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NUCLEAR ASPECTS OF
HEAVY ISOTOPE PRODUCTION IN N-REACTOR

P. F. Nichols

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NUCLEAR ASPECTS OF
HEAVY ISOTOPE PRODUCTION IN N-REACTOR

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NUCLEAR ASPECTS OF HEAVY ISOTOPE PRODUCTION IN N-REACTOR

I. PRODUCTION METHODS

The isotopes Cm^{242} , Cm^{244} , Np^{237} , Pu^{238} , and U^{233} can be produced in N-Reactor from the nuclear processes listed below.

a) Cm^{242}

In this process, the β decay from Pu^{241} to Am^{241} should be allowed to occur outside of the reactor in order to eliminate the destruction of Pu^{241} from the capture and fission reactions.

b) Cm^{244}

c) Np^{237}

or

d) Pu^{238}

Pu^{238} is also produced by α particle decay of Cm^{242}

e) U^{233}

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In the case of the two Cm isotopes, an attractive source material in practice would be high exposure plutonium from power reactors, recycled plutonium, or plutonium from other sources with a high concentration of the higher Pu isotopes, although the chain must be initiated somewhere with U^{238} . Chemical separations facilities capable of removing Cm would be required.

Since both Pu^{239} and Pu^{241} are fissionable isotopes and appear in large quantities in all but the highest exposures of plutonium, the reactor could be fueled with the feed material for the production of Cm^{244} . Alternatively, target rods could be fabricated of high exposure plutonium, with the bulk of the fissions coming from other fuel material, such as uranium enriched in U^{235} , other plutonium, or U^{233} in a suitable matrix. Fission neutrons supplied by any of the three fissionable isotopes have equal production value, so the question of which fuel to use is reduced to an economic question of which fuel can be used to supply the fission neutrons most economically. The nuclear utility of a fuel mixture is proportional to the value of $\Sigma_a (\eta - 1)$ for the mixture. The values of Σ_a and η are averaged over the entire neutron energy spectrum.

The use of target rods loaded with Am^{241} which has been separated from high exposure plutonium with a long (~ 1 year or more) storage history, probably represents the most attractive mode of production of Cm^{242} . In this latter case the reactor could be fueled with any of the three fuels listed above for the production of Cm^{244} .

The production of U^{233} from Th^{232} feed material is analogous to the production of Pu^{239} from U^{238} feed material. Again, any of the three fissionable isotopes could be used as fuel, in principle. Plutonium enrichment of the

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feed material itself represents one possible mode of operation. Alternative methods which are probably more desirable involve the use of thorium in targets which are physically separate from enriched uranium or plutonium fuel pieces.

The isotope Np^{237} is produced from both U^{235} and U^{238} in reactors fueled with uranium of low enrichment. For unirradiated uranium Np^{237} production from both sources is roughly comparable. The production rate from recycled uranium which is rich in U^{236} is of course higher. The most obvious choice of fuel for the production of Np^{237} is U^{235} since destruction of U^{235} leads either to fission or the formation of U^{236} .

The Np^{237} which is formed in the processes discussed above can be fabricated into target elements and irradiated to yield Pu^{238} . This step in the production of Pu^{238} can utilize any of the fissionable isotopes for fuel.

II. PRODUCTION RATES

Some rough estimates of the production capacities of the various isotopes in N-Reactor are given below. Although a range is given in the production rates, the numbers are very tentative, and the actual production rates might well fall outside of the range given. Further study and definition of the production rates is planned as part of our research and development program.

a) Cm^{242} and Pu^{238}

Following the procedure listed below in items 1, 2, and 3,

1. Start with 720 kg of plutonium which has been obtained from 2000 MWD/T irradiation of uranium fuel,
2. Store the 720 kg of Pu for one year and remove the Am^{241} which has accumulated,

3. Irradiate the Am^{241} for one additional year in the reactor. it is estimated that 300 to 400 gm of Pu^{238} would be produced along with 100 to 150 gm of Cm^{242} .

Upon continued irradiation of the plutonium, and separation and irradiation of Am^{241} over a ten year recycle program, the estimated total production is 10 to 15 kg of Pu^{238} and 5 to 8 kg of Cm^{242} .

b) Cm^{244}

If 720 kg of plutonium which has been obtained from 2000 MWD/T irradiation of uranium fuel is irradiated for an additional year, the production of Cm^{244} would be in the neighborhood of 500 to 1000 gm of Cm^{244} .

c) Np^{237}

Production of Np^{237} would amount to 7-12 kg of Np^{237} per year from 3 cycle irradiation.

d) Pu^{238}

Further irradiation of target material prepared from the Np^{237} would convert about 10 per cent of the Np^{237} to Pu^{238} at N-Reactor flux levels during an irradiation period of one year.

e) U^{233}

With highly enriched fuel material and Th target material the production capacity for U^{233} in N-Reactor would have a maximum of 800 to 1000 kg annually.

III. NUCLEAR ADVANTAGES OF N-REACTOR

The advantage which N-Reactor holds over the other Hanford reactors is in the magnitude of the epithermal flux ratio. For nuclides that are formed

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principally by resonance absorption, this advantage can be large. The figures below are based on the assumption that the reactors are operating at their normal operating levels. In the production of Cm^{244} and Cm^{242} this difference in production rate is quite important. The production of Pu^{241} from Pu^{240} and the production of Pu^{243} from Pu^{242} would both proceed at a rate roughly 35 to 40 per cent faster per target atom than in the other Hanford reactors. The production of Am^{242} from Am^{241} would proceed at a rate roughly 15 to 20 per cent faster per target atom than in the other reactors. The production of Th^{233} a precursor of U^{233} , would proceed roughly 20 per cent faster per target atom.

In the production of plutonium with a higher Pu^{240} content, N-Reactor also holds an advantage over the Savannah River reactors because of the higher neutron temperatures in N-Reactor. The flux level is probably up to a factor of two higher in the Savannah River reactors, but this advantage could be overcome in N-Reactor by using flux trap techniques. The flux can be increased by a factor of four or so by removing the uranium loading in selected process tubes. In small quantities of target material, most of this flux advantage from the flux trap could be maintained. This technique would be applicable for cases in which relatively small quantities of very valuable target material such as Np^{237} were to be irradiated.

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