Ir, Au, Re, Cr and Mo. The neutrons that interact with the target material can produce one or more of ^{32}P, ^{35}S, ^{192}Ir, ^{198}Au, ^{186}Re, ^{51}Cr, and ^{99}Mo. Accordingly, methods are also provided for modifying materials within target material. The methods can include providing neutrons to target material with a uranium-comprising annulus. Methods are also provided for characterizing material within a target material. The method can include providing filtered neutrons to the target material within a uranium-comprising annulus to activate the material for neutron activation analysis. In accordance with example characterization implementations, the target material can be placed in the target assembly with a liner composed of cadmium or boron carbide, and radiation provided to create a reasonably fast neutron spectrum, inside the target material so that the effects of fast neutrons can be used to characterize the target material. In a method for producing radioisotopes, using one or more of these assemblies, reactors, and/or methods when the target material is molybdenum can give a molybdenum-99 activity of at least 1 Ci/g, but it can also range from 1-25 Ci/g. Other activity can include 0.2-50 Ci/g. In order to provide target assemblies to reactors and remove from same, rabbit or shuttle systems can be utilized. Rabbit systems can include pneumatic systems to automatically transport the target material to and from the reactor core. For example, the target material can be positioned in a transport capsule, and the transport capsule can be positioned into the sending station of the pneumatic tube. The target material in the capsule can then be pneumatically transported to the reactor core. At the completion of the designated irradiation period, the target material in the capsule can then be pneumatically transported to the receiving station of the pneumatic tube.

[0054] By way of example and for purposes of example only, FIGS. **13-15** depict data acquired from different target configurations in the core of research test reactors using uranium zirconium hydride ($UZrH_x$) fuel. Modeling the performance of unique target assemblies under a variety of conditions can be performed consistent with MCNPX 2.6.0 Extensions, by Hendricks et. al., 2008). The data can be based on the core design and fuel configuration of the research reactor located at Washington State University (WSU) in Pullman, Wash. The research reactor at WSU is a 1-MegaWatt with Training, Research, Isotopes, General Atomics (TRIGA) fuel and a thermal neutron flux of about $2e10^{12}$ neutron/centimeter^2-sec outside the core. In this case "outside the core" refers to position **126** on FIG. **12**. The profile of the predicted neutron flux is depicted in FIG. **15**, where "Water D**8** position refers to **126** and "Center" refers to **124** of FIG. **12**. Example target materials included pressed molybdenum with a bulk density of 8 g/cc. The target configurations could include 1) molybdenum cylinders, 2) molybdenum cylinders and annuli surrounded by beryllium, and 3) molybdenum cylinders surrounded by UZrH fuel with and without beryllium or lead reflectors/absorbers. The configurations are further described below in relation to the discrete zone in which the target assembly may be placed within the reactor:

[0055] Water Hole D**8**—calculations for very small target only for reference information. (Core position D**8** refers to the perimeter of the core surrounded by the core pool as shown as **126** in FIG. **12**.)

[0056] Water Hole D**5**—11 slugs/target material 3 cm tall, 2 cm diameter stacked from core center. (Core position D**5** refers to a location at the core center as shown as **124** in FIG. **12**.)

[0057] Beryllium Shield—Same configuration as water hole above except shielded with beryllium shield.

[0058] Be Shield—11 slugs/target material 3 cm tall, 2 cm diameter stacked from core center with a 0.25-cm beryllium reflector surrounding the molybdenum.

[0059] Be Cylinder—11 annuli 3 cm tall, 0.25 cm thick, inner diameter 2 cm with a beryllium cylinder 2 cm in diameter at the center.

[0060] Fuel Annulus—1 molybdenum slug/target material 38 cm tall, 2 cm diameter inside of a fuel annulus 0.7 cm thick, inner radius 1.05 cm.

[0061] Fuel Annulus+Be—same as above but surrounded by a beryllium reflector 0.16 cm thick and an inner radius of 1.74 cm. In practice the outer radius of the fuel annulus would be 1.75 cm, so the inner radius of the beryllium reflector would be slightly larger.

[0062] Fuel Annulus+Pb—same as above, but replace beryllium with lead (Pb).

[0063] Fuel Annulus+Be-Hydrogen—same as "Fuel Annulus+Be" except the hydrogen inside the zirconium hydride fuel can be removed from the material description.

[0064] Fuel Annulus+Pb-Hydrogen—same as "Fuel Annulus+Pb" but hydrogen has been omitted from the fuel material description.

[0065] Each of the test conditions described above is based on 144 hours of irradiation. FIG. **13** shows the production of ^{99}Mo in a specimen target located out-of-core from 12 to 144 hours. After 72 hours, the production of ^{99}Mo is 3.8 curie. After 144 hours, the production of ^{99}Mo is only 5.6 Ci, or only 1.8 Ci more than produced during the first 72 hours. The two target positions for the purpose of modeling calculations are graphically shown in FIG. **12** as positions **124** and **126**. Position **126** (D**8**) is outside of the core, and position **124** (D**5**) is inside the core where the higher flux is produced.

[0066] Each core position (D**5**) may have four fuel elements configured as shown in FIGS. **9** and **10**, for example. A molybdenum target can replace one of the fuel elements in the assembly. The modeling results are shown in Table 1 below. The data can indicate that it is possible to produce about 1000 Ci @ 1.0 Ci/g in a single fuel annulus and a beryllium reflector (1 target position at peak flux in D**5**). Alternatively, about 1000 Ci @ 0.4 Ci/g may be produced with a larger molybdenum target cylinder in just water. The data further indicates that a four-fold increase in the total curie values can be achieved with four targets replacing four fuel locations. A four-fold improvement in production and in specific activity can be achieved by replacing the natural molybdenum target (24% ^{98}Mo) with an enriched ^{98}Mo target (96% ^{98}Mo).

TABLE 1

Summary of Data-144-Hr Irradiation of In-Core Mo Metal Powder; 8 g/cc, 2-cm Diameter

Geometry	^{99}Mo Activity (Ci)	Activity (Ci/gm)	Cell Mass (g)	
Water Hole D8 Out of core	5.57	0.074	75.39	(a)
Water Hole	31.78	0.4216	75.39	(a)
Beryllium Reflector	31.65	0.4199	75.39	(a)
Beryllium Center	33.70	0.4471	75.39	(a) (b)
Fuel Annulus	852.0	0.8921	955.04	
Fuel Annulus + Beryllium Reflector	960.7	1.0059	955.04	