Neutron Moderation: From Quanta to Continuum

Iyad Al-Qasir
Nuclear Data Group

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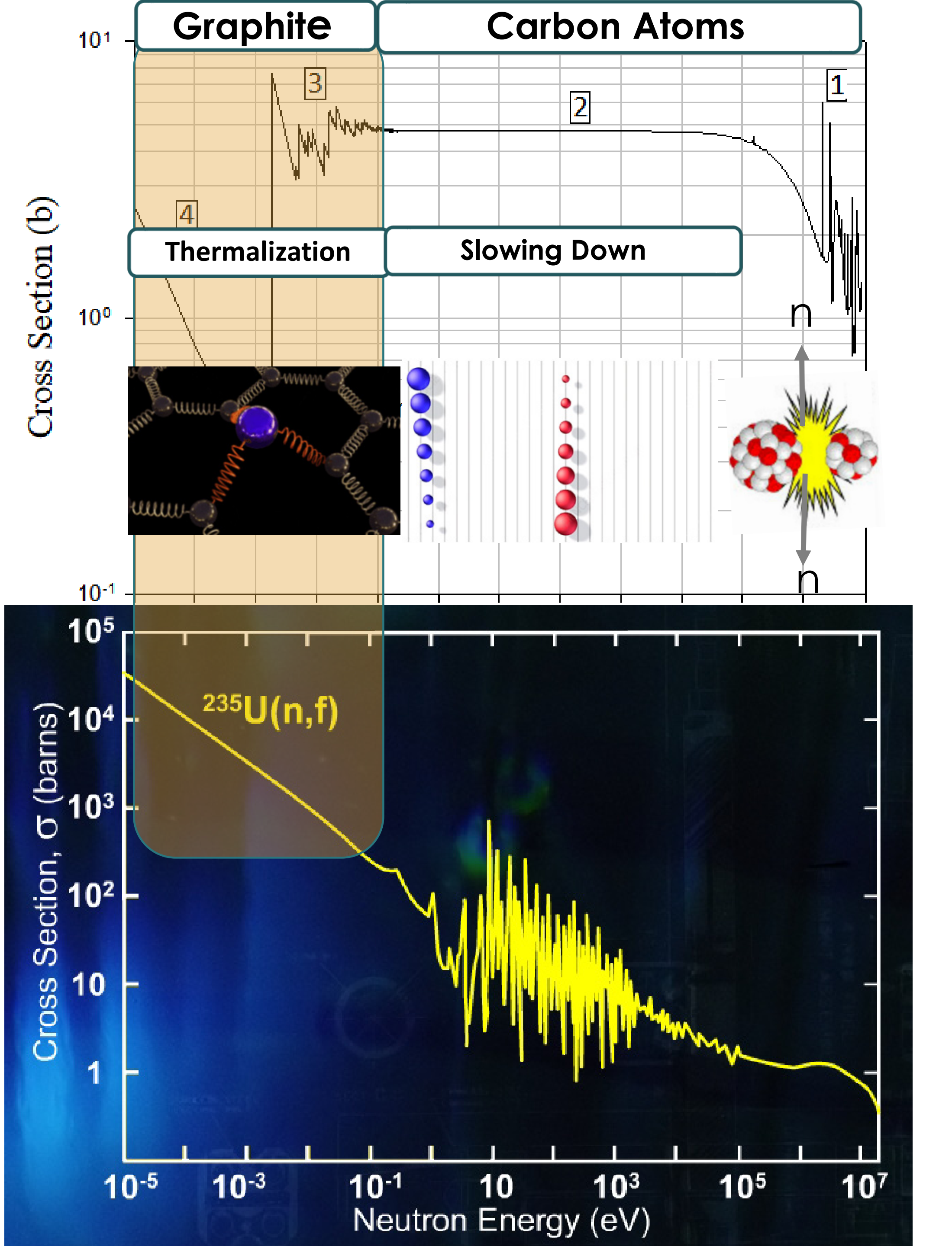
Neutron Moderation

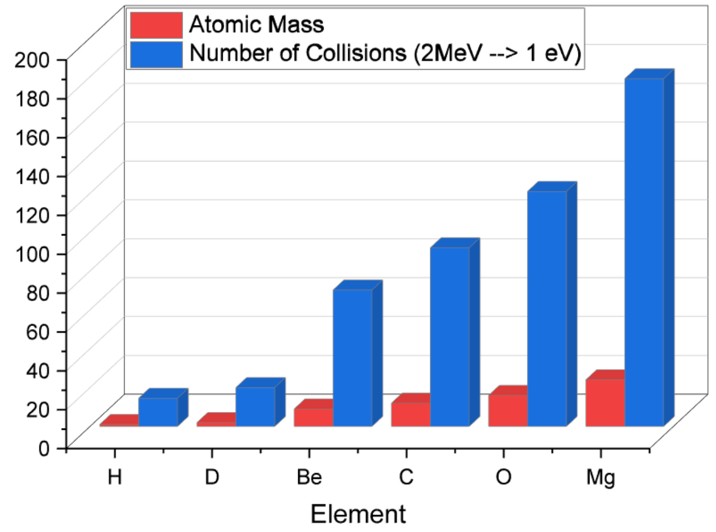
Property	Category
▪Low Atomic Mass Number ▪High scattering cross section ▪Low absorption cross section	Neutronic
▪High Thermal Conductivity	Thermal
▪High Strength	Mechanical
▪Good stability under irradiation	Radiation Eff.
▪High oxidation Resistivity	Chemical

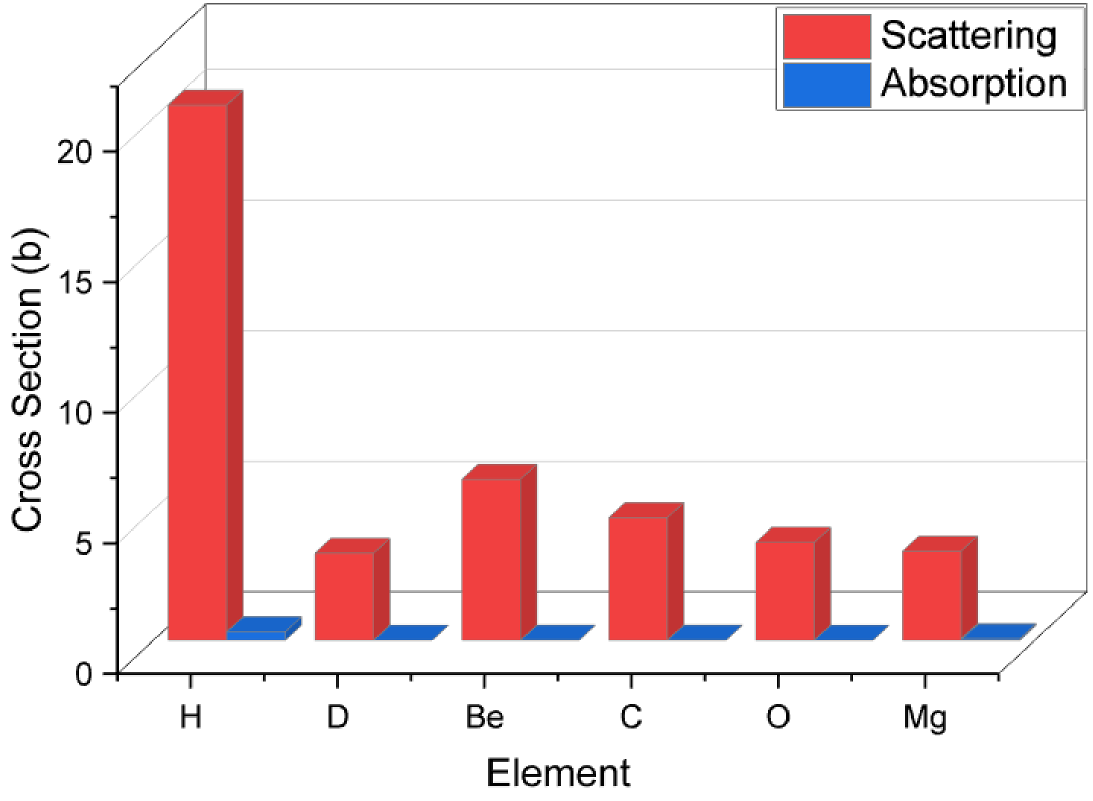


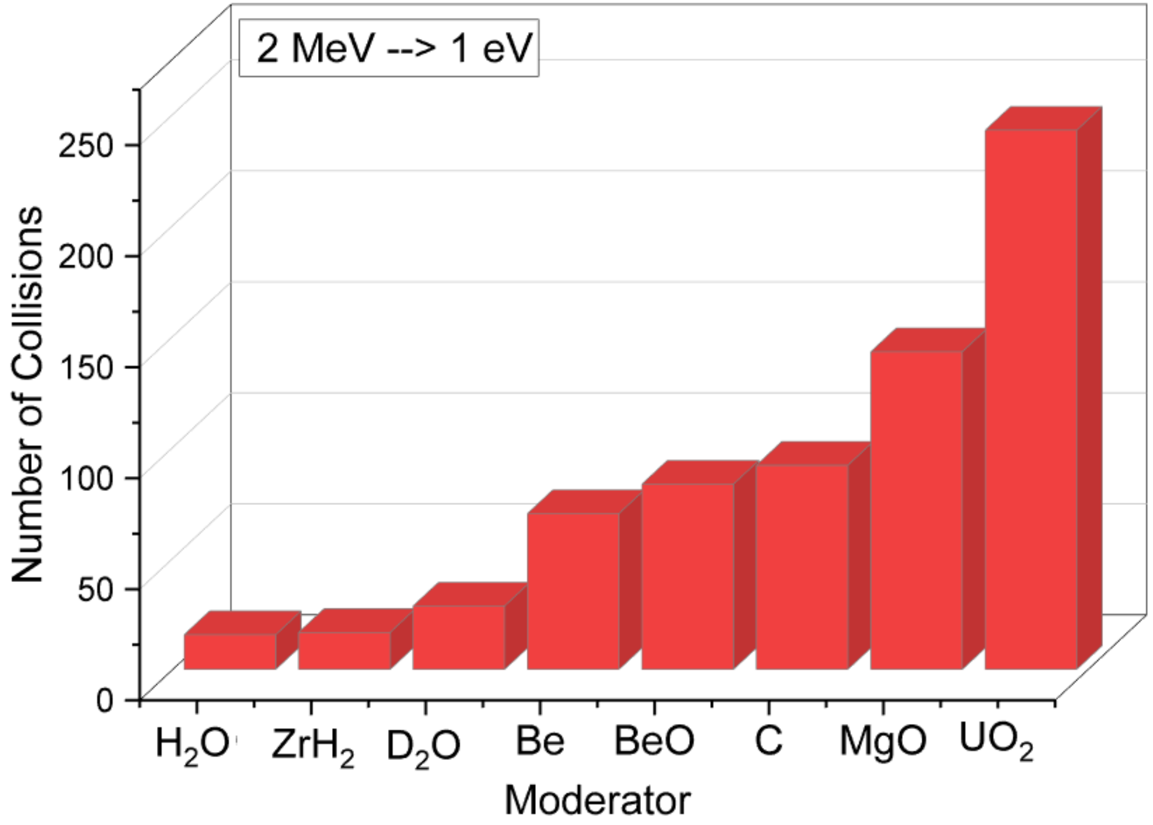
Neutron Moderation

- Low Atomic Mass Number
- High scattering cross section
- Low absorption cross section

Neutronic







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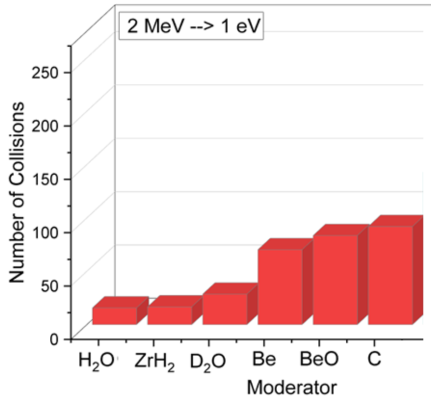
Neutron Moderation



- Historically, core moderator and reflector materials consist of relatively simple compounds of a simple material type or simple composition (e.g, H_2O, D_2O, Be, BeO, Graphite, ZrH_2).
- Recently, compact thermal fission reactors are of increased interest due to their potential to lower construction cost, enhance safety, and portability to remote areas.
- They are also considered as a point-source for process industrial heat
- The compact nature of these cores requires good neutron economy as well as preserving other thermal, mechanical, chemical properties, etc. How do we achieve this?

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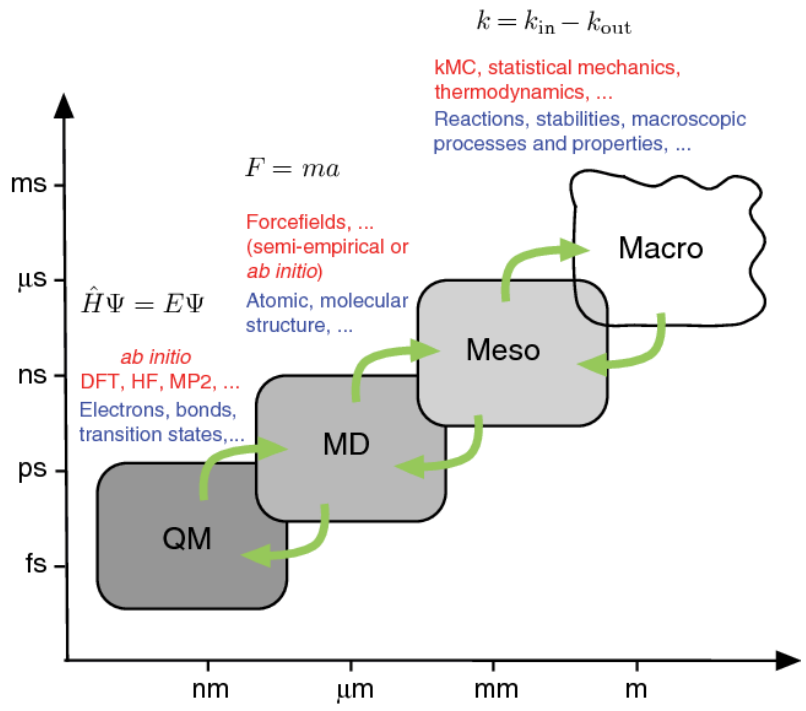
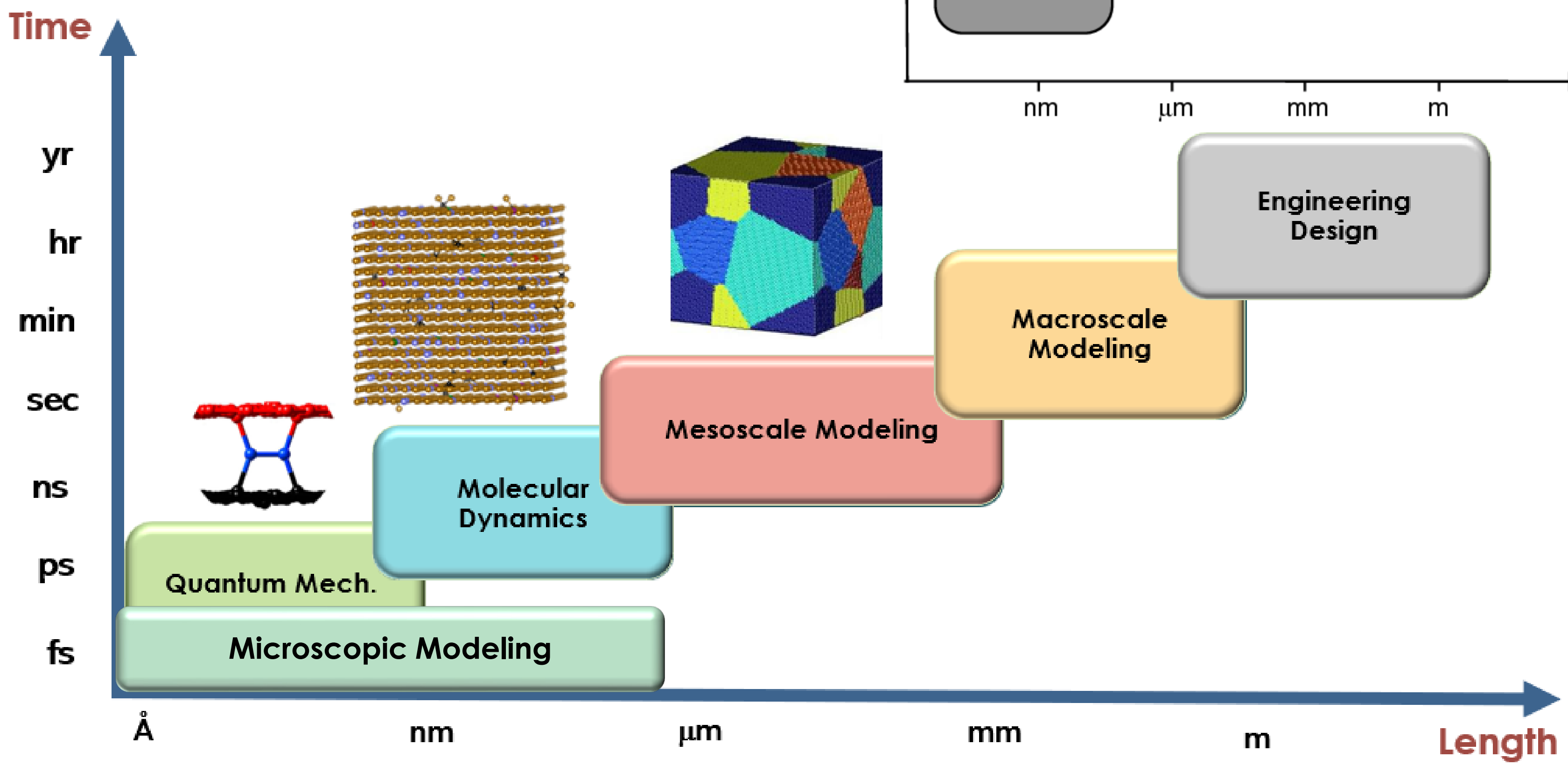
Multiscale Modeling

- **Hierarchical Understanding**
- **Predictive Capabilities**
- **Accelerated Development**





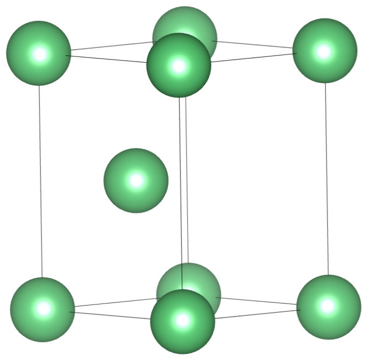
Moderators Doping

Isotope	Ab (%)	Scatt. XS	Abs. XS
^{9}Be	100	7.63	0.0076
^{11}B	80	5.77	0.0055
^{15}N	0.37	5.21	0.000024
^{88}Sr	82.58	6.42	0.058
Zr		6.46	0.185
^{94}Zr	17.28	8.4	0.0229

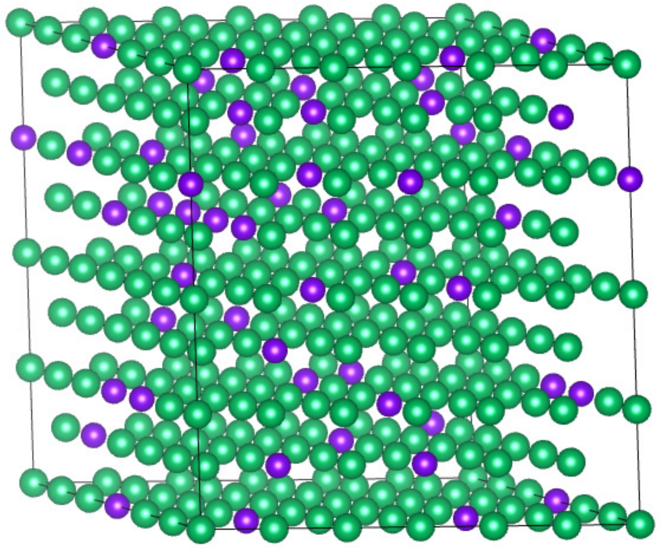
- Low Atomic Mass Number
- High scattering cross section
- Low absorption cross section

Neutronic

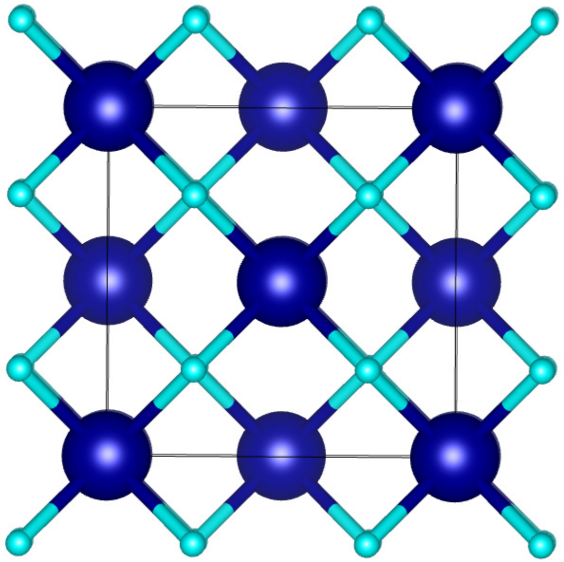
Be-Metal



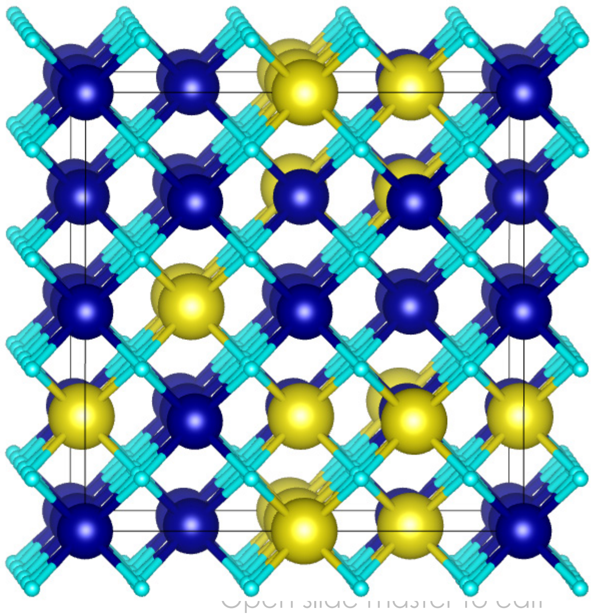
$Be_{1-x}{}^{15}N_x$



ZrH_2



$Zr_{1-x}Sr_xH_2$



Engineering Design/ Two Phase Composite Moderators

- Composite materials are formed by combining two or more materials that have quite different properties, and they do not dissolve or blend into each other
- The ultimate goal, is to arrive at a bulk material that is structurally and neutronically superior to traditional moderators (graphite, Be, BeO, etc.)
- Could be tailored to properties of interest such as thermal conductivity, strength, or fracture toughness

Snead et al., *J. Asian Ceram. Soc.* **10**, 9 (2022).

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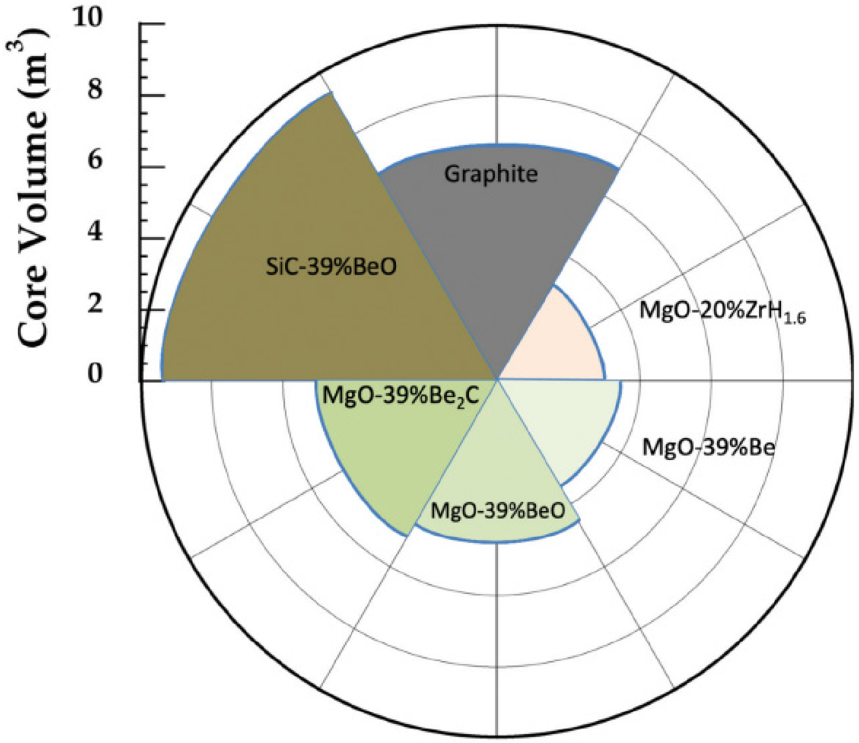
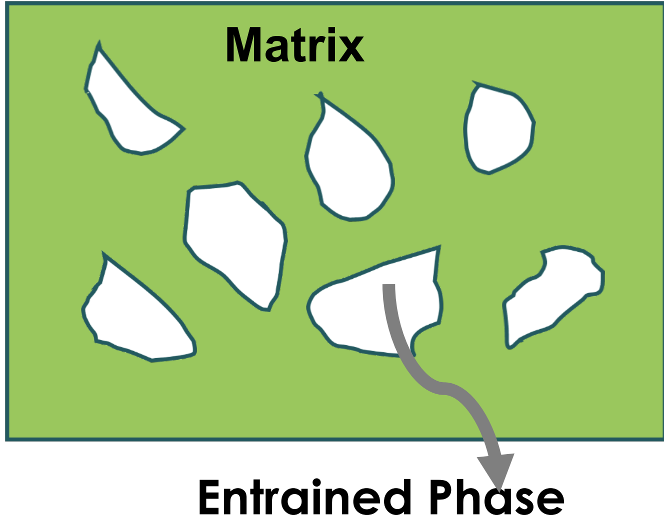
Example: Two Phase Composite Moderator

	Entrained Phase	Matrix Phase
Scattering	High	Fair
Absorption	Low	Low
Thermal Conductivity	Fair	High
Radiation resistivity	Fair	Good
Mechanical Stability	Fair	Good
Examples	Graphite, Be, **$Be_4{}^{11}B$**, BeO, **Be_2C**, **YH_{2-x}**, **ZrH_{2-x}**	MgO, SiC





Entrained Phase refers to a phase or component of a mixture that is carried along or transported by another medium or phase.

Be_2C: reacts with moisture to form Be(OH)2. However, as an entrained phase it will not

YH_{2-x}, ZrH_{2-x}: High dense matrix forms barriers that prevents hydrogen leakage

MgO-based composite moderators can exhibit considerably smaller critical volumes when compared to nuclear graphite

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Thank you