CLAIMS

1. An apparatus for producing reaction-product nuclei from reactant nuclei, the apparatus comprising:

a plurality of reactant nuclei and a plurality of moderating nuclei wherein the moderating nuclei comprise nuclei of atoms that are chosen from a group consisting of deuterium, tritium, helium-4, lithium-7, beryllium, boron-11, carbon, nitrogen-15, oxygen, fluorine, neon-20 and neon-22; and

a neutron source that is neither a nuclear reactor nor a subcritical assembly, in proximity to the reactant nuclei sufficient to produce reaction-product nuclei by neutron capture;

wherein the reactant nuclei comprise molybdenum-98;

wherein the rate of molybdenum-98 nuclei neutron capture divided by the rate of the neutron source's neutron production is greater than approximately 1%;

wherein the mass of molybdenum-98 is less than approximately 1000 kg; and

wherein the mass of moderating nuclei is at least 1 kg.

2. The apparatus of claim 1, wherein the mass of molybdenum-98 is less than approximately 100 kg.

3. The apparatus of claim 1, wherein the mass of molybdenum-98 is less than approximately 25 kg.

4. The apparatus of claim 2, wherein the rate of reactant nuclei neutron capture divided by the rate of the neutron source's neutron production is greater than approximately 5%.

5. The apparatus of claim 1, further comprising the use of temperature control capable of maintaining at least 2 different regions of the apparatus at different temperatures;

wherein at least one region is cooled to a temperature below 250 degrees Kelvin, and, optionally, wherein the temperature control comprises the use of a cryogenic fluid.

6. The apparatus of claim 1, further comprising at least one neutron reflector at least partially surrounding the pluralities of reactant nuclei and moderating nuclei, wherein the reflector comprises moderating nuclei and wherein the reflector thickness is greater than approximately 20 centimeters and less than approximately 15 meters.

7. The apparatus of claim 1, further comprising both an outer and an inner neutron reflector that reflect neutrons towards regions containing higher densities of reactant nuclei.

8. The apparatus of claim 1, wherein the pluralities are arranged in one or more approximately parallel layers, and wherein at least one layer is distinct from another layer on the basis of elemental composition, concentration of chemical species, density or temperature.

9. A system for producing a decay product from a reactant using a neutron source, comprising:

a plurality of reactant nuclei and a plurality of moderating nuclei wherein the moderating nuclei comprise nuclei of atoms that are chosen from a group consisting of deuterium, tritium, helium-4, lithium-7, beryllium, boron-11, carbon, nitrogen-15, oxygen, fluorine, neon-20 and neon-22; and

a neutron source;

wherein the reactant nuclei comprise molybdenum-98;

wherein the rate of molybdenum-98 nuclei neutron capture divided by the rate of the neutron source's neutron production is greater than approximately 1%;

wherein the mass of molybdenum-98 is less than approximately 100 kg; and

wherein the mass of moderating nuclei is at least 1 kg.

10. The system of claim 9, wherein the neutron source is a nuclear reactor or subcritical assembly.

11. The system of claim 9, wherein the neutrons are generated by a source that is neither a reactor nor a subcritical assembly.

12. The system of claim 9, further comprising at least one neutron reflector comprising moderating nuclei, wherein the neutron reflector at least partially surrounds the layers of the pluralities of reactant and moderating nuclei, and wherein the thickness of the neutron reflector is greater than approximately 20 centimeters and less than approximately 15 meters or further comprising both an outer and an inner neutron reflector that reflect neutrons towards regions of the pluralities containing higher densities of reactant nuclei.

13. The system of claim 9, further comprising temperature control capable of maintaining at least 2 different regions of the apparatus at different temperatures, wherein at least one region is cooled to a temperature below 250 degrees Kelvin, and optionally, wherein the temperature control comprises a cryogenic fluid.

14. The apparatus of claim 1 or the system of claim 9, further comprising a target configured to emit neutrons when impacted by accelerated particles;

wherein the target is comprised of atoms chosen from a group consisting of deuterium, tritium, helium-4, lithium-7, beryllium, boron-11, carbon, nitrogen-15, oxygen, fluorine, neon-20, neon-22, tantalum, tungsten, lead, mercury, thallium, thorium, uranium, neptunium and other transuranics, and

wherein the accelerated particles enter the system via an access channel configured to accept greater than 50 percent of the accelerated particles that impinge upon the access channel.

15. A system for producing reaction-product nuclei, comprising reactant nuclei, a neutron source in proximity to the reactant nuclei sufficient to produce

reaction-product nuclei by neutron capture and wherein at least 100 g of the system is cooled to a temperature at or below approximately 250 Kelvin.

16. A system according to claim 15, wherein the reactant nuclei comprise molybdenum-98.

17. A system according to claim 16, wherein the rate of molybdenum-98 nuclei neutron capture divided by the rate of the neutron source's neutron production is greater than approximately 1%.

18. A system according to claim 17, further comprising moderating nuclei wherein the moderating nuclei comprise nuclei of atoms that are chosen from a group consisting of deuterium, tritium, helium-4, lithium-7, beryllium, boron-11, carbon, nitrogen-15, oxygen, fluorine, neon-20 and neon-22.

19. An apparatus for producing reaction-product nuclei from reactant nuclei, the apparatus comprising:

a neutron source;

a first plurality of reactant nuclei having a first average microscopic thermal neutron capture cross section;

a collection of isotopes consisting of those isotopes whose nuclei species capture at least 1% of all emitted neutrons from a neutron source and which are not reactant nuclei;

a second plurality of nuclei consisting of all nuclei from the collection of isotopes, wherein at least approximately 90% of the nuclei have microscopic thermal neutron capture cross-sections that are lower than the microscopic thermal neutron capture cross-section of any of the reactant nuclei, and wherein the total mass of the second plurality of nuclei is greater than approximately 1 kilogram; and

wherein the neutron source is in proximity to the reactant nuclei sufficient to produce reaction-product nuclei by neutron capture.

20. A method for producing decay-product nuclei from a reactant isotope using a neutron source, the method comprising:

generating neutrons;

preparing a first plurality of reactant nuclei having a first average microscopic thermal neutron capture cross section;

preparing a collection of isotopes consisting of those isotopes whose nuclei species capture at least 1% of all emitted neutrons from a neutron source and which are not reactant nuclei;

preparing a second plurality of nuclei consisting of all nuclei from the collection of isotopes, wherein at least approximately 90% of the nuclei have microscopic thermal neutron capture cross-sections that are lower than the microscopic thermal neutron capture cross-section of any of the reactant nuclei, and wherein the total mass of the second plurality of nuclei is greater than approximately 1 kilogram; and

irradiating the plurality with the neutrons such that a reaction product is generated when the neutrons are captured by the reactant nuclei.