Nuclear decommissioning: Turning waste into Wealth

The chemistry of cake

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  - impurities,
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Yellowcake and its uses

Yellowcake refers to a substance produced after purification and concentration of uranium from ore, using acid leaching techniques and consists of ~80% triuranium octoxide (U_3O_8).

Impure uranium ore consists of UO_2, UO_3, U_3O_8 and impurities.
Purification of uranium ore and extraction of U_3O_8 (yellowcake) comprise the first stage in the cycle that leads to reactor fuel.

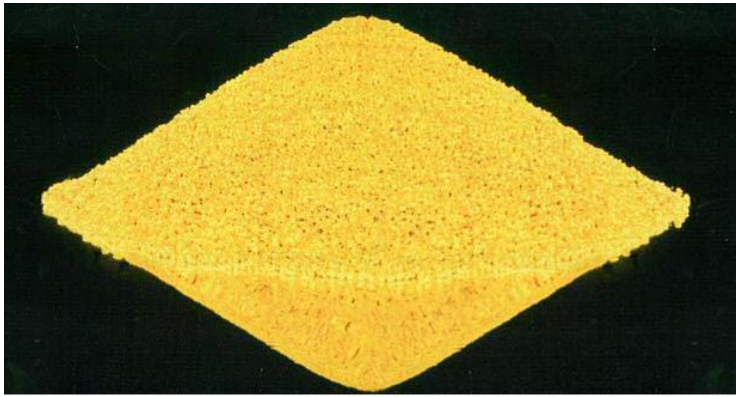
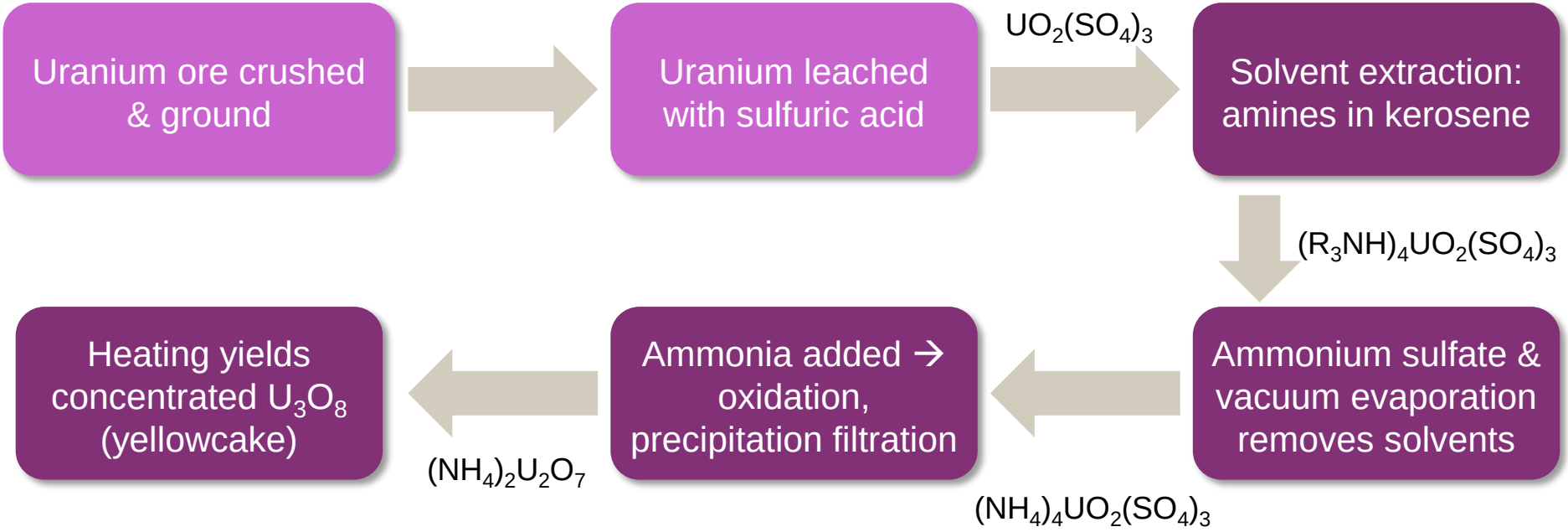


Image credit: Argonne National Laboratory

Density: 9.6 g/m^3 BP: 2878 °C

Yellowcake extraction 1



Leaching

Uranium ore crushed & ground

Prior to leaching, the crushed ore is heated to ~750 °C to decompose compounds that could effervesce.

Uranium leached with sulfuric acid

Leaching with sulfuric acid (H_2SO_4):
For the case of (amphoteric oxide) UO_3.

$$UO_3(s) + 2H^+(aq) \rightarrow UO_2^{2+}(aq) + H_2O$$

$$UO_2^{2+}(aq) + 3SO_4^{2-}(aq) \rightarrow UO_2(SO_4)_3^{4-}(aq)$$

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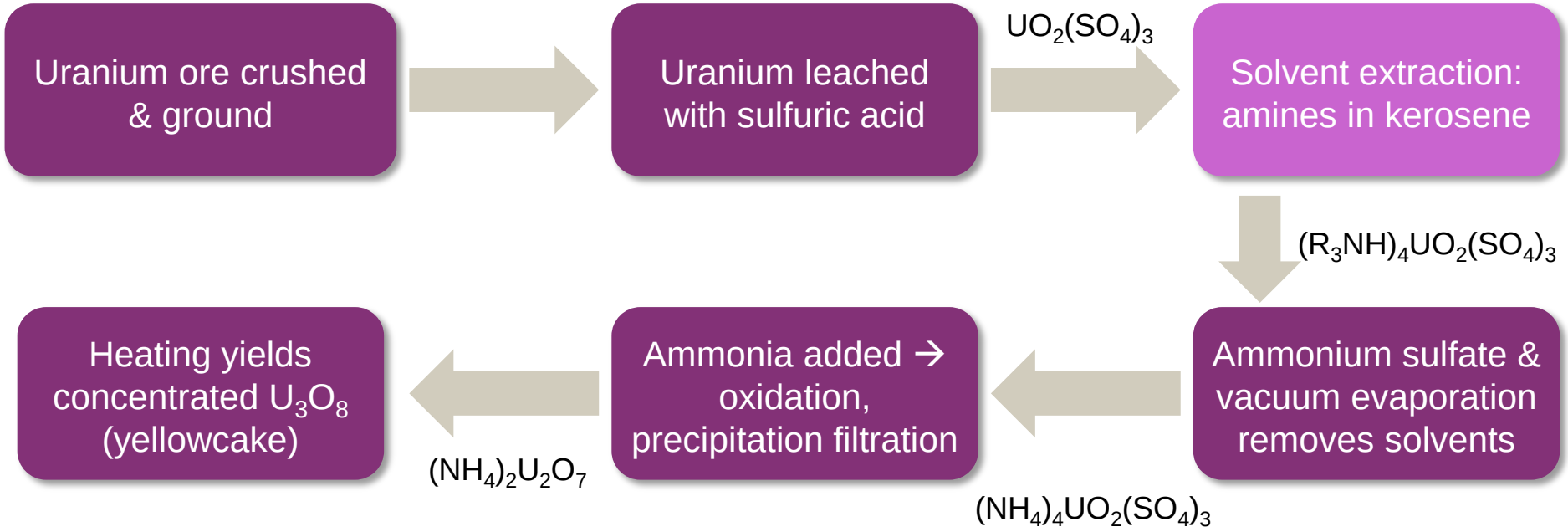
Yellowcake extraction 2



Solvent extraction

Solvent extraction: amines in kerosene

Solvent extraction with tertiary amines in kerosene (note phase change for UO_2):

$2R_3N(org) + H_2SO_4 \rightarrow (R_3NH^+)_2SO_4$

[R = alkyl grouping $\rightarrow C_nH_{2n+1}$]

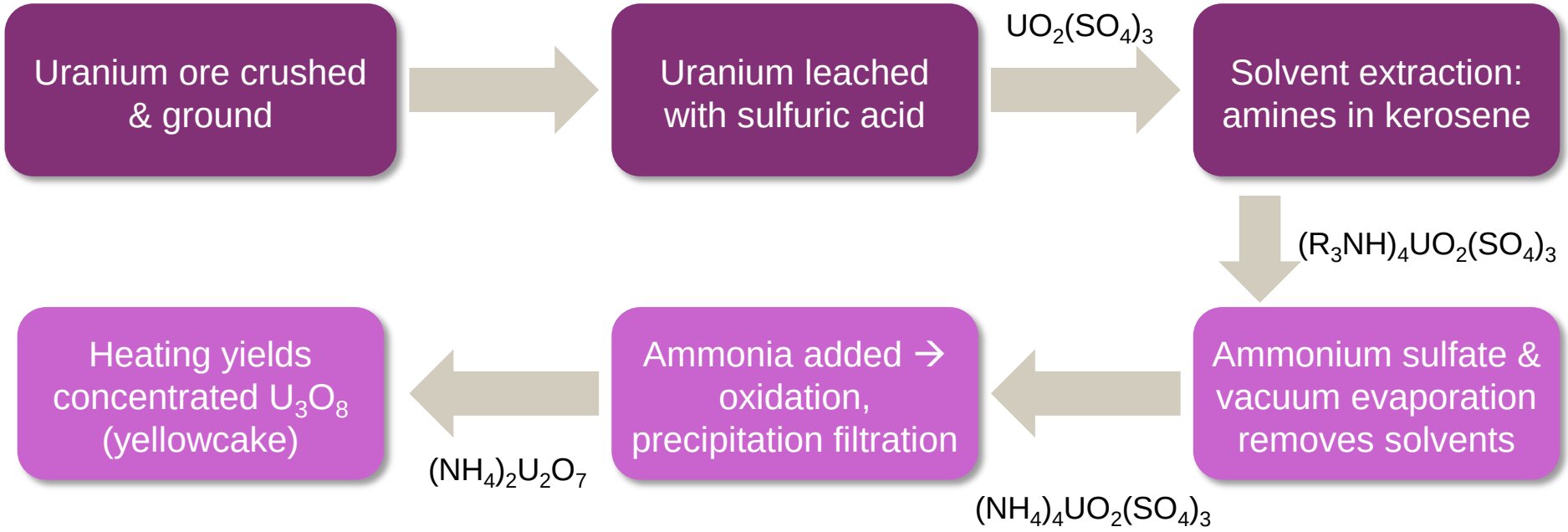
$2(R_3NH^+)_2SO_4^{2-}(org) + UO_2(SO_4)_3^{4-}(aq) \rightarrow$

$(R_3NH^+)_4UO_2(SO_4)_3^{4-}(org) + 2SO_4^{2-}(aq)$

Loaded solvent is treated to remove impurities.

Impurities (*e.g.* silica, zirconates) stay in aqueous phase.

Yellowcake extraction 2



Precipitation & oxidation 1

Ammonium sulfate & vacuum evaporation removes solvents

Addition of ammonium sulfate followed by heating removes solvents:

$(R_3NH^+)_4UO_2(SO_4)_3^{4-}(org) + 2(NH_4)_2SO_4(aq) \rightarrow 4R_3N(org) + (NH_4)_4UO_2(SO_4)_3(aq) + 2H_2SO_4(aq)$

Return of acid and amine.

Precipitation & oxidation 2

Ammonia added → oxidation, precipitation filtration

Heating yields concentrated U_3O_8 (yellowcake)

Precipitation of $(NH_4)_2U_2O_7$ using gaseous ammonia:

$6NH_3(g) + 2UO_2(SO_4)_3^{4-} + 3H_2O \rightarrow (NH_4)_2U_2O_7(s) + 2(NH_4)_2SO_4$

Return of ammonium sulfate.

Heating ammonium diuranate precipitate, $(NH_4)_2U_2O_7$, produces U_3O_8 (yellowcake).

Yellowcake summary

Additional purification steps before leaching include:

- NaCl followed by heating to convert silver to silver chloride.
- Addition of $NaNO_3$ to oxidise UO_2 to UO_3.

Yellowcake is the starting point for UF_6 production:

- UF_6 is used to enrich content of ^{235}U.
- UF_6 can be converted to UO_2 e.g. for AGR/CANDU (reactor fuel).

Bibliography 1

Sources/further reading

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Bibliography 2

Sources/further reading

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- Contents page image from the Uranium Information Center

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