New Nuclear—The Promise of Fusion

Miles Turner

National Centre for Plasma Science and Technology

Dublin City University

Negotiating New Sciences in Society

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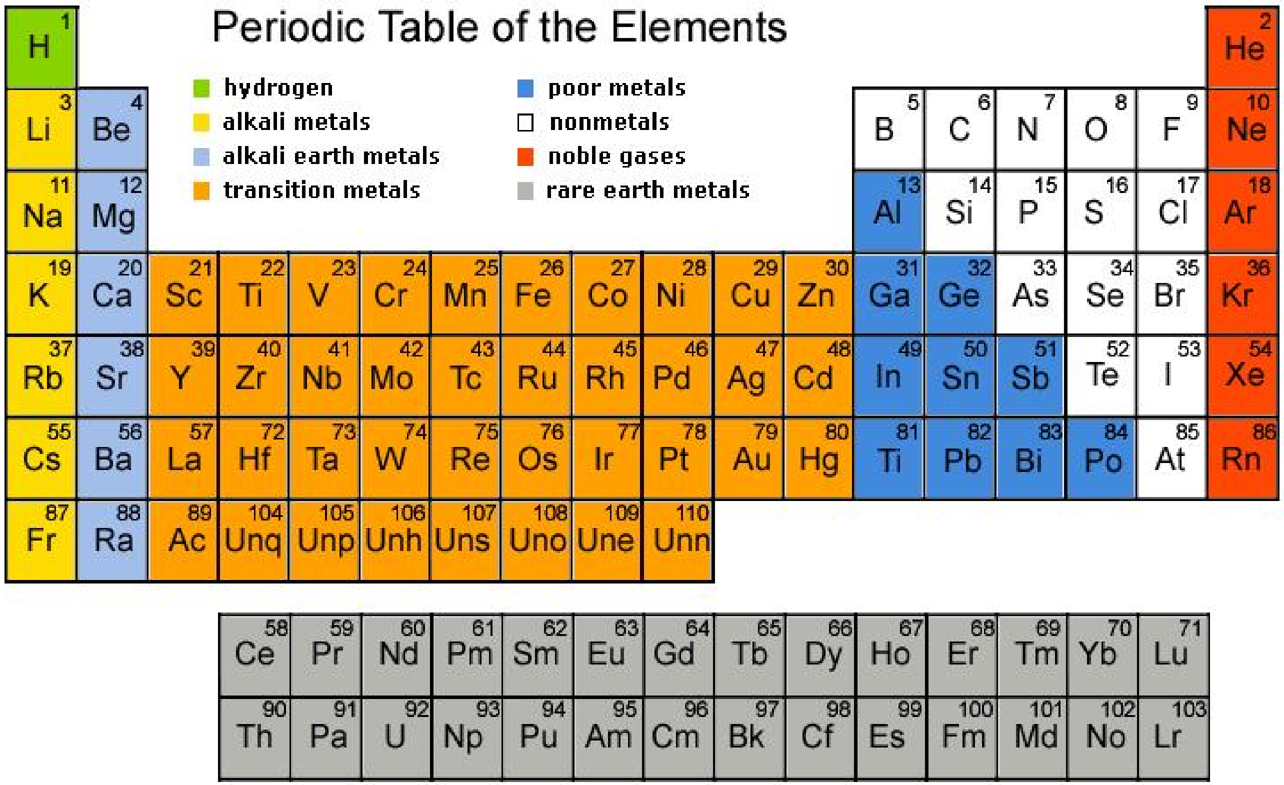
Agenda

- What is nuclear fusion?
- Why is nuclear fusion a desirable energy source?
- Why don't we use fusion energy today?
- When will we be able to produce energy from fusion?

Nuclear Energy



- The most stable elements are in mid-table (Iron)

- More stable = Less energy

- Therefore, energy can be released in two ways:

  1. Combining light nucleii to make heavier ones (fusion)

  $$ {}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + e^{+} + \nu_e + 0.42\ \mathrm{MeV} $$

  2. Splitting heavy nucleii to make lighter ones (fission)

  $$ n + {}^{235}_{92}\mathrm{U} \rightarrow {}^{89}_{36}\mathrm{Kr} + {}^{144}_{56}\mathrm{Ba} + 3n + 177\ \mathrm{MeV} $$

Promise of Fusion Energy

- Fuel is abundant (water)
- Waste products are harmless
- Dangerous accidents are unlikely
- Practically unlimited scaling

Practice

- The only practical reaction is:

$$^2_1\text{D} + ^3_1\text{T} \rightarrow ^2_2\text{He} + n + 18\ \text{MeV}$$

  with the auxiliary process

$$n + ^6_3\text{Li} \rightarrow ^3_1\text{T} + ^2_2\text{He}$$

- So the fuels are Li and D

- But small amounts of T must be handled

- And neutrons are a problem

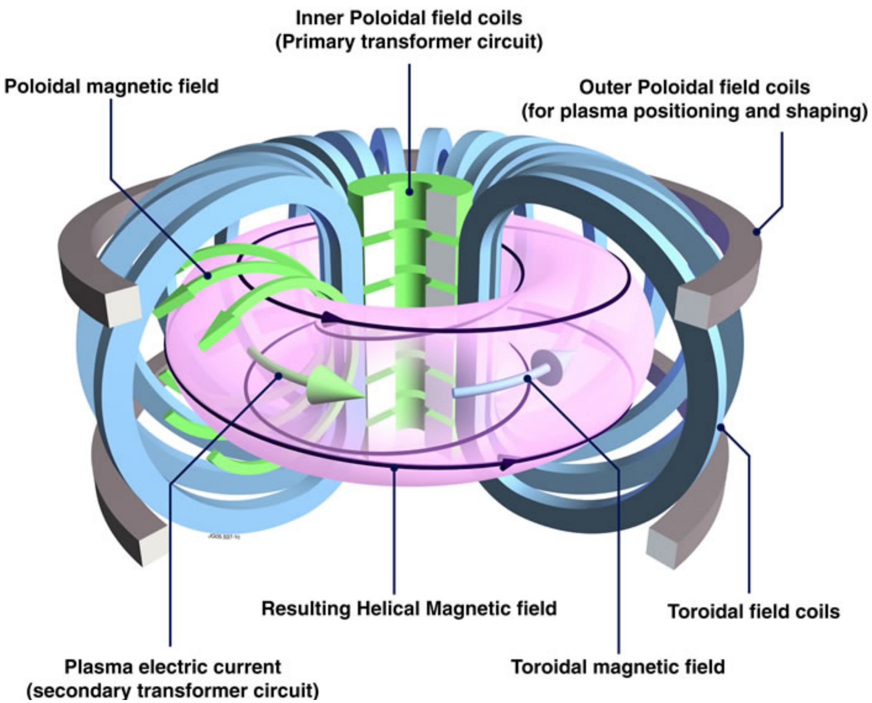
Problems

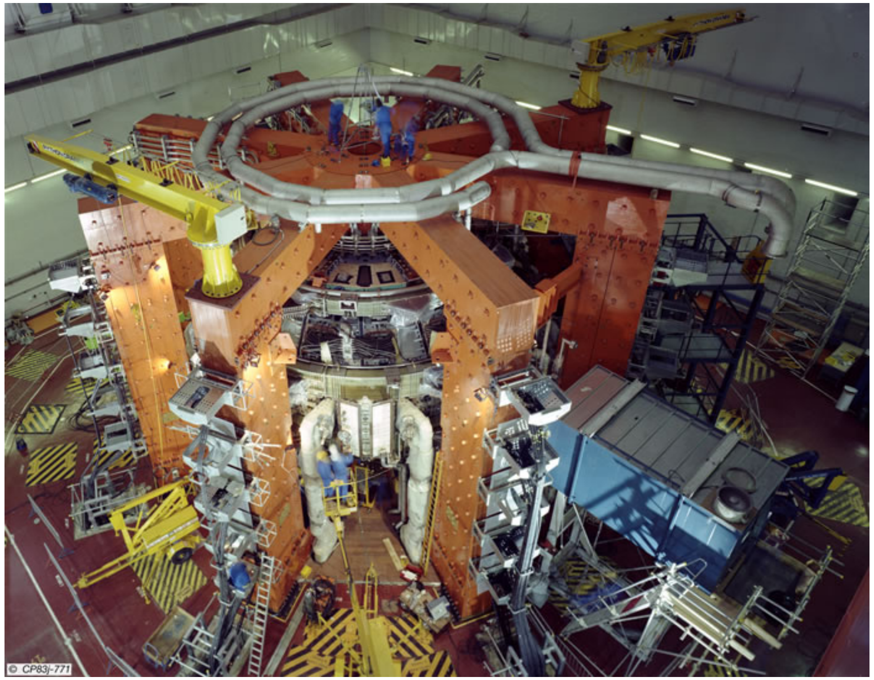
1. Producing the conditions for fusion (*e.g.* temperature of 10 000 000 K)

2. Tritium management (producing enough to sustain a closed cycle reactor, avoiding accumulation)

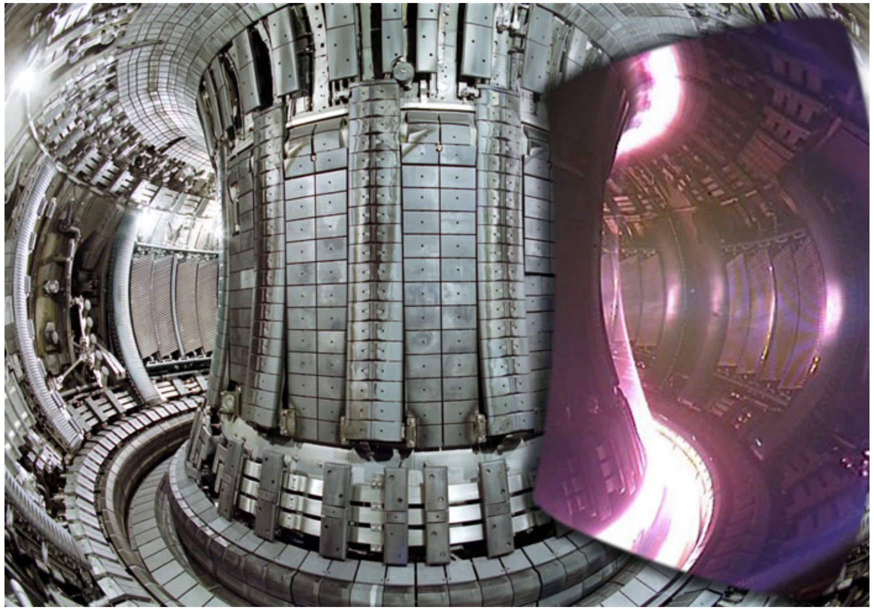
3. Avoiding reactor activation (by fast neutrons)

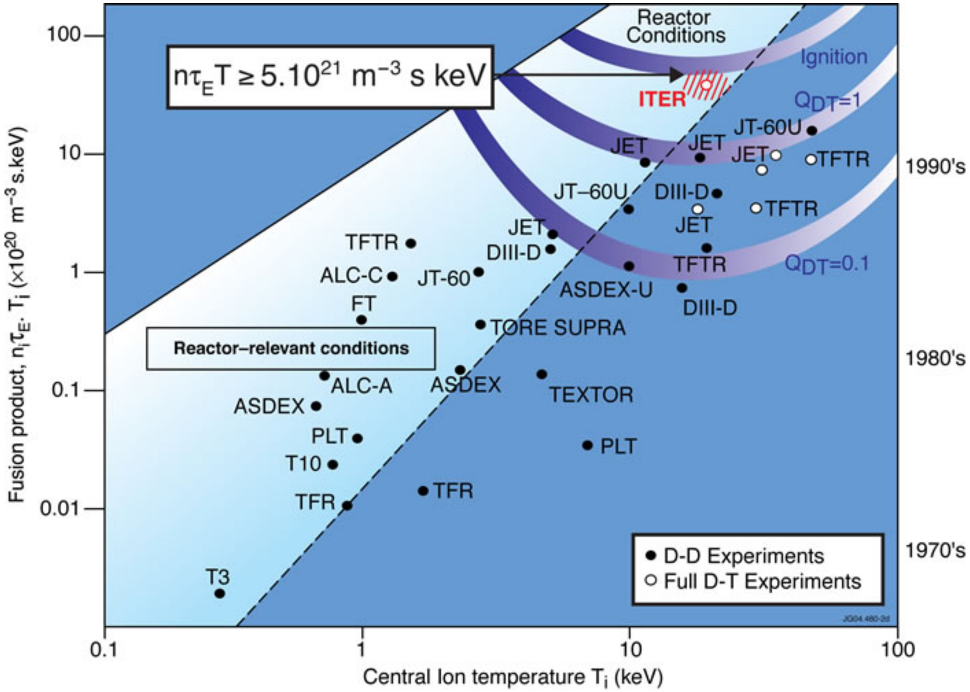
Present Status: Conditions for Fusion





Present Status: Conditions for Fusion





Present Status

- We know how to produce the conditions for fusion

  (Relatively modest extrapolation from JET)

- There is a clear concept for closed-cycle tritium management

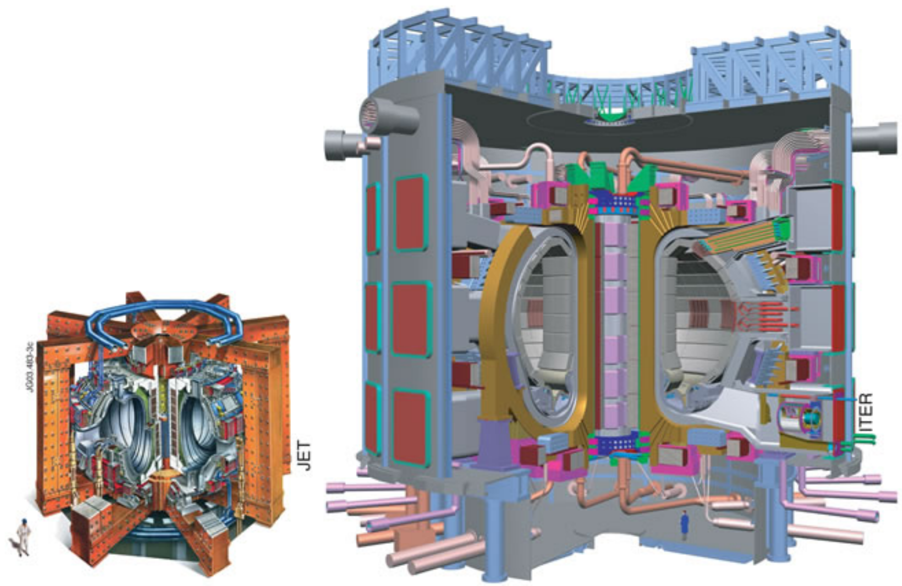
  (Based on experience with JET)

- Work has hardly started on the materials issues

  (No relevant experimental facilities)

What next? Iter

- International consortium
- Located in France
- Addressing:
  1. Conditions for fusion
  2. Tritium management
- Operating by 2018



Future Programme

- Iter experimental programme should conclude about 2030
- IFMIF (materials experiment) begins construction (in Japan) shortly
- Iter and IFMIF will inform DEMO (prototype commercial reactor)
- DEMO commissioned about 2040
- Large scale commercial exploitation thereafter

Conclusion

- Fusion energy has compelling advantages

- Technicalities are difficult, but probably surmountable

- Problems:

  1. Final cost is unknown

  2. May be too late (and is difficult to accelerate)

  3. Very complex programme