Producing high-purity Nickel and Cobalt

Application of ion exchange resins

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Agenda

1. What is the aim of treatment?
2. Matching the target metal with the correct ion exchange resin
3. Design configuration
4. Resin characteristics (mechanical) to suit the design
5. Conclusions

01 What is the aim of the treatment?

Ion exchange resins in hydrometallurgy

Bulk recovery

Ion exchange resins are used to recover the main metal of interest

- Gold
- Uranium

Impurity removal

Ion exchange resins are used to remove low levels of impurities from a high-concentration background

- High purity CoSO4 crystals
- Nickel metal

What do we want from the resin?

- High selectivity for the target metal of interest
- Good rejection of other components
- High capacity
- Low leakage
- Ease of elution
- Robust – to ensure a long life

02 Choosing the best resin for the task

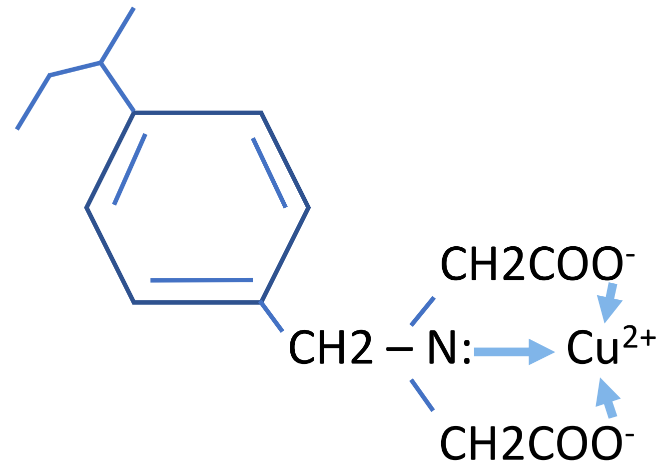
Choosing the right resin (chemistry)

Impurity	Type of resin	Commercial examples
Uranium	Strong base anion exchange	Purolite MTA8000 Dow Ambersep 4400
Copper and Zinc	Amino-methyl phosphonic acid Iminodiacetic acid D2EHPA-impregnated	Purolite MTS9500, Lanxess TP260 Purolite MTS9300, Lanxess TP207 Purolite MTX7010, Lanxess OC1026
Cadmium	Amino-methyl phosphonic acid D2EHPA-impregnated Thiourea	Purolite MTS9500, Lanxess TP260 Purolite MTX7010, Lanxess OC1026 Purolite MTS9140, Lanxess TP214
Nickel	Bis-picolyl amine	Dow M4195 Purolite MTS9600 Lanxess TP220

Chelating resins

Chela:
a latin word for pincers

Iminodiacetic acid (IDA) resin



Combination of
- ion exchange
- electron pair sharing

Chelating Resins: Selectivity range

Example: **iminodiacetic acid (IDA) resin**

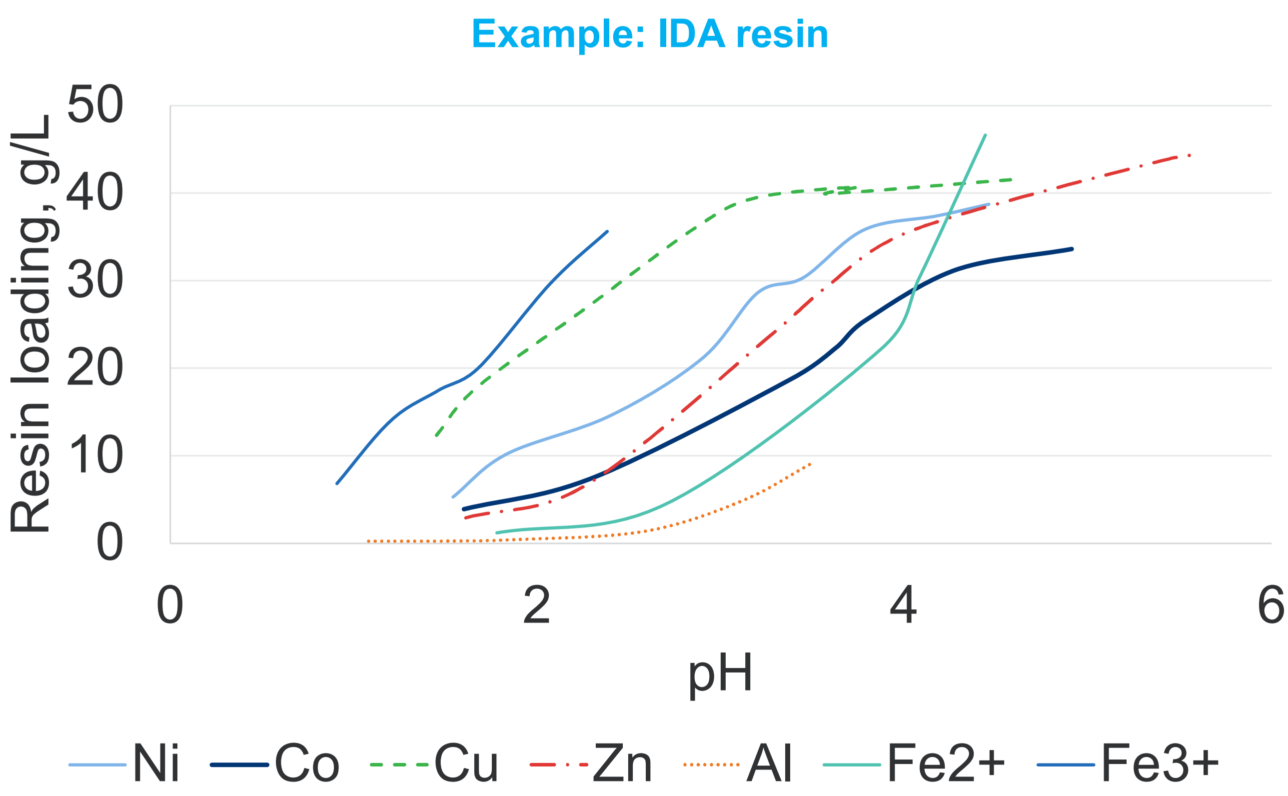
Selectivity:

$Fe^{3+} > Al^{3+} > Cu^{2+} >> Ni^{2+} > Cd^{2+} > Zn^{2+} > Co^{2+} >> Mn^{2+} > Ca^{2+} > Mg^{2+} > Na^{+} \sim Li^{+}$

- **Iron** should be removed prior to IX
- Good selectivity over alkaline earths (magnesium and calcium)
- Good selectivity over alkali metals (sodium and lithium)

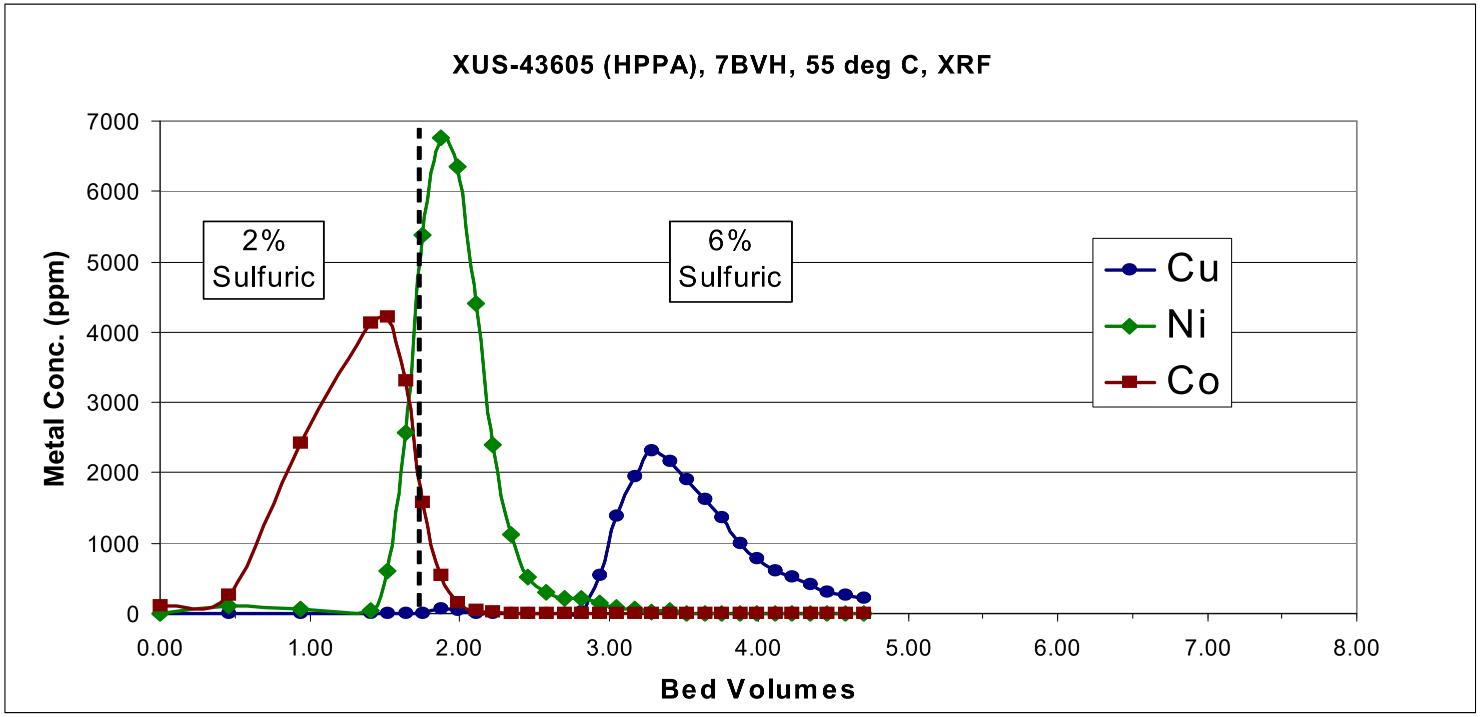
Chelating Resins: Selectivity vs pH

- Resin loading is dependent on the pH of the solution
- pH control is critical



Chelating Resins: split elution

- Additional separation can be achieved during elution
- Less strongly held metal (Co) eluted <u>first</u> with <u>lower concentration acid</u>
- Cu (more strongly held) requires more concentrated acid



Marston et al, Alta Metallurgical Conference 2010

Marston et al, Alta Metallurgical Conference 2010

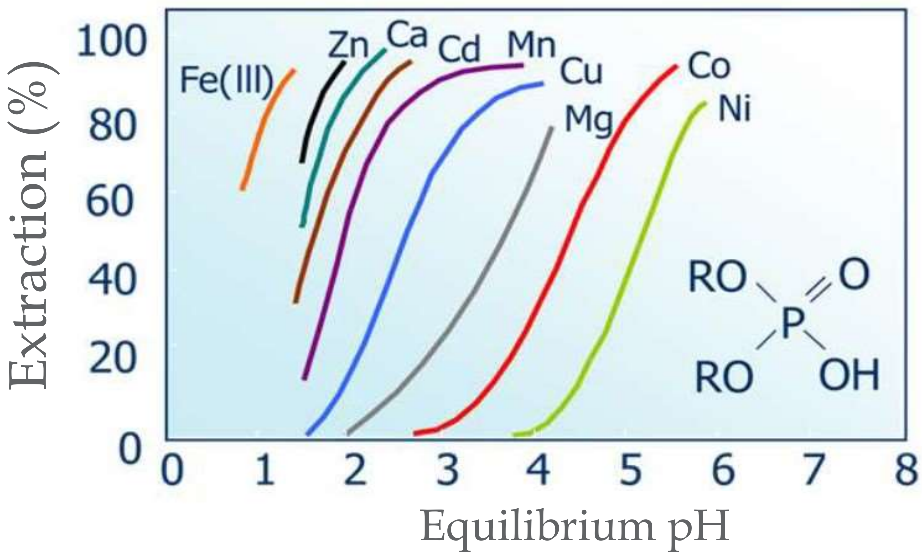
Solvent-impregnated resins

- Organic solvent incorporated into ion exchange resin
- Has physical characteristics of an ion exchange resin
  - Reactor design/engineering as for fixed bed ion exchange systems
- Has chemical characteristics of the solvent:
  - selectivity range
  - pH dependence
- Application: production of high-purity liquors

Solvent-impregnated resins

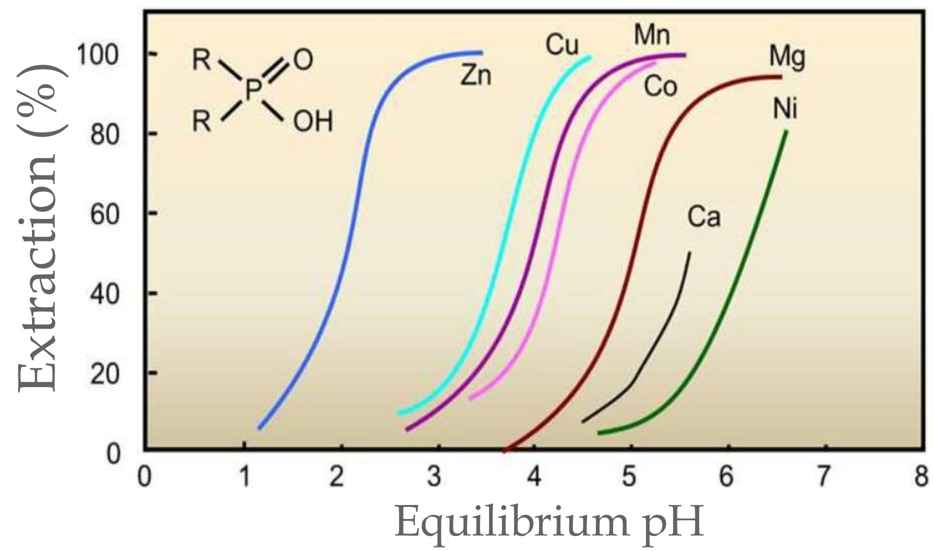
D2EHPA

Removal of Fe, Zn, Ca, Cd from Co and Ni



TMPPA

Removal of Zn, Cu, Co from Ni



Dr Kathy Sole, Alta 2018, keynote address

A note of caution

- Published graphs are generated with all components in equal concentrations
- Real solutions have vastly varying concentrations

  For example:
  - 50 mg/L Cu and 50 g/L Ni
  - Ni:Cu = 1000

- Both selectivity and pH dependence is affected by the relative concentration of elements
- Test work in the specific matrix is essential to establish relative metal loading

03 Contactor design

Ion exchange reactor design

The choice of IX contactor design is based on the solids content of the feed

Solids content	Ion exchange reactor
Clear liquid, < 1 ppm solids	Fixed bed column
Liquid with some solids, <500 ppm	Fluidised bed column
Pulp, 10 – 50 % solids	Resin-in-pulp (RIP) - agitated vessels

Fixed bed design

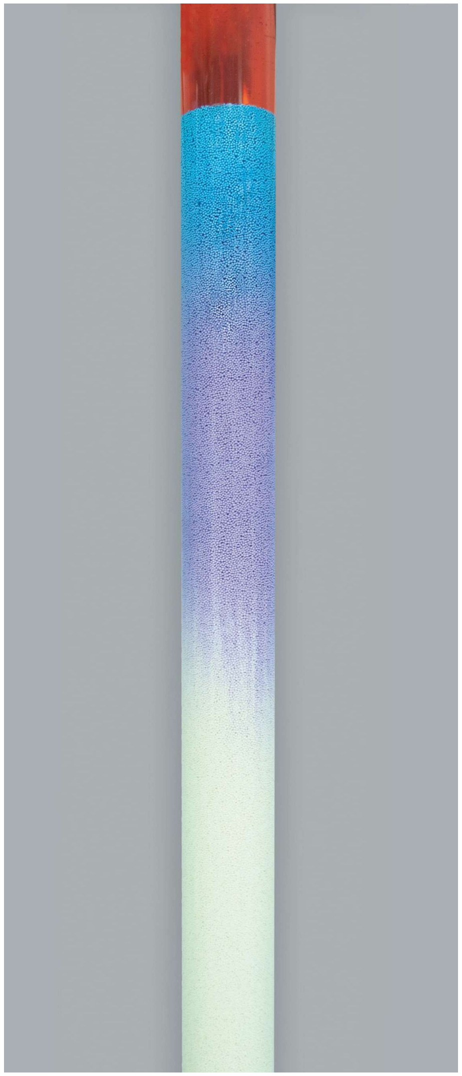
- Best for impurity removal tasks
- A fixed or packed bed of resin, i.e. no movement/fluidisation of the resin during forward flow conditions
- Theory: the resin bed is divided into an infinite number of horizontal plates, each having a different concentration than the plate above and below it
- A concentration gradient is established across the vertical of the resin bed
- This ensures very low leakage to the Barren liquor

Resin selectivity at work

Feed liquor:
4 g/L cobalt
0.2 g/L copper
Sulphate salts

Downflow

MTS9500 (AMP resin)

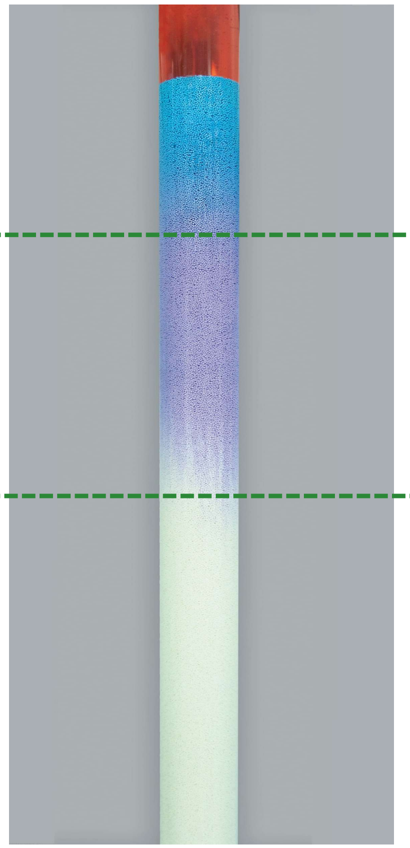


Resin is fully loaded with blue copper

Purple, showing a mixture of blue copper and pink cobalt loaded onto the resin

Beige, similar colour as fresh resin, no metals have loaded onto this portion yet

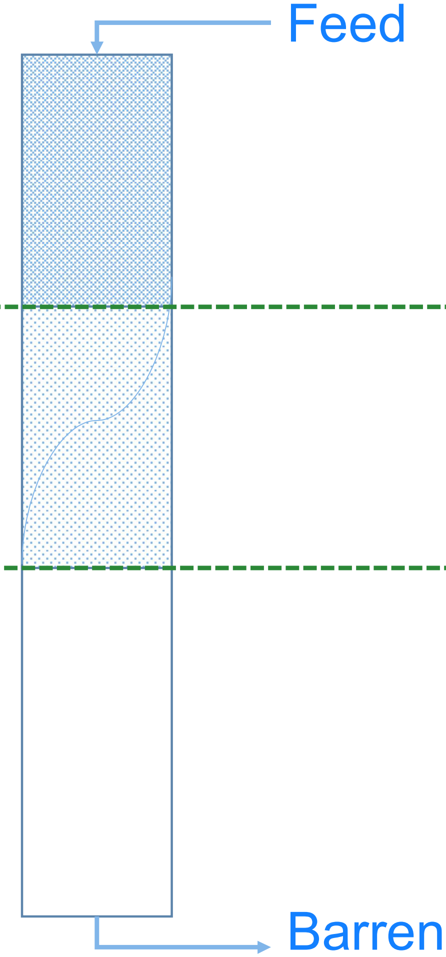
Fixed bed design: Mass Transfer Zone



Section containing
Fully loaded resin

Mass transfer zone

Section containing
as yet unloaded
resin



Fixed bed design: options

Continuous operation is most efficient
Ion exchange operates in a batch-continuous manner:

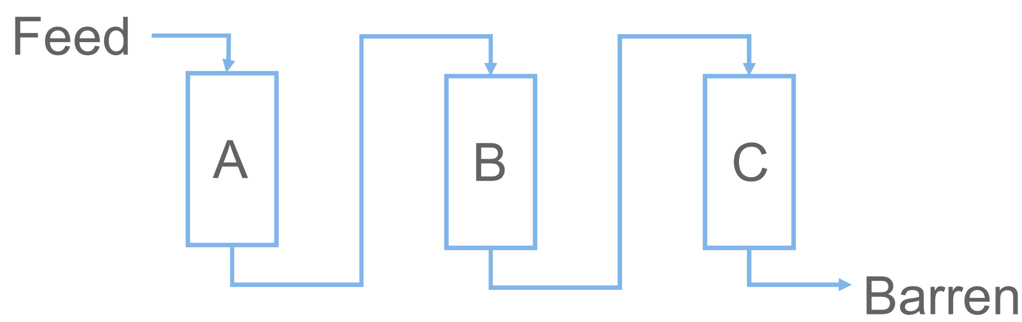
Continuous sorption – stop – continuous elution – stop

Multi-column systems approaches continuous operation
- 20 to 30 columns
- Each receiving a different liquor (Feed solution, washwater, eluant)

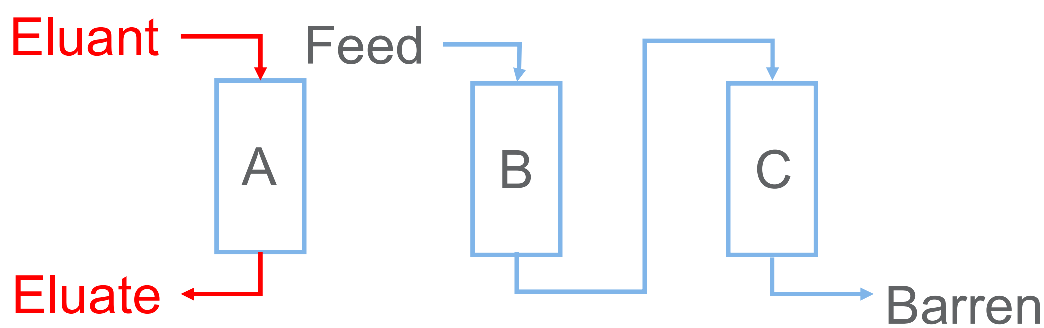
Merry-go-round or lead-lag-lag system, 3 columns in series
- Offers flexibility
- Simpler and cheaper

Merry-go-round system

Upon start-up

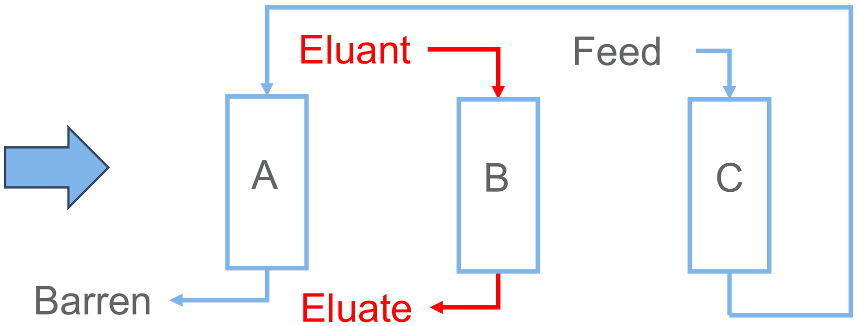


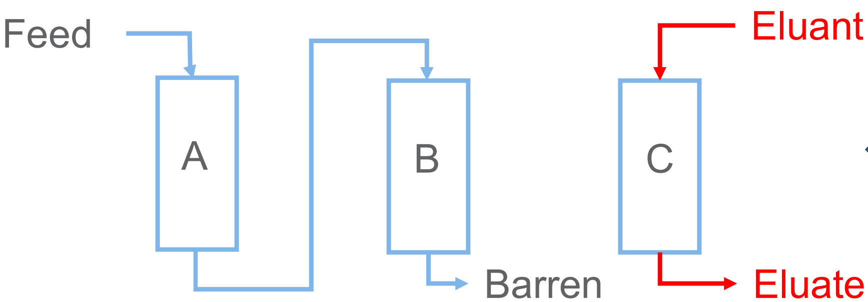
At the end of Cycle 1



Merry-go-round system

At the end of Cycle 2

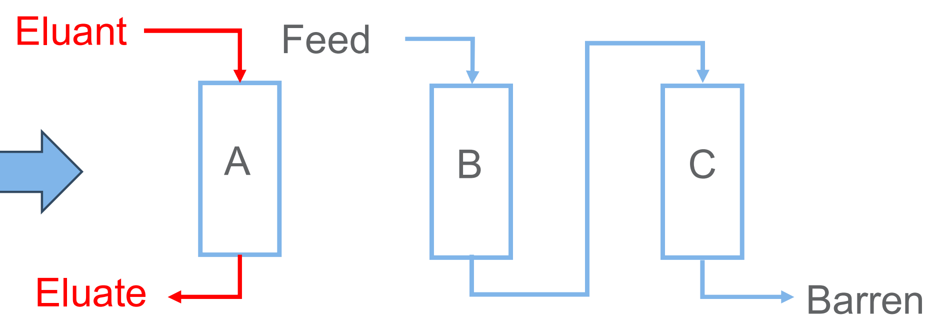




At the end of Cycle 3

At the end of Cycle 4

(similar to configuration at the end of Cycle 1)



Merry-go-round system: advantages

Ensures maximum resin capacity utilisation on the first column

Ensures low leakage from the last column

Merry-go-round system: advantages

Ensures maximum resin capacity utilisation on the first column

- Low resin volume
- Smaller plant, smaller footprint = low capex
- Reduced reagent consumption = low opex

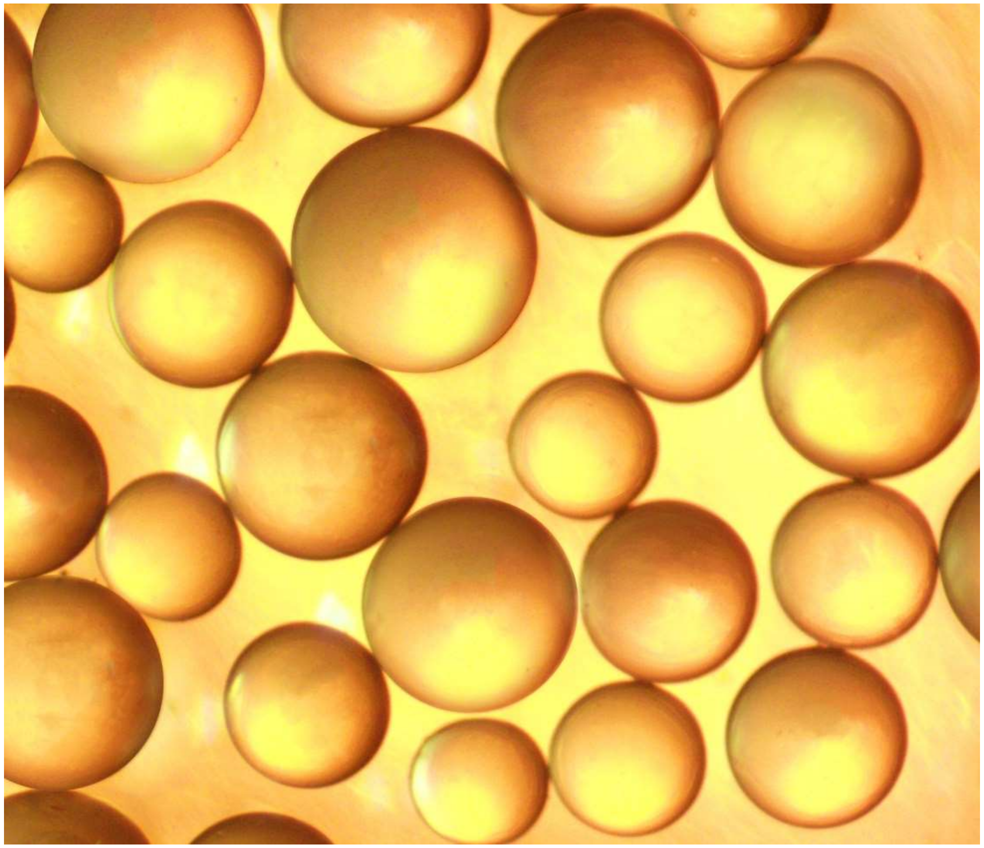
Ensures low leakage from the last column

- A polishing zone is maintained at the outlet
- Ensure specification of final product is met
    - final product fetches high price
    - Avoid penalties for low quality

04 Resin characteristics to suit the design

Choosing the right resin (mechanical)

- Particle size distribution
- Mechanical strength



Choosing the right resin: particle size distribution

A small particle size ensures fast kinetics
BUT
also causes high pressure drop across a column

Standard grading: 300 to 1200 micron

Narrow size distribution: 600 to 800 micron

- Uniform kinetics – all resin beads participate equally
- Low pressure drop

Choosing the right resin: physical strength

Causes of resin attrition

- Physical handling
  - pumping,
  - transfer between vessels
- Osmotic shock
  - swelling and shrinking due to exposure to different liquors

Physical strength can be measured in various ways:

- Breaking weight: typically >500 g per bead
- Russian Ball Mill parameter: >92% perfect beads after 6 hours of milling
- Critical in resin-in-pulp (RIP) systems
- Less critical in fixed bed operations

Choosing the right resin: mechanical

IX resins typically last 3 to 5 years
Annual top-up of 5 to 10% required
Complete replacement of the inventory at the end of life

How to take care of the resin:

- Minimise physical handling
- Minimise temperature shock
- Inspect vessel internals regularly to prevent losses

CONCLUSIONS

Conclusions

Ion exchange can be used in a wide range of application

- Bulk recovery of target metals
- Removal of impurities to low ppm, even ppb, levels

Different resins are used to target specific impurities

- selectivity range
- pH dependent
- affected by relative concentrations of elements

Considerations: ion exchange

- What is the target metal(s) or impurity
- Matrix, e.g. acidic (sulphate, chloride, etc) or alkaline (cyanide, sodium carbonate, etc)
- Solution pH
- Recovery from pulp (RIP), clear solution (fixed bed) or ‘dirty’ liquors (fluidised bed)
- Presence of competing ions (which ions, relative concentrations)
- Solution temperature
- Integration with other unit operations, i.e. choice of elution reagent is often dictated by requirements/limitations of downstream processes
- Environmental limitations, e.g. use of sodium