SA0

A Presentation on Uranium(U)

By:

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4th October 2023

Slide 1

SA0

Hello, from my side slides are ready please make changes if you want and submit it. [@Viirto Miikka]

Singh Ashish; 2023-10-04T05:18:56.374

Outline

- History and Discovery
- Physicochemical properties
- Production
- Application
- Storage and Handling

History of Uranium :

- Natural uranium oxide can be traced back to the Roman Empire; it was used to add yellow color to ceramic (AD 79)
- Also used as a coloring agent in the glass industry in the Middle Ages
- In the early 19th century, the known old source was the Habsburg silver mines (Czech Republic)
- One of the largest producers of Uranium was Germany (SDAG), which was shut down by the end of the Cold War

https://www.firstpost.com/explainers/enriched-uranium-in-iran-nuclear-bomb-dangers-12229372.html
https://www.popsci.com/uranium-nuclear-energy-weapons/

Discovery

This element was discovered by Prof. Martin Heinrich Klaporth (German) as an oxide of Uranium (1789)

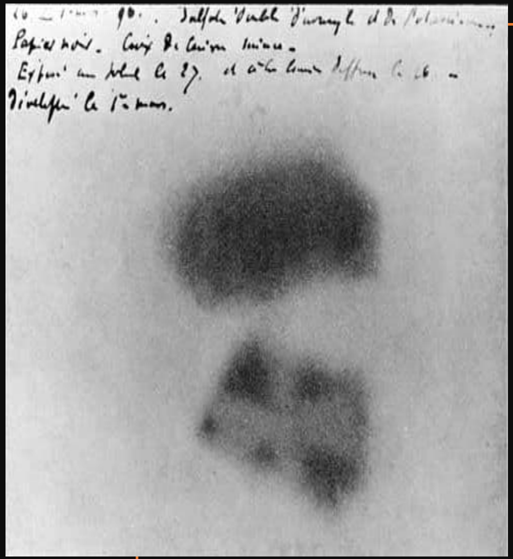
He named the newly discovered metal after the planet Uranus(the Greek God of the sky)

The first sample of Uranium metal was isolated by Prof. Eugene-Melchior Peligot (French) from its oxide (1841)

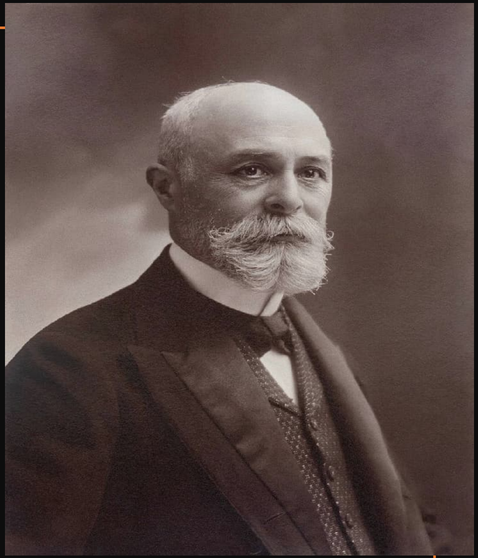
Radioactivity of Uranium was discovered by Henri Becquerel (1896)

Martin Heinrich Klaproth

Eugène-Melchior Péligot



Photographic plate



Henri Becquerel

https://en.wikipedia.org/wiki/Main_Page

Natural abundance and occurrence

- Uranium is a naturally occurring radioactive element with no stable isotopes.

- There are 22 known isotopes of Uranium

- It has two highly occurring isotopes: ^{238}U(99.3%) and ^{235}U(0.720%) with half-life of 4.468×10^{9} and 7.04×10^{8} year

- Naturally occurring Uranium is found in three isotopes: ^{238}U, ^{235}U and ^{234}U

Table 1. ^{238}U, ^{234}U and U-nat concentrations in water samples.

Isotope and sample code	Sample activity	Sample salinity	Sample structure	Chemical recovery (%)	Activity ($Bq.kg^{-1}$) (AQCS)	Activity ($Bq.kg^{-1}$) (Obtained)	Uncertainty ($Bq.kg^{-1}$) (AQCS)	Uncertainty ($Bq.kg^{-1}$) (Obtained)
U-238(423)	High activity	Low salinity	Synthetic	67	0.238	0.1898	0.0012	0.0134
U-238(426)	Low activity	High salinity	Natural	22	0.026	0.02935	0.0072	0.004788
U-238(430)	Medium activity	High salinity	Synthetic	34	0.077	0.08296	0.0012	0.006541
U-238(098)	High activity	Low salinity	Synthetic	79	486	596.767	1.5	39.876
U-234(423)	High activity	Low salinity	Synthetic	67	0.239	0.1853	0.0017	0.0131
U-234(426)	Low activity	High salinity	Natural	22	0.09	0.1096	0.019	0.0125
U-234(430)	Medium activity	High salinity	Synthetic	34	0.088	0.09854	0.0017	0.007563
U-234(098) (Standard)	High activity	Low salinity	Synthetic	79	468	572.395	2.3	38.356
U-nat(423)	High activity	Low salinity	Synthetic	67	19.17*	15.26*	0.096*	1.523*
U-nat(426)	Low activity	High salinity	Natural	22	2*	2.363*	0.56*	0.4762*
U-nat(430)	Medium activity	High salinity	Synthetic	34	6.21*	6.667*	0.098*	0.733*
U-nat(098)	High activity	Low salinity	Synthetic	79	39200*	47960*	120*	4539*

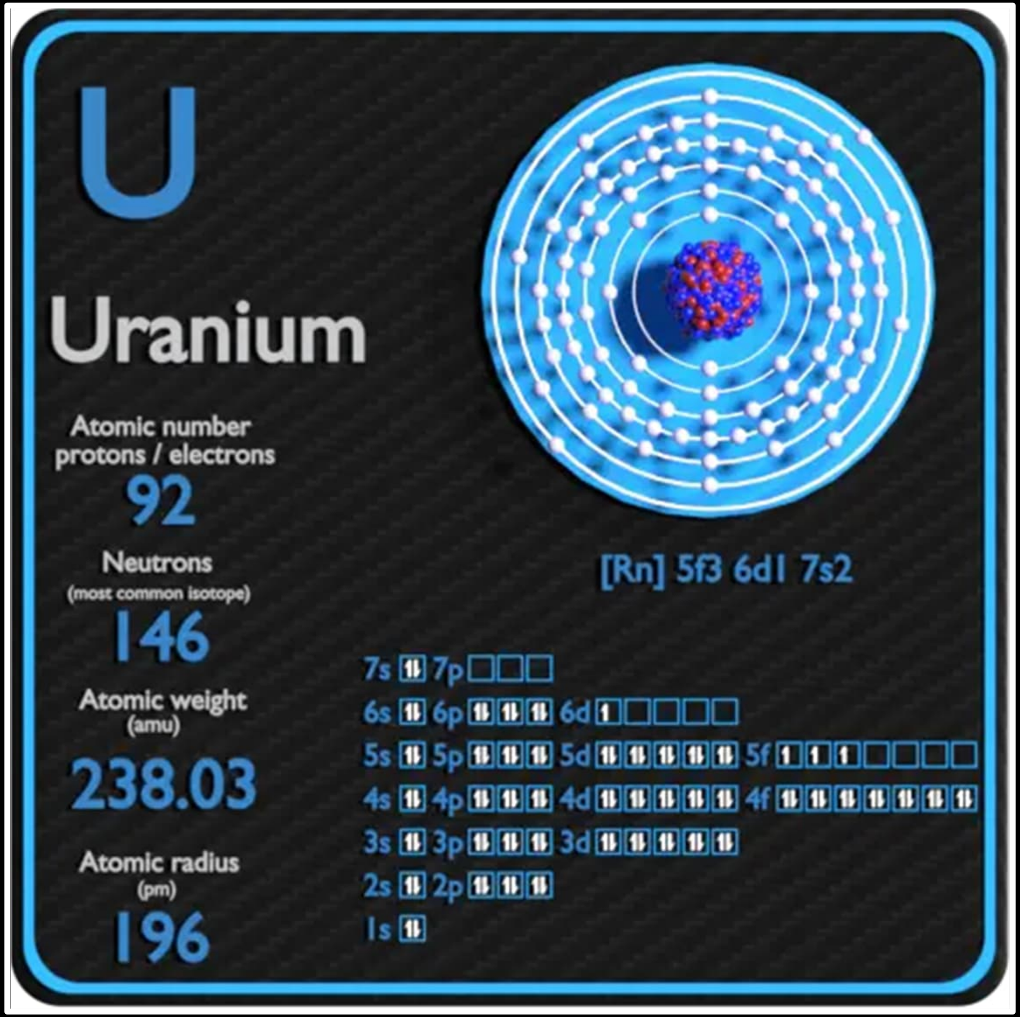
*The natural uranium unit (U-nat) is in μg/kg.

List of Isotopes of Uranium

https://ur.javamem.com/pictures/isotopes-of-uranium

Elemental properties of Uranium

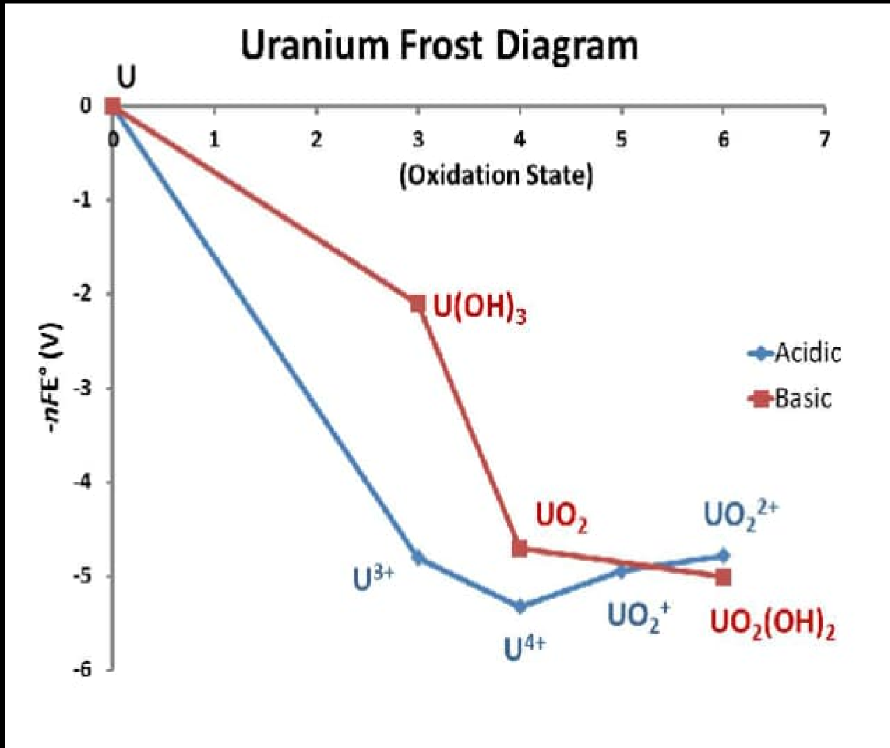
- ❑ It makes 2-4 ppm of earth’s crust (naturally occurring)
- ❑ Uranium belongs to actinide elements
- ❑ It can be found in different minerals, such as carnotite, uraninite, and pitchblende (not in metallic form)
- ❑ Uranium metal can exist in three different allotropic forms: Rhombic, Tetragonal, and Body-centered cubic



https://cdn-0.material-properties.org/wp-content/uploads/2020/09/Uranium-protons-neutrons-electrons-configuration.png
https://www.atsdr.cdc.gov/ToxProfiles/tp150-c4.pdf

Elemental properties of Uranium

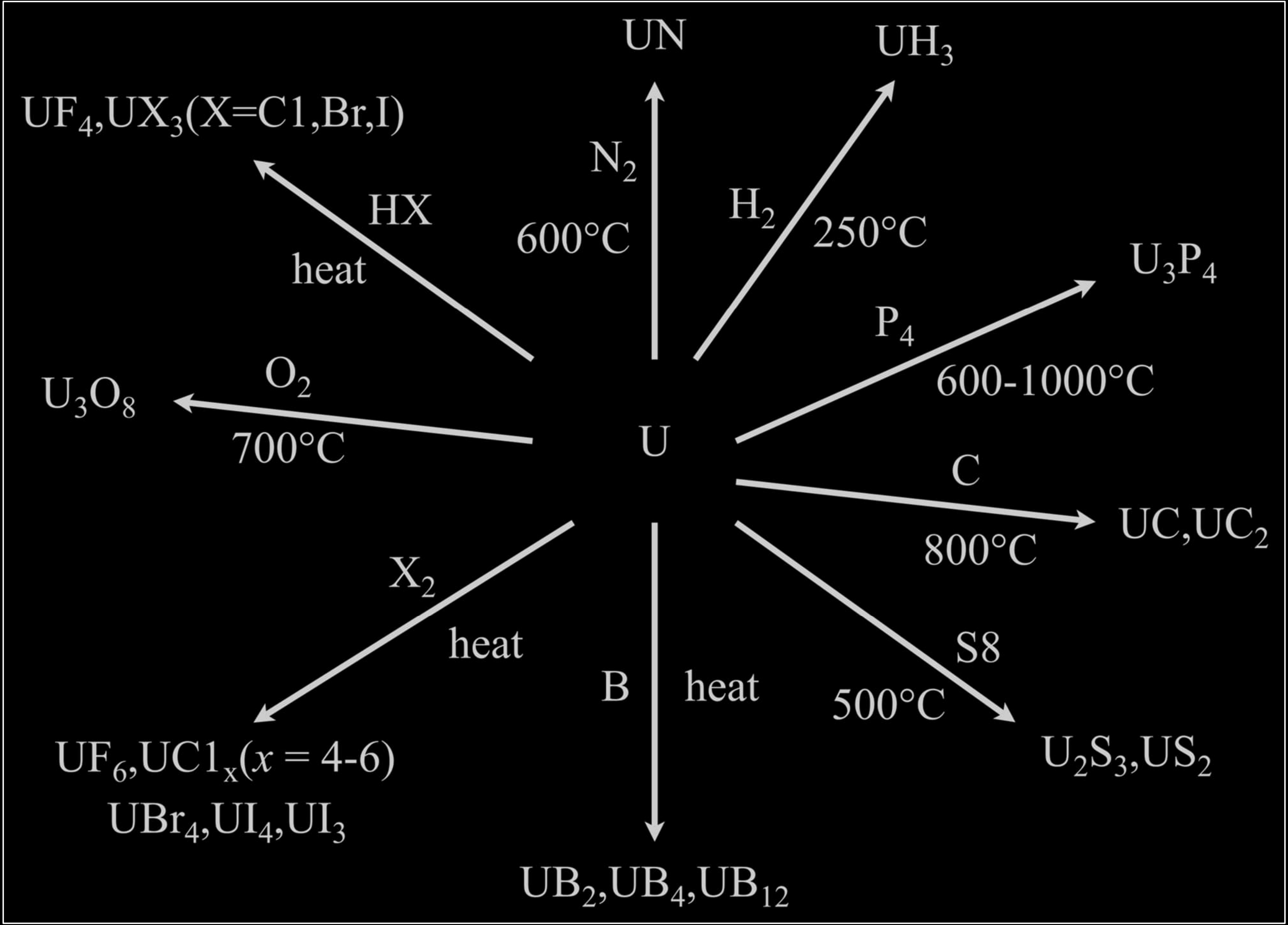
- ❑Uranium can form solids solutions and intermetallic compounds with many of the metals
- ❑ It is auto-pyrophoric in nature so that it can burn (air, water, and oxygen)
- ❑ Uranium can exist in five oxidation states: +2, +3, +4, +5, and +6
- ❑It is radioactive in nature.



https://www.atsdr.cdc.gov/ToxProfiles/tp150-c4.pdf
https://www.chegg.com/homework-help/questions-and-answers/refer-uranium-frost-diagram-complete-questions-uranium-frost-diagram-stable-u-stable-acid--q75916471

Reactivity

[Rn] $7s^2\ 5f^3\ 6d^1$
Uranium +IV most common



https://en.wikipedia.org/wiki/Uranium

Uranium compounds

- Oxides: UO_2, UO_3. Nuclear fuel production, redoxing agent

- Uranates, compounds with alkali or alkaline earth metals: Li_4UO_5. Nuclear fuel (int.)

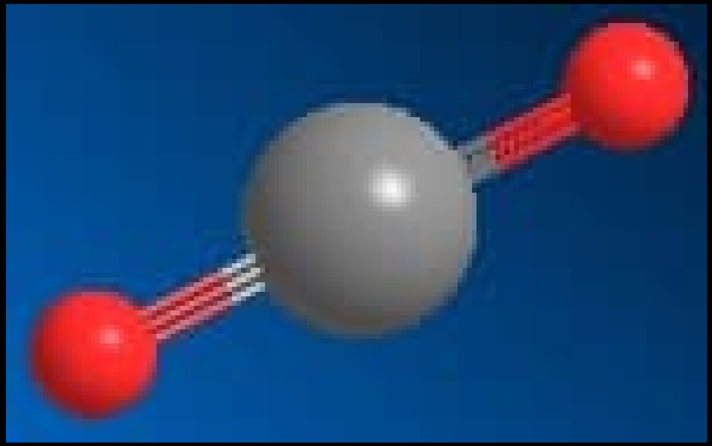
- Uranium halides (F, Cl, Br, I): UCl_3. Metallic uranium production.
  - Oxidation state +3 to +6

- Uranium hydrides: UH_3. Redoxing agent, hydrogen/deuterium/tritium separation

- Borohydrides, $U(BH_4)_4$. Studies on reactivity and surface hydrides [2]

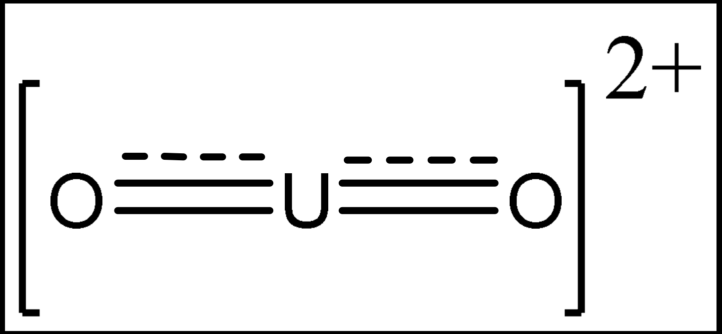
- Nitrogen and phosphorus compounds

Advanced Inorganic Chemistry. F. Albert Cotton et.al. 6th edn. John Wiley & Sons, Chichester, 1999,
[2] https://inis.iaea.org/collection/NCLCollectionStore/_Public/40/086/40086470.pdf

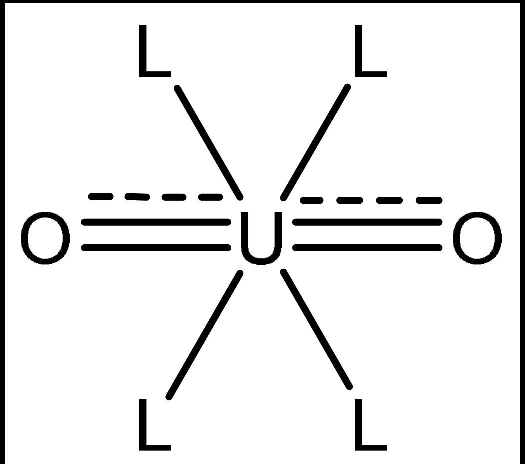


Uranyl

UO_2^{2+}



- High oxidation state: U at +6
- potential for photoredox transformations
- Broad absorption range: The absorption primarily within the blue-light region (400–480 nm)
- Uranyl complexes hold promise as candidates for photoredox catalysis in organic transformations.



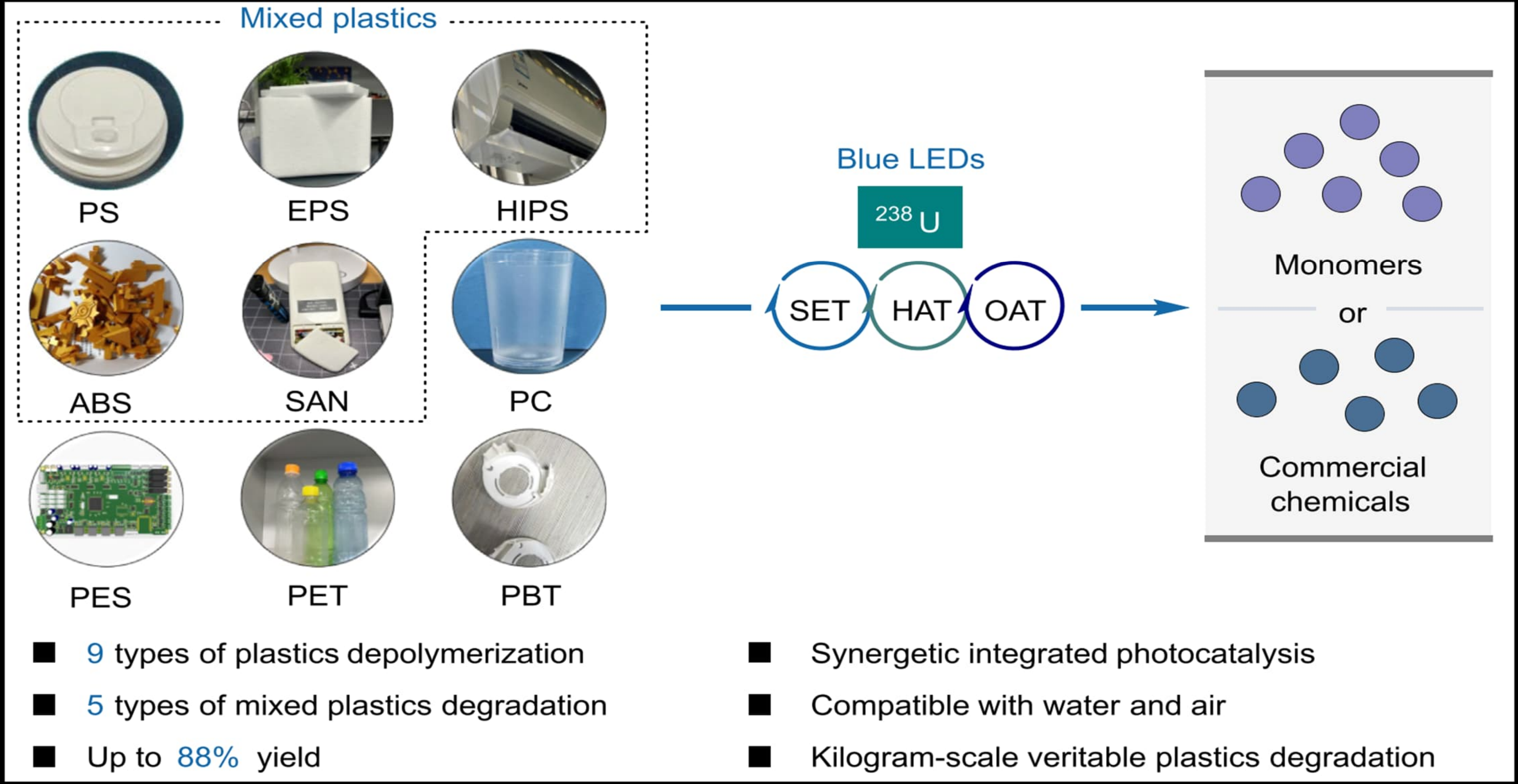
Advanced Inorganic Chemistry. F. Albert Cotton et.al. 6th edn. John Wiley & Sons, Chichester, 1999

Degeneration of plastics using uranyl

SET = single electron transfer

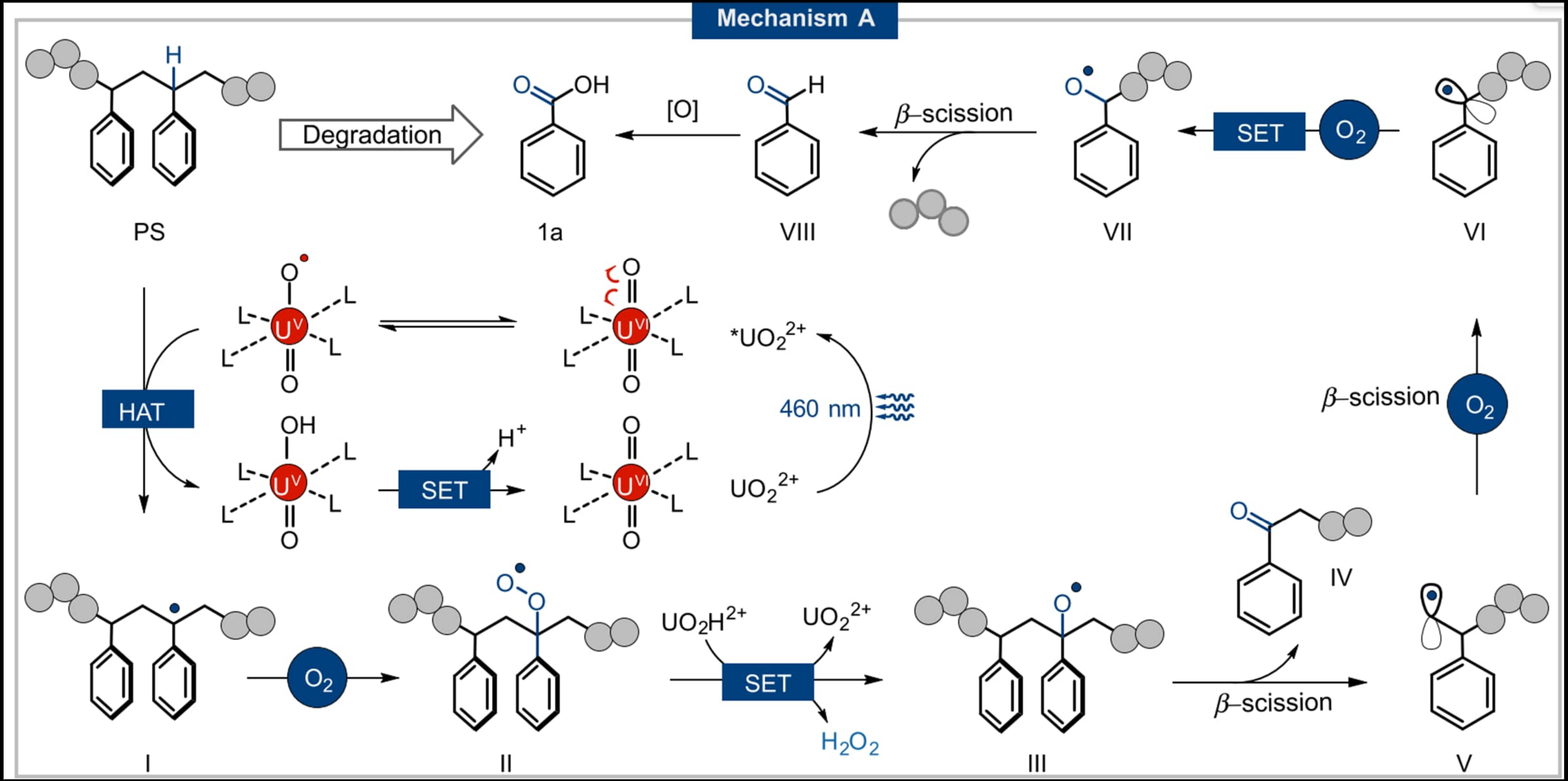
HAT = hydrogen atom transfer

OAT = oxygen atom transfer



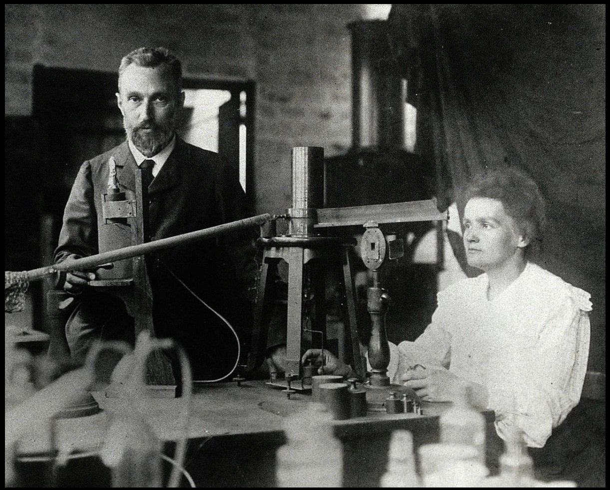
Meng, J., Zhou, Y., Li, D., & Jiang, X. (2023). Degradation of plastic wastes to commercial chemicals and monomers under visible light. *Science Bulletin*, *68*(14), 1522–1530. https://doi.org/10.1016/j.scib.2023.06.024

Catalytic reaction of uranyl



Meng, J., Zhou, Y., Li, D., & Jiang, X. (2023). Degradation of plastic wastes to commercial chemicals and monomers under visible light. *Science Bulletin*, *68*(14), 1522–1530. https://doi.org/10.1016/j.scib.2023.06.024

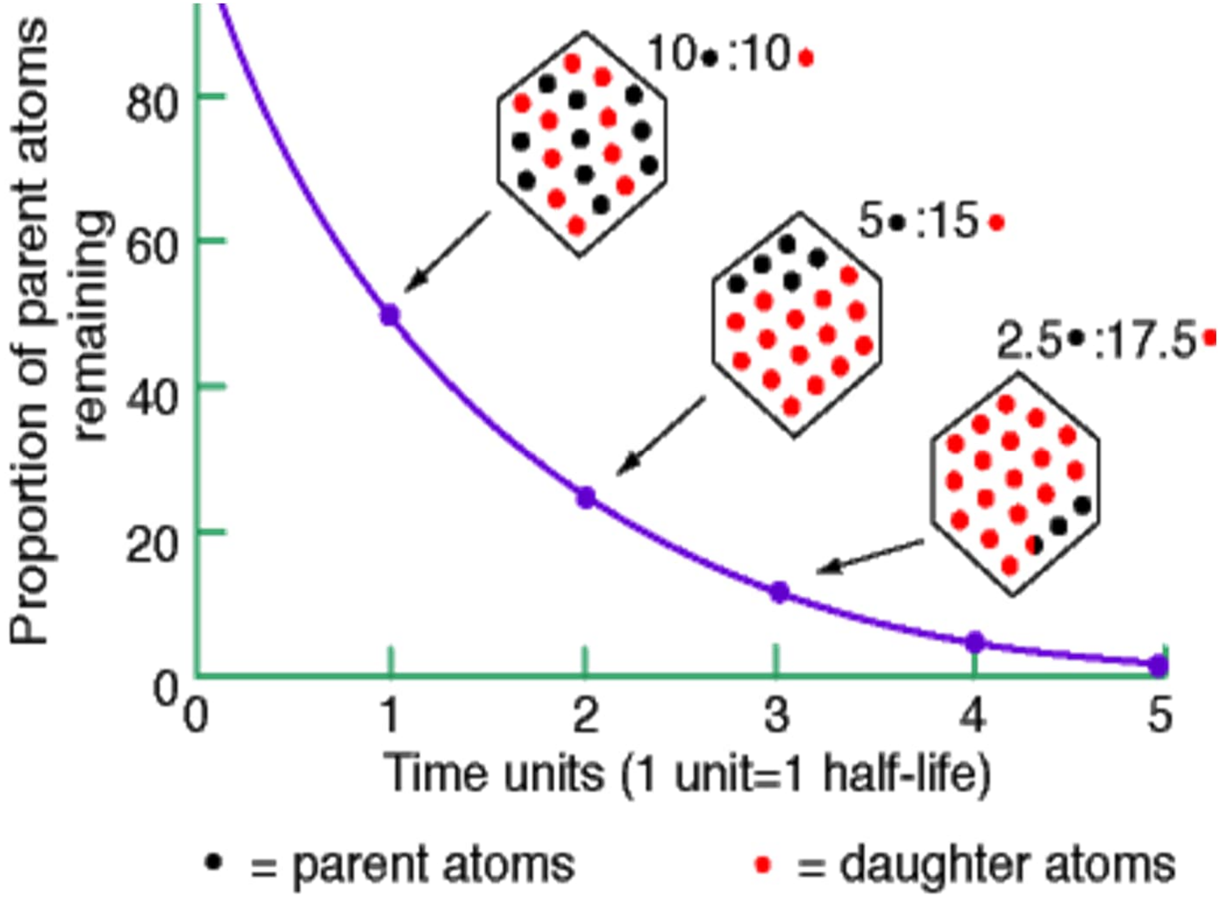
Radioactive Decay

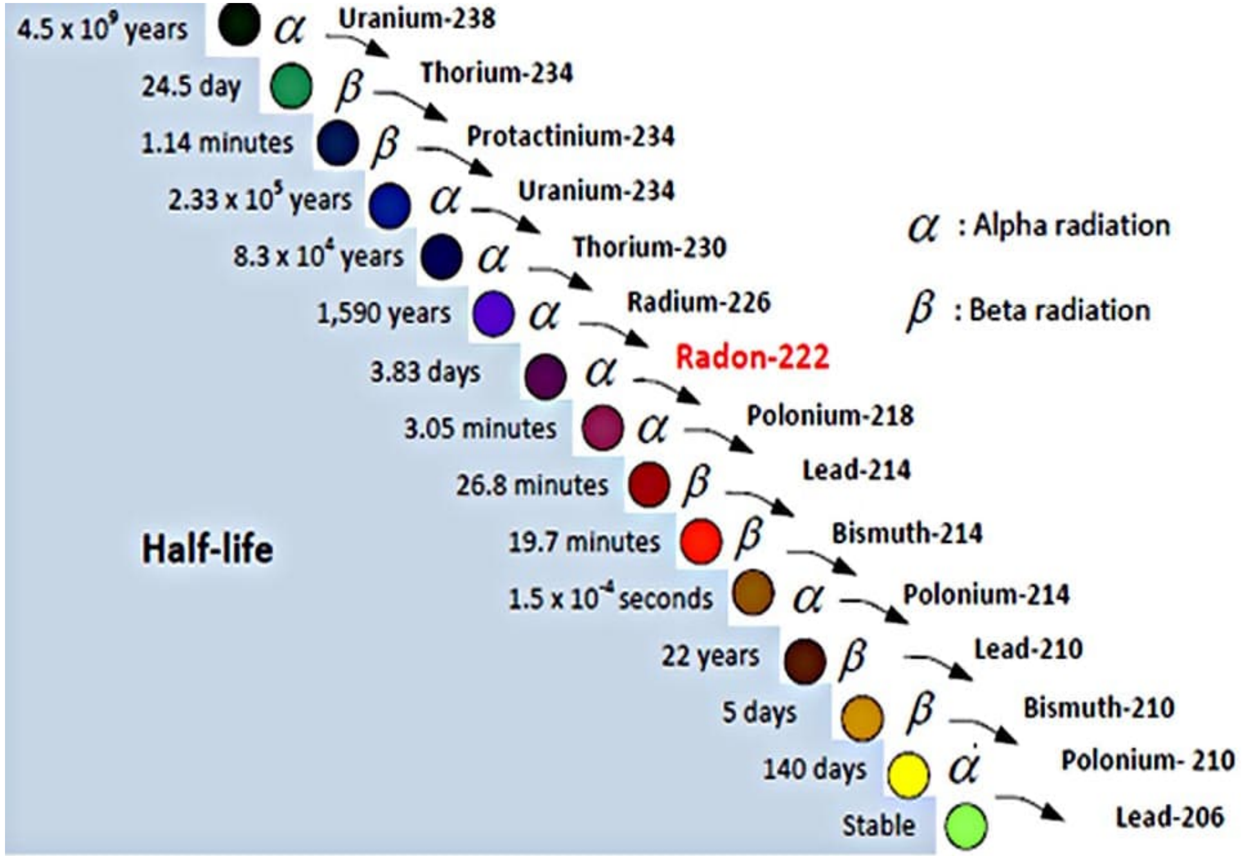


Decay Type	Radiation Emitted	Generic Equation	Model
Alpha decay	${}^{4}_{2}\alpha$	${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}X' + {}^{4}_{2}\alpha$	Parent → Daughter, Alpha Particle
Beta decay	${}^{0}_{-1}\beta$	${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}X' + {}^{0}_{-1}\beta$	Parent → Daughter, Beta Particle
Positron emission	${}^{0}_{+1}\beta$	${}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}X' + {}^{0}_{+1}\beta$	Parent → Daughter, Positron
Electron capture	X rays	${}^{A}_{Z}X + {}^{0}_{-1}e \longrightarrow {}^{A}_{Z-1}X' + \text{X ray}$	Parent, Electron → Daughter, X ray
Gamma emission	${}^{0}_{0}\gamma$	${}^{A}_{Z}X^{*} \xrightarrow{\text{Relaxation}} {}^{A}_{Z}X' + {}^{0}_{0}\gamma$	Parent (excited nuclear state) → Daughter, Gamma ray
Spontaneous fission	Neutrons	${}^{A+B+C}_{Z+Y}X \longrightarrow {}^{A}_{Z}X' + {}^{B}_{Y}X' + C\,{}^{1}_{0}n$	Parent (unstable) → Daughters, ENERGY, Neutrons

https://www.nuclear-power.com/radioactive-decay/

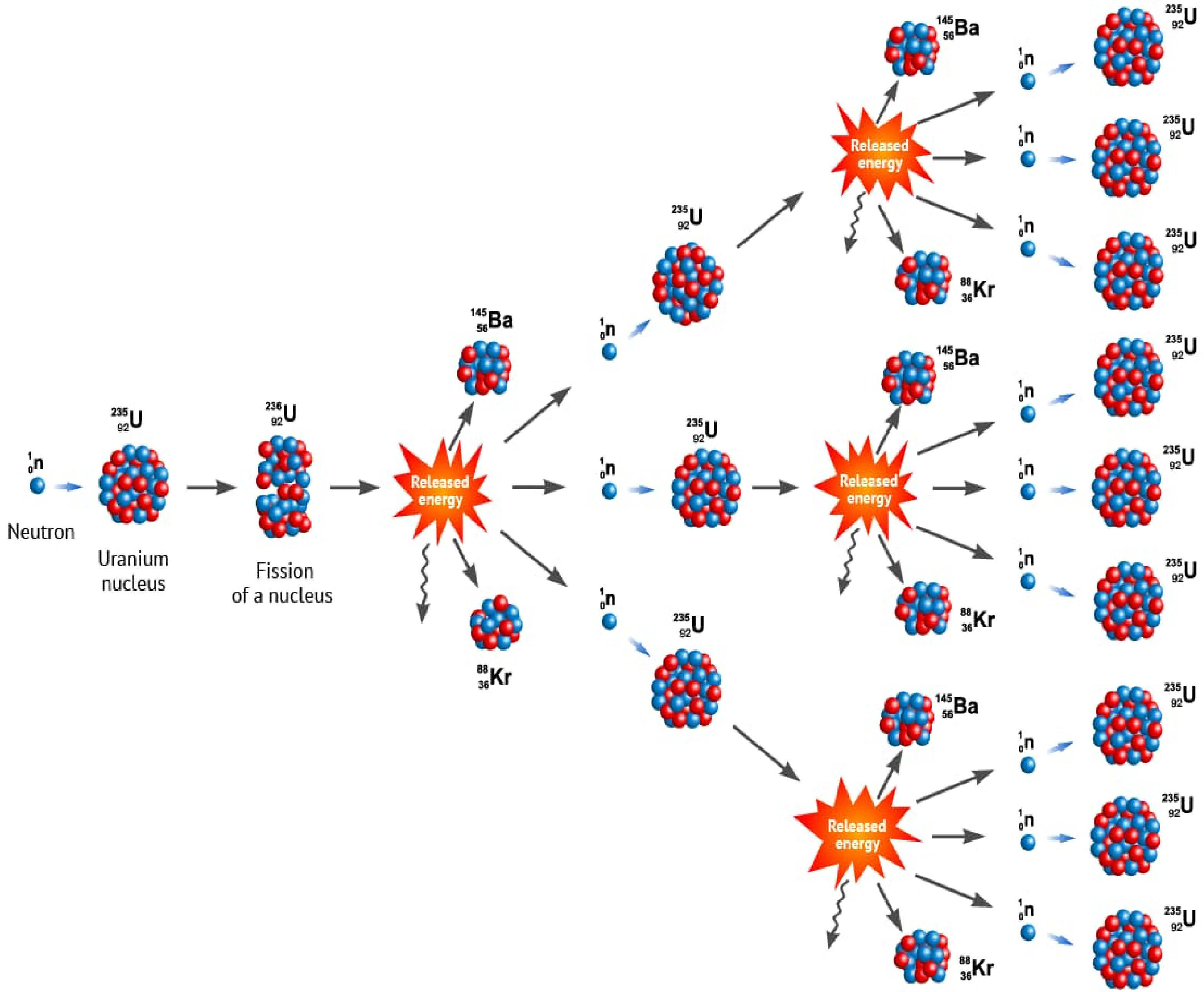
Radioactivity and half-life





https://schoolworkhelper.net/half-life-radioactive-elements-decay-over-time/

Uranium Nuclear Fission chain reaction



https://www.energyencyclopedia.com/en/nuclear-energy/the-nuclear-power-industry/fission-chain-reaction

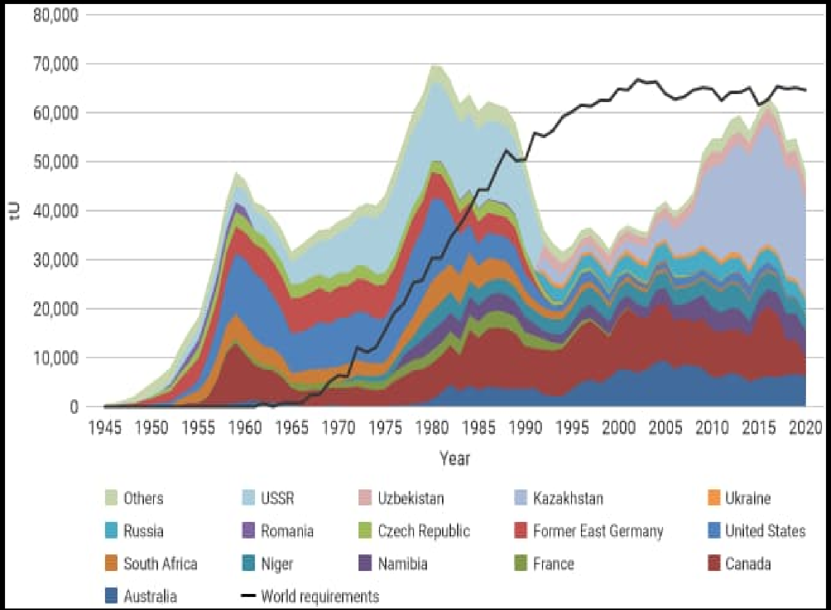
Uranium Production

- Two-thirds of the world's production of uranium from mines is from Kazakhstan, Canada and Australia

- In 2022, Kazakhstan produced the largest share of uranium from mines (43% of the world supply)

- World uranium production and reactor requirements

Country	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Kazakhstan	22,451	23,127	23,607	24,689	23,321	21,705	22,808	19,477	21,819	21,227
Canada	9331	9124	13,325	14,039	13,116	7001	6938	3885	4693	7351
Namibia	4323	3255	2993	3654	4224	5525	5476	5413	5753	5613
Australia	6350	5001	5654	6315	5882	6517	6613	6203	4192	4553
Uzbekistan (est.)	2400	2400	2385	3325	3400	3450	3500	3500	3520	3300
Russia	3135	2990	3055	3004	2917	2904	2911	2846	2635	2508
Niger	4518	4057	4116	3479	3449	2911	2983	2991	2248	2020
China (est.)	1500	1500	1616	1616	1692	1885	1885	1885	1600	1700
India (est.)	385	285	385	385	421	423	308	400	600	600
South Africa (est.)	531	573	393	490	308	346	346	250	192	200
Ukraine	922	926	1200	808	707	790	800	744	455	100
USA	1792	1919	1256	1125	940	582	58	6	8	75
Pakistan (est.)	45	45	45	45	45	45	45	45	45	45
Brazil	192	55	40	44	0	0	0	15	29	43
Iran (est.)	0	0	38	0	40	71	71	71	21	20
Czech Republic	215	193	155	138	0	0	0	0	0	0
Romania	77	77	77	50	0	0	0	0	0	0
France	5	3	2	0	0	0	0	0	0	0
Germany	27	33	0	0	0	0	0	0	0	0
Malawi	1132	369	0	0	0	0	0	0	0	0
Total world	59,331	56,041	60,304	63,207	60,514	54,154	54,742	47,731	47,808	49,355
tonnes U_3O_8	69,966	66,087	71,113	74,357	71,361	63,861	64,554	56,287	56,377	58,201
% of world demand	91%	85%	98%	96%	93%	80%	81%	74%	76%	74%



Uranium resources by country in 2021

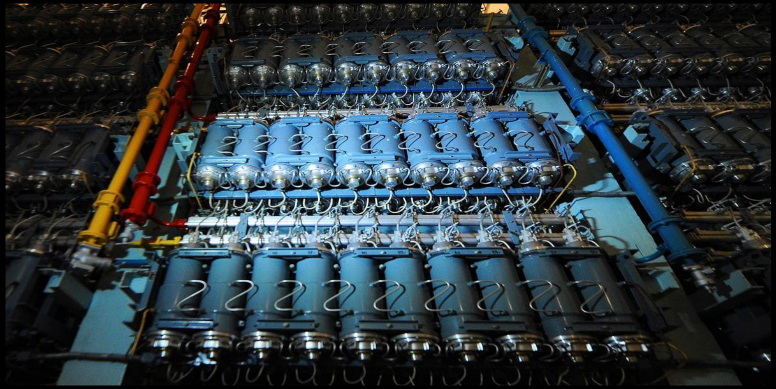
	tonnes U	percentage of world
Australia	1,684,100	28%
Kazakhstan	815,200	13%
Canada	588,500	10%
Russia	480,900	8%
Namibia	470,100	8%
South Africa	320,900	5%
Niger	311,100	5%
Brazil	276,800	5%
China	223,900	4%
Mongolia	144,600	2%
Uzbekistan	131,300	2%
Ukraine	107,200	2%
Botswana	87,200	1%
USA	59,400	1%
Tanzania	58,200	1%
Jordan	52,500	1%
Other	266,600	5%
World total	6,078,500	

https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx

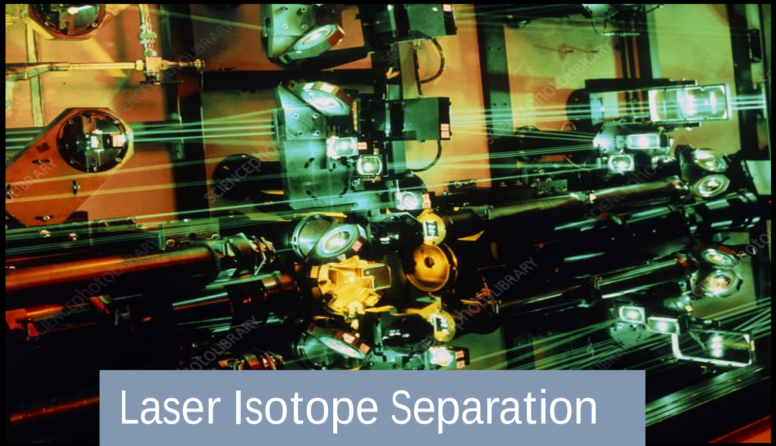
Uranium Enrichment

- It is an important step for converting mined uranium into nuclear fuel
- Uranium (Yellow cake; U_3O_8) is mined from uranium ore by chemical reactions and separation process
- During enrichment, the concentration of ^{235}U is increased for nuclear fuel
- Enrichment methods are Gaseous diffusion, Gas centrifuges, and Laser Isotope Separation

Gas Diffusion



Gas Centrifuge

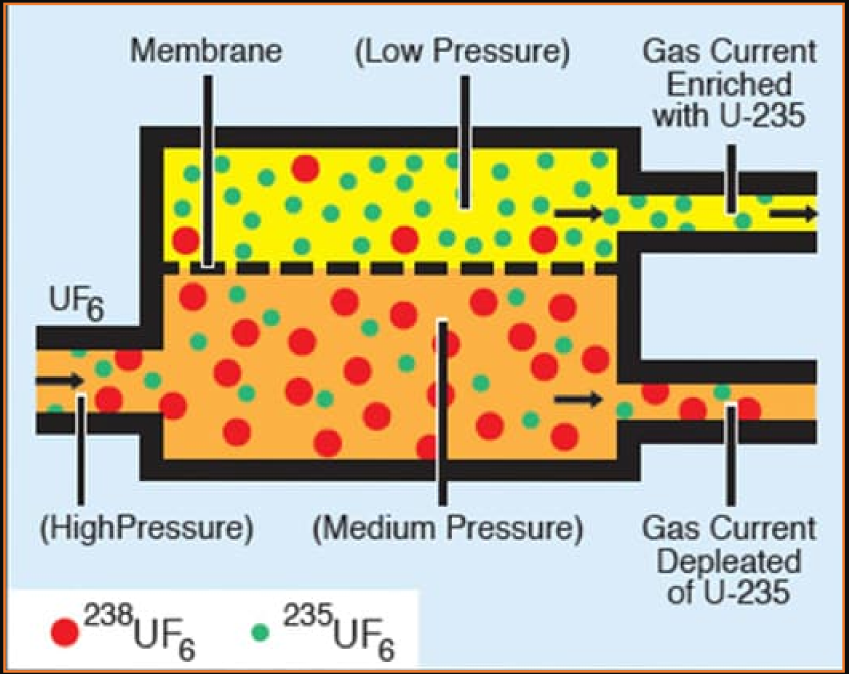


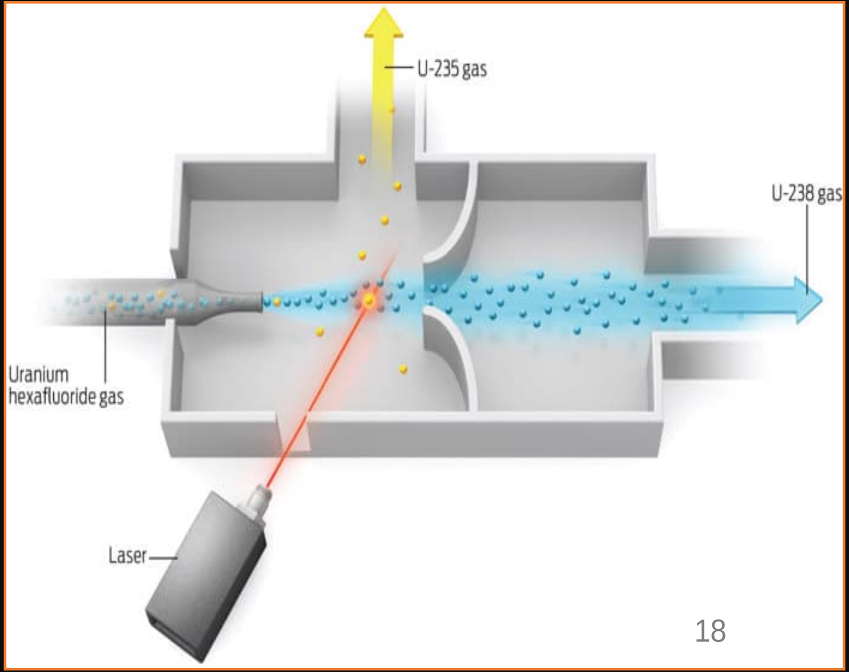
Laser Isotope Separation

https://energyeducation.ca/encyclopedia/Uranium_enrichment

Gas Diffusion and Laser Isotope Separation

- UF_6 (Uranium Hexafluoride) is produced chemically and changed into a gas by applying higher temperature and decreasing the pressure
- Since $^{235}UF_6$ is lighter than other nuclei, it moves faster through pipe (not used anymore)
- Laser separation requires less energy because it uses the light of specific energy to evaporate ^{235}U nuclei only
- But it is still in the developing stage

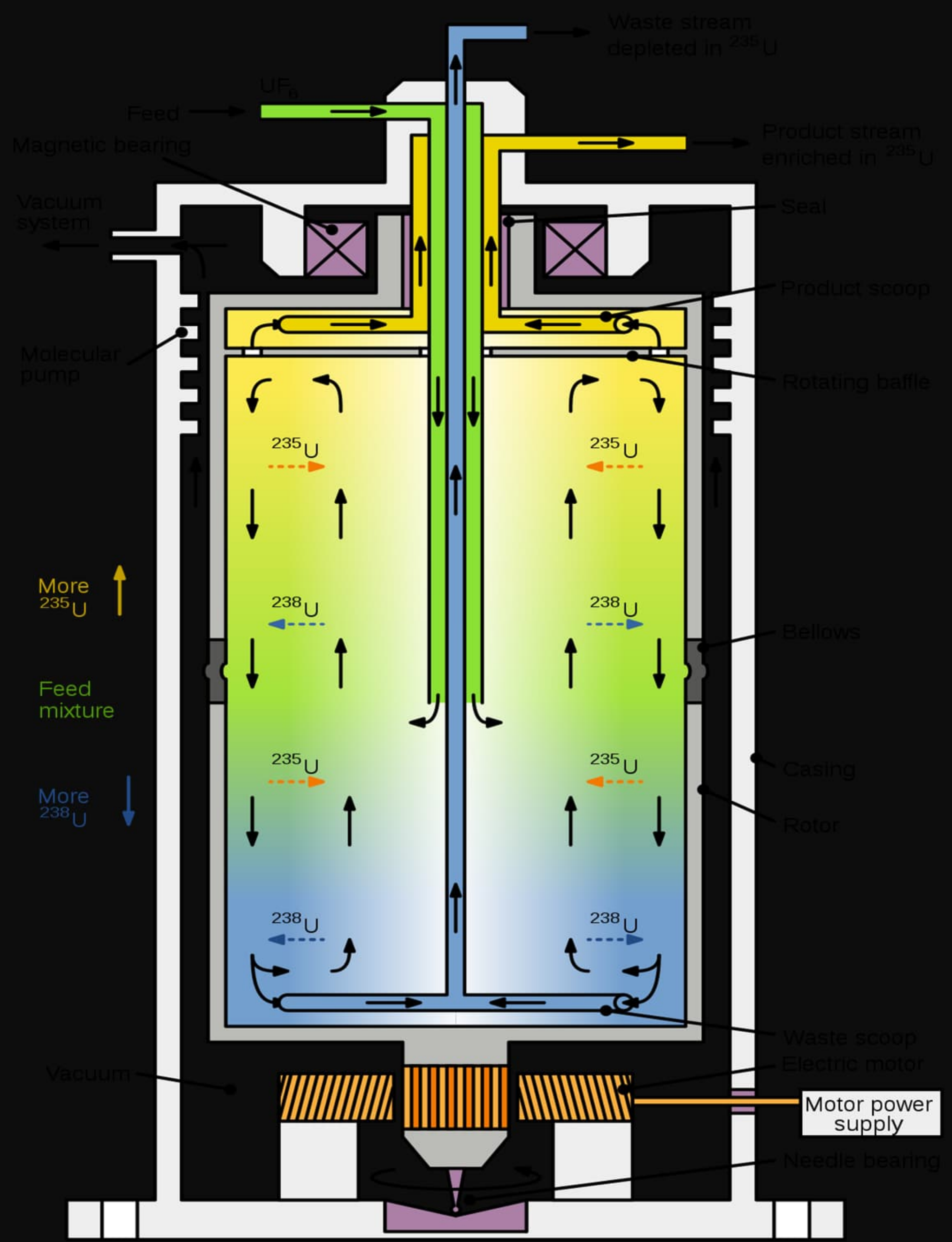




https://chem.libretexts.org/Ancillary_Materials/Exemplars_and_Case_Studies/Case_Studies/Nuclear_Energy_for_Today%27s_World/09._Uranium_Enrichment

Gas Centrifuge
Enrichment of Uranium

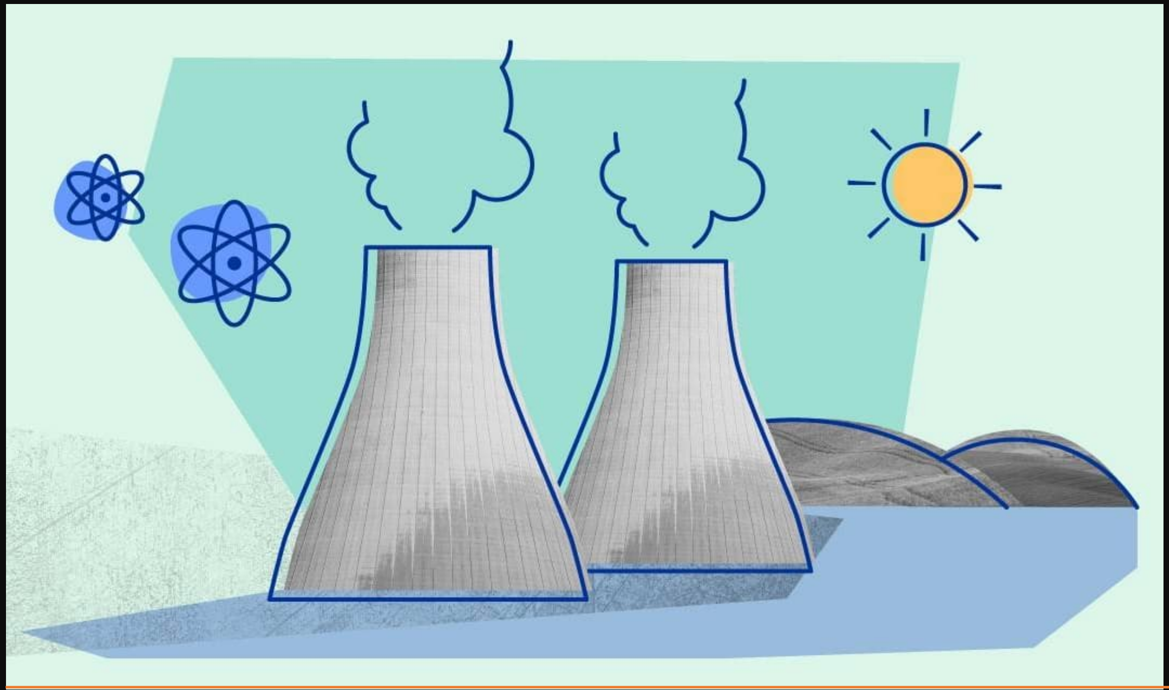
- ❑ Depends on the mass differences of the molecule
- ❑ On putting the gas into the cylinder with the rotor to separate different nuclei
- ❑ It requires only 3% of energy, which is required in gas diffusion
- ❑ It holds less uranium than the gas diffusion technique

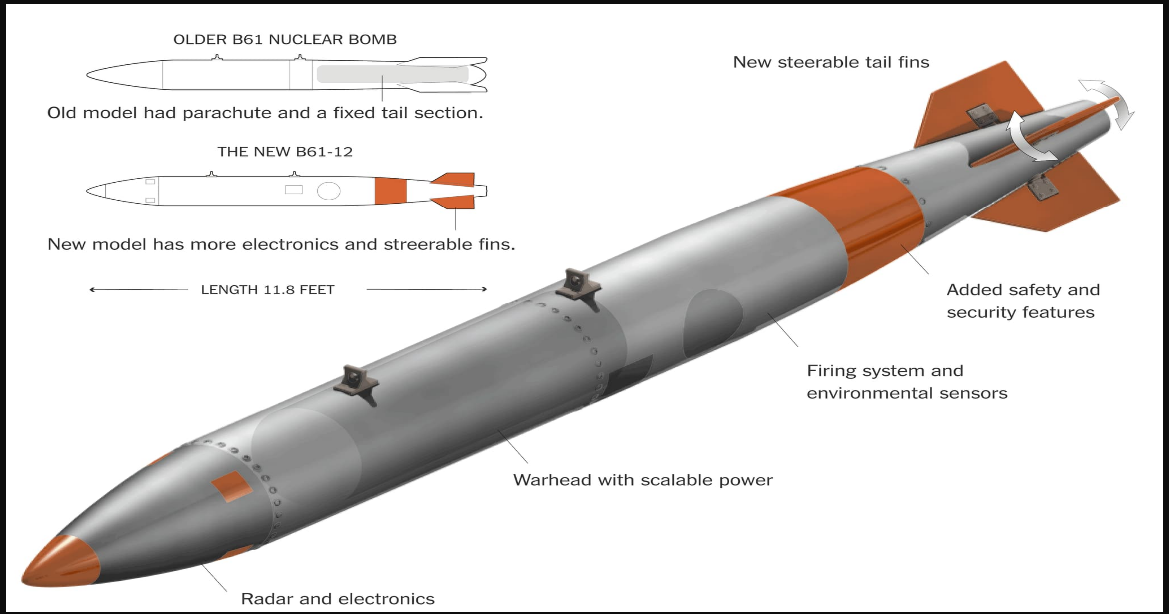


https://science.howstuffworks.com/uranium-centrifuge.htm

Application of Uranium

- ❑ Energy Generation
- ❑ Medicine
- ❑ In Agriculture
- ❑ In Building Material
- ❑ In Nuclear Weapons

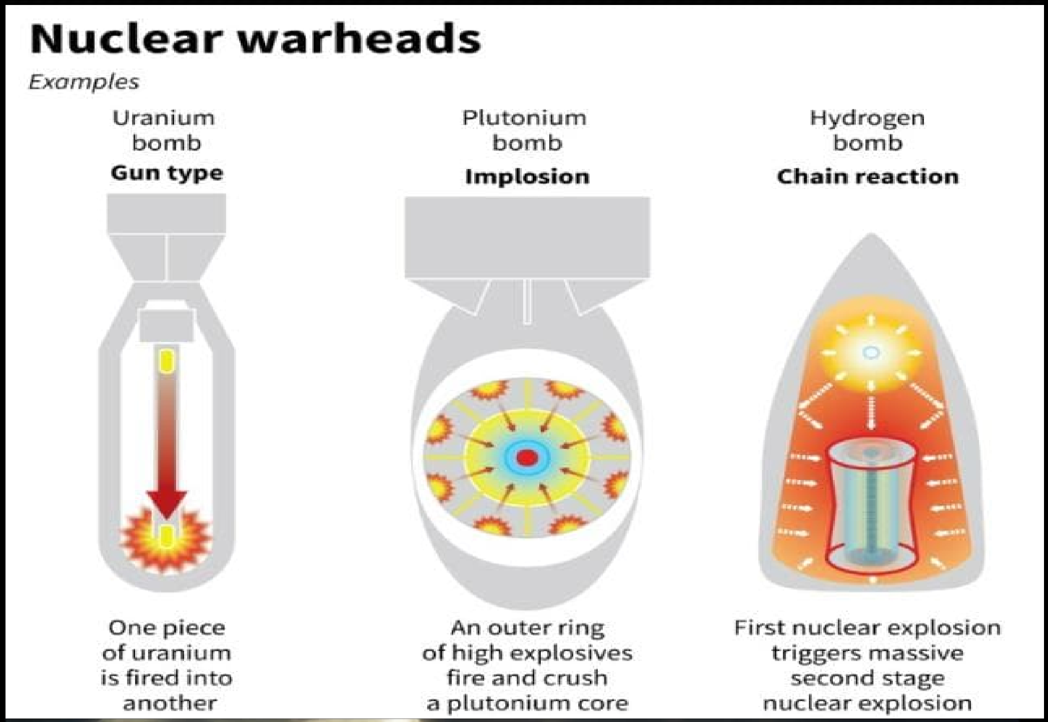




https://www.nytimes.com/2016/01/12/science/as-us-modernizes-nuclear-weapons-smaller-leaves-some-uneasy.html

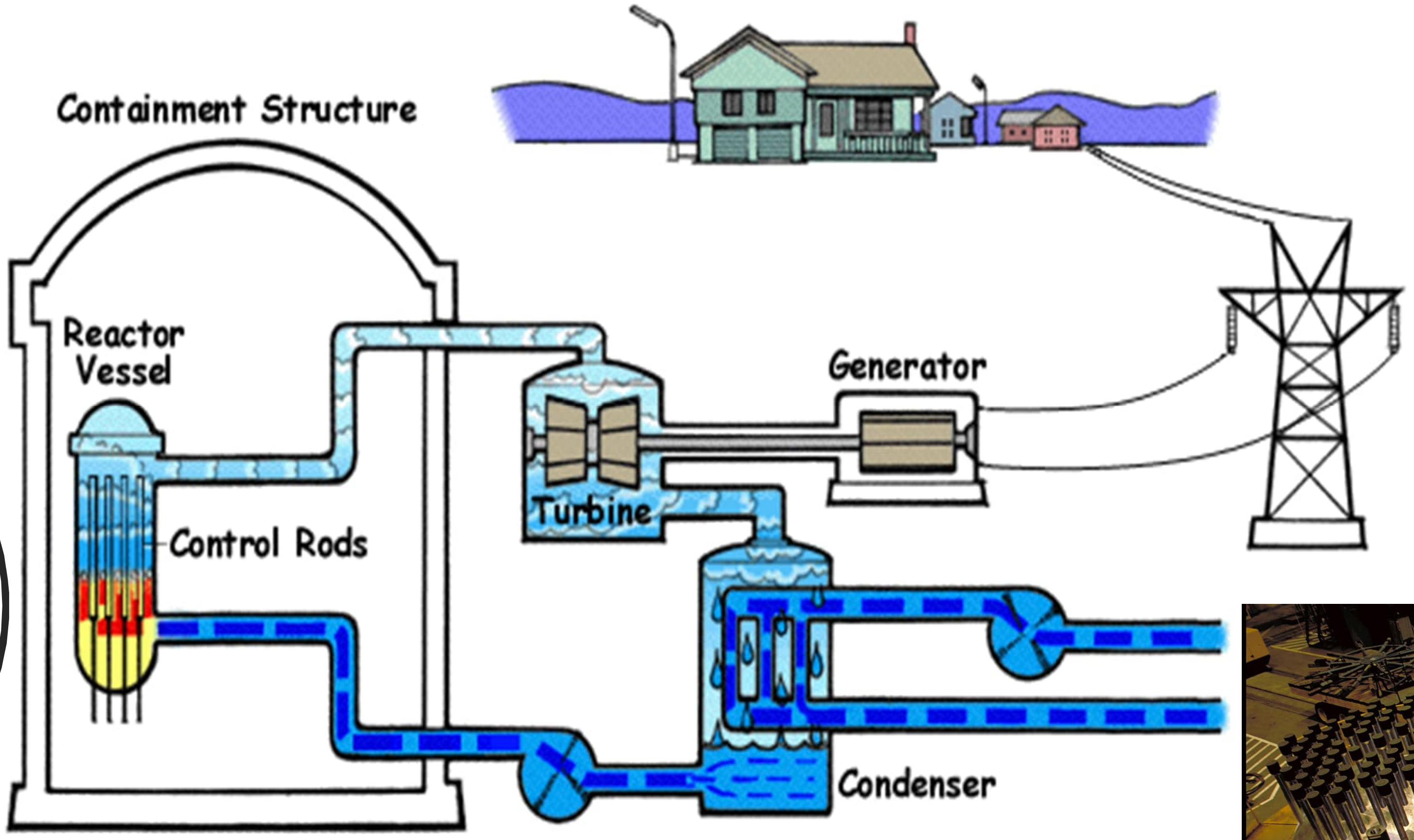
Weapon of Mass Destruction

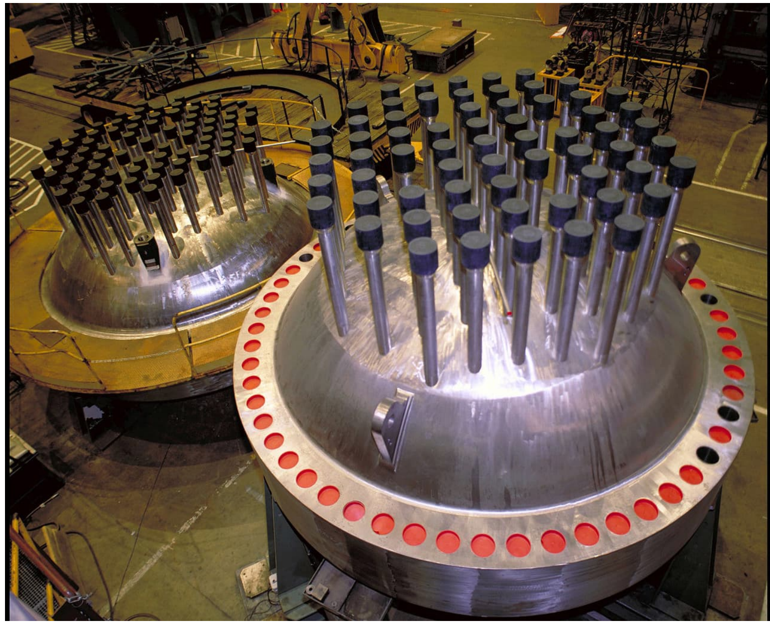
- It uses uncontrolled nuclear chain reaction
- It is the combination of Chemical explosives, nuclear fission, and nuclear fusion
- First chemical explosive put around subcritical uranium sphere
- This puts the other sphere's atoms closer together. Once it is dense, it creates neutrons, which leads to the nuclear chain reaction.
- Then BOOOOM



https://www.britannica.com/technology/nuclear-weapon/Basic-two-stage-design

Nuclear Energy





https://www.linquip.com/blog/nuclear-power-plant-guide/

Civilian use of Uranium

Depleted uranium

- Isotope composition: U-238 99.75 %, U-235 0.25 %
- High density 19.1 g/cm^3 (Pb density 11.34 g/ cm^3)

Can be used as:

- Aircraft counterweights
- Radiation shields
- Ballast (sailboats)
- Industrial X-ray

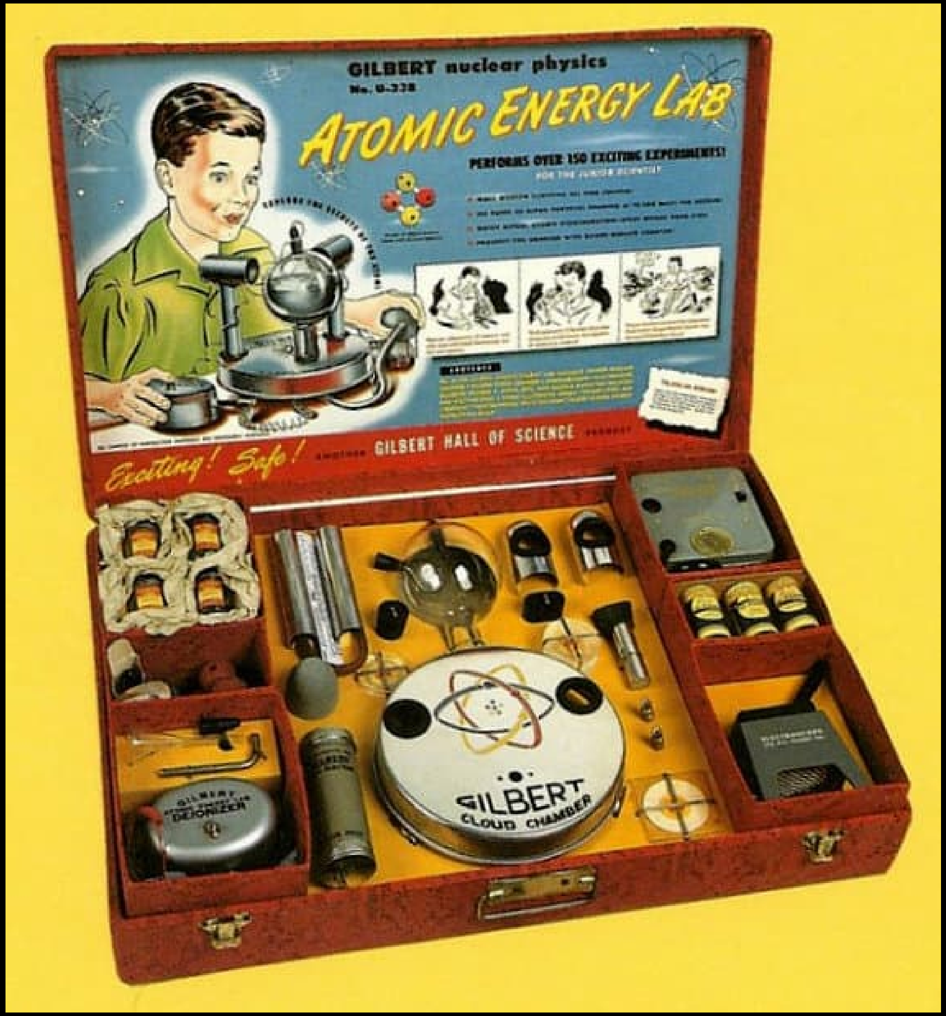
Material	Halving thickness (cm)	Halving thickness (g/cm^3)
Lead	1	12
Concrete	6.1	20
steel	2.5	20
Depleted uranium	0.2	3.9

Can also be used in military applications for example penetrating ammunition and armors

https://en.wikipedia.org/wiki/Depleted_uranium
https://www.nuclead.com/radiationshielding/

Other usage of Uranium

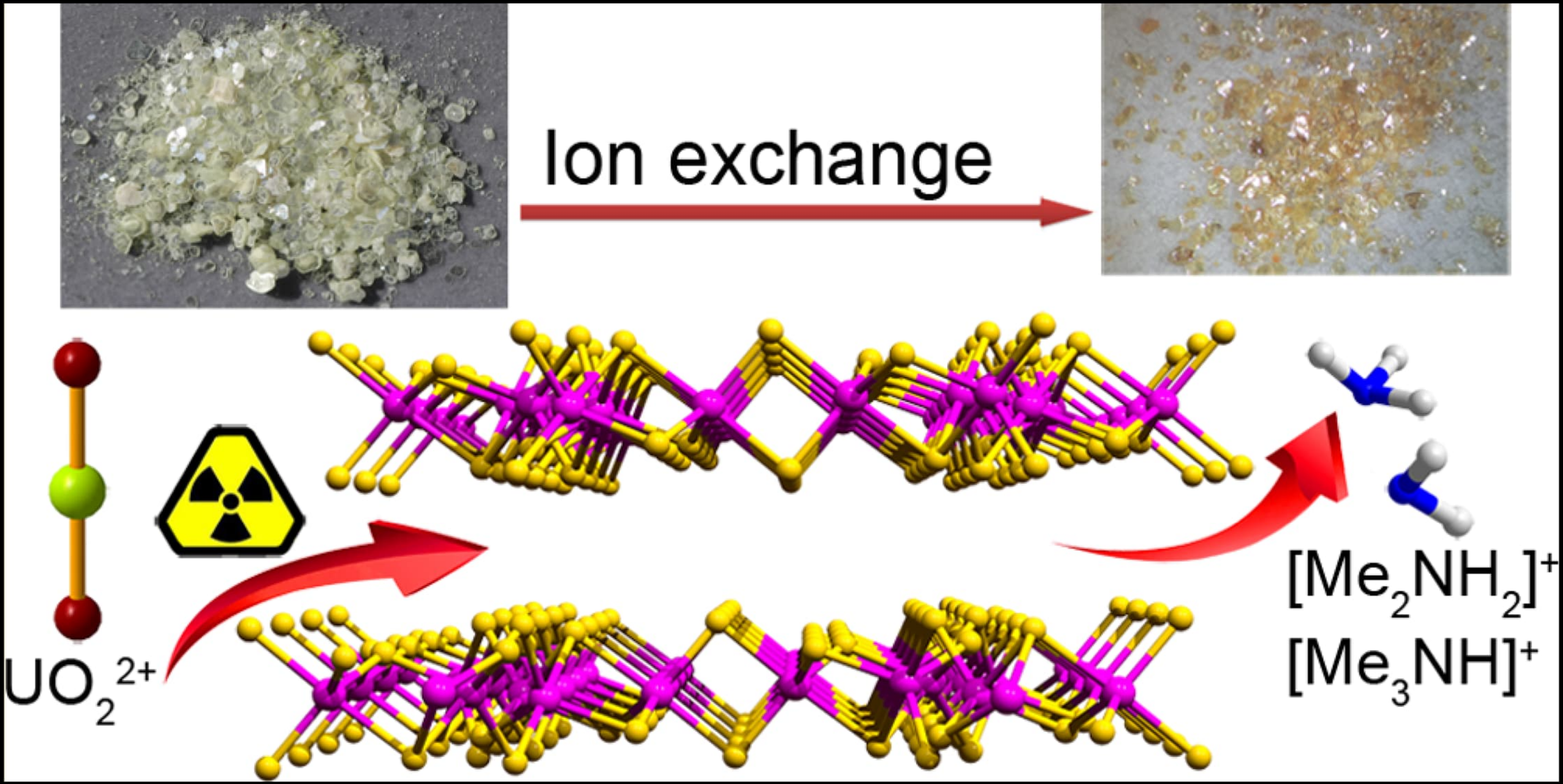
1950's



1940-1990

Currens studies

Removal and recovery of uranium

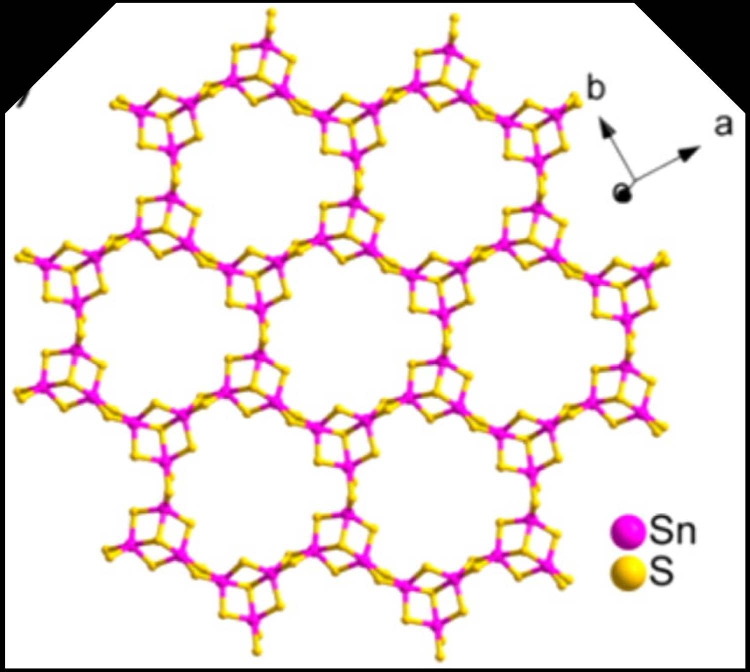


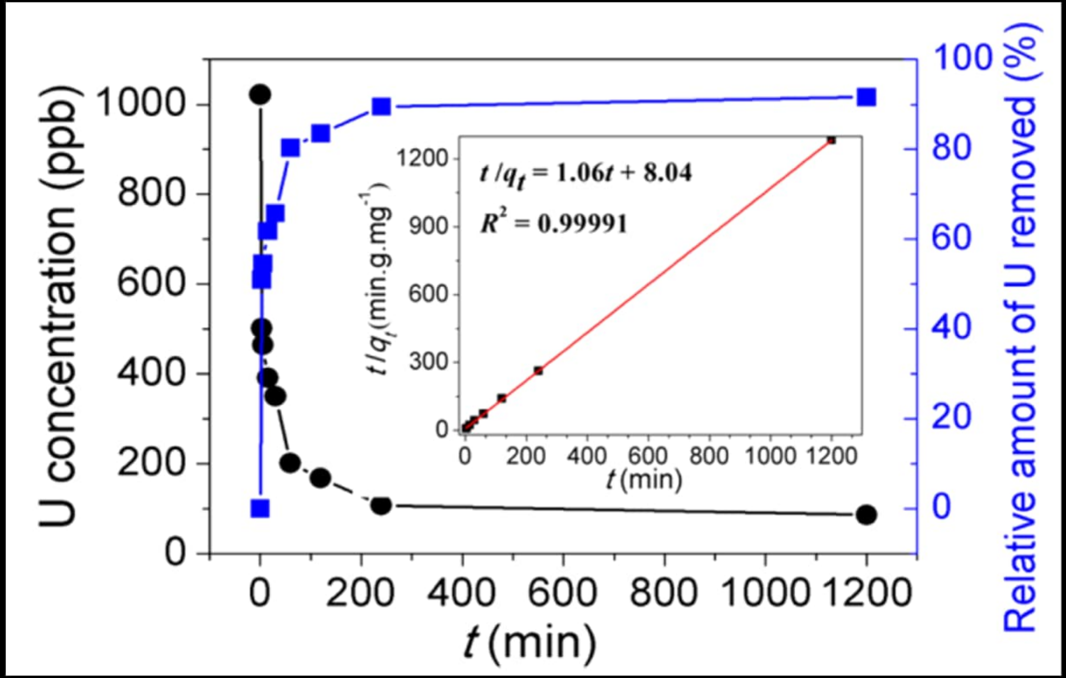
$(Me_2NH_2)1.33(Me_3NH)0.67Sn_3S_7{\cdot}1.25H_2O$ (FJSM-SnS)

Feng, M., Sarma, D., Qi, X. H., Du, K., Huang, X., & Kanatzidis, M. G. (2016). Efficient removal and recovery of uranium by a layered Organic–Inorganic hybrid thiostannate. *Journal of the American Chemical Society*, *138*(38), 12578–12585. https://doi.org/10.1021/jacs.6b07351

Ion exchange

- Can be used to clean nuclear waste solutions in the future?
- Promising results: uranium-exchange capacity of 338.43 mg/g





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Nuclear waste handling

- Low-level waste (VLLW and LLW)
  - 90 % of waste: clothing, tools, equipment
- Intermediate-level waste (ILW)
  - Reactor components, filters, etc.
- High-level waste (HLW)
  - Nuclear waste, for example, spent fuel

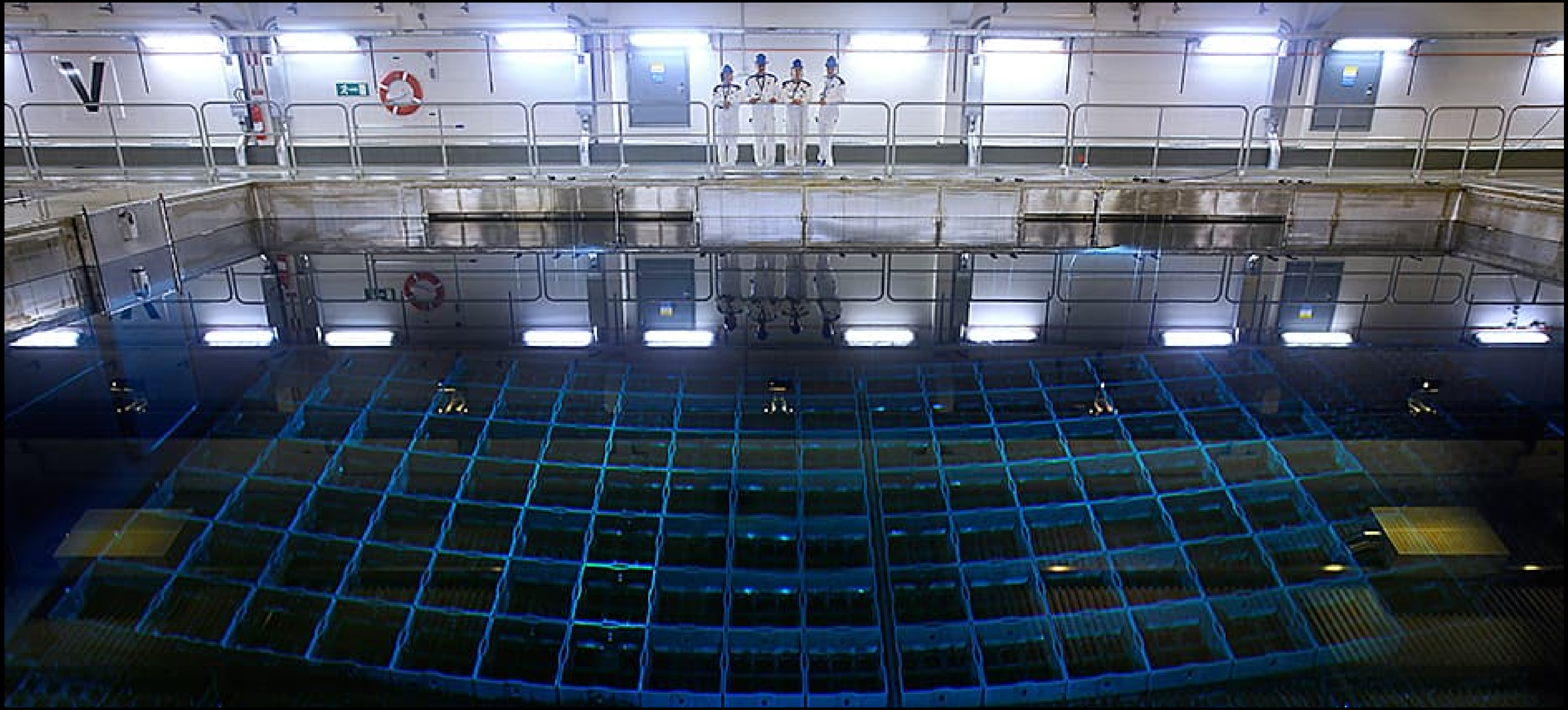
IAEA estimation 2022	Solid waste in storage (m^3)	Solid waste in diposal (m^3)
VLLW	2,918,000	11,842,000
LLW	1,471,000	18,499,00
ILW	2,740,000	133,000
HLW	29,000	0

- Pre-treatment
  - Sorting and segmenting → contaminated and non-contaminated
- Treatment and conditioning
  - Concentrating, solidifying, encapsulating
- Disposal
  - Interim or final disposal

https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-waste/storage-and-disposal-of-radioactive-waste.aspx

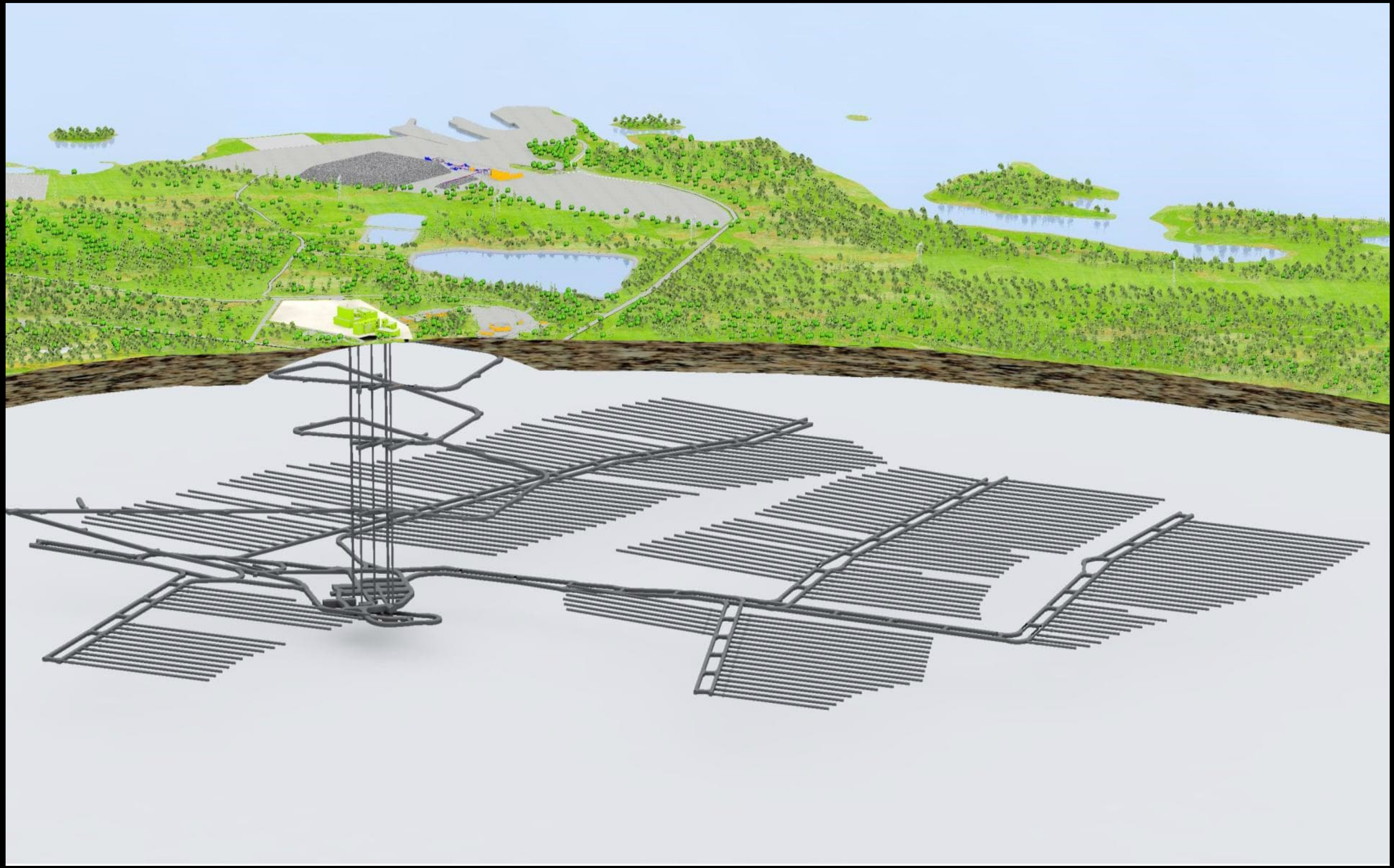
Interim storage ponds for used fuel
SKB – CLAB (Sweden)

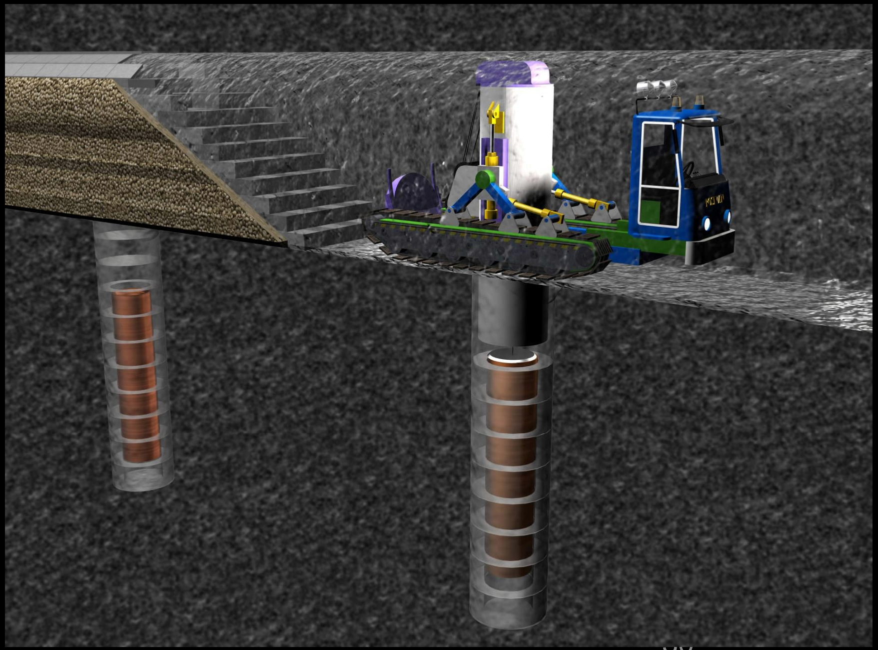
Capasity: 8000 tkg



https://skb.com/our-operations/clab/

Final disposal Posiva – Onkalo (Finland)





10 km of tunnels, operation time 100 years
Capacity: 6500 tkg + additional plans to expand

https://www.posiva.fi/en/index/media/material.html

Nuclear disasters

Chernobyl, USSR 1986

Fukushima, Japan 2011

The End