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# Actinide ($An^{89-103}$)

## Properties

The Actinides or actinide series of chemical elements comprises the 15 metals with atomic numbers 89 through 103, from actinium through lawrencium. The actinide series mostly corresponds to the filling of the 5f electron shell, although actinium and thorium lack any 5f electrons, and curium and lawrencium have the same number as the preceding element. While actinium and the late actinides behave similarly to the lanthanides, the elements thorium, protactinium, and uranium are much more similar to transition metals in their chemistry, with neptunium and plutonium occupying an intermediate position.

The only two actinides found in appreciable quantities in the Earth's crust are thorium and uranium. Small quantities of plutonium and neptunium are present in uranium orders. Actinium and protactinium occur as decay products of certain thorium and uranium isotopes. The other actinides are considered synthetic elements. If they occur naturally, it is part of a decay scheme of a heavier element.

**Table 1**. Properties of the Actinides.

| Chemical element | Atomic number | Atomic Weight | Density ($g/cm^3$) | Melting Point ($^oC$) | Electrode potential, V, $E^o$ ($An^{4+}/An^0$)<br>$E^o$ ($An^{3+}/An^0$) | Oxidation States | Abundance in Earth's crust, ppm |
|---|---|---|---|---|---|---|---|
| Actinium (Ac) | 89 | 227 | 10.07 | 1050 | -<br>-2.13 | 2, 3 | $5 \times 10^{-15}$ % |
| Thorium (Th) | 90 | 232.04 | 11.78 | 1842 | -1.83<br>- | 2, 3, 4 | 16 |
| Protactinium (Pa) | 91 | 231.04 | 15.37 | 1568 | -1.47<br>- | 2, 3, 4, 5 | $10^{-12}$ % |
| Uranium (U) | 92 | 238.03 | 19.06 | 1132 | -1.38<br>-1.66 | 2, 3, 4, 5, 6 | 4 |
| Neptunium (Np) | 93 | 237 | 20.45 | 639 | -1.30<br>-1.79 | 2, 3, 4, 5, 6, 7 | Traces in U minerals |
| Plutonium (Pu) | 94 | 244 | 19.84 | 639 | -1.25<br>-2.00 | 2, 3, 4, 5, 6, 7 | $3 \times 10^{-20}$ % |
| Americium (Am) | 95 | 243 | 11.7 | 1176 | -0.90<br>-2.07 | 2, 3, 4, 5, 6, 7 | Traces in U minerals |
| Curium (Cm) | 96 | 247 | 13.51 | 1340 | -0.75<br>-2.06 | 2, 3, 4, 5, 6 | NA |
| Berkelium (Bk) | 97 | 247 | 14.78 | 986 | -0.55<br>-1.96 | 2, 3, 4 | NA |
| Californium (Cf) | 98 | 251 | 15.1 | 900 | -0.59<br>-1.97 | 2, 3, 4 | NA |
| Einsteinium (Es) | 99 | 252 | 8.84 | 860 | -0.36<br>-1.98 | 2, 3, 4 | NA |
| Fermium (Fm) | 100 | 257 | 9.7 | 1530 | -0.29<br>-1.96 | 2, 3 | NA |
| Mendelevium (Md) | 101 | 258 | 10.3 | 830 | -<br>-1.74 | 2, 3 | NA |
| Nobelium (No) | 102 | 259 | 9.9 | 830 | -<br>-1.2 | 2, 3 | NA |
| Lawrencium (Lr) | 103 | 266 | 15.6 | 1630 | -<br>-2.1 | 3 | NA |

Actinides share the following common properties:

- All of these elements are silver-colored metals that are solid at room temperature and pressure. Their electrical resistivity varies between 15 and 150 μOhm·cm [1].
- They all have very large atomic & ionic radii and exhibit an unusually large range of physical properties.
- All are radioactive. These elements have no stable isotopes.
- Actinides are highly electropositive.
- The metals have a silvery color but tarnish readily in air. These elements are pyrophoric, particularly as finely divided powders. They react with boiling water or dilute acid to release hydrogen gas.
- Actinides are dense metals with distinctive structures and numerous allotropes. Plutonium has seven, and uranium, neptunium and californium three. The exception is actinium, which has fewer crystalline phases.
- Actinide metals tend to be fairly soft. The hardness of thorium is similar to that of soft steel, so heated pure thorium can be rolled in sheets and pulled into wire. Thorium is nearly half as dense as uranium and plutonium, but is harder than either of them.
- These elements are malleable and ductile.
- All of the actinides are paramagnetic.
- Actinides combine directly with most nonmetals.
- Actinides display several valence states (more than the lanthanides). Most are prone to hybridization.
- The actinides prepared by reduction of $AnF_3$ or $AnF_4$ with vapors of Li, Mg, Ca, or Ba at 1100 - 1400°C.

## Plating Solutions

Actinium, thorium, protactinium, uranium, neptunium, plutonium, and americium can be plated from aqueous and organic solutions [2-6]. Uranium and thorium can be electrodeposited from ethanol solutions containing 0.02 M natural uranyl and 0.02 M natural thorium nitrate, each with 3.6 M ammonium nitrate [4]. Protactinium can be deposited by using ammonium formate-sulphuric acid aqueous solution. Eighty per cent of protactinium was electrodeposited from 0·1 N ammonium formate-0·1 N sulphuric acid solution under a constant current density of 80 $mA/cm^2$ at room temperature [5]. Uranium, plutonium and americium can be electroplated from the solutions, containing ammonium chloride, ammonium oxalate and ammonium sulphate [6].

## Applications

All actinides are radioactive and release energy upon radioactive decay. Naturally occurring uranium and thorium, and synthetically produced plutonium are the most abundant actinides on Earth. These are used in nuclear reactors and nuclear weapons. Uranium and thorium also have diverse current or historical uses. About half of the produced thorium is used as the light-emitting material of gas mantles. Thorium is also added into multicomponent alloys of magnesium and zinc. So the Mg-Th alloys are light and strong, but also have high melting point and ductility and thus are widely used in the aviation industry and in the production of missiles. Americium is used in the ionization chambers of most modern smoke detectors.

## References:

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