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The Power of the Stars How Nuclear Fusion Could Power the Future

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THE POWER OF THE STARS

How Nuclear Fusion Could Power the Future

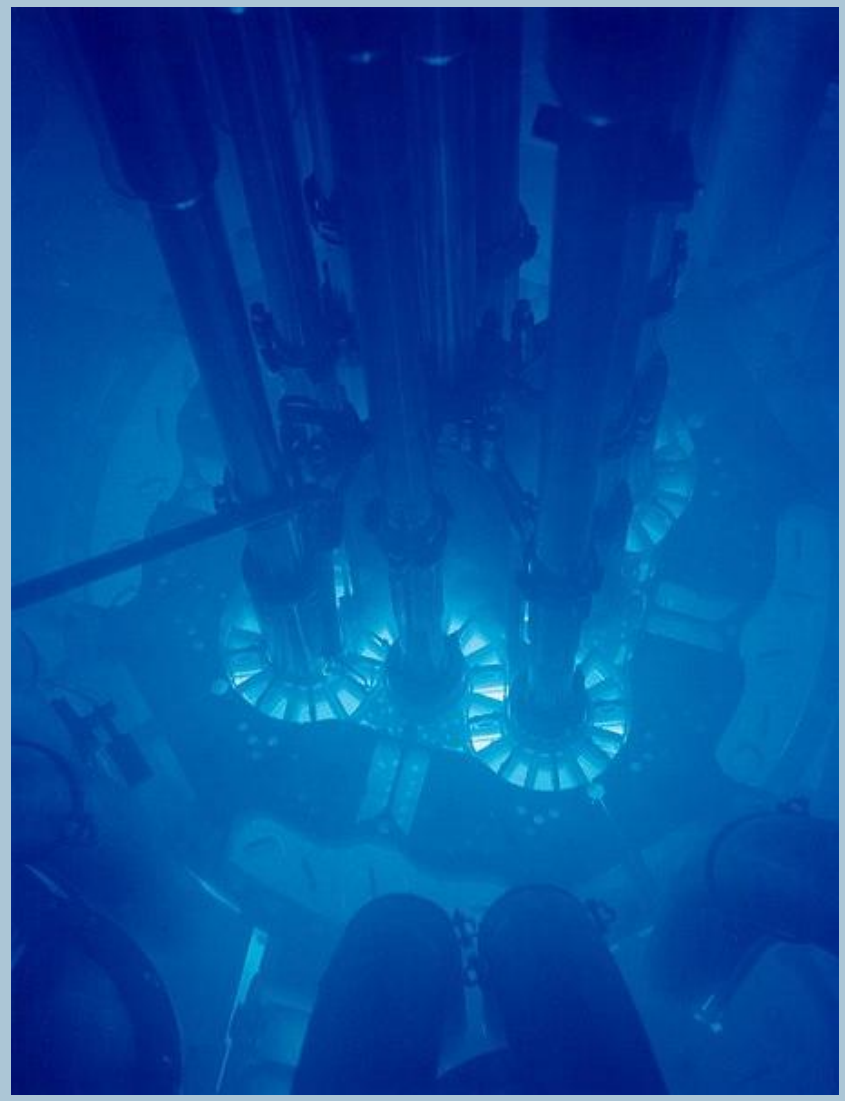
Fossil Fuels

Image Credit:http://wal-lab.com/petroleum/

The Energy Crisis

Alternative Energy?

Nuclear Fission – A Temporary Solution



Advanced Test Reactor Core – Argonne National Laboratory

Image credit: https://www.flickr.com/photos/35734278@N05/3954062594/

Nuclei and Isotopes

Nucleus – The internal core of an atom, composed of protons and neutrons, orbited by electrons

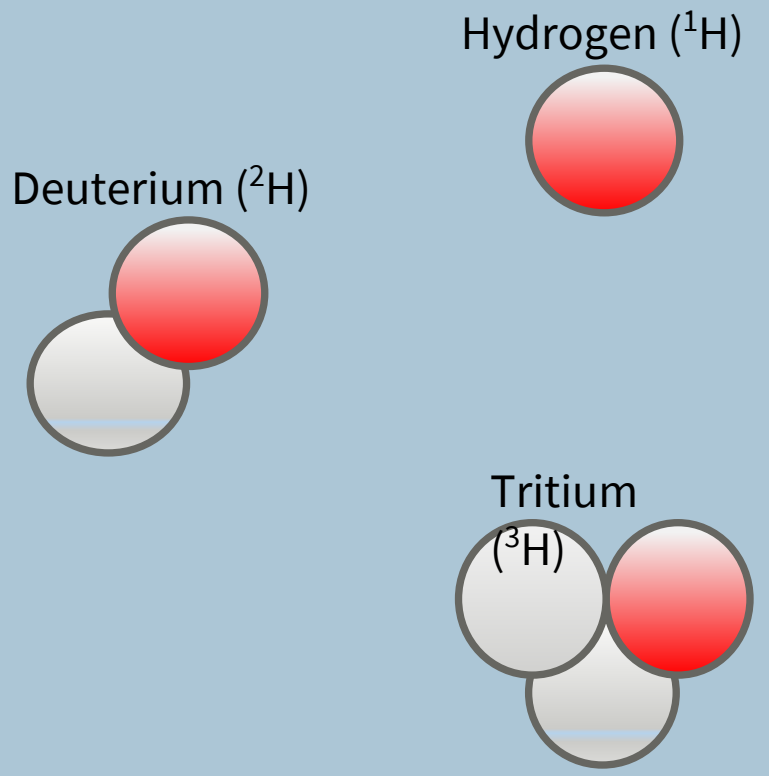
Isotope – A variation of a nucleus with a different number of neutrons.

Differentiated by a specific number.

Usually have identical chemical properties

The “atomic mass” of an element is the average of its isotopic masses.

Example Isotopes: Hydrogen

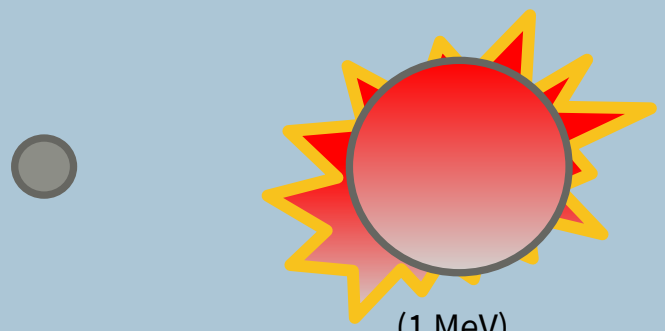


Fission Reactions

Certain heavy isotopes (i.e. ^{235}U) break apart when destabilized by an incoming projectile (a neutron)

The nucleus splits into fission products, and releases excess nuclear binding energy.

Some fission processes, such as ^{235}U, emit additional neutrons. This can be used to create a self-sustaining chain reaction.



Problems with Fission Energy

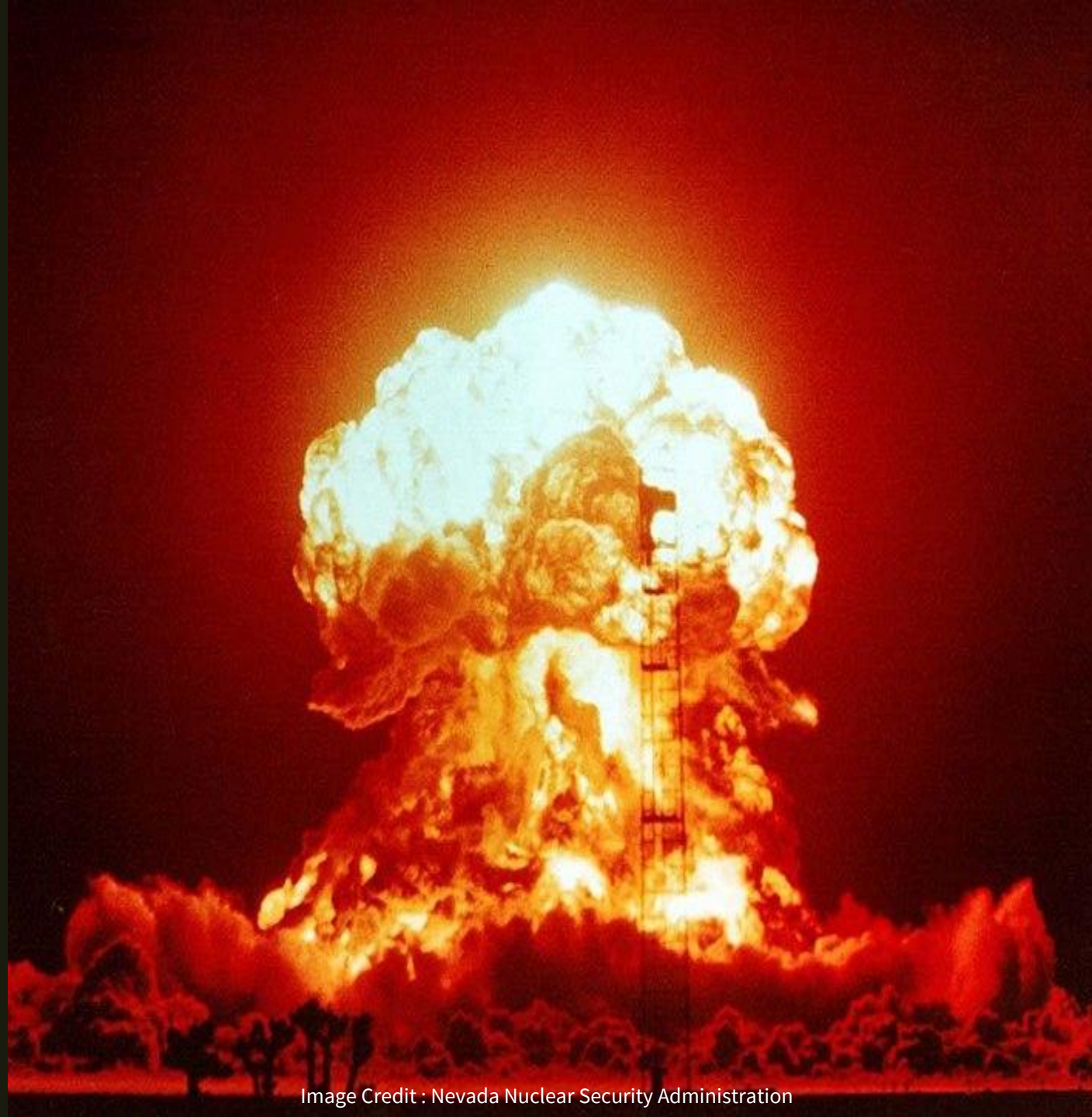


Image Credit : Nevada Nuclear Security Administration

The Solution: Fusion Power

MAST Tokamak Core (timelapse)

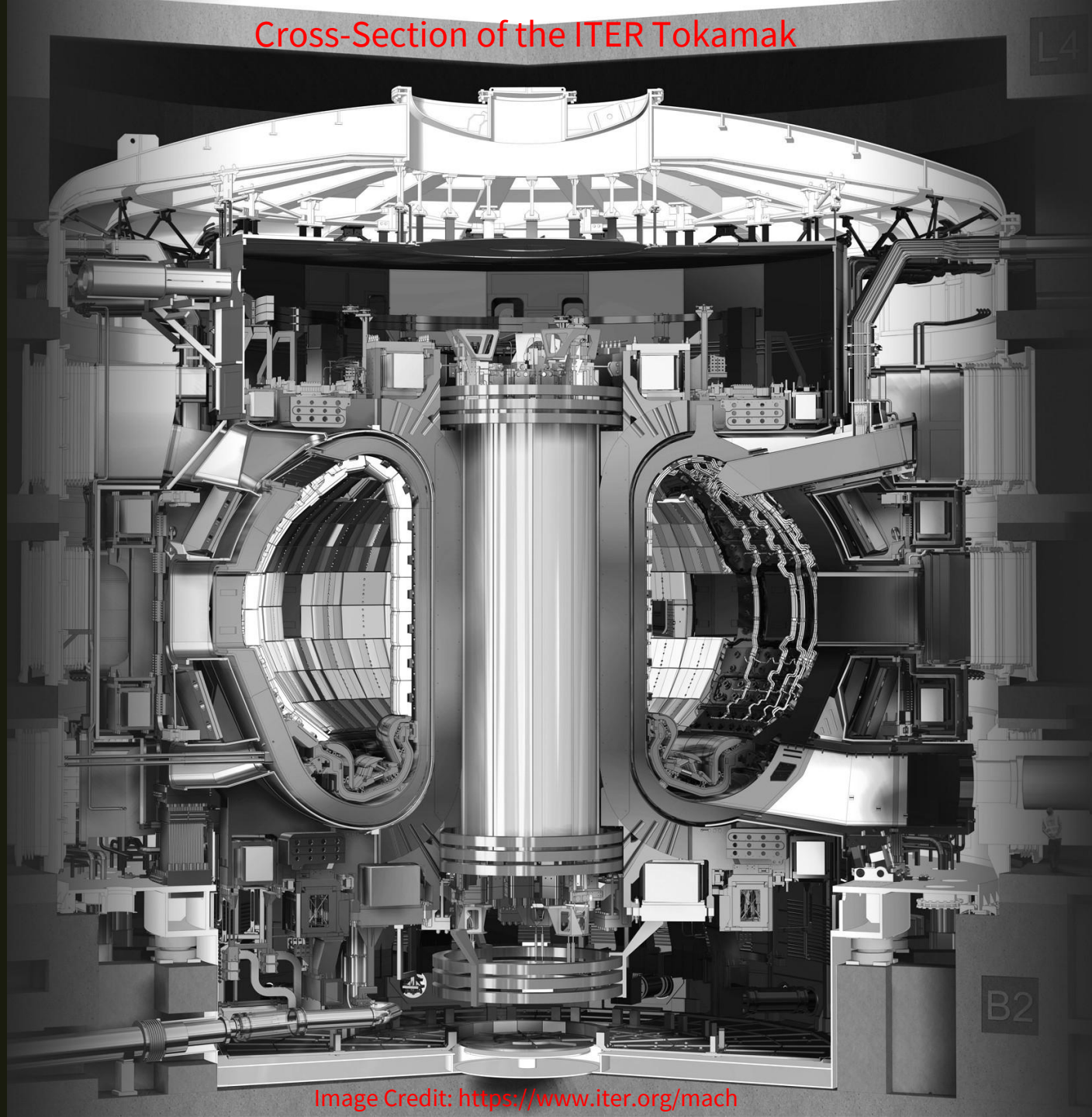
Image Credit: Culham Centre for Fusion Energy

The Tokamak

Model Tokamak: The ITER

International **E**xperimental

Thermonuclear **R**eactor



FUSION FUELS

Power versus Efficiency

Characteristics of Good Fusion Fuels

Extracting Energy

$$
\begin{aligned}
\mathrm{D} + \mathrm{D} &\xrightarrow{50\%} \mathrm{T}(1.01\,\mathrm{MeV}) + \mathrm{p}(3.02\,\mathrm{MeV}) \\
&\xrightarrow{50\%} \mathrm{He}^3(0.82\,\mathrm{MeV}) + \mathrm{n}(2.45\,\mathrm{MeV}) \\
\mathrm{D} + \mathrm{T} &\longrightarrow \mathrm{He}^4(3.5\,\mathrm{MeV}) + \mathrm{n}(14.1\,\mathrm{MeV}) \\
\mathrm{D} + \mathrm{He}^3 &\longrightarrow \mathrm{He}^4(3.6\,\mathrm{MeV}) + \mathrm{p}(14.7\,\mathrm{MeV}) \\
\mathrm{T} + \mathrm{T} &\longrightarrow \mathrm{He}^4 + 2\mathrm{n} + 11.3\,\mathrm{MeV} \\
\mathrm{He}^3 + \mathrm{T} &\xrightarrow{51\%} \mathrm{He}^4 + \mathrm{p} + \mathrm{n} + 12.1\,\mathrm{MeV} \\
&\xrightarrow{43\%} \mathrm{He}^4(4.8\,\mathrm{MeV}) + \mathrm{D}(9.5\,\mathrm{MeV}) \\
&\xrightarrow{6\%} \mathrm{He}^5(2.4\,\mathrm{MeV}) + \mathrm{p}(11.9\,\mathrm{MeV}) \\
\mathrm{p} + \mathrm{Li}^6 &\longrightarrow \mathrm{He}^4(1.7\,\mathrm{MeV}) + \mathrm{He}^3(2.3\,\mathrm{MeV}) \\
\mathrm{p} + \mathrm{Li}^7 &\xrightarrow{20\%} 2\ \mathrm{He}^4 + 17.3\,\mathrm{MeV} \\
&\xrightarrow{80\%} \mathrm{Be}^7 + \mathrm{n} - 1.6\,\mathrm{MeV} \\
\mathrm{D} + \mathrm{Li}^6 &\longrightarrow 2\mathrm{He}^4 + 22.4\,\mathrm{MeV} \\
\mathrm{p} + \mathrm{B}^{11} &\longrightarrow 3\ \mathrm{He}^4 + 8.7\,\mathrm{MeV} \\
\mathrm{n} + \mathrm{Li}^6 &\longrightarrow \mathrm{He}^4(2.1\,\mathrm{MeV}) + \mathrm{T}(2.7\,\mathrm{MeV})
\end{aligned}
$$

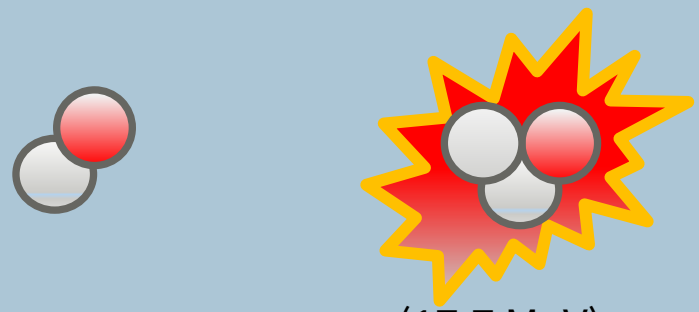
Hydrogen Isotopes:

The D-T Fusion Reaction

Deuterium and Tritium collide and fuse to produce ^{4}He and eject a neutron.

The majority of the reaction's energy (roughly 14 MeV) manifests as the kinetic energy of the neutron.

This energy is converted to a usable form with "neutron blankets" containing ^{9}Be and Li metal.



(17.7 MeV)

The Benefits of D-T Fuel

Issues with D-T Fuel

:ards,

An Alternative?

Producing Helium

An Alternative Source of Helium-3

of

Benefits of ^{3}He

tron

…and the Disadvantages

Final Thoughts

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