Measurement of Hydrogen T_1 and T_2 Relaxation Times in Copper Sulfate Solutions Using PNMR

PNMR Hydrogen Relaxation Times

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Outline

What is PNMR?

PNMR, or Pulsed Nuclear Magnetic Resonance, falls under the umbrella of MRI techniques that many of us are familiar with.

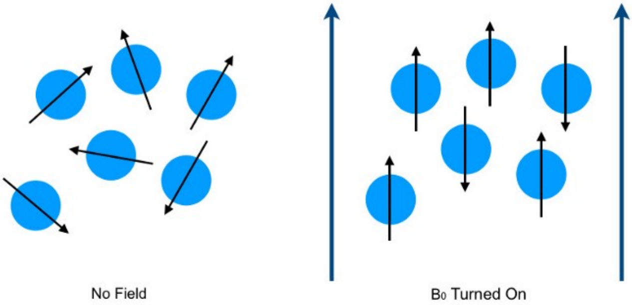

Figure: Initial Polarization [3]

Relaxation Path

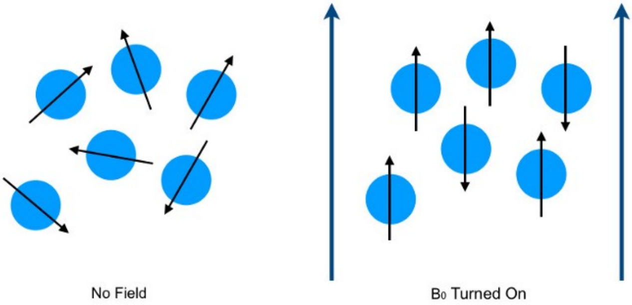

Figure: [1]

Relaxation Path

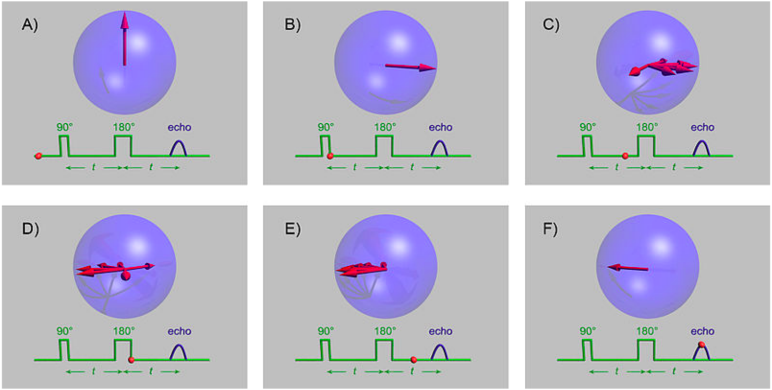

Figure: General Relaxation Path [1]

Pulsed Nuclear Magnetic Resonance

TABLE II: Mico-reactor design specifications

Design Criteria	USNC MMR™	X-Energy Xe-100™
Reactor type	Modular HTGR	Modular HTGR
Power Output (MWth)	15	200
Enrichment ($\%\ ^{235}U$)	13	15.5
Cycle Length (years)	20	online refuel
Fuel form	TRISO compacts	TRISO pebbles
Reactor Lifetime	20 years	60 years
Coolant	He	He

Fuel

- TRIstructural ISOtropic fuel has core of uranium, carbon, and oxygen: and is coated in layers of ceramic
- Roughly the size of billiard balls
- Load follows
- Fuel transitions directly to dry-cask storage

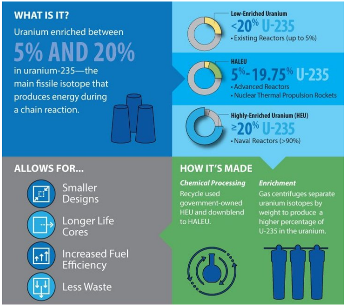

Figure: DOE HALEU Overview

Conventional MRI

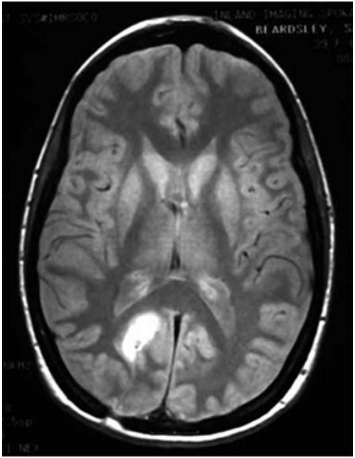

Figure: MRI Scan of a Brain [4]

Conventional MRI

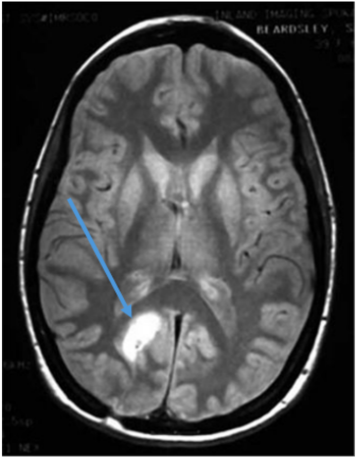

Figure: MRI Scan of a Brain [4]

Metabolite Identification

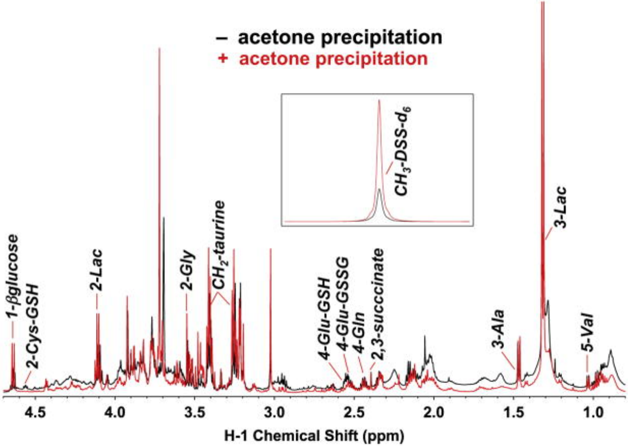

Figure: [2]

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Transition Scenarios

Scenario Details:

- SMR deployments begin in 2025
- Scenarios run from 1965 to 2090
- UF_6 processing capacity limits enrichment facilities
- All scenarios incorporate existing reactors, decommissioning on current timelines (e.g. Dresden generating station is active until 2029)

TABLE I: Fuel cycle scenarios

Scenario No.	Advanced Reactor	Demand Growth
1	None	N/A
2	USNC MMR	No growth
3	X-energy Xe-100	No growth
4	USNC MMR	1% growth
5	X-energy Xe-100	1% growth

Figure:

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Mass and SWU

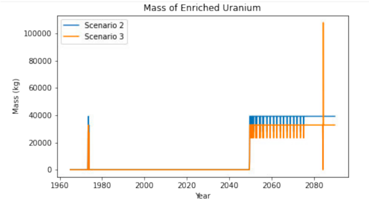

Figure: Mass of Enriched Uranium.

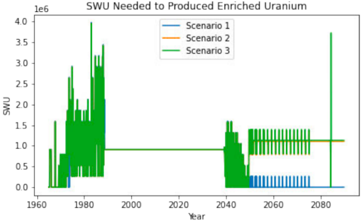

Figure: Separative Work Units needed for enrichment.

Conclusions and Energy Use

- Transition will require a mixture of HALEU production methods and deployments
- Scenario 2 never reaches required power level
- Scenario 3 requires more SWU than 2 due to higher enrichment

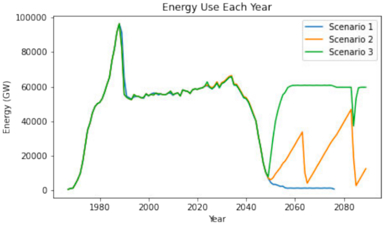

Figure: Energy use in each year.

Further Analysis of Sample K

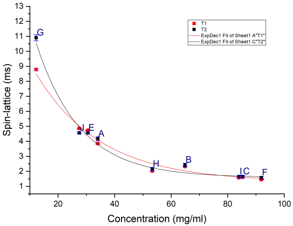

Figure: Fit without Sample K

- The T_1 fit indicates a concentration of 37.9
- The T_2 fit indicates a concentration of 33.4

Superficial literature review revealed no indication that this range of concentrations should behave differently.

References I

[1] Spin echo, 2020.

[2] Teresa W.-M. Fan and Andrew N. Lane.
Applications of nmr spectroscopy to systems biochemistry, 2017.

[3] Ben Nashman.
How to measure a system without touching it: Magnetic resonance, 2018.

[4] Tamije S. Perumal and Viji Palanisamy.
Performance analysis of clustering algorithms in brain tumor detection of mr images, 2011.

Acknowledgement

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Frequency Deviation

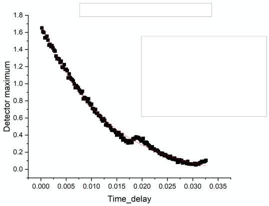

Figure: Sample D $[3.37 \pm 1.6x10^{-2}]$: T_1

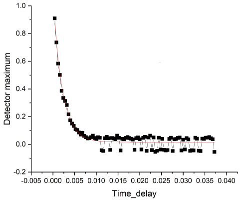

Figure: Sample H $[53.3 \pm 8.1x10^{-2}]$: T_2