Massachusetts Institute of Technology Nuclear Science and Engineering

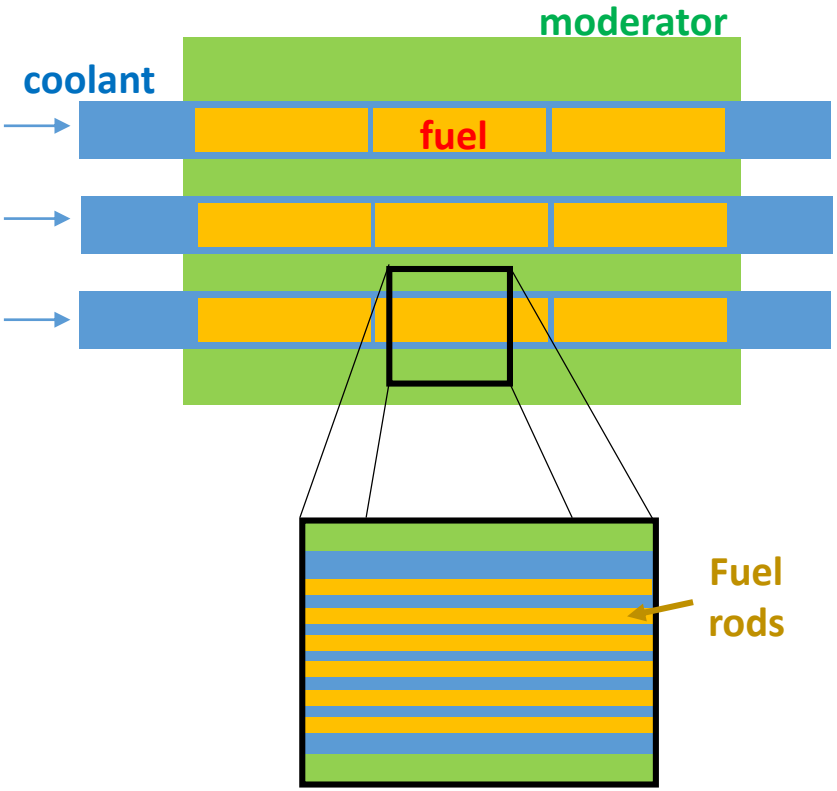
Doctoral Qualifying Oral Exam. Part 2 Question. Nuclear Reactor Engineering

May-June 2017

Liquid metal cooled thermal reactor

An exotic concept is proposed that aims at leveraging liquid metal coolant for a thermal spectrum reactor. Two potential coolants are being considered, Sodium (Na) and Gallium (Ga), in combination with four candidate moderators (Water, Heavy water, Graphite and Beryllium).

The basic configuration of the reactor is shown in figure. Horizontal flow tubes host fuel slugs composed of separate fuel rods (much like a CANDU design) and the moderator is physically separated from the rector coolant.



- **Electrical Output 500MWe [market driven output]**
- **Operating Pressure To be defined**
- **Fuel Slugs with dimension to be optimized for coolant selection**

You are asked to evaluate the following aspects of the liquid metal cool concept. As far as possible give quantitative answers to the questions below:

1. Discuss advantages and disadvantages of both Na and Ga coolant options, trying to cover all aspects of reactor design.

2. Compare and discuss the selection of the neutron moderator, including the aspects related to reactor control.

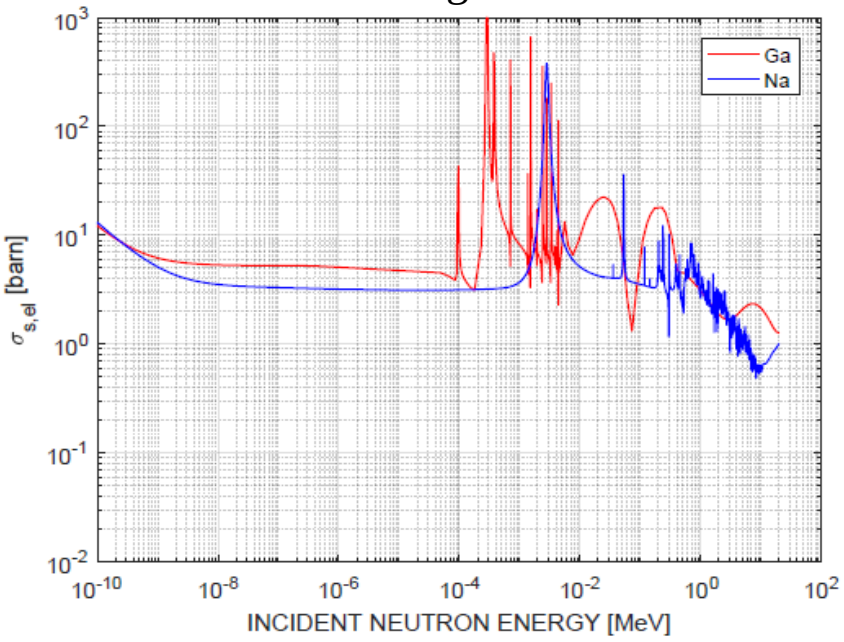
3. Discuss economics and safety implications deriving from the use of a liquid metal coolant and the moderator of your choice.

Candidate coolants properties

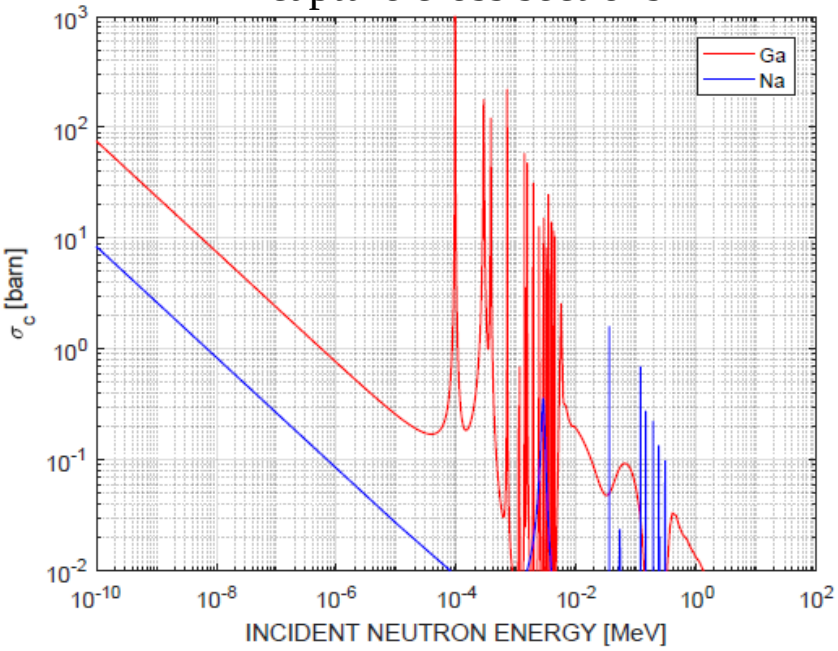
	Na	Ga
Melting point[a] (°C)	98	30
Boiling point[a] (°C)	883	2204
Thermal conductivity[b] (W/m°C)	~80.9	~45.6
Thermal capacity[b], ρc_p (MJ/m^3 °C)	~1.2	~2.3
Density[b] (g/cm^3)	~0.9	~6.0
Viscosity[b] [Pa.s]	4.64e-3	2.34E-3
Atomic number	23.0	69.7
Solidification	contracts by 2.5%	expands by 3.1%
Toxicity	No	No
Reactivity with air/water	Yes	No
Corrosiveness	Low	High
Cost	Low	High

[a] at 0.1 MPa; [b] at 200°C, 0.1 MPa

elastic scattering cross sections

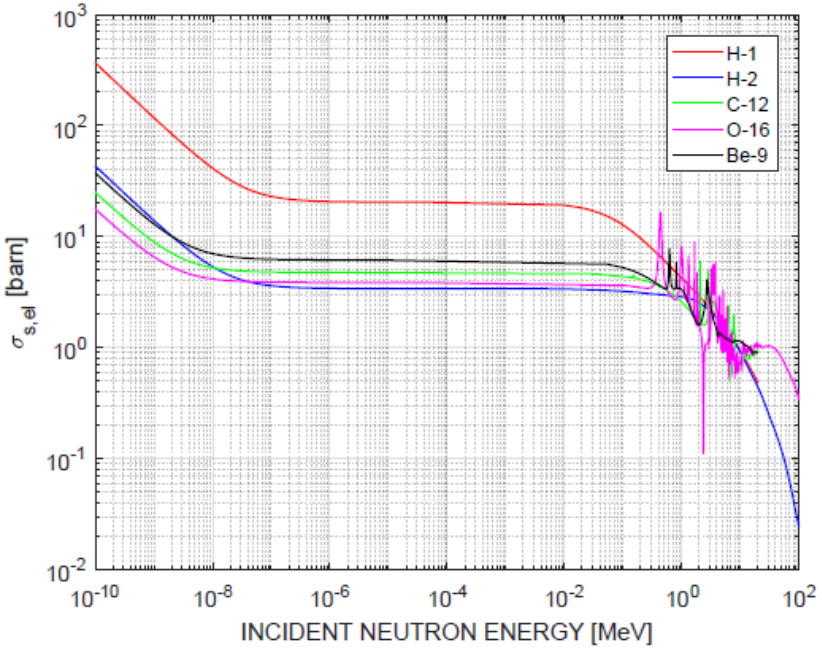


capture cross sections



Candidate moderators properties

elastic scattering cross sections



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