

# Uranium

## Solvent Extraction

59 <b>Pr</b> Praseodymium 140.90765	60 <b>Nd</b> Neodymium 144.242	61 <b>Pm</b> Promethium (145)
91 <b>Pa</b> Protactinium 231.03588	92 <b>U</b> Uranium 238.02891	93 <b>Np</b> Neptunium (237)

 **BASF**

We create chemistry

# BASF technology for the recovery of uranium from acid leach solutions

## History

The Mining Solutions unit of BASF (formerly Cognis) has been intimately involved in uranium processing technology since 1957. That was when we introduced Alamine® 336 to the mining industry as the first commercially available tertiary amine solvent extraction (SX) reagent for the recovery and concentration of uranium.

Prior to 1957, ion exchange (IX) was the accepted route for the recovery of uranium from acid leach solutions. With Alamine® 336 vastly improving the solvent extraction process, BASF reagents now offered the advantages of reduced costs, reduced use of nitrates and chlorides, and the capacity to produce a high-purity uranium product.

The proven advantages of the Alamine® 336 SX process caused many operations to combine SX with their existing Ion Exchange (IX) processes by adding an SX circuit following IX – flow sheets known as ELUEX or BUFFLEX. Other plants made a complete conversion to the Alamine® 336 SX flow sheet and the majority of the new uranium projects installed SX capacity and no IX. By the end of the 1970s, eighty percent of the USA's uranium production – then the largest producer – used the BASF Alamine® 336 SX process and flow sheet.

## Significant changes

Uranium production slowed considerably after the Three Mile Island (1979) and Chernobyl (1986) disasters. Both events brought nuclear power into disfavor and severely reduced the demand for uranium. The use of uranium from spent nuclear arms to produce energy as fuel further limited the mining and processing of the mineral.

During these unfavorable times, many companies within the industry lost a vast amount of know-how as experienced engineers and metallurgists, associated with the expansionist years of the 1950s through the early 1980s, either retired or moved into other industries.

Understanding the eventual value and importance of nuclear power, BASF maintained its commitment to optimizing uranium recovery and retained its core expertise in uranium SX technology.

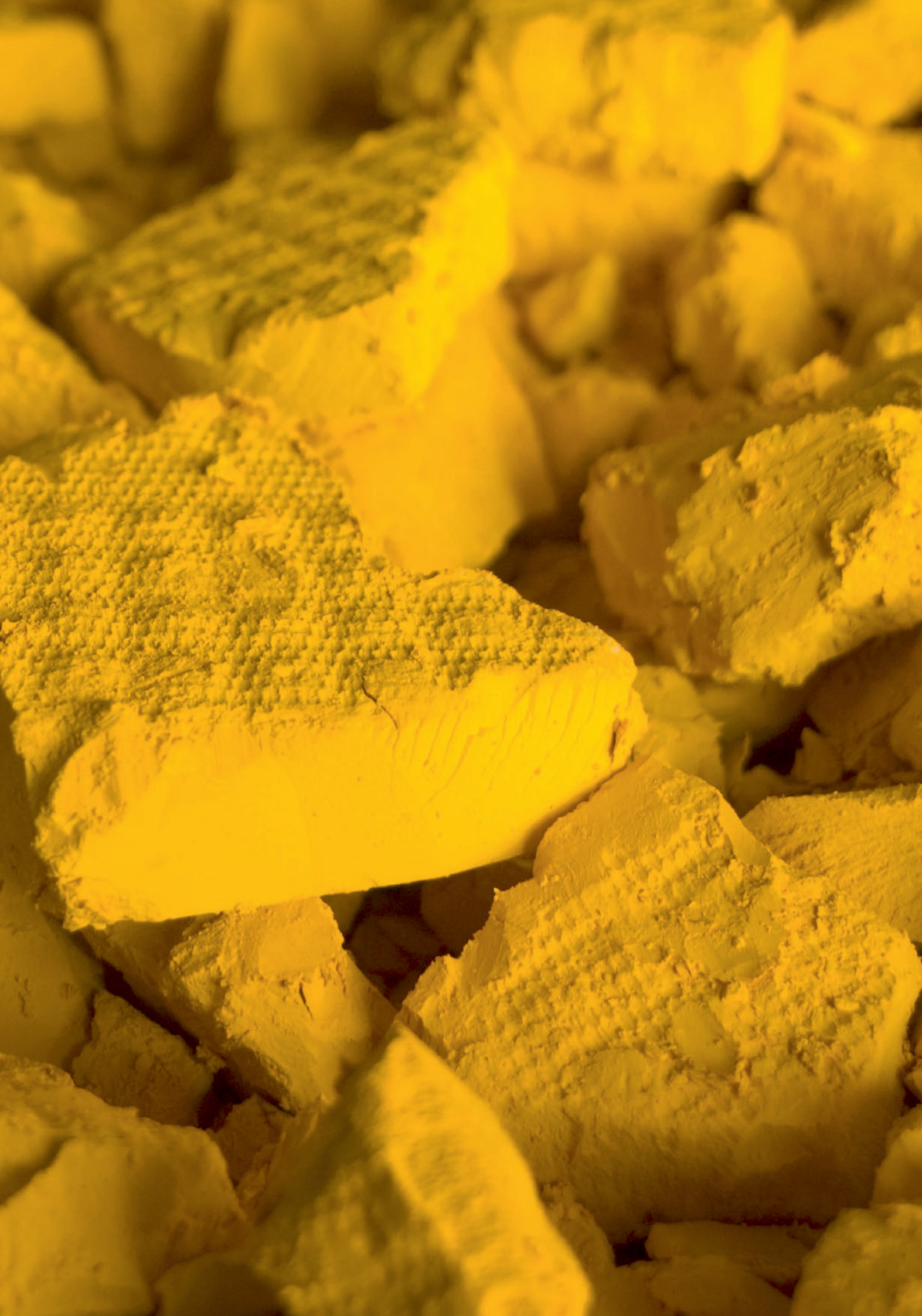
BASF has a variety of reagent technologies that can reduce or eliminate problems in the uranium recovery process.

[Contact us to discuss your particular situation.](#)

Uranium mine







## The future

Today, the future of the uranium industry looks favorable, with an expected increase of uranium needed to meet energy demand. Uranium inventories are at manageable levels and the pressure to create low-cost, high-purity stockpiles is increasing.

BASF is committed to supporting the growing demands of the industry and maintaining its leadership role in uranium SX technology.

## MSP® Minesite Services Program

BASF provides uranium SX technical expertise through its MSP® Minesite Services Program. Our specialized program can help you address specific technical issues, reduce costs and improve the rate of recovery and concentration of uranium. This support is available through all BASF Mining Solutions offices worldwide.

## COMMON CHEMISTRY FOR THE PROCESSING OF URANIUM

<b>LEACHING</b>	$\text{UO}_2 + \text{Fe}^{3+} \rightarrow \text{UO}_2^{2+} + \text{Fe}^{2+} \text{ (acid soluble)}$ $\text{UO}_2^{2+} + \text{H}_2\text{SO}_4 \rightarrow \text{UO}_2\text{SO}_4$
<b>SOLVENT EXTRACTION (SX)</b>	<p><b>Pre-protonation</b></p> $2\text{R}_3\text{N} + 2\text{H}^+ + \text{SO}_4^{2-} \rightarrow (\text{R}_3\text{NH}^+)_2\text{SO}_4^{2-}$ <p><b>Extraction</b></p> $\text{UO}_2(\text{SO}_4)_3^{4-} + 2(\text{R}_3\text{NH}^+)_2\text{SO}_4 \rightarrow (\text{R}_3\text{NH}^+)_4\text{UO}_2(\text{SO}_4)_3 + 2\text{SO}_4^{2-}$ <p><b>Stripping</b></p> $(\text{R}_3\text{NH}^+)_4\text{UO}_2(\text{SO}_4)_3 + 4\text{NH}_4\text{OH} \rightleftharpoons 4\text{R}_3\text{N} + 4\text{H}_2\text{O} + (\text{NH}_4)_2\text{UO}_2(\text{SO}_4)_2 + (\text{NH}_4)_2\text{SO}$
<b>AMMONIUM PRECIPITATION</b>	$(\text{NH}_4)_2\text{UO}_2(\text{SO}_4)_2 + (\text{NH}_4)_2\text{SO}_4 + 6\text{NH}_4\text{OH} \rightarrow (\text{NH}_4)_2\text{U}_2\text{O}_7 + 2(\text{NH}_4)_2\text{SO}_4 + 3\text{H}_2\text{O}$ <p><b>Calcination</b></p> $(\text{NH}_4)_2\text{U}_2\text{O}_7 + \text{heat} > 580 \text{ deg C} \rightarrow \text{U}_3\text{O}_8$

## Reactions most commonly found in uranium processing

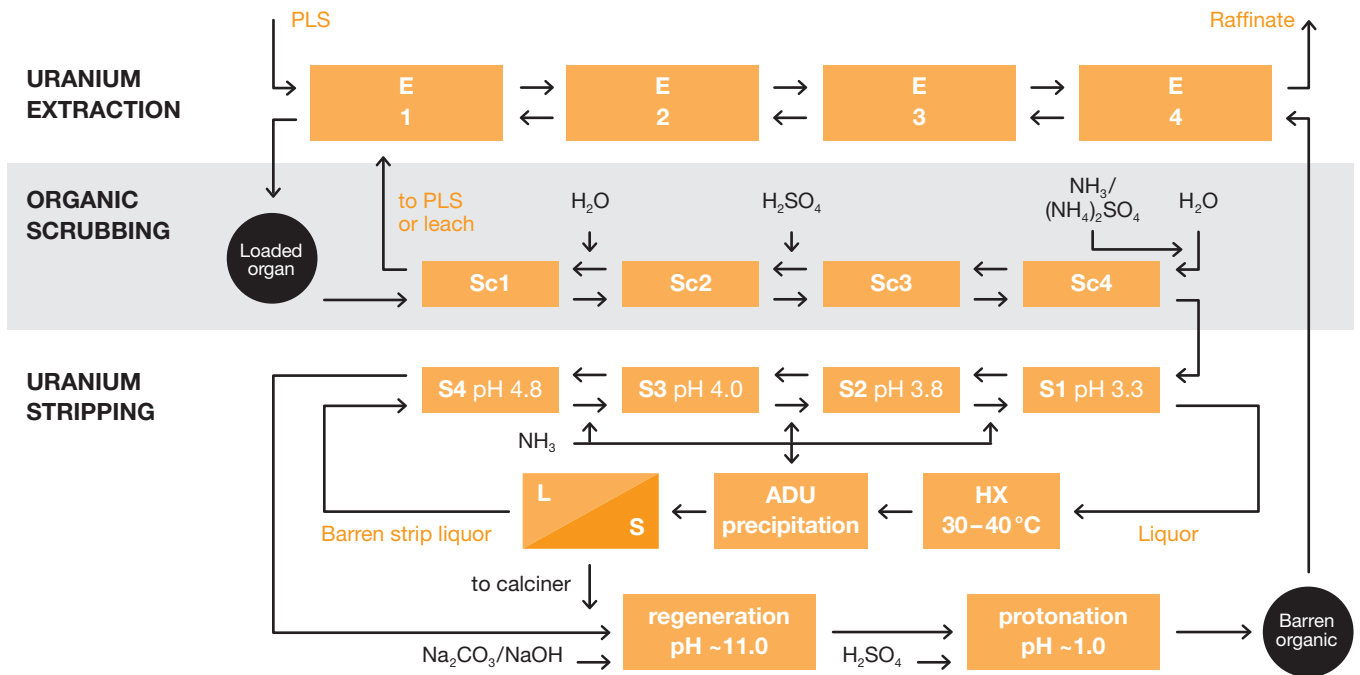
Uranium SX using tertiary amines has been employed as the technology of choice for many years. It is still considered state-of-the-art technology today.

Leaching of uranium minerals, accomplished in the hexavalent state, is enhanced by ferric oxidation. An oxidant, such as manganese dioxide, sodium perchlorate or hydrogen peroxide, is employed to convert ferrous iron to ferric iron.

In the SX circuit, the clarified leach solution comes into contact with the organic phase comprising Alamine® 336, a longchain alcohol employed as a solvation modifier, and a suitable diluent. Often, the organic phase comes into contact with an acidified aqueous solution that preloads the amine with sulphate or bisulphate anions to enhance selectivity for uranium in the succeeding extraction stage. During extraction, uranyl sulphate is extracted into the organic phase by the amine in exchange for the sulphate anion.

Since uranium extraction is an anion exchange process, other anions may also extract into the organic phase. To prevent these anions from transferring to the final product as impurities, several scrubbing stages may be employed using, for example, acidified water, followed by aqueous ammonia. Further additions of ammonia are employed to strip uranyl sulphate from the organic phase as the pH value is gradually increased, while taking care not to precipitate uranium salts. Finally, uranium is often precipitated as ammonium diuranate (ADU) which, after drying, is calcined to produce high purity uranium oxide, frequently greater than 99% pure.

## TYPICAL URANIUM SX FLOW SHEET



## Technical challenges

### Molybdenum “impurities”

Molybdenum and, to a lesser extent, vanadium are co-extracted with uranium. Both will report as impurities unless suitable changes in the chemistry of the system are employed. Molybdenum, in particular, can cause significant emulsion problems – the so-called blue or green goo – depending upon the relative concentration of molybdenum and Alamine reagent, the type of Alamine reagent, and the oxidation state of the molybdenum present. BASF solved this potential problem by developing Alamine® 304 for leach solutions in which molybdenum is present in higher concentrations.

### Carbonaceous material

Carbonaceous material, such as humates, fulvates or man-made organic compounds, can load onto amines, slowly “poisoning” the organic phase to the point that it will no longer extract uranium. BASF has developed techniques for reagent/solvent regeneration to reduce or eliminate this potential problem.

### Silica levels

Soluble silica is produced in the leaching stage. High levels of silica (> 500 ppm) will cause problems with phase separation, stable emulsion formation and crud formation. Control is achieved through the use of suitable coagulants and preferred mixing continuities. BASF has developed technology to help you choose flocculants and coagulants compatible with the SX process.

### Oxidation/nitration

At high oxidation potential levels, particularly when nitrates are present, amine or diluent may be degraded. Precautionary techniques have been developed for such extreme cases.

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