The $^{3}He(d,p)He^{4}$ Nuclear Fusion Reaction as a Source of Mega-voltage Protons for the Production of Fluorine-18 for PET Applications.

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Declaration

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Michael Paul Barnes

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1. Abstract

Fluoro-deoxyglucose (FDG) labeled with fluorine-18 is commonly used in positron emission tomography (PET) imaging. PET imaging is a powerful tool used primarily in the diagnosis and management of cancer. The growth of PET has been limited partly by the difficulties associated in producing fluorine-18. This project involves a theoretical investigation of a novel method of producing fluorine-18 utilising proton generation via the $^{3}He(d,p)^{4}He$ nuclear reaction.

Currently the most common method of producing fluorine-18 for PET is with a medical cyclotron that accelerates protons to mega-voltage energies. These protons are then directed onto a target rich in oxygen-18. This initiates the $^{18}O(p,n)^{18}F$ reaction to produce fluorine-18. The $^{3}He(d,p)^{4}He$ reaction, utilized for the present study, has a Q-value of 18.35 MeV and this results in protons being produced at energies similar to that produced in a medical cyclotron. This reaction was investigated as an alternative proton source for the $^{18}O(p,n)^{18}F$ reaction. The expected advantage of this method over the cyclotron is that particles need only be accelerated to keV energies rather than the tens of MeV that a medical cyclotron accelerates protons to. This is expected to significantly reduce the cost and associated size of the system.

Two systems based on the $^{3}He(d,p)^{4}He$ reaction were designed and calculations were performed to determine the respective yields of fluorine-18. The first system involved separate targets for the $^{3}He(d,p)^{4}He$ and $^{18}O(p,n)^{18}F$ reactions. Helium-3 ions are initially fired onto a deuterated plastic target. A heavy-water (H_2O^{18}) target is placed immediately behind this plastic target to absorb mega-voltage protons produced by the reaction $^{3}He(d,p)^{4}He$ in the plastic. The second system involved a single, super heavy water (D_2O^{18}) target onto which helium-3 is fired so that both the $^{3}He(d,p)^{4}He$ and $^{18}O(p,n)^{18}F$ reactions can occur concurrently in the one target.

The input parameters of energy and beam current for the helium-3 beam required for the $^{3}He(d,p)^{4}He$ reaction were selected on the basis of the performance

of currently available ion sources and in particular the saddle-field ion source. Practical considerations such as radiation safety, target degradation and lifetime and ultra high vacuum (UHV) issues were also investigated to further determine the feasibility of the two systems.

With the beam current and energy at the extreme limits of the saddle-field ion source it was calculated that insufficient fluorine-18 could be produced daily to supply a PET facility with FDG. It was also found that the high helium-3 beam currents and energy required to produce significant amounts of fluorine-18 resulted in prohibitive temperature rises in the targets that would likely result in target vaporization.