§19. A Radioactive Fusion Source

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We consider a fusion cell consisting of Ra-226 in CD_2 or CDT plastic. Radium follows a decay-chain: ^{226}Ra --> ^{222}Rn --> ^{218}Po --> ^{214}Pb. The first three nuclei emit in turn α particles of 4.7 MeV, 5.8 MeV and 6.0 MeV. The half-lives are 1622 years, 3.8 days and 3.05 min respectively, so the second and third alphas follow rapidly after the first.

The alphas lose energy mainly to bound and free electrons of the target material. In CDT plastic, α particles make primary knock-on C, D, and T ions by Coulomb collisions. These ions make additional (secondary) knock-on ions.

We are writing computer codes to analyze energy transfers important for fusion:

a.) **Fusion reactions**: we tabulate the energy-dependent cross-section $\sigma(E)$ for DD, DT, and D-He^3 fusion reactions.
b.) **Fast ion energy loss:** we form the stopping-power dE/dx for α, C, D, and T projectiles in Ra, CD_2, and CDT plastic. [1]
c.) **Collision cascade production of knock-on ions**: we solve integral equations which calculate how many D, T knock-on ions are produced by Coulomb collisions of energetic α particles or other ions.

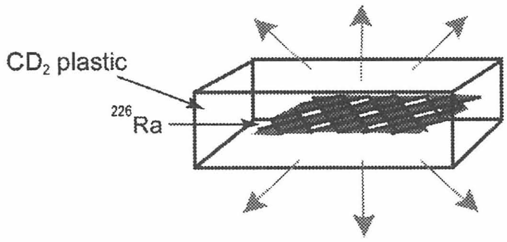

Figure 1: Conceptual drawing of a fusion cell based on a thin layer of radioactive material embedded in plastic containing fusion fuel.

We solve coupled integral equations for the energy-distributions

$$N_\alpha(E),\quad N_C(E),\quad N_D(E),\quad N_T(E)$$

Electrons take most of the energy and secondary knock-ons have low energies, so the first-generation (primary) knock-ons are most important.

Our computer code follows the energy transfers and calculates fusion reactions of energetic D, T hitting static D and T target atoms. The results do not depend on the geometrical arrangement as long as the radium is thin to alphas.

We performed calculations for two radioactivity-driven fusion cells:
(1.) A ^{226}Ra - CD_2 cell gives **7.5 10^5** fusion reactions per hour per gram of radium.
(2.) A ^{226}Rd - CDT cell gives **6.0 10^6** fusion reactions per hour per gram of radium. This cell has higher output but a shorter lifetime set by decay of the tritium.

Neither of these cells produces enough reactions to make an interesting energy source. The fusion energy release is less than the radioactive self-heating, and higher neutron yields are apparently produced by Po-Be or Ra-Be neutron sources. However the DT cell produces 14 MeV fusion neutrons and might be useful as a neutron source for scientific experiments.

We also studied a cell consisting of radon gas mixed with pure DT. This cell has no energy loss to carbon and benefits from the short half-life of Rn. The calculation for this cell predicts an amazing **1.9 10^{12}** neutrons per hour per gram of radon. However since radon has only a three-day half-life, it seems clear that fabrication of such a cell would be very difficult

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Acknowledgement We are grateful to various colleagues, especially Dr. Tomita of NIFS, who helped us find useful data in unpublished or informal form.

References

[1] H. H. Anderson and J. F. Ziegler, *The Stopping and Ranges of Ions in Matter* (vols. 3-4), Pergamon Press, New York, 1972.

[2] This work was presented as an invited talk in the Inertial Fusion Science and Applications (IFSA) conference held in Kyoto, Japan during September, 2001.