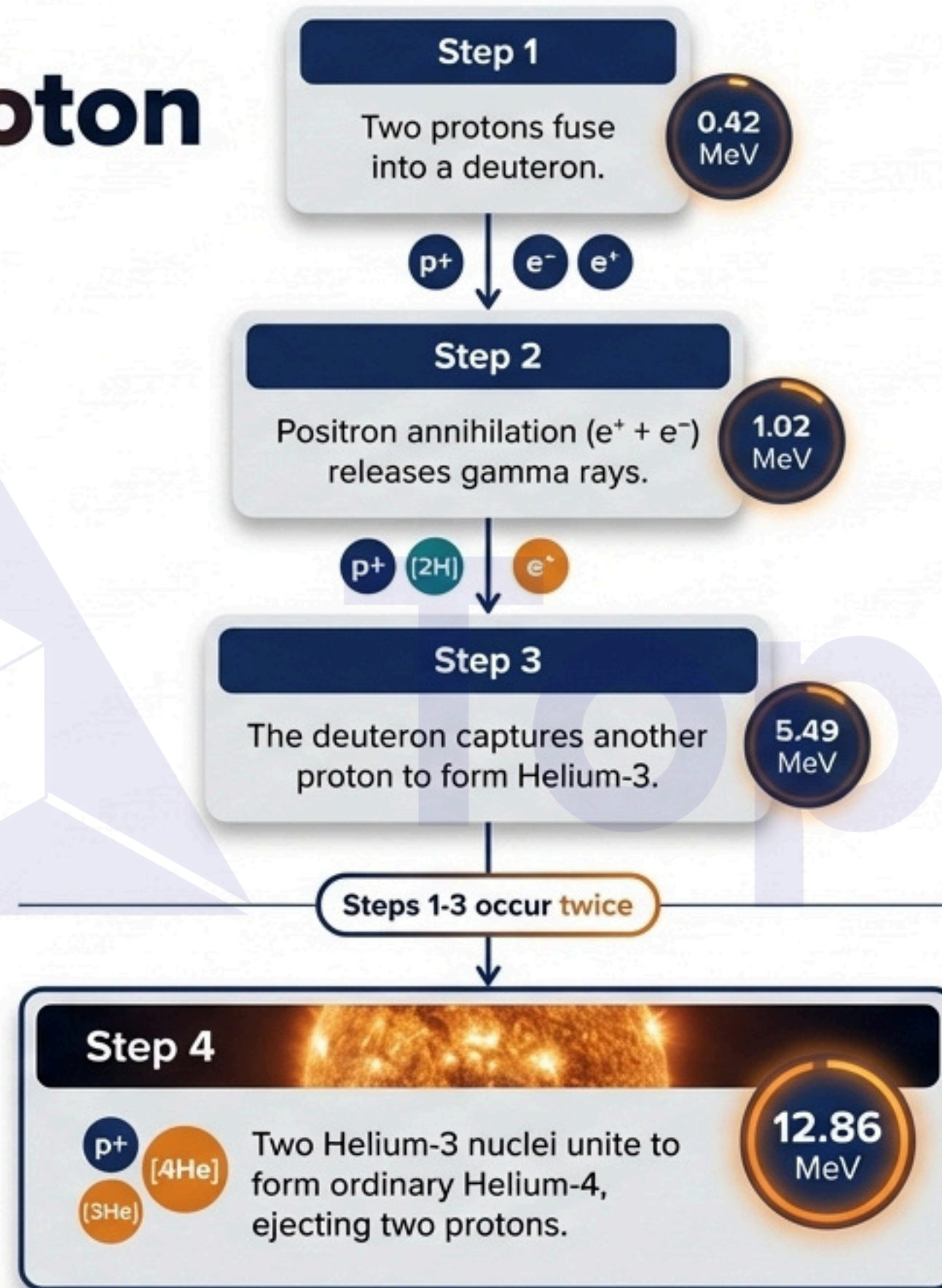
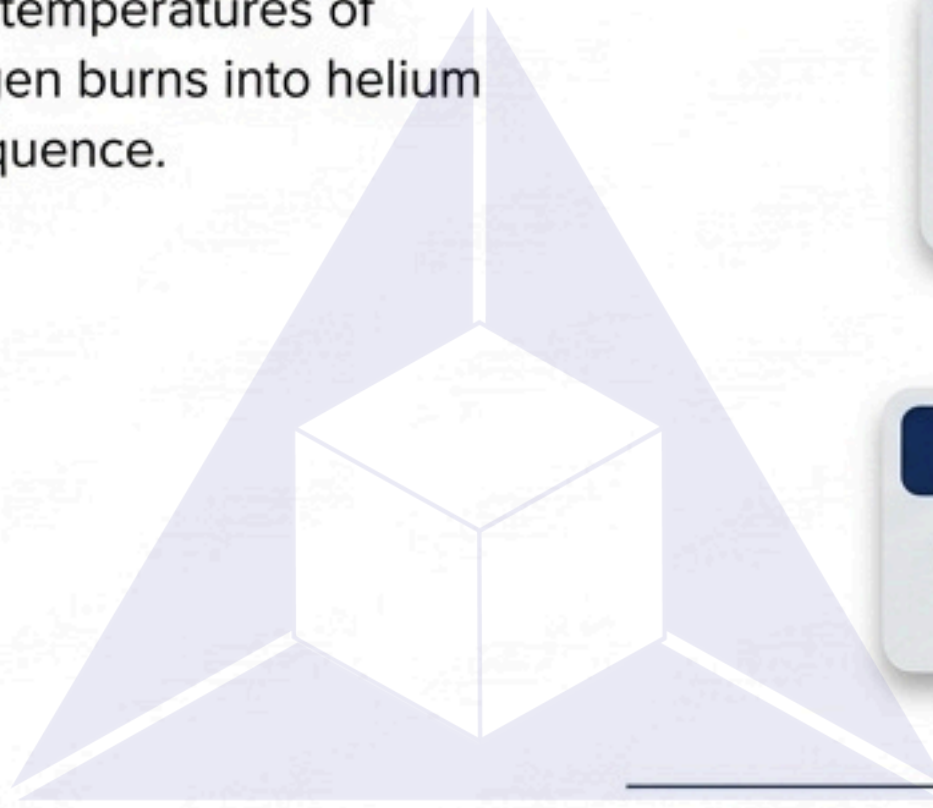
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THE OVEN CONDITIONS

The Proton-Proton Fusion Chain

Driven by interior temperatures of 1.5×10^7 K, hydrogen burns into helium in a multi-step sequence.



The Net Reaction: Equation (13.15)



Four hydrogen atoms combine to form a Helium-4 atom.

Total Energy Released: 26.7 MeV

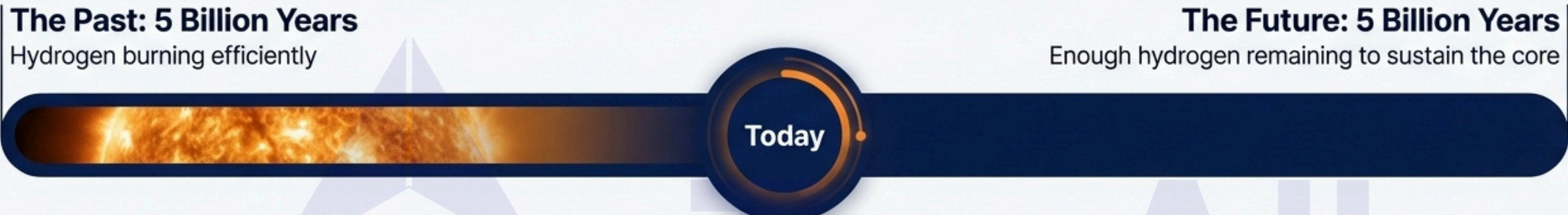
Why Stars Keep Shining

The Past: 5 Billion Years

Hydrogen burning efficiently

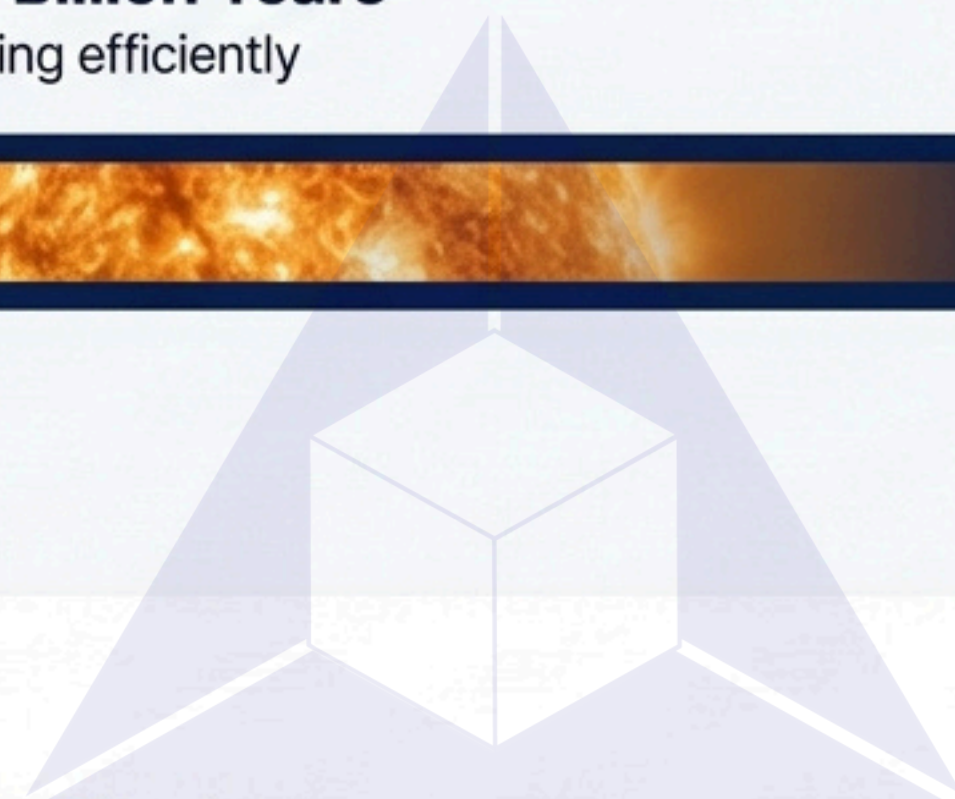
The Future: 5 Billion Years

Enough hydrogen remaining to sustain the core



The diagram shows a horizontal timeline bar. The left portion is filled with a fiery orange and yellow texture, representing the past 5 billion years. The right portion is a solid dark blue, representing the future 5 billion years. A circular marker with an orange ring and a white dot is positioned at the center of the bar, labeled 'Today'.

Today



The Core Fuel

The fuel in the sun is the hydrogen in its core. It has been steadily burning into helium for 5 billion years, establishing a stable energy output.

What happens when the fuel runs out?

Once hydrogen is depleted, the core cools and collapses under gravity. This collapse radically raises the temperature, expanding the Sun's outer envelope until it turns into a Red Giant.

Key Takeaways

- ✓ **The Source:** The Sun generates energy through thermonuclear fusion—combining light nuclei into heavier ones.
- ✓ **The Physics:** Heavier nuclei (like Helium) are more tightly bound. The resulting mass defect is converted into pure energy ($E = mc^2$).
- ✓ **The Chain:** The Proton-Proton cycle overcomes the Coulomb barrier at high temperatures to burn hydrogen into helium.
- ✓ **The Net Result:** 4 Protons combine to form 1 Helium atom, releasing exactly 26.7 MeV of energy.
- ✓ **The Timeline:** Our Sun possesses enough hydrogen fuel in its core to continue shining for another 5 billion years.



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