Research Article

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Supplementary Text

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Accelerate charged particles of light such as protons to a certain energy and radiation a suitable target X (p, n) Y, a neutron source is generated.

1. They are cheaper and smaller.
2. More safety and less gamma contamination.
3. The neutrons produced are often low in energy.hey have a more limited neutron energy spectrum.
4. They are easier to make.
5. Can be installed in or near the hospital.
6. They are adjustable and controllable.

Heat Transfer Calculation

1. Equivalent Diameter:

$$D_e = 4\times\frac{\mathrm{A}_c}{\mathrm{P}_{wetted}} = 4\times\frac{8\times0.35}{2(8+0.35)} = 0.76cm$$

2. Reynolds Number:

$$R_e = \frac{v.D_{e.\rho}}{\eta} = \frac{100\times0.67\times6.095}{0.09} = 2.15\times10^4$$

3. Prandel Number:

$$pr = \frac{c_p.\eta}{k} = \frac{0.37\times0.019}{0.406} = 0.0173$$

4. Peclet number: Pe = Re.Pr = 2.15*104 *0.0173 = 371.95

5. Nusselt Number: $Nu = 5.8 + 0.02\,pe^{0.8} = 8.0772$

Suitable Material and Interaction

1. Sustainability of target material at high temperature.

2. Materials should be selected as such that the product activity has the least energy.

3. Appropriate Q and reaction threshold energy.

4. Suitable absorption cross-sectional for the production of more neutrons.

Heat Transfer Calculation

- Neutron Source ^{9}Be (p, n) ^{9}B
- Melting point Temperature = 1287°C
- Heat Conductivity = 201 W/m.°C
- Energy Threshold Reaction = 2MeV

Due to the linear drop in proton energy in beryllium, a lot of heat will be generated at its surface.

Number of protons in 1mA flow:

$$\frac{1\times 10^{-3}}{1.6\times 10^{-19}}=6.242\times 10^{15}\frac{n}{s}$$

The power of the beam is equal to: heat transfer:

$$6.242\times 10^{15}\times 30\times 10^{6}\times 1.6\times 10^{-19}=30kw$$

The Following is a General Description of Beryllium

Heat flow at the beryllium surface is calculated as following:

$$q"=\frac{30\times 10^{3}}{\pi r^{2}}=597.133\frac{w}{cm^{2}}\approx 600\frac{w}{cm^{2}}$$

The cooling fluid flow is obtained from the following equation:

$$m^{o}=\frac{q"\times A_{tot}}{c_{p}(T_{out}-T_{in})}=\frac{600\times 8^{2}}{0.37(90-30)}=1729.79\frac{g}{s}$$

The width of cooling channel is 0.35 cm:

$$y=\frac{m^{o}}{\rho v\chi}=\frac{1729.79}{6.095\times 100\times 8}=0.35cm=3.5mm$$

Summary of BNCT Treatment of Cancer

1. A modality for killing cancer cells is boron neutron capture therapy. Its principal is based on the

^{10}B (n, α) 7Li reaction, which release two heavy charged particles that deposit their energy in a very short distance.

2. A typical definition for the epithermal energy range is used, namely 0.5 eV to 10 keV [1].
3. Because the range of alpha particles and lithium nucleus are too short, healthy tissue surrounding the affected cell is spared [2].
4. In practice, for a deep-seated tumor along the desired slow neutrons, there are many undesired radiations that are produced.
5. The core gamma-rays and capture gamma-rays' interactions by surrounding materials, as well as the recoil proton and ^{14}N (n, p) ^{14}C reactions producing undesired radiation.
6. Hence, an accelerator-based neutron source (ABNS) has been favored in many applications including the BNCT [3,4].
7. Accelerators have some benefits over Research Reactors such as higher safety, easier operation, lower gamma-ray emission, larger size, more cost effective, easier start-up and shut down, and the neutron energy spectrum can be better tuned for treatment.
8. Nowadays, using a cyclotron to produce a neutron beam is a favorable method for AB-BNCT application.
9. 1mA current of 30 MeV protons is under consideration in this project.
10. However, we confirmed that a sufficient epithermal-neutron yield based on the ^{9}Be (p, n) ^{9}B reaction could be obtained with an optimum beam-shaping assembly.
11. The benefit of this system is lower activity and higher neutron yield compared to spallation reactions involving heavy materials.
12. To optimize the whole setup and maximize the neutron flux the Monte Carlo code MCNPX 2.6 is used to simulate the system.

13. A cooling system is required to increase the flux and reduce the irradiation time. We present gallium cooling system for this purpose.
14. The melting point of lithium is 180^{0}C, much lower than that of beryllium (1278^{0}C) [8,9].
15. Regarding these facts we selected ^{9}Be (p, n) ^{9}B reaction with 30 MeV protons which has a higher neutron yield compared to ^{7}Li (p, n)^{7}B reaction as well as lower activation level compared to W and Ta [10, 11].
16. We are going to use a cyclotron accelerator promising a 1mA proton beam at 30 MeV, which generates maximum energy from our cyclotron at the Cyclotron Institute for Atomic Energy Research Organization. Neutron yield in (p, n) reaction varies with proton energy.
17. We used an 8cm diameter uniform proton beam as the simulation. We did try to find out the best geometry for the highest neutron flux. Therefore, we decided to choose a V shape target, Figure 2 with an opening angle of 30^{o} degrees in such a way that the entire proton beam.
18. Finding sources for research is important but using unreliable sources will hurt your credibility and make your arguments seem less powerful. It is important to be able to identify which sources are credible. This ability requires an understanding of depth, objectivity, currency, authority, and purpose. Whether or not your source is peer-reviewed, it is still a good idea to evaluate it based on these five factors. An article that has been peer-reviewed is credible, but it still might not be completely relevant to your assignment. These five areas give you a way to reduce a large body of sources into the specific information that you need to include. This process will enhance the credibility of your writing and lead you to more accurate conclusions.