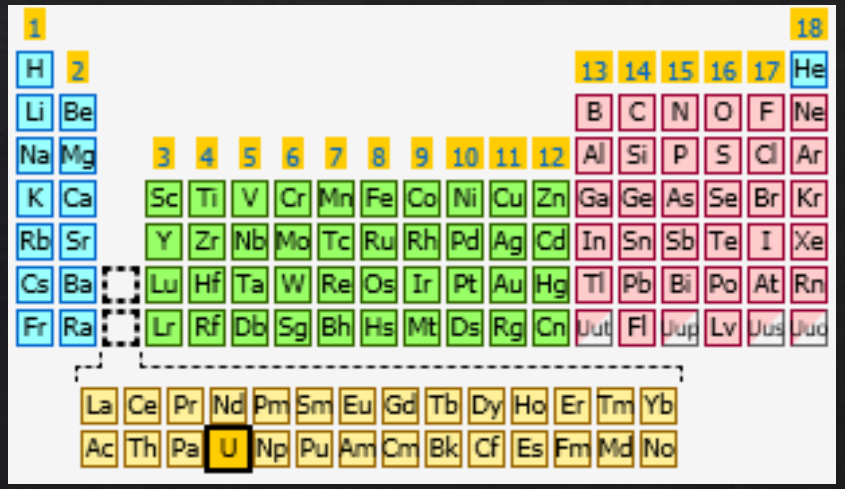
Uranium

Discovery

- Discovered in 1789 by Martin Heinrich Klaproth
- Named after planet Uranus
- Radioactive properties discovered in 1896 by Henri Becquerel
- Constitutes 2-4 ppm of Earth’s crust
- In 2019, production amount was 54 752 tons of pure Uranium
- Kazakhstan produces the highest amount with 22 808 tons
- Australia has the largest resources with almost 2 millions of tons of Uranium on its soil

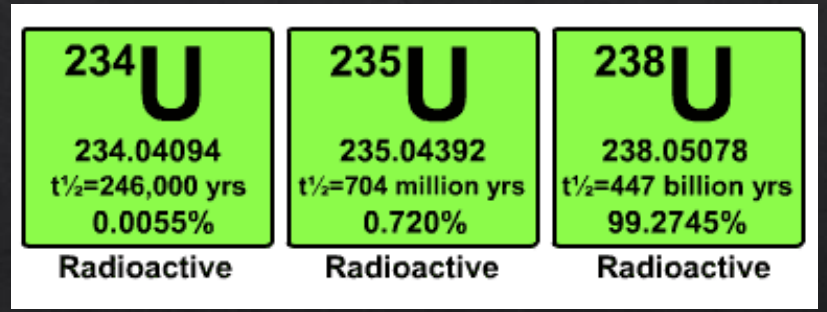
Chemistry of Uranium

- Atomic number is 92
- Atomic weight 238.03 u
- Actinide which belongs to the period 7
- Electron configuration [Rn] $5f^3 6d^1 7s^2$
- Pure uranium is coloured silvery-white
- Uranium metal has very high density (70% more dense than lead)
- Oxidation states: +1, +2, +3, **+4**, +5 and **+6**
- Melting point 1133 °C
- Atomic radius 240 pm



Isotopes

- Uranium has three isotopes present in nature: ^{238}U, ^{235}U and ^{234}U
- The most abundant isotope is ^{238}U (99.28 %)
- Artificially possible to produce other isotopes
- All of them are radioactive but only ^{235}U is fissionable in nature
- When ^{238}U bombarded with neutrons, ^{239}Pu is generated

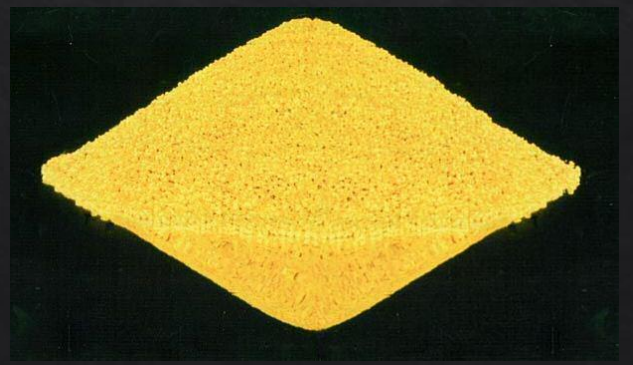


Compounds

- The most common uranium oxide forms are U_3O_8 and UO_2
- Uraninite ore consists mostly of UO_2
- U_3O_8 is the most stable form of uranium
- UO_2 slowly converts to U_3O_8 at ambient temperatures
- Yellow cake is a uranium oxide concentrate produced from uranium ores
  - Consists mostly of U_3O_8

Uranium dioxide

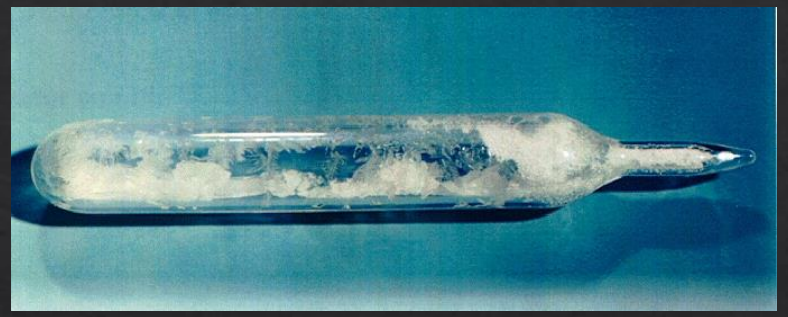
Triuranium octoxide



Yellow cake (urania)

Compounds

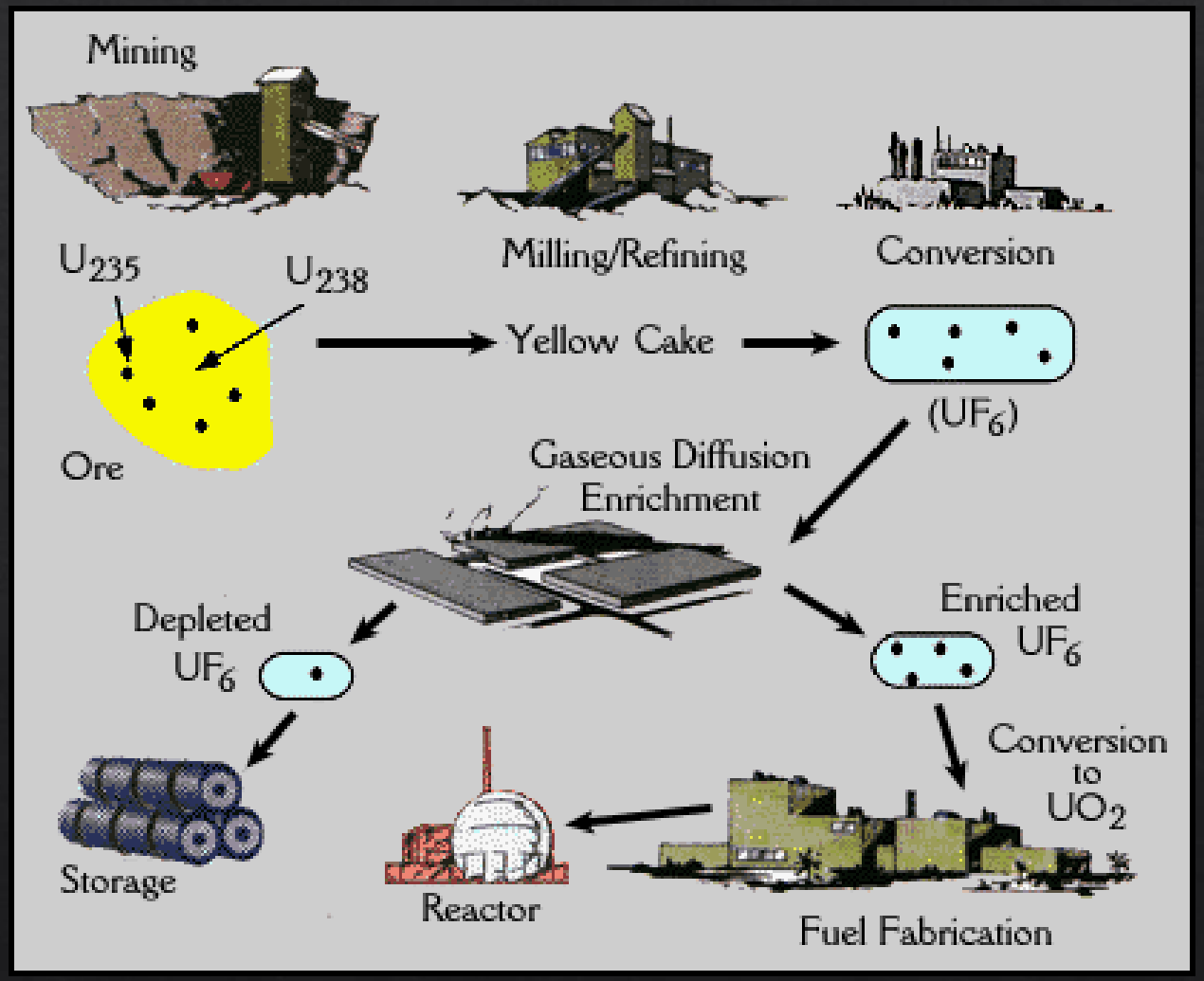
- UF_6 is used in uranium enrichment process
- UF_4 is an intermediate between UF_6 and uranium oxides
- UF_4 can also be used in molten salt reactors that use molten fluoride salts as coolant and/or fuel



Uranium hexafluoride

Uranium tetrafluoride

Uranium processing



Compounds

- UH_3 is black or dark gray powder
  - Forms when uranium is heated to 250 °C in a vacuum followed by introduction of H_2 gas
  - Very reactive
  - Used as a starting material in many reactions
- Other compounds: e.g. nitrides, chlorides, bromides, organometals, complexes

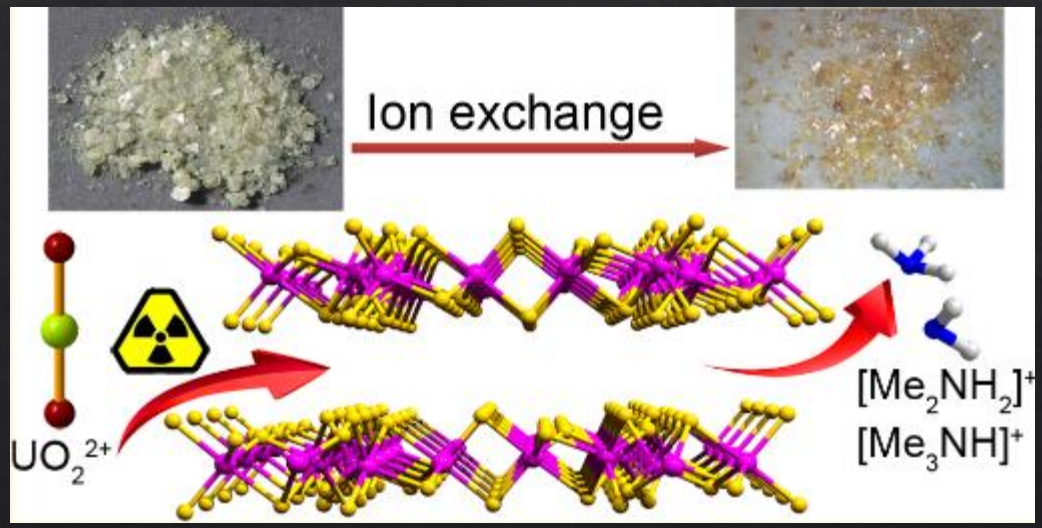
Reagent	*Reaction temperature* (°C)	*Product*
O_2	ignites at room temperature	U_3O_8
H_2O	350	UO_2
H_2S	400–500	US_2
N_2	250	U_2N_3
NH_3	250	U_2N_3
PH_3	400	UP
Cl_2	250	UCl_4
CCl_4	250	UCl_4
	possibility of explosion at 25°C	
HCl	250–300	UCl_3
HF	200–400	UF_4
Br_2	300–350	UBr_4
HBr	300	UBr_3
CO_2	300	UO_2

Applications

- Energy production from U-235
- Breeder reactor
- Military use
  - Nuclear weapons and submarines
- Ammunition and armour from depleted uranium

Efficient Removal and Recovery of Uranium by a Layered Organic–Inorganic Hybrid Thiostannate

- Uranium is one of the most radioactive elements in nuclear wastes, occurring in the form of soluble UO_2^{2+} (uranyl)
- UO_2^{2+} can be removed from nuclear waste solutions with chalcogenide $(Me_2NH_2)_{1.33}(Me_3NH)_{0.67}Sn_3S_7 \cdot 1.25H_2O$ **(FJSM-SnS)**
- FJSM-SNs is highly selective and stabile in pH of 2.1 - 11



Mei-Ling, F., Debajit, S., Xing-Hui, Q., Ke-Zhao, D., Xiao-Ying, H. &Mercouri, G. K. 2016. Efficient Removal and Recovery of Uranium by a Layered Organic-Inorganic Hybrid Thiostannate. Journal of the American Chemical Society 138 (38). https://pubs.acs.org/doi/abs/10.1021/jacs.6b07351

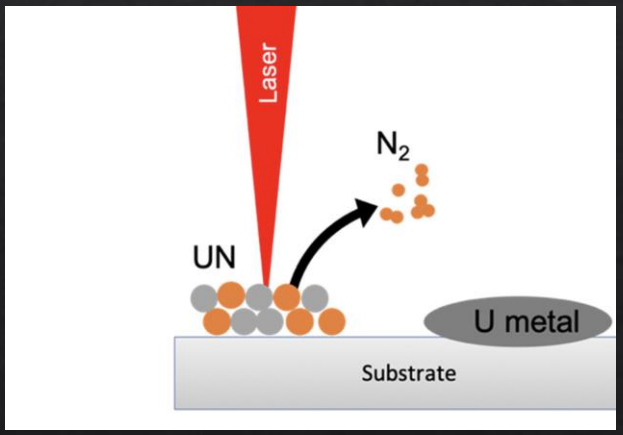
Half-metallicity in uranium intermetallics

- Intermetallic compounds containing uranium has been studied due to reactivity of 5f electrons
- Possibility to push properties of 5f electrons in to one or other direction by alloying uranium with other metals
- Phenomenas like low-symmetry crystal structures, conventional superconductivity, ferromagnetic superconductivity etc.
- Recent studies suggest that UFe and UCo compounds act as half-metals

Sachs, M., Karttunen, A. J. & Kraus, F. 2019. Half-metallicity in uranium intermetallics : Crystal structure prediction of a high-pressure phase of UCo. Journal of Physics Condensed Matter , vol. 31 , no. 2 , 025501. https://doi.org/10.1088/1361-648X/aaeeca

Extraction of uranium via laser

- Producing gram quantities of uranium is challenging due to extreme thermal requirements
- In novel computational thermodynamic approach, uranium was extracted from uranium nitride at temperature exceeding 2500 K
- By irradiating uranium nitride with controlled laser under several gaseous conditions including high-vacuum resulted in yield up to 96 % of uranium metal
- Rapid cooling needed as well



Childs, B. C., Martin, A. A., Perron, A., Moore, E. E., Idell, Y., Heo, T. W., ... & Landa, A. (2020). Formation of high purity uranium via laser induced thermal decomposition of uranium nitride. *Materials & Design*, 108706.

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