
Neutron flux monitoring

GSTR flux

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ABSTRACT

The absolute values of the neutron flux over the vertical axis of the core can be computed by irradiating a sample and determining the neutron flux received from spectrometry results. Knowing the absolute neutron flux values at different positions in or out the core can be used to obtain local peak factor in the fuel elements, more precise fuel burnup, the production rate of fission products, and other useful information. Well chosen target materials are used. They are irradiated for a given period of time, after which the samples decay until they can be used in the spectrometry chamber. Their activation are used to compute the neutron flux they experienced within the reactor.

Sodium is used in this experiment to calculate the flux in the central thimble. The results obtained are inconclusive.

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A very valuable measurement obtained from a reactor core is the neutron flux. Its computation allow the iperator to know what the core and fuel elements are subjected to, in terms of local power peak, temperature and irradiation. In a reactor such as the GSTR, used mainly for sample irradiation, knowing the flux seen by the samples in the different testing tubes is very important. This allows for the irradiation to be done for an adequate period of time. Neutron detectors can give a good idea of the overall flux in the core, but are oblivious to local effects. The theory is based off of the course material [2].

1.1 Target selection

The sample to be irradiated needs to be chosen carefully. The choice depends on the threshold energy, the corresponding cross section of the element and its half-life. Table 1.1 presents potential elments that could be used for thermal flux monitoring.

Gold is an obvious candidate, its high cross-section allowing for lower concentrations and its half-life being long enough to give the operator some time, and potentially do several measurements over the course of a week to confirm the results. The half-life is also short enough that after a month, the sample would be back to its normal activation state. Aluminium use in a neutron flux monitoring case is limited by its short half-life. The samples activation would have to be measured in an unrealistically constrained time. Dysprosium presents a very high cross-section and a reasonable half-life. All things considered, for our experiment, Sodium is an obvious choice, due to its abundance in high purity form and its 15 hours half-life.

NaCl compound, used in this project, can be obtained at high purity at low cost. The other activated isotopes created by irradiation of Sodium present either a very short (T_{20} , few sec-

Table 1.1: Foil element characteristics after irradiation

Foil Element	Reaction	Threshold energy (keV)	Cross-section (b)	Half-life
Gold	(n, γ)	thermal	98.8	2.69d
Aluminium	(n, γ)	thermal	0.23	2.3m
Dysprosium	(n, γ)	thermal	920	139m
Sodium	(n, γ)	thermal	0.53	15h

onds) or fairly high (Na_{22} , several years) half-life, thus not compromising the results from the spectrometry.

1.2 Target activation

In order to compute the irradiation time needed as well as the decay time to apply to the sample, one can use equation 1.1. This equation gives the sample activation given a theorized flux after the irradiation of the sample in the core during t . It can then be plugged into equation 1.2 in order to compute the expected sample activation after a decay time T .

$$(1.1) \quad A_0 = \sigma \phi \frac{m}{A} \frac{N_A}{c} (1 - e^{-\lambda t})$$

Where:

A_0 = Activity at the end of the irradiation (Ci)

σ = Microscopic neutron cross-section (cm^2)

ϕ = Neutron flux ($n.cm^{-2}.s^{-1}$)

m = Mass of the target isotope (g)

A = Atomic weight of the target isotope

λ = Decay constant of the radionuclide (s^{-1})

t = Irradiation time (s)

N_A = Avogadro constant

c = Conversion factor from number of disintegrations per second to Curies : $3.7 * 10^{10}$

$$(1.2) \quad A_1 = A_0 e^{-\lambda T}$$

Where:

A_1 = Activity at the end of the decay period (Ci)

T = Decay time after irradiation (s)

In the case of the NaCl compound considered, Table 1.2 gives the intermediate calculation steps. It considers that Chlorine-38 represents 25% of the total Chlorine activated, the other 75%

Table 1.2: Specific data for NaCl compound

NaCl	Na_{24}	Cl_{38}
$\sigma (cm^{-2})$	$5.3 * 10^{-25}$	$3.55 * 10^{-23}$
$m (g)$	$1.57 * 10^{-4}$	$6.07 * 10^{-5}$
A	22.9898	35.453
$\lambda (s^{-1})$	$1.28 * 10^{-5}$	$3.10 * 10^{-4}$

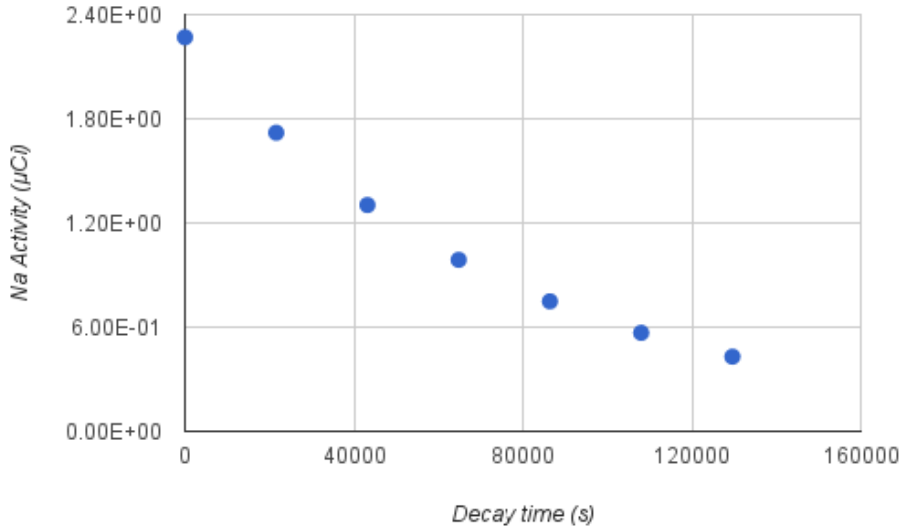


FIGURE 1.1. Activity of the sample after irradiation.

being considered stable (half-life around 300000 years). A mass of 0.4 mg of NaCl compound is considered. Considering a neutron flux estimated at $10^{13} n.cm^{-2}.s^{-1}$ within the central thimble, and an irradiation time of five minutes, the activity estimated right after the five minutes irradiation is 2.27 μCi for the Sodium, and 879 μCi for the Chlorine. Figure 1.1 presents the activity change with time during the decay period. A decay time of around 24 hours was chosen. It can be noted that the activity provided by the Chlorine-38 disappears almost completely after 10 half-life, around 6 hours.

The experiment will consequently measure the activation from samples of 0.4 mg of NaCl placed over a 20 cm distance in the core. It is expected, if the flux estimates of $10^{13} n.cm^{-2}.s^{-1}$ is correct, to obtain an activity of around 0.7 μCi during the spectrometry data experiments, a day after the irradiation.

It is interesting to note that starting after around five half-lives of irradiation time, the sample can be considered irradiated at saturation. This means that the equilibrium between the buildup of radioisotopes through irradiation and the decay of those isotopes in the sample has been

reached. At this point, the sample activity will reach a plateau. In the case of our experiment, the sample will not be anywhere near saturation levels, since this would imply an irradiation time greater than three days.

1.3 Spectrometry

The samples activities are measured using a spectrometer. A more detailed explanation of the spectrometer use can be found in a previous report [1].

1.4 Flux calculation

From the samples activities A_1 measured at various axial positions in the reactor, the mass m associated with the sample and its irradiation time t and decay time T known, it is possible, using equation 1.3 computed trivially from equations 1.1 and 1.2, to obtain the neutron flux profile in the reactor.

$$(1.3) \quad \phi = \frac{A_1}{\sigma \frac{m}{A} \frac{N_A}{c} (1 - e^{-\lambda t}) e^{-\lambda T}}$$

1.5 Procedure

The flux can be measured at different radial positions in the core, using existing sample testing tubes in the GSTR: lazy susan, central thimble and R1 dry tube. The location analyzed in this particular experiment is the central thimble.

A vertical span of 20 centimeters is considered. Every two centimeters, approximately, a sample will be placed. The samples need to be weighed carefully and irradiated for the right amount of time. This ensures that the activity levels of the samples are not so high that the samples cannot be easily manipulated or so low that the activity cannot be accurately measured. The irradiation time and the decay time must be practical from a GSTR operator standpoint. These constraints, coupled with Equations 1.1 and 1.2, allowed us to compute the given sample weight (0.4 mg), irradiation time (5 minutes) and decay time (24 hours).

The target sample are placed in an irradiation container, hold in position by a piece of foam. The position and weight of each target is carefully measured. Gloves need to be worn in order to not contaminate the samples.

The reactor is brought to full power and the sample positionned around the estimated location of the flux peak by the operators. Once the sample has been irradiated and decayed for the given times, the target are taken out of the foam and their activity is measured using the spectrometer.

RESULTS

In this section, the results are given. And they're shit. This presents what results are shown, etc. Not much to say actually, besides showing the plot. This is a simple lab. We discuss about the uncertainties too.

2.1 Results**2.2 Uncertainties**

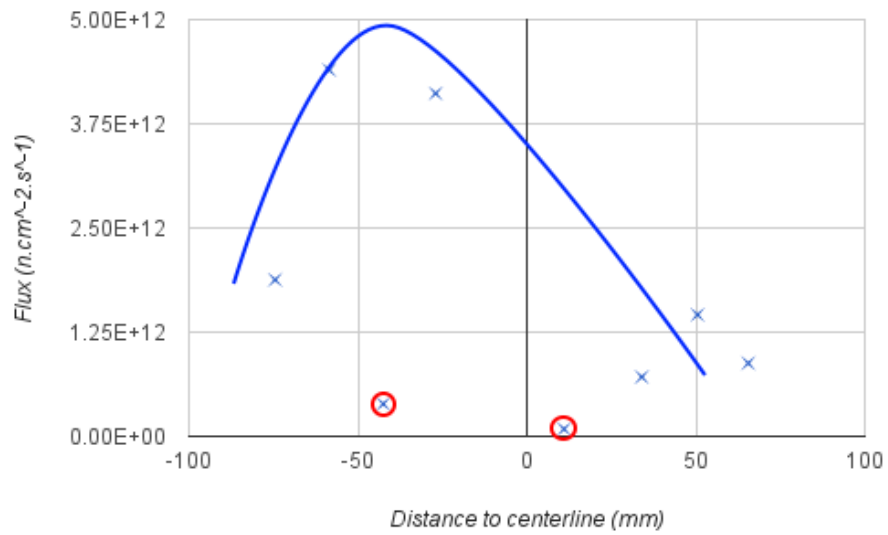


FIGURE 2.1. Thermal neutron flux seen in the samples.

CHAPTER

3

CONCLUSION

Experiment is shit.



DETAILED DATA TABLES

This appendix presents the raw data from the experiment in table ??.

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