

# Hydrometallurgy Applications: Puromet™ and Purogold™ Resins For Metals Removal, Recovery and Separation



This Application Guide presents information for using ion exchange technology for the primary recovery of metal or the removal of impurities to increase the value and purity of the final product.



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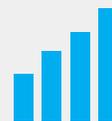
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Above is the Bingham Canyon mine in Utah, known as the world's largest man-made excavation at more than 0.8 km (0.5 mi) deep and 4 km (2.5 mi) wide.

This Application Guide presents information for using ion exchange technology for the primary recovery of metal and the removal of impurities to increase the value and purity of the final product.

Metals can be extracted from ores using several methods, including chemical solutions (hydrometallurgy), heat (pyrometallurgy) or mechanical means.

Hydrometallurgy is the process of extracting metals from ores by dissolving the ore containing the metal of interest into an aqueous phase and recovering the metal from the resulting pregnant liquor. This process provides a very cost-effective and environmentally friendly technique for extracting and concentrating a wide range of metals. Various hydrometallurgical processes may be used in the same flowsheet, such as combining ion exchange and solvent extraction to recover and purify uranium. Hydrometallurgical processes can also be combined with non-hydrometallurgical extractive metallurgy processes.

## Applications of Ion Exchange

Ion exchange technology is used for the primary recovery of metals of interest as well as the removal of specific impurities to increase the value and purity of the final product.

A wide variety of process streams benefit from applying ion exchange resins, as shown in Table 1.

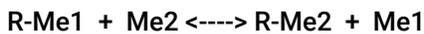
**TABLE 1 Applications of Ion Exchange in Hydrometallurgy**

Origin of Stream to Be Treated	Ion Exchange Application
Pregnant Leach Liquor, After Heap, Autoclave or Agitated Leach	Primary recovery of metal(s) of interest, e.g., gold, uranium
Volatile Compounds Captured in Off-Gases From Smelters and Roasters	Recovery of rhenium from off-gases produced by roasting of molybdenite and smelting of copper concentrates
Slags and Calcines From Roasting and Smelting Operations	Recovery of various metal(s) of interest, after leaching of the residues
Electrolyte	Removal of impurities from non-ferrous metal electrolytes to improve process efficiency and ensure higher metal purity
Tailings Treatment	Recovery of copper, cobalt, gold, etc. from historical mine tailings, as well as current arisings
Acid Mine Drainage	Treatment of process water to enable recycling or safe disposal

# Ion Exchange Resins

Ion exchange resins are synthetic polymer materials carrying chemically or physically bound functional groups capable of exchanging or capturing specific ions. These reactions are reversible, allowing the ion exchange resins to be used in multiple cycles of adsorption/desorption.

The following simple expression can be used to describe the principle of ion exchange:



The character "R" denotes the polymer matrix of a resin with a functional group fixed on it that is capable of ionic or coordinate bonding with a mobile ion "Me1." While "Me1" is an ion that is initially bound to the functional group of "R," "Me2" is an ion that is present in the solution. As a result of the ion exchange reaction, the "Me2" ion replaces the "Me1" ion on the resin.

Ion exchange resins are usually produced in the form of spherical beads. The typical bead size ranges from 300–1,300 microns (50-16 US mesh). The degree of particle size uniformity and the average particle diameter can vary widely. Resins with a particle size of <200 um (0.008 in) or > 2,000 um (0.079 in) are produced for special applications.

Copolymers of styrene or acrylic or methacrylic acid derivatives, with a crosslinking agent – typically divinylbenzene – serve as the polymer base. Due to crosslinking, the copolymer has a high-temperature tolerance and does not dissolve in conventional aqueous media (acidic and alkaline) or organic solvents.

Depending on the functional group, ion exchange resins have distinct selectivities for different metal cations or anions. This resin characteristic can be used to selectively remove a specific metal from a background containing high concentrations of other (unwanted) metals.

Another resin class is chelating resins which are liquid extractants adsorbed onto polymeric adsorbents. These are known as solvent impregnated resins. This approach significantly expands the range of functional groups that can be made available in bead form. The resulting product retains the same selectivity range as that of the liquid solvent, but with the mechanical characteristics of a solid bead. This means that the same well-known design and engineering principles that applies to standard ion exchange resins, applies to this special range of products. Solvent impregnated resins find application in the removal of specific impurities to low levels.

# Examples of Selectivity Ranges for Different Types of Ion Exchange Resins

## Carboxylic Resins - i.e., Purolite C104Plus range

$\text{Cu}^{2+} > \text{Pb}^{2+} > \text{Zn}^{2+} > \text{Cd}^{2+} > \text{Ni}^{2+} > \text{Ca}^{2+}$

## Phosphonic Resins - i.e., Puromet MTS9560

$\text{Cu}^{2+} > \text{Zn}^{2+} > \text{Cd}^{2+} > \text{Mn}^{2+} > \text{Co}^{2+} > \text{Ni}^{2+} > \text{Ca}^{2+}$

## Aminophosphonic Resins (at Acidic pH) - i.e., Puromet MTS9500

$\text{Fe}^{3+} > \text{Bi}^{3+} > \text{Sb}^{3+} > \text{Pb}^{2+} > \text{Fe}^{2+} > \text{Zn}^{2+} > \text{Cu}^{2+} > \text{Mn}^{2+} > \text{Ca}^{2+} > \text{Mg}^{2+} > \text{Ni}^{2+} > \text{Co}^{2+} > \text{Na}^+$

## Iminodiacetic Resins - i.e., Puromet MTS9300

$\text{Cr}^{3+} > \text{In}^{3+} > \text{Fe}^{3+} > \text{Al}^{3+} > \text{Hg}^{2+} > \text{UO}_2^{2+} > \text{Cu}^{2+} > \text{Pb}^{2+} > \text{Ni}^{2+} > \text{Cd}^{2+} > \text{Zn}^{2+} > \text{Co}^{2+} > \text{Fe}^{2+} > \text{Mn}^{2+} > \text{Ca}^{2+} > \text{Mg}^{2+}$

## Strong Acid Cation Resins - i.e., Puromet MTC1600H

$\text{Fe}^{3+} > \text{Ca}^{2+} > \text{Fe}^{2+} > \text{Cu}^{2+} > \text{Mg}^{2+} > \text{K}^+ > \text{NH}_4^+ > \text{Na}^+ > \text{H}^+$

## Strong Base Anion Resins - i.e., Puromet MTA8000PP

$\text{SO}_4^{2-} > \text{CO}_3^{2-} > \text{NO}_3^- > \text{Cl}^- > \text{HCO}_3^- > \text{F}^- > \text{OH}^-$

## Bis-Picolylamine Resins - i.e., Puromet MTS9600

$\text{Cu}^{2+} > \text{Ni}^{2+} > \text{Fe}^{3+} > \text{Zn}^{2+} > \text{Co}^{2+} > \text{Cd}^{2+} > \text{Fe}^{2+} > \text{Mn}^{2+}$

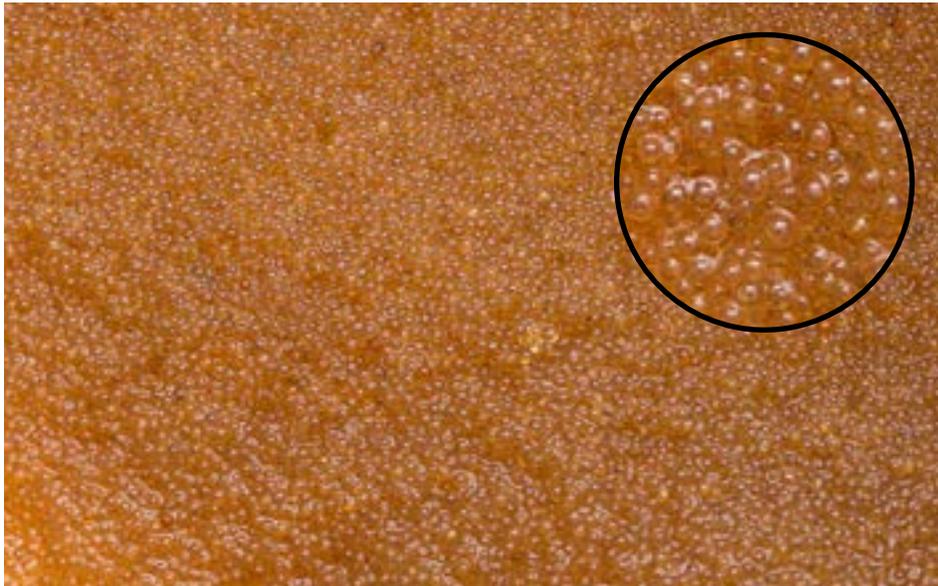
## Solvent Impregnated Resins

D2EHPA (di-2-ethyl-hexyl-phosphoric acid):  $\text{Fe}^{3+} > \text{Zn}^{2+} > \text{Ca}^{2+} > \text{Cd}^{2+} > \text{Mn}^{2+} > \text{Cu}^{2+} > \text{Mg}^{2+} > \text{Co}^{2+} > \text{Ni}^{2+}$

i.e., Puromet MTX7010

Bis-2,4,4-trimethylpentyl-phosphinic acid:  $\text{Fe}^{3+} > \text{V(IV)} > \text{Zn}^{2+} > \text{Al}^{3+} > \text{Cu}^{2+} > \text{Mn}^{2+} > \text{Co}^{2+} > \text{Mg}^{2+} > \text{Ca}^{2+} > \text{Ni}^{2+}$  (sulfate matrix)

i.e., Puromet MTX8010



Ion exchange resin in aqueous media.

All the characteristics of ion exchange resins are interdependent, and the choice of resin is often a trade-off between the different technical parameters of the resin.

Parameters that are controlled during the manufacturing of ion exchange resins:

## **Functionality**

Determines the selectivity of the resin for certain metals over others.

## **Ion Exchange Capacity**

A high capacity is desirable to reduce the size of the plant and, subsequently, the cost of capital investment and elution reagents.

## **Mechanical Stability**

The ability of the resin to withstand breakage from abrasion and handling.

## **Particle Size Distribution**

Smaller beads are used in fixed bed operations treating clarified liquors that benefit from the improved kinetics of smaller beads. Resin-in-pulp (RIP) operations require larger beads to ease the separation of the loaded resin and pulp.

## **Osmotic Stability**

The ability to endure multiple changes in solution concentration, acidity and/or alkalinity.

# Ion Exchange Contactor Design

Ion exchange contactors perform two key functions:

- They provide conditions that favor efficient mass transfer between the process solution and the ion exchange resin.
- They ensure the efficient mechanical separation of the ion exchange resin from the solution or pulp.

Ion exchange contactor designs are quite diverse, varying as a function of the properties of the medium being treated, the resin used and capital expense optimization considerations. The selection of a suitable ion-exchange contactor design is a function of, amongst others, the suspended solid content of the pregnant flow, as summarized in Table 2.

**TABLE 2 Choice of Ion Exchange Contactor Based on Solids Content of Feed**

Solids Content	Ion Exchange Contactor
Clear Liquid, < 1 ppm Solids	Fixed bed column
Liquid with Low Solids Content, up to 1,000 ppm	Fluidized bed column
Pulp, 10–50% Solids	Resin-in-pulp (RIP): air agitated Pachuca or mechanically agitated vessel

In a fixed bed operation, any solids present in the pregnant leach solution (PLS) will collect on the top of the resin bed (in the case of down-flow operation). Over time, this may form a dense layer that will lead to an increase in pressure drop across the resin bed and consequently to an increase in the mechanical load on the resin and excessive consumption of energy to pump the solution. Therefore, efficient clarification of the liquor prior to the ion exchange unit operation is critical. It is also customary to provide periodic backwashing of the resin, either in the same or in a separate vessel.

In the case of fluidized bed operation, the upward flow of solution ensures expansion of the resin bed, typically up to two fold times against initial height or up to 100%. In this instance, the resin does not retain the suspended solids, and the solids can move freely past the resin beads with the solution. Vessels consisting of vertical stages are also much taller than fixed bed systems to allow for expansion of the resin bed.

When processing large flows, it makes sense to use continuous or semi-continuous processes. Resin contactor designs treating clarified or partially clarified liquors vary widely. They can include fixed and moving resin beds with two columns in series (lead-lag), a three-column system (merry-go-round) and systems using multiple columns in sequence with special valves that manage the distribution of the different liquors to the various columns.

Ion exchange resins may also be contacted directly with leached pulp, negating the need for solid-liquid separation. This potentially results in significant cost savings, especially in the case of ores with a high clay content that is difficult to filter.

The use of ion exchange resins makes it possible to avoid this expense since sorption on resins is accomplished directly from the pulps. A resin may be added to a pulp after leaching, called resin-in-pulp, or leaching and sorption may happen simultaneously. This is referred to as “resin-in-leach” (RIL). An added advantage of the RIL process is that the sorption of a valuable component from a pulp’s liquid phase continuously reduces the concentration of the component being sorbed in the pulp, thereby shifting the chemical equilibrium. This makes it possible to increase the degree of a given component’s recovery from the mineral particles by several percentage points.

The density and viscosity of a pulp depend on the pulp particle size, concentration of solids, and the nature of the minerals being processed. For example, some pulps have very high clay content resulting in poor filterability, even at relatively low solids content. In such cases, RIP or RIL offers an economical solution. RIP operations consist of a series of stirred tanks where the resin and pulp move counter-currently.

To ensure efficient separation of resin and pulp via mechanical screening, resin that is several hundred microns larger than the maximum mineral particle size should be used.

Table 3 indicates a typical size ratio for RIP operations.

**TABLE 3** Size Ratio for Resin Separation in Resin-in-Pulp Operations

Equipment	Particle Size
Resin	< 1% finer than 700 $\mu\text{m}$ (0.028 in); typically 800-1,300 $\mu\text{m}$ (2016 US mesh) with minimal fines content
Mechanical Screen Effective Opening (Orifice, Slit) Size	600 $\mu\text{m}$
Mineral Particles in a Pulp	Maximum 250 $\mu\text{m}$ (0.010 in); 75% finer than 200 $\mu\text{m}$ (0.008 in)

The optimum resin bead size distribution should be selected based on the specific characteristics of the system.

**TABLE 4** Optimum Resin Bead Size Distribution

Resin Grading	Average Bead Diameter	System
Puopack® (Gel)	600–700 µm (0.024-0.028 in)	Fixed and fluidized beds
Puopack (Macroporous or Acrylic)	650–850 µm (0.026-0.033 in)	Fixed and fluidized beds
Resin-in-Pulp (RIP)	850 (800–1,300) µm; 0.033 (0.031-0.051 in)	Resin-in-pulp



Multi-contaminant removal in a fixed bed ion exchange system.

# Principles of Project-Specific Resin Volume Estimation

To make an initial estimate of ion exchange plant size, it is necessary to calculate the resin volume that is sufficient to reach the performance target. This is calculated from the mass balance equation for the target metal:

## Mass Balance

$$C_{\text{PLS}} \times F_{\text{PLS}} = C_{\text{R}} \times F_{\text{R}}$$

- $C_{\text{PLS}}$ : Metal concentration in PLS,  $\text{kg}/\text{m}^3_{\text{PLS}}$
- $F_{\text{PLS}}$ : Flow rate of PLS,  $\text{m}^3_{\text{PLS}}/\text{h}$
- $C_{\text{R}}$ : Operating metal capacity of the resin,  $\text{kg}/\text{m}^3_{\text{R}}$
- $F_{\text{R}}$ : Flow rate of the resin,  $\text{m}^3_{\text{R}}/\text{h}$

## Ion Exchange Resin Flow Rate

$$F_{\text{R}} = (C_{\text{PLS}} \times F_{\text{PLS}}) / C_{\text{R}}$$

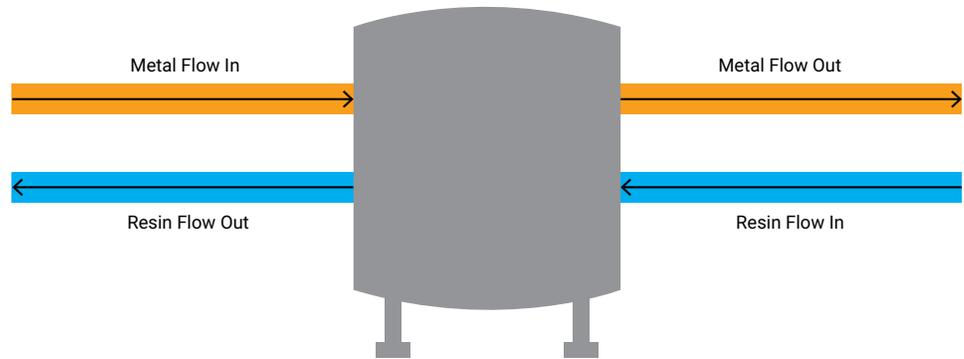
## Total Resin Inventory ( $\text{m}^3$ )

$$V_{\text{R}} = F_{\text{R}} \times (T_1 \times k + T_2 + T_3)$$

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**FIGURE 1**

**Depiction of Mass Flow in a System Containing Resin and Solution/Pulp**



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Where:

**PLS:** Pregnant Leach Solution

**R:** Resin

**T<sub>1</sub>:** Residence time at sorption provided that:

- Concentration of the metal in the barren is reduced to the target limits (i.e., < 5 ppm for most uranium projects)
- Resin metal capacity reaches maximum

A resin “safety” volume should be provided for the sorption stage; for this volume, the T<sub>1</sub> parameter should be multiplied by a safety factor, k, with a value of 1.1–1.5 (the process designer selects the actual value).

**T<sub>2</sub>:** Residence time for desorption

**T<sub>3</sub>:** Residence time in auxiliary operations

Reduce CAPEX by minimizing F<sub>R</sub> and T

- To minimize the F<sub>R</sub>, the resin capacity utilization must be maximized
- To minimize T<sub>1</sub>, a resin must have the best ion exchange kinetics
- To minimize T<sub>2</sub>, a resin must have efficient desorption; e.g., complete and rapid
- To minimize T<sub>3</sub>, the desorption and regeneration processes must be simple to avoid or minimize additional processing steps

# Selecting the Optimum Resin

There are several important considerations in choosing the correct resin:

## **The Target Metal**

If the metal is valuable, maximum recovery will be critical. For impurities, the most efficient targeted removal of the metal, while minimizing loss of valuable metal, is an essential factor.

## **The Solution Matrix**

Acidic (sulfate, chloride, etc.) or alkaline (cyanide, sodium carbonate, etc.).

## **The Solution pH**

Performance of resins is affected by the solution pH.

## **Total Suspended Solids or Pulp Concentration**

This determines the contactor type required and the physical properties of the resin (e.g., size and physical strength).

## **Presence of Competing Ions**

It is crucial to choose a resin with a high selectivity for the metal of interest.

## **The Solution Temperature**

While increased temperatures generally benefit most reactions, ion exchange resins are temperature sensitive. For hydrometallurgical applications, a maximum operating temperature of 60 °C (140 °F) is usually recommended.

## Integration With Other Unit Operations

For example, the choice of elution reagent is often dictated by the requirements/limitations of downstream processes.

## Process Flexibility

Consider if it is possible to change the pH of the solution to benefit the ion exchange unit operation while having minimal impact on the rest of the circuit.

## Environmental Limitations

As an example, the choice of elution/regeneration reagents is influenced by disposal regulations.



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Laboratory test work forms an important part of any project.

**TABLE 5 Suggested Purolite Resins for Hydrometallurgical Applications**

Target Metal	Detail	Puromet Resin(s)
Antimony & Bismuth	Various liquors and waste waters	MTS9500 MTS9510PF MTS9570
Cobalt, Copper, Nickel, Zinc	Acidic liquors or pulps	MTS9300 MTS9301 MTS9600
Copper & Zinc Impurity Removal	Cobalt and nickel electrolyte	MTS9500
Gold	Acidic liquors or pulps	MTS9140 MTS9200*
Iron	Electrolyte purification	MTS9500 MTS9570
Mercury	Various liquors and waste waters	MTS9140 MTS9200
Molybdenum	Acidic liquors or pulps	MTA1011
Precious Metals	Acidic liquors or pulps	MTS9100 MTS9140 MTS9200 MTS9850
Rare Earth Elements	Acidic liquors or pulps	Selection of cation exchange and complexing resins
Rhenium	Acidic liquors or pulps	MTA1701 MTA1721
Uranium	Liquors or pulps	MTA4601PF MTA4801PF MTA5012 MTA5014 MTA5601 MTA6001 MTA6002PF MTA6601 MTA8000PP

Target Metal	Detail	Purogold Resin(s)
Gold	Cyanide liquors and pulps	MTA1930 MTA9920
Gold	Thiosulfate leach	MTA5011 MTA5013 MTA5015

Note: All anion and cation resins may be converted to specific ionic form.

\*Puromet MTS9200 can only be used in acidic conditions, as it is not stable in alkaline conditions.







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