**REBCO Transmutation text for Chris’ paper**

REBCO superconducting tape consists of multiple materials, including two 20 µm thick copper layers on either side and a thick (50 µm) Hastelloy substrate that supports a 1 µm thick layer of YBa2Cu3O7-x superconductor on a Ag buffer layer. Several different nuclear reactions can take place when REBCO is subjected to a fast neutron field, causing damage to the material. These include displacement damage due to elastic scattering and hydrogen embrittlement and swelling arising from (n,p) and (n,a) reactions. In addition to damage, these reaction will cause transmutation of the elements in REBCO. The table below shows the largest transmutation products on the four constituent elements in REBCO along with the energetic threshold for the reaction that causes their formation.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Target | Reaction | Product (lifetime) | s14 (mb) | s1 (mb) | sth (b) |
| 89Y | (n,g) | 90Y (64 h) → 90Zr | - | - | 1.3 |
| 89Y | (n,2n) | 88Y (107 d) | 823 | - | - |
| 89Y | (n,p) | 89Sr (51 d) | 23 | - | - |
| 89Y | (n,pn) | 88Sr (stable) | 58 | - | - |
| 89Y | (n,a) | 86Rb (18.6 d) | 5 | - | - |
| 63Cu | (n,g) | 64Cu (12.7 h) | - | - | 4.5 |
| 63Cu | (n,2n) | 62Cu (9.7 m) | 417 | - | - |
| 63Cu | (n,p) | 63Ni (101 y) | 59 | 1 | - |
| 63Cu | (n,pn) | 61Ni (stable) | 419 | - | - |
| 63Cu | (n,a) | 60Co (5.3 y) | 44 | - | - |
| 65Cu | (n,g) | 66Cu (5.1 m) → 60Zn | - | - | 4.5 |
| 65Cu | (n,2n) | 64Cu (12.7 h) | 837 | - | - |
| 65Cu | (n,p) | 65Ni (2.5 h) | 20 | - | - |
| 65Cu | (n,pn) | 64Ni (stable) | 36 | - | - |
| 65Cu | (n,a) | 62Co (1.5 m) | 14 | - | - |
| 16O | (n,g) | 17O (stable) | - | - | 4.5 |
| 17O | (n,np) | 16N (stable) | 1 |  |  |
| 16O | (n,p) | 16N (6 s) | 42 | - | - |
| 16O | (n,a) | 13C (stable) | 142 | - | - |
| 16O | (n,an) | 12C (stable) | 124 | - | - |

Given the limited thickness of the tape, the thin-target formula is appropriate to determine nuclear reaction rates in the constituent materials:

Where *s* is the reaction cross section, *r* is the density of the material and *x* is the thickness.

Perhaps the most concerning of these transmutations reactions are on oxygen, whose role is central to high temperature superconductors. Here, the role of 14 MeV neutrons is particularly important.

Let’s assume a tokamak geometry with inner and outer diameters of 1.0 and 2.5 m respectively and a plasma chamber with elliptical cross section with major/minor axes of 2 and 1.5 m (which is roughly that of the DIII-D experiment being run by General Atomics). If this device were to evolve 1 GW of fusion power, then the total neutron fluence would be ≈2.7x1014 n/cm2/s. Given that the total 16O(n,a) and (n,an) cross sections is 266 mb @ 14 MeV, this implies a conversion rate of:

In one year of continuous operation this equates to 0.23% of all oxygen in the REBCO. Note that the corresponding values for the transformation of yttrium into strontium and copper into zinc would be ≈0.7% respectively.