Uranium Extraction

The Key Issues for Processing

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Presentation Flow

- Key Process Drivers
- Circuit Selection – Acid Leaching
- Circuit Selection – Carbonate Leaching
- Leaching Process
- Recent Technical Innovations
- Conclusions

Major Flowsheet Influences

- Capital and Operating Costs
- Ore Mineralogy
- Ability to Pre-Concentrate
  - Screening
  - Radiometric
  - Density
- Acid versus Alkaline Leaching
- Presence of Other Metals eg V, Mo, Fe, etc

Key Cost Elements

Capital Costs

Process Area	% Total
Crushing/Grinding	22.8
Leach/Filtration	49.0
Eluex	21.1
Precipitation/Drying/Packaging	3.4
Reagent Handling	3.7
Total	100.0

Operating Costs

Item	% Total
Reagents	38.4
Operating Labour	27.7
Operating Consumables	4.6
Maintenance Labour and Spares	10.8
Electrical and Heat Energy	18.5
Total	100.0

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Influence of Mineralogy

- Tetravalent Ores
  - Low solubility
  - Need oxidants
  - Association with carbonate

- Hexavalent Ores
  - Less common
  - Often associated with clay / calcrete

- Multiple Oxides
  - Complex and refractory

- Association with Carbon or Phosphates

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Acid or Carbonate Leach

	Carbonate	Acid
Acid Consumption	>75 – 100 kg/t	<75 – 100 kg/t
Leach Kinetics	Slower	Generally Rapid
Leachant	Recirculated	Single Contact
Selectivity	High	Low
Filterability	Slower	Usually Good
Materials	Mild Steel	Stainless/FRP/RL

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Ability to Upgrade

- Screening
  - Uranium in fines (Langer Heinrich, WDL)

- Gravity
  - DMS (Radium Hill)

- Radiometric Sorting
  - Used on coarser fraction (WDL, WRC, Mary Kathleen)

  - Particularly applicable to vein deposits

Ability to Upgrade

Rössing Radiometric Sorting Plant

- Sorting in sizes 80 to 300mm
- Capacities up to 300 tph
- Modular construction
- Can “dial in” the grade

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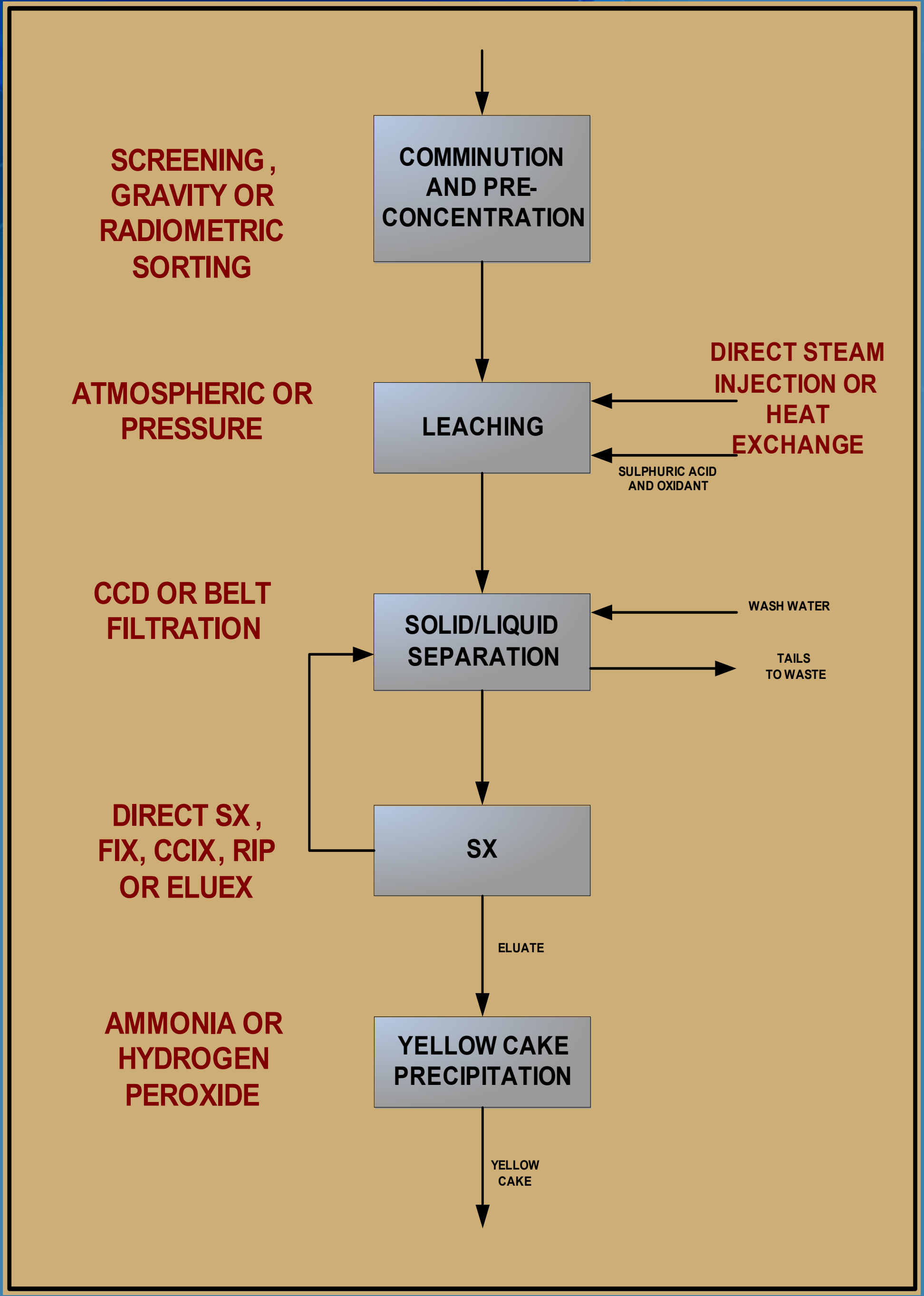
Acid Leaching Options



Acid Leaching – Equipment Innovation

OKO/SepTor column Plant

- Resin-In Pulp - Transfer from Gold and Base Metals
- Carousel IX
- Column SX – Lowers both Capex and Opex

Acid Leaching – Scale and Grade

U_3O_8 Tenor & Project Capacity

- ELUEX — U_3O_8 < 0.35 g/l
  Higher flows 500 – 700 m^3/h
- SX — Lower flows
  Column SX greatly extends range
  High U_3O_8 tenors (>0.9 g/L)

U3O8 Selectivity

ELUEX > SX and Weak Base IX > Strong Base IX

Acid Leaching – Selectivity

Impurity	Separation Technique	
	SX	IX
Vanadium	• Reduction to V^{4+} prior to SX • Hydrogen peroxide pptn of uranium • Thermal methods post uranium pptn	• Hydrogen peroxide pptn of uranium • Thermal methods post uranium pptn • Salt roast of the main feed
Molybdenum	• Separate U and Mo stripping circuits • Activated carbon adsorption • Reductive scrubbing • Use of secondary amines • Hydrogen peroxide pptn of uranium • Prior pptn from pregnant solutions	• Prior pptn from pregnant solutions
Arsenic	• Crowd off in extraction • Low pH scrubbing after extraction • Precipitation from pregnant solution	• Pptn from pregnant solution
Silica	• Remove with Polyox • Scrubbing post the extraction step	• Use of Polyox to ppt colloidal silica
Ferric Iron	• Crowd off in extraction • Low pH scrubbing post extraction	• Crowd off in adsorption • Selective precipitation from eluates • Reduction to the Fe^{2+} state prior to IX • pH adjustment prior to IX

Acid Leaching – PLS Properties

- Liquor pH and Eh

pH Ranges

Process	Normal Feed pH range
SX – Tertiary amine	<1.0 to 2.0
SX – D2EHPA	<1.0 to 1.8
IX – Strong Base	1.5 to 2.0
IX – Weak Base	1.5 to 2.0

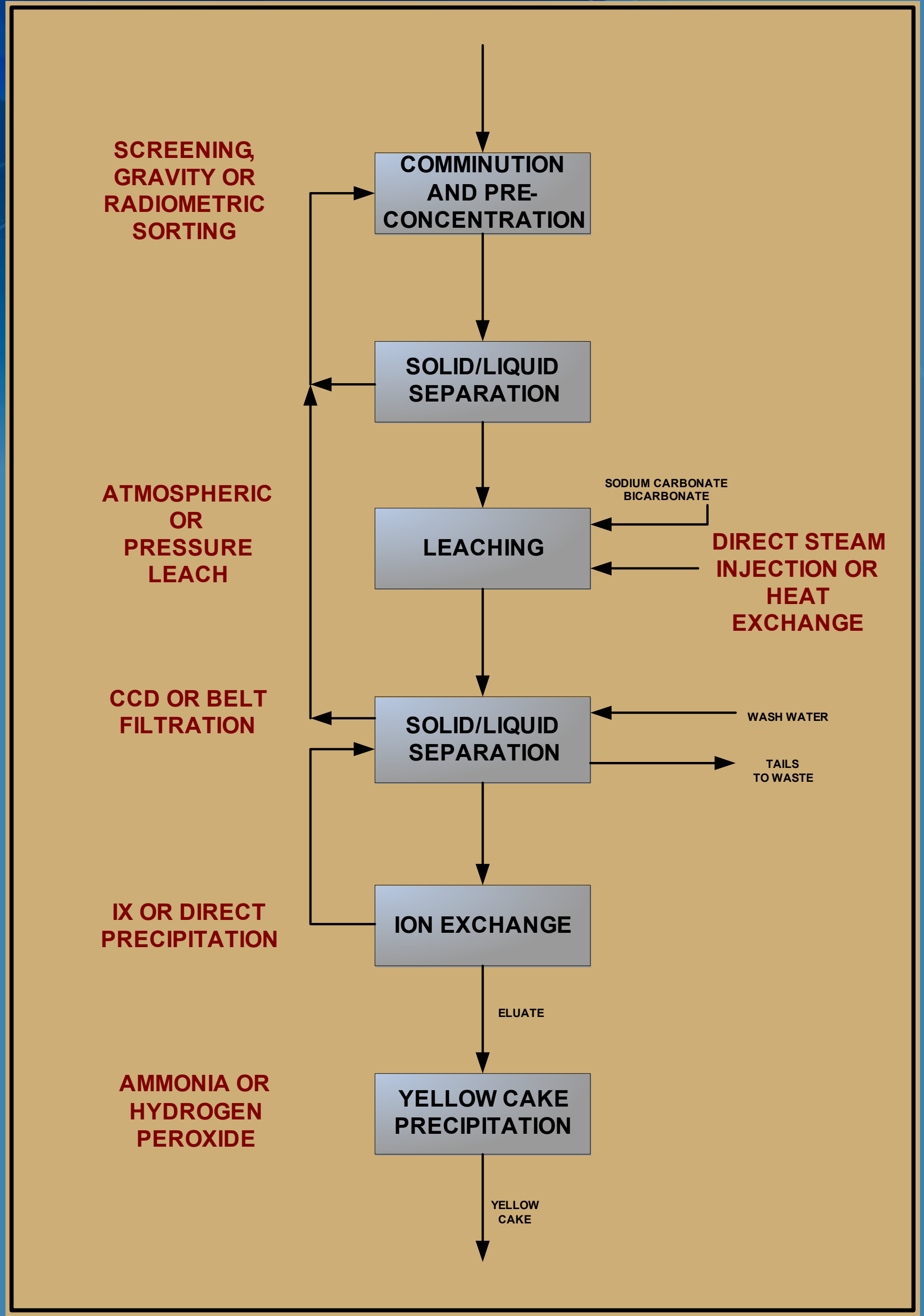
Amine SX, Strong Base, Weak Base – emf > -400 – 500mV

Cationic IX – Extracts U^{+4}

Acid Leach Parameters

- 40 – 70°C typical
- Residence time 12- 24 h
- Use pressure leach for highly refractory ores or ores with pyrite
- Acid consumption typically 40 to 60 kg/t solids feed
- Typical oxidants – pyrolusite (MnO_2), sodium chlorate, Fe^{3+}, Caro's

Carbonate Leaching Options



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Carbonate Leaching – Selectivity

Impurity	Separation Technique
Vanadium	• Treatment of bulk precipitates: - Thermal methods - Dissolution and re-precipitation • Pptn prior to uranium eg with $FeSO_4$ or $PbSO_4$ • Precipitation with peroxide
Molybdenum	• Bleed recycle solutions from the circuit • Adsorption onto activated carbon • Precipitation of ferric molybdate
Sodium	• Dissolution of sodium diuranate and re-ppt • Use of hydrogen peroxide precipitation
Silica	• Dissolution and re-precipitation • Modify leaching conditions

Carbonate Leaching – Reagent Use

Optimisation of Carbonate Consumption

- Recirculate IX barren to mill circuit
- Use IX barren in penultimate CCD
- Make up reagents in process liquor
- Minimise gland seal
- Indirect heat transfer
- Belt filters versus CCD

Benefits of Elevated Temperature

- Generation of acid from sulphides
- Increased recovery of U_3O_8
- Accelerated leach times
- Reduced reagent consumption
- Lower energy input by using flash stream
- Use of Heat Exchange

Summary of Technical Innovations

- Radiometric Sorting
- Column SX – Roxby – Very rapid extraction kinetics
- Resin-In-Pulp – CleanTeQ Technology
- Carousel IX – OKO SepTor
- Latest pressure leach technology
- Heat recovery to conserve energy
- More selective precipitation – H_2O_2

Conclusions

- No “automatic” flowsheet choice
- Key drivers are mineralogy, cost, acid usage, ability to upgrade
- Process selection criteria include throughput, selectivity, costs
- New advances will impact selection:
  - Radiometric sorters
  - New generation IX and RIP
  - Column SX
  - Autoclave technology