Nuclear Fusion
Nuclear Fission vs. Nuclear Fusion
Coulombic force vs Strong nuclear force
<table>
<thead>
<tr>
<th></th>
<th>Reaction</th>
<th>Products</th>
<th>Energies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>D + T</td>
<td>^4He + n</td>
<td>3.5 MeV + 14.1 MeV</td>
</tr>
<tr>
<td>2.</td>
<td>D + D</td>
<td>T + p</td>
<td>1.01 MeV + 3.02 MeV (50%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>^3He + n</td>
<td>0.82 MeV + 2.45 MeV (50%)</td>
</tr>
<tr>
<td>3.</td>
<td>D + ^3He</td>
<td>^4He + p</td>
<td>3.6 MeV + 14.7 MeV</td>
</tr>
<tr>
<td>4.</td>
<td>T + T</td>
<td>^4He + 2n + 11.3 MeV</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>^3He + ^3He</td>
<td>^4He + 2p</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>^3He + T</td>
<td>^4He + p + n + 12.1 MeV (51%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>^4He + D + 9.5 MeV (43%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>^4He + n + 0.5 MeV + p + 11.9 MeV (6%)</td>
</tr>
<tr>
<td>7.</td>
<td>D + ^6Li</td>
<td>2 ^4He</td>
<td>22.4 MeV</td>
</tr>
<tr>
<td>8.</td>
<td>p + ^6Li</td>
<td>^4He + ^3He</td>
<td>1.7 MeV + 2.3 MeV</td>
</tr>
<tr>
<td>9.</td>
<td>^3He + ^6Li</td>
<td>2 ^4He + p</td>
<td>16.9 MeV</td>
</tr>
<tr>
<td>10.</td>
<td>p + ^11B</td>
<td>3 ^4He</td>
<td>8.7 MeV</td>
</tr>
</tbody>
</table>
Advantages over Fission

• Readily available fuels which are not radioactive
• Virtually no radioactive waste
• No chance of meltdown
• Fuels and products cannot easily be used to produce weapons
Challenges: Neutrons

The D-T fusion reaction produces a neutron with 14.1 MeV of kinetic energy as compared to 2 MeV neutrons produced in an average fission reaction.

Types of Neutron Radiation Damage

- Microscopic:
  - Changes in the lattice organization of the material (displaces atoms, creates interstitials)
  - Excitation of atoms, heating
  - Activation - can induce radioactivity in materials

Source: "Neutron Radiation"

Examples of Defects in Lattice Structure
Challenges: Extreme temperatures
Challenges: Q values

\[ Q = \frac{Fusion\ energy}{Energy\ required\ to\ maintain\ fusion} \]

Almost all current reactor designs have a Q value of less than 1, meaning they require more energy to maintain fusion than they produce.
Inertial Confinement
Uses powerful lasers

1. 
2. 
3. 
4. 

This laser bank at the National Ignition Facility in California can produce a laser shot that delivers **500 TW** of power.
Thermonuclear (controlled)

Uses strong magnetic fields to contain super hot plasma and squeeze it into fusible densities.
(uncontrolled)

- Uses a fission reaction to quickly compress and fuse a fusion fuel
- Relatively easy to construct
- Large output power compared to input (huge Q)
- One drawback...
Enough energy to run the entire US for \( \frac{3}{4} \) of a day was released in a fraction of a second.

\[
57 \times 10^6 \text{ tons TNT} \times 1.17 \times 10^3 \frac{\text{kWh}}{\text{ton TNT}} = 5.8 \times 10^{10} \text{kWh}
\]