### Q1: What recovery efficiency is achieved for lithium, cobalt, nickel, and manganese using a non-Na precipitant-based chemical precipitation process?

\*\*A1:\*\* The recovery efficiencies achieved using a non-Na precipitant-based chemical precipitation process are 98.1% for lithium (Li), 97.1% for cobalt (Co), 96.1% for nickel (Ni), and 95.7% for manganese (Mn). These results were obtained under conditions of 2 M H2SO4 + 6 vol.% H2O2 leachate solution, a solid-to-liquid ratio of 75 g/L, leaching at 60 °C for 120 minutes with an agitation speed of 350 rpm.

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### Q2: How effective is the low-temperature sulfation process in recovering metals from NCM523 batteries?

\*\*A2:\*\* The low-temperature sulfation process achieves leaching efficiencies of 99.43% for lithium (Li), 99.87% for nickel (Ni), 98.88% for cobalt (Co), and 99.19% for manganese (Mn). This is achieved at a roasting temperature of 350 °C using (NH4)2S2O8 as the leaching agent.

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### Q3: What are the optimized leaching conditions for recovering valuable metals from spent LiNi1/3Co1/3Mn1/3O2-based batteries?

\*\*A3:\*\* The optimized leaching conditions include 1 M H2SO4, 1 vol.% H2O2, a stirring speed of 400 rpm, a pulp density of 40 g/L, and leaching at 40 °C for 60 minutes. Under these conditions, the leaching efficiencies are 99.7% for lithium (Li), nickel (Ni), cobalt (Co), and manganese (Mn).

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### Q4: What is the recovery efficiency of FePO4 from lithium extraction slag using H3PO4 treatment?

\*\*A4:\*\* The recovery efficiency of FePO4 from lithium extraction slag reaches up to 99.53% for nickel (Ni), 98.08% for copper (Cu), and 97.65% for manganese (Mn). Optimal recovery conditions include 1.5 mol/L H3PO4, an H3PO4-to-HCl molar ratio of 3:1, a liquid-to-solid ratio of 10 mL/g, leaching at 90 °C for 3 hours.

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### Q5: What are the leaching efficiencies achieved for nickel, cobalt, and manganese using starch as a reductant?

\*\*A5:\*\* Leaching efficiencies of 98.07% for nickel (Ni), 96.52% for cobalt (Co), and 98.06% for manganese (Mn) are achieved using starch as a reductant. The optimal conditions include 1.5 mol/L H2SO4, 6 g/L starch, a stirring speed of 500 rpm, leaching at 80 °C for 60 minutes.

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### Q6: What leaching efficiencies are achieved using the NH3 + (NH4)2SO4 + Na2SO3 system?

\*\*A6:\*\* Using the NH3 + (NH4)2SO4 + Na2SO3 system, leaching efficiencies are 96.2% for lithium (Li), 89.9% for cobalt (Co), and 90.1% for nickel (Ni) under optimized conditions: 1.5 mol/L (NH4)2SO4, 0.5 mol/L Na2SO3, 4 mol/L NH3, a solid-liquid ratio of 10:1, leaching time of 180 minutes at 90 °C.

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### Q7: What recovery efficiencies are achieved for cobalt, manganese, and lithium in the precipitation process?

\*\*A7:\*\* Recovery efficiencies are 96.5% for manganese (Mn), 96% for nickel (Ni), and 98.84% for lithium (Li) in a precipitation process using potassium permanganate for Mn separation, and sodium carbonate for lithium precipitation at 100 °C for 40 minutes.

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### Q8: What are the optimal conditions for leaching Ni, Co, Mn, and Li using solid sodium bisulfate?

\*\*A8:\*\* The optimal conditions for leaching include 1 mol/L NaHSO4, 3 vol.% H2O2, a pulp density of 20 g/L, leaching for 30 minutes at 70 °C. Under these conditions, the leaching efficiencies are 93.0% for nickel (Ni), 91.5% for cobalt (Co), 95.5% for manganese (Mn), and 96.6% for lithium (Li).

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### Q9: How effective is the low-temperature roasting process in recovering lithium and cobalt?

\*\*A9:\*\* The low-temperature roasting process recovers 97% of lithium (Li) and 99% of cobalt (Co) under optimal conditions of 550 °C roasting for 1 hour, followed by 30 minutes of water leaching with a solid-to-liquid ratio of 50 g/L.

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### Q10: What are the leaching efficiencies for Ni and Mn using HCl as a leaching agent?

\*\*A10:\*\* Leaching efficiencies of 99% for nickel (Ni) and 99% for manganese (Mn) are achieved in 90 minutes using 1.75 M HCl at 50 °C.

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### Q11: What are the recovery rates of valuable metals from spent LIBs using ammonium sulfate roasting?

\*\*A11:\*\* Recovery rates are 99.99% for lithium (Li), 99% for nickel (Ni), 98.1% for cobalt (Co), and 90% for manganese (Mn) under conditions of a roasting temperature of 450 °C, roasting time of 30 minutes, and a 3:1 mass ratio of ammonium sulfate to lithium battery materials.

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### Q12: How effective is a mixed organic acid system in recovering Co and Li?

\*\*A12:\*\* A mixed organic acid system achieves leaching efficiencies of 97% for cobalt (Co) and 99% for lithium (Li) under conditions of 1.3 mol/L benzenesulfonic acid, 1.5 mol/L formic acid, a solid-to-liquid ratio of 30 g/L, and a reaction time of 40 minutes at 50 °C.

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### Q13: What is the efficiency of a deep eutectic solvent (DES) in recovering Li and Co from spent LIBs?

\*\*A13:\*\* The DES system achieves recovery efficiencies of 99% for lithium (Li) and 98% for cobalt (Co) under optimal conditions of 90 °C, a solid-to-liquid ratio of 20 g/L, and a reaction time of 2 hours.

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### Q14: How does the addition of glucose improve the recycling of spent NCM materials?

\*\*A14:\*\* The addition of glucose as a reductant improves leaching efficiencies to 90.14% for nickel (Ni), 90.58% for cobalt (Co), 98.66% for manganese (Mn), and 98.53% for lithium (Li) under conditions of 1 mol/L dl-malic acid, 0.5 g/g glucose, a leaching temperature of 90 °C, and a pulp density of 25 g/L for 120 minutes.

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### Q15: What recovery rates are achieved for DMC and DEC in a spent LIBs distillation process?

\*\*A15:\*\* Recovery efficiencies of 100% for dimethyl carbonate (DMC) and 79.40% for diethyl carbonate (DEC) are achieved at a distillation temperature of 130 °C for 120 minutes.

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### Q16: What is the recovery efficiency for lithium using ammonium sulfite roasting?

\*\*A16:\*\* The recovery efficiency for lithium (Li) is 94.06% under the optimal conditions of a roasting temperature of 750 °C, a Na2SO3-to-cathode material molar ratio of 3.0, and a roasting period of 2 hours.

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### Q17: How efficient is the NaOH-assisted low-temperature roasting for Li recovery?

\*\*A17:\*\* The NaOH-assisted low-temperature roasting achieves a lithium recovery efficiency of 96.7% with a purity of 99.9% under a roasting temperature of 150 °C.

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### Q18: What are the recovery efficiencies achieved using mixed electrode materials?

\*\*A18:\*\* Recovery efficiencies of 97% for cobalt (Co) and 99% for lithium (Li) are achieved under conditions of 1.3 mol/L benzenesulfonic acid, 1.5 mol/L formic acid, a solid-to-liquid ratio of 30 g/L, and a reaction time of 40 minutes at 50 °C.

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### Q19: How effective is the roasting process for recovering Ni, Co, and Mn from SPS?

\*\*A19:\*\* Recovery efficiencies of 98.5% for cobalt (Co), 98.6% for manganese (Mn), and 95.6% for nickel (Ni) are achieved during leaching with hydrogen peroxide followed by selective extraction and purification steps.

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### Q20: How efficient is the leaching process using glycine for cobalt recovery?

\*\*A20:\*\* The leaching efficiency for cobalt (Co) is 61.8% under conditions of 0.936 M glycine, a pulp density of 19.9 g/L, and a temperature of 74 °C, reaching a maximum of 89.7% at 100 °C with 1.24 M glycine and a pulp density of 13.8 g/L.

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### Q21: What are the recovery rates for lithium and cobalt using organic acids and hydrogen peroxide?

\*\*A21:\*\* Recovery rates are 98.5% for lithium (Li) and 97.8% for cobalt (Co) using 1 M citric acid, 3 vol.% H2O2, a solid-to-liquid ratio of 20 g/L, and a reaction temperature of 50 °C for 90 minutes.

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### Q22: How efficient is a two-step precipitation process for recovering rare earth elements (REEs)?

\*\*A22:\*\* The two-step precipitation process achieves 97.6% recovery of neodymium (Nd) and 96.8% recovery of dysprosium (Dy) using 2 M NaOH in the first step, followed by oxalic acid precipitation at 60 °C.

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### Q23: What are the leaching efficiencies for Li and Co from spent batteries using formic acid?

\*\*A23:\*\* Leaching efficiencies are 98.3% for lithium (Li) and 97.5% for cobalt (Co) under conditions of 1.5 M formic acid, a pulp density of 25 g/L, and a reaction time of 60 minutes at 70 °C.

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### Q24: How does microwave-assisted leaching improve the recovery of metals from LIBs?

\*\*A24:\*\* Microwave-assisted leaching improves leaching efficiencies to 99.2% for lithium (Li), 98.7% for cobalt (Co), and 98.9% for nickel (Ni) using 2 M H2SO4, a microwave power of 800 W, and a reaction time of 10 minutes.

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### Q25: What recovery rates are achieved using hydrometallurgical methods for NCM batteries?

\*\*A25:\*\* Recovery rates of 98.9% for nickel (Ni), 97.4% for cobalt (Co), and 95.6% for manganese (Mn) are achieved using 1.5 M sulfuric acid, a solid-to-liquid ratio of 30 g/L, and leaching at 60 °C for 90 minutes.

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### Q26: How effective is a bioleaching process for recovering metals from spent batteries?

\*\*A26:\*\* Bioleaching achieves recovery efficiencies of 90.1% for lithium (Li), 85.5% for cobalt (Co), and 86.7% for nickel (Ni) using Aspergillus niger at a temperature of 30 °C over 7 days.

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### Q27: What is the efficiency of supercritical CO2 extraction for recovering lithium from brines?

\*\*A27:\*\* Supercritical CO2 extraction achieves 95% lithium (Li) recovery using a pressure of 120 bar, a temperature of 50 °C, and a reaction time of 4 hours.

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### Q28: How efficient is solvent extraction for recovering rare earth elements?

\*\*A28:\*\* Solvent extraction achieves recovery efficiencies of 99.5% for neodymium (Nd) and 98.8% for praseodymium (Pr) using 0.2 M D2EHPA in kerosene, a phase ratio of 1:1, and a reaction time of 15 minutes.

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### Q29: What leaching efficiencies are achieved using ammonium chloride for LIBs?

\*\*A29:\*\* Leaching efficiencies of 97.1% for lithium (Li) and 96.5% for cobalt (Co) are achieved using 3 M NH4Cl, a solid-to-liquid ratio of 20 g/L, and a reaction time of 2 hours at 80 °C.

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### Q30: How effective is electrowinning for recovering cobalt and nickel?

\*\*A30:\*\* Electrowinning achieves recovery efficiencies of 98.6% for cobalt (Co) and 97.8% for nickel (Ni) at a current density of 200 A/m2 and an electrolyte temperature of 60 °C over 3 hours.

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### Q31: What recovery rates are achieved using a pyrolysis method for LIB recycling?

\*\*A31:\*\* Recovery rates are 98% for lithium (Li), 96.8% for cobalt (Co), and 95% for nickel (Ni) through pyrolysis at a temperature of 500 °C for 2 hours, followed by water leaching at 70 °C.

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### Q32: How effective is a two-stage hydrometallurgical process for recycling rare earth elements?

\*\*A32:\*\* The two-stage hydrometallurgical process achieves recovery efficiencies of 98.4% for neodymium (Nd) and 96.9% for dysprosium (Dy) using 1.2 M HNO3 in the first stage, followed by selective precipitation with oxalic acid.

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### Q33: What are the recovery rates for manganese and cobalt using bioleaching with Thiobacillus ferrooxidans?

\*\*A33:\*\* Bioleaching using Thiobacillus ferrooxidans achieves recovery rates of 92% for manganese (Mn) and 85% for cobalt (Co) at a temperature of 30 °C over 14 days.

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### Q34: How efficient is the ionic liquid [Bmim][Cl] for recovering metals from LIBs?

\*\*A34:\*\* The ionic liquid [Bmim][Cl] achieves leaching efficiencies of 96.7% for lithium (Li), 95.3% for cobalt (Co), and 94.1% for nickel (Ni) at 80 °C with a solid-to-liquid ratio of 15 g/L.

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### Q35: What are the recovery efficiencies for nickel and cobalt using a sulfate roasting method?

\*\*A35:\*\* The sulfate roasting method achieves recovery efficiencies of 97.8% for nickel (Ni) and 98.1% for cobalt (Co) at a roasting temperature of 600 °C and a reaction time of 2 hours.

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### Q36: What are the leaching efficiencies for lithium and manganese using citric acid?

\*\*A36:\*\* Citric acid achieves leaching efficiencies of 97.5% for lithium (Li) and 93.8% for manganese (Mn) under conditions of 1.5 M citric acid, a solid-to-liquid ratio of 25 g/L, and a reaction time of 60 minutes at 60 °C.

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### Q37: How effective is an ammoniacal leaching process for rare earth element recovery?

\*\*A37:\*\* Ammoniacal leaching achieves recovery efficiencies of 96% for neodymium (Nd) and 95% for praseodymium (Pr) under conditions of 3 M NH4OH, a leaching temperature of 70 °C, and a reaction time of 2 hours.

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### Q38: What recovery rates are achieved using a hydrothermal process for LIB materials?

\*\*A38:\*\* The hydrothermal process achieves recovery rates of 98.2% for lithium (Li), 97.4% for cobalt (Co), and 96.6% for nickel (Ni) at 180 °C and a pressure of 10 MPa over 4 hours.

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### Q39: How effective is a microwave-assisted pyrolysis method for recycling NCM batteries?

\*\*A39:\*\* Microwave-assisted pyrolysis achieves recovery efficiencies of 97.3% for cobalt (Co), 96.8% for nickel (Ni), and 95.9% for manganese (Mn) at 800 W for 20 minutes.

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### Q40: What are the leaching efficiencies for metals using sulfuric acid and hydrogen peroxide?

\*\*A40:\*\* The combination of sulfuric acid and hydrogen peroxide achieves leaching efficiencies of 98.8% for lithium (Li), 97.5% for cobalt (Co), and 96.3% for nickel (Ni) under conditions of 2 M H2SO4, 5 vol.% H2O2, and a reaction time of 60 minutes at 70 °C.

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### Q41: How efficient is a deep eutectic solvent (DES) in recovering cobalt and nickel?

\*\*A41:\*\* A DES system achieves recovery efficiencies of 97.2% for cobalt (Co) and 95.8% for nickel (Ni) using 80 °C, a solid-to-liquid ratio of 20 g/L, and a reaction time of 120 minutes.

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### Q42: What recovery rates are achieved for nickel and manganese using sodium bisulfate as a leaching agent?

\*\*A42:\*\* Using sodium bisulfate (NaHSO4) as a leaching agent, the recovery rates achieved are approximately 93.0% for nickel (Ni) and 95.5% for manganese (Mn) under optimal conditions of 1 mol/L NaHSO4, 3 vol.% H2O2 as a reductant, leaching at 70 °C for 30 minutes with a pulp density of 20 g/L.

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### Q43: How effective is oxalic acid in recovering lithium and cobalt from lithium-ion batteries?

\*\*A43:\*\* Oxalic acid achieves leaching efficiencies of 99.95% for lithium (Li) and 98.1% for cobalt (Co) under optimized conditions: a solid-to-liquid ratio of 15 g/L, leaching time of 3 hours at 75 °C, and a stirring speed of 400 rpm.

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### Q44: What are the leaching efficiencies for lithium and manganese using a combined oxalic and tartaric acid leaching system?

\*\*A44:\*\* A combined oxalic and tartaric acid leaching system achieves leaching efficiencies of 99.88% for lithium (Li) and 90% for manganese (Mn) under conditions of 0.1 mol/L oxalic acid, a solid-to-liquid ratio of 20 g/L, and a reaction temperature of 60 °C.

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### Q45: What is the efficiency of graphite regeneration from spent lithium-ion batteries?

\*\*A45:\*\* Graphite regeneration achieves a recovery efficiency of 98.0% and a purity level of 99.7% under optimal conditions of 0.006 mol/L sodium dodecyl sulfonate, 0.25 mol/L methanesulfonic acid, and 10 vol.% hydrogen peroxide at 60 °C for 1.5 hours.

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### Q46: What recovery efficiencies are achieved using a tandem deep eutectic solvent (DES) system?

\*\*A46:\*\* The tandem DES system achieves recovery efficiencies of 99.2% for lithium (Li), 96.1% for nickel (Ni), 95.2% for cobalt (Co), and 97.8% for manganese (Mn) under optimized process conditions of 118 °C, a reaction time of 17 minutes, a solid-to-liquid ratio of 42 g/L, and a molar ratio of 3:1 ethylene glycol to tartaric acid.

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### Q47: What is the efficiency of leaching cobalt using glycine?

\*\*A47:\*\* Glycine achieves a cobalt (Co) leaching efficiency of 61.8% under optimized conditions of 0.936 M glycine, a pulp density of 19.9 g/L, and a temperature of 74 °C. The efficiency increases to 89.7% at 100 °C with 1.24 M glycine and a pulp density of 13.8 g/L.

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### Q48: How efficient is pyrolysis in recovering cobalt and lithium from spent Li-ion batteries?

\*\*A48:\*\* Pyrolysis achieves recovery efficiencies of 96.8% for cobalt (Co) and 88.7% for lithium (Li) at a temperature of 800 °C with a residence time of 10 minutes. The process uses coal as a carbonaceous reducing agent.

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### Q49: What are the recovery rates of nickel and cobalt using ammonium sulfate roasting?

\*\*A49:\*\* Recovery rates of 99.99% for nickel (Ni) and 100% for cobalt (Co) are achieved using ammonium sulfate roasting under optimal conditions of a 3:1 mass ratio of ammonium sulfate to battery material, a roasting temperature of 450 °C, and a roasting time of 30 minutes.

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### Q50: What recovery efficiencies are achieved using formic acid-assisted leaching for Ni-Cd batteries?

\*\*A50:\*\* Formic acid-assisted leaching achieves recovery efficiencies of 95% for cobalt (Co), 95% for cadmium (Cd), and 81% for nickel (Ni) under conditions of 90 °C, 4 hours, and a liquid-to-solid ratio of 30 mL/g. Using 15% H2O2 as an oxidizing agent increases nickel recovery to 99.7%.

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### Q51: What leaching efficiencies are achieved using PTSA and hydrogen peroxide for lithium cobalt oxide recovery?

\*\*A51:\*\* Using p-toluene sulfonic acid (PTSA) and hydrogen peroxide (H2O2), leaching efficiencies of ~100% for lithium (Li) and 99% for cobalt (Co) are achieved at 80 °C with 0.9 vol.% H2O2 and 1.5 mol/L PTSA, and a solid-to-liquid ratio of 30 g/L.

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### Q52: How effective is roasting with sodium sulfite for recovering lithium from NCM materials?

\*\*A52:\*\* Roasting with sodium sulfite achieves a lithium (Li) recovery efficiency of 94.06% under conditions of 750 °C, a molar ratio of Na2SO3 to cathode material of 3.0, and a roasting time of 2 hours.

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### Q53: What are the efficiencies of Li and Fe recovery using DES and ozone?

\*\*A53:\*\* A deep eutectic solvent (DES) combined with ozone achieves recovery efficiencies of ≥92.2% for lithium (Li) and ≤1.6% for iron (Fe) under optimized conditions of 40 °C, 6 hours, and a molar ratio of 8:1 ethylene glycol to choline chloride.

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### Q54: What are the recovery rates for metals using ammonium carbonate leaching?

\*\*A54:\*\* Ammonium carbonate leaching achieves recovery rates of 99.1% for copper (Cu), while maintaining leaching efficiencies below 4% for nickel (Ni), cobalt (Co), and manganese (Mn) at 80 °C and a concentration of 0.25 mol/L ammonium carbonate.

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### Q55: What recovery efficiencies are achieved in the distillation of dimethyl carbonate and diethyl carbonate?

\*\*A55:\*\* Distillation achieves recovery efficiencies of 100% for dimethyl carbonate (DMC) and 79.40% for diethyl carbonate (DEC) at a distillation temperature of 130 °C for 120 minutes.

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### Q56: What are the recovery rates for lithium and cobalt using PTSA-assisted leaching?

\*\*A56:\*\* PTSA-assisted leaching achieves recovery rates of 95% for lithium (Li) and 93% for cobalt (Co) under conditions of 1.5 mol/L PTSA, a solid-to-liquid ratio of 30 g/L, and a reaction time of 60 minutes at 80 °C.

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### Q57: How effective is bioleaching in recovering metals from LIBs?

\*\*A57:\*\* Bioleaching using \*Aspergillus niger\* achieves recovery efficiencies of 90.1% for lithium (Li), 85.5% for cobalt (Co), and 86.7% for nickel (Ni) under conditions of 30 °C for 7 days.

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### Q58: What leaching efficiencies are achieved using sulfuric acid and acetic acid mixture?

\*\*A58:\*\* A mixture of sulfuric acid (SA) and acetic acid achieves leaching efficiencies of 99% for lithium (Li), 98% for cobalt (Co), and 90% for nickel (Ni) under optimized conditions of 1.25 M SA, 0.55 M acetic acid, and a leaching temperature of 95 °C.

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### Q59: What are the recovery efficiencies for manganese and cobalt using potassium permanganate?

\*\*A59:\*\* Using potassium permanganate, recovery efficiencies are 96.5% for manganese (Mn) and 96% for cobalt (Co) under conditions of a molar ratio of manganese ions to potassium permanganate of 2:1 and a pH of 2, with a reaction time of 30 minutes.

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### Q60: What recovery rates are achieved for copper and nickel using a nitric acid system?

\*\*A60:\*\* A nitric acid system achieves recovery rates of 99.7% for copper (Cu) and 98.5% for nickel (Ni) under conditions of 2 M HNO3, a solid-to-liquid ratio of 25 g/L, and a reaction time of 2 hours at 80 °C.

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### Q61: How efficient is the recovery of rare earth elements (REEs) using oxalate precipitation?

\*\*A61:\*\* Oxalate precipitation achieves recovery efficiencies of 99.3% for neodymium (Nd) and 98.9% for dysprosium (Dy) under conditions of 1 M oxalic acid, a reaction temperature of 60 °C, and a reaction time of 90 minutes.

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### Q62: What are the recovery efficiencies of lithium and cobalt using a citric acid leaching system?

\*\*A62:\*\* A citric acid leaching system achieves recovery efficiencies of 97.8% for lithium (Li) and 96.2% for cobalt (Co) under conditions of 1 M citric acid, a solid-to-liquid ratio of 20 g/L, and a reaction temperature of 50 °C for 2 hours.

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### Q63: What is the efficiency of ammoniacal leaching for nickel and cobalt recovery?

\*\*A63:\*\* Ammoniacal leaching achieves efficiencies of 95.6% for nickel (Ni) and 94.2% for cobalt (Co) under conditions of 2 M NH4OH, a solid-to-liquid ratio of 25 g/L, and a reaction time of 4 hours at 60 °C.

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### Q64: What is the maximum recovery efficiency for cobalt (Co) and lithium (Li) using the ultrasonication and sulfate radical coupling system?

\*\*A64:\*\* The maximum recovery efficiencies are 97.33% for cobalt (Co) and 99.25% for lithium (Li) under optimal conditions of 5.5 minutes acoustic time, 168 W operating power, 86 °C temperature, and a 1:60 cathode foil to S-solution ratio (mg/mL).

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### Q65: What are the optimal conditions for minimizing aluminum (Al) loss during the recycling process?

\*\*A65:\*\* The minimum loss rate of aluminum (Al) is 4.13%, achieved under conditions of 5.5 minutes acoustic time, 168 W power, 86 °C, and a 1:60 cathode foil to S-solution ratio (mg/mL).

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### Q66: What are the leaching efficiencies for Ni, Co, and Mn using SO2 and pressure leaching?

\*\*A66:\*\* The leaching efficiencies are 99.6% for nickel (Ni), 99.3% for cobalt (Co), and 99.6% for manganese (Mn) at 0.25 MPa SO2 partial pressure, 70 °C, and 60 minutes reaction time.

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### Q67: How does the selective solvent extraction process impact the purity of the recovered metals?

\*\*A67:\*\* The selective solvent extraction process removes trace impurities, achieving a high-purity Ni-Co-Mn solution while avoiding the loss of valuable metals.

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### Q68: What are the leaching efficiencies of Li, Mn, Co, and Ni after in-situ reduction pretreatment of cathode material?

\*\*A68:\*\* The leaching efficiencies are 100% for lithium (Li), 98.13% for manganese (Mn), 97.27% for cobalt (Co), and 97.37% for nickel (Ni) under calcination at 600 °C without oxygen.

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### Q69: What is the role of carbon in the in-situ reduction pretreatment process?

\*\*A69:\*\* Carbon inherently contained in the cathode material induces in-situ reduction and collapses the oxygen framework, enhancing subsequent leaching efficiency.

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### Q70: What are the leaching efficiencies for Li and P using NaOH as a leaching agent?

\*\*A70:\*\* The leaching efficiencies are 98.2% for lithium (Li) and 99.9% for phosphorus (P) under conditions of 2 mol/L NaOH, 50:1 mL/g L/S ratio, 50 °C temperature, and 2 hours leaching time.

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### Q71: What by-products are obtained from the NaOH-based leaching process?

\*\*A71:\*\* The by-products are Li3PO4 and Fe2O3, obtained from the leaching solution and residue, respectively.

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### Q72: How does the separator-mediated roasting process impact the Li+ leaching efficiency?

\*\*A72:\*\* The Li+ leaching efficiency reaches 93.2% after separator-mediated roasting at 500 °C for 2 hours, significantly higher than roasting without reductant (25.2%) or with graphite (26.1%).

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### Q73: What are the primary reduction products formed during separator-mediated roasting?

\*\*A73:\*\* The reduction products are CoO and Li2CO3, formed through reducing gas generation and interaction with the cathode material.

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### Q74: What is the role of crushing and grinding in recycling CIGS thin-film solar panels?

\*\*A74:\*\* Crushing delaminates the glass substrate, while grinding decoats target materials, achieving an 80% recovery rate for indium and concentrating critical metals in fine particles (<38 µm).

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### Q75: What critical metals are recovered from CIGS panels, and at what concentrations?

\*\*A75:\*\* Indium is recovered at >1500 ppm, gallium at >480 ppm, and molybdenum at >1500 ppm in fine particle fractions.

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### Q76: What is the lithium recovery efficiency using lignocellulosic biomass pyrolysis gas?

\*\*A76:\*\* The lithium recovery efficiency is 99.99%, with a purity of 98.3% achieved at 500 °C using biomass pyrolysis gas as a reductant.

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### Q77: How does CO gas contribute to the reduction process?

\*\*A77:\*\* CO gas, generated during biomass pyrolysis, induces the collapse of the oxygen framework in lithium transition metal oxides, enhancing metal recovery.

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### Q78: What leaching efficiencies are achieved using acetic acid and ascorbic acid?

\*\*A78:\*\* Leaching efficiencies are 99.8% for Ni, Co, and Mn, and 99.9% for Li under conditions of 1 mol/L acetic acid, 0.1 mol/L ascorbic acid, 4 V working voltage, 25 °C, and 70 minutes reaction time.

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### Q79: What is the rate-controlling step in the mixed acid leaching process?

\*\*A79:\*\* The surface chemical reaction is identified as the rate-controlling step in the leaching process.

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### Q80: What is the lithium recovery efficiency in the water-leaching process after pyrolysis treatment?

\*\*A80:\*\* The lithium recovery efficiency is 92.17% during the water-leaching process, with the remaining 7.83% recovered through reductant-free acid leaching.

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### Q81: How does pyrolysis treatment facilitate subsequent leaching processes?

\*\*A81:\*\* Pyrolysis removes the organic binder and thermally reduces Co3+ to Co2+, enhancing the leaching efficiency of electrode materials.

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### Q82: What selective separation efficiency is achieved using low-viscosity DES for lithium ions?

\*\*A82:\*\* A selective separation efficiency of 99.98% for lithium ions is achieved under leaching parameters of 1:1 ratio, 60 °C temperature, and 15 minutes reaction time.

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### Q83: How does the proposed DES strategy align with the circular economy principles?

\*\*A83:\*\* The DES strategy allows in-situ regeneration of precursors, reintroducing nonrenewable resources into the supply chain and minimizing environmental impact.

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### Q84: What is the leaching efficiency of lithium from spent anode material (SAM) under water leaching treatment?

\*\*A84:\*\* The leaching efficiency of lithium is 92.82% under optimal conditions of 80 °C, 60 g/L solid-to-liquid ratio, 300 rpm agitation speed, and 60 minutes leaching time.

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### Q85: How is graphite recovered from SAM, and at what efficiency?

\*\*A85:\*\* Graphite is recovered by exfoliation during water leaching, achieving a 100% recovery rate.

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### Q86: What leaching efficiencies are achieved for Co and Li using ascorbic acid as a leaching and reducing agent?

\*\*A86:\*\* Leaching efficiencies of 94.8% for cobalt (Co) and 98.5% for lithium (Li) are achieved using 1.25 mol/L ascorbic acid at 70 °C, with a leaching time of 20 minutes and a solid-to-liquid ratio of 25 g/L.

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### Q87: What additional materials are recovered during ultrasonic washing of spent LIBs?

\*\*A87:\*\* Copper is recovered from anode materials after manual separation from cathodes.

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### Q88: What leaching efficiencies are achieved using a DES composed of ethylene glycol and hydroxylamine hydrochloride?

\*\*A88:\*\* Leaching efficiencies of 99.7% for lithium (Li) and 88.0% for cobalt (Co) are achieved under conditions of 80 °C temperature, 8 hours reaction time, and 83.3 mg/g solubility of LiCoO2.

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### Q89: How does the DES system improve lithium-ion battery recycling sustainability?

\*\*A89:\*\* The DES system simplifies the separation procedure, avoids metal co-precipitation, and allows reclamation and reuse of residual components, promoting cost-effectiveness and environmental sustainability.

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\*\*Q90:\*\* What recovery rates are achieved for lithium and cobalt using oxalic acid leaching?

\*\*A90:\*\* Recovery rates of 98% for lithium (Li) and 97% for cobalt (Co) are achieved under conditions of 150 min retention time, 95 °C heating temperature, 15 g/L solid-to-liquid ratio, and 400 rpm rotation rate.

\*\*Q91:\*\* What are the advantages of using oxalic acid for LIB recycling?

\*\*A91:\*\* Oxalic acid provides a simplified and high-efficiency process for LIB recycling, with enhanced leaching mechanisms and selective recovery of valuable metals.

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\*\*Q92:\*\* What are the optimal leaching conditions for achieving high recovery of Li and Co using lactic acid?

\*\*A92:\*\* Optimal conditions are 0.5 mol/L lactic acid, 0.02 mol/L ascorbic acid, a solid-to-liquid ratio of 2 g/L, 90 °C temperature, and 360 minutes leaching time, achieving recovery efficiencies of 99% for lithium (Li) and 98% for cobalt (Co).

\*\*Q93:\*\* How does lactic acid compare to other organic acids in dissolution behavior?

\*\*A93:\*\* Lactic acid demonstrates superior dissolution behavior for LiCoO2 materials compared to previously used organic acids, enhancing the leaching process efficiency.

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\*\*Q94:\*\* What recovery efficiencies are achieved for Li and Co using microwave-assisted deep eutectic solvents (DES)?

\*\*A94:\*\* Recovery efficiencies of 100% for lithium (Li) and 100% for cobalt (Co) are achieved under optimal conditions of 70 °C temperature, 10 minutes leaching time, and a 5:0.1 g/g liquid-solid ratio.

\*\*Q95:\*\* What are the advantages of adding water to DES during the recycling process?

\*\*A95:\*\* Adding water reduces the viscosity of the DES, improving flow properties and enhancing the leaching efficiency for lithium and cobalt.

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\*\*Q96:\*\* What is the role of NaHSO4 in enhancing the recovery of manganese and cobalt?

\*\*A96:\*\* NaHSO4 acts as a leaching agent, achieving recovery efficiencies of 98.4% for manganese (Mn) and 97.6% for cobalt (Co) under optimal conditions of 80 °C, a solid-to-liquid ratio of 20 g/L, and 2 hours reaction time.

\*\*Q97:\*\* What is the impact of reaction temperature on the recovery efficiency of metals using NaHSO4?

\*\*A97:\*\* Increasing the reaction temperature to 80 °C significantly enhances recovery efficiencies, facilitating efficient metal dissolution and improved leaching kinetics.

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### Q98: What are the recovery efficiencies for cobalt and manganese in a hydrochloric acid-based recycling process?

\*\*A98:\*\* The hydrochloric acid-based recycling process achieves recovery efficiencies of 97.5% for cobalt (Co) and 95.8% for manganese (Mn) under optimal conditions of 2 M HCl, a solid-to-liquid ratio of 20 g/L, and a reaction time of 120 minutes at 80 °C.

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### Q99: What is the lithium recovery rate in a sulfuric acid leaching system for spent LIBs?

\*\*A99:\*\* The lithium recovery rate in a sulfuric acid leaching system is 98.3%, achieved under conditions of 1.5 M H2SO4, 2 vol.% H2O2 as a reducing agent, a leaching temperature of 75 °C, and a solid-to-liquid ratio of 25 g/L.

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### Q100: How effective is sodium hydroxide in removing aluminum from spent battery materials?

\*\*A100:\*\* Sodium hydroxide achieves a removal efficiency of 94.2% for aluminum (Al) under conditions of 3 M NaOH, a reaction temperature of 60 °C, and a reaction time of 90 minutes.

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### Q101: What recovery efficiencies are achieved for nickel and cobalt using a citric acid-based leaching method?

\*\*A101:\*\* The citric acid-based leaching method achieves recovery efficiencies of 96.7% for nickel (Ni) and 94.3% for cobalt (Co) under conditions of 1 M citric acid, a solid-to-liquid ratio of 30 g/L, and a reaction time of 2 hours at 70 °C.

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### Q102: What are the leaching efficiencies for lithium and phosphorus in a mixed-acid system?

\*\*A102:\*\* The leaching efficiencies for lithium (Li) and phosphorus (P) in a mixed-acid system are 99.2% and 98.8%, respectively, achieved using 2 M H2SO4 and 0.5 M H3PO4, with a reaction time of 90 minutes at 85 °C.

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### Q103: What is the optimal roasting temperature for maximizing cobalt recovery from spent LIB cathodes?

\*\*A103:\*\* The optimal roasting temperature for cobalt recovery is 550 °C, yielding a recovery efficiency of 97.8% after subsequent sulfuric acid leaching.

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### Q104: What recovery efficiencies are achieved for rare earth elements using a double sulfate precipitation method?

\*\*A104:\*\* The double sulfate precipitation method achieves recovery efficiencies of 99.1% for neodymium (Nd) and 98.6% for dysprosium (Dy) under conditions of 1.5 M Na2SO4 and a precipitation temperature of 60 °C.

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### Q105: How effective is bioleaching in recovering lithium and manganese from spent batteries?

\*\*A105:\*\* Bioleaching using \*Acidithiobacillus ferrooxidans\* achieves recovery efficiencies of 89.5% for lithium (Li) and 91.2% for manganese (Mn) under conditions of 30 °C, pH 2.5, and a reaction time of 10 days.

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### Q106: What are the recovery rates for nickel and cobalt using ammonium sulfate roasting?

\*\*A106:\*\* Recovery rates of 98.9% for nickel (Ni) and 99.7% for cobalt (Co) are achieved using ammonium sulfate roasting at 450 °C with a 3:1 ammonium sulfate-to-cathode material ratio.

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### Q107: What are the leaching efficiencies for lithium and cobalt using an oxalic acid-based process?

\*\*A107:\*\* The oxalic acid-based process achieves leaching efficiencies of 98.7% for lithium (Li) and 96.5% for cobalt (Co) under conditions of 0.8 M oxalic acid, a solid-to-liquid ratio of 25 g/L, and a reaction time of 60 minutes at 75 °C.

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### Q108: How efficient is electrochemical recovery of lithium and cobalt from spent LIBs?

\*\*A108:\*\* Electrochemical recovery achieves efficiencies of 95.3% for lithium (Li) and 94.8% for cobalt (Co) under conditions of 3 V applied voltage, a reaction time of 8 hours, and an electrolyte temperature of 40 °C.

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### Q109: What are the leaching efficiencies of lithium and manganese using a DES system?

\*\*A109:\*\* A DES system composed of choline chloride and oxalic acid achieves leaching efficiencies of 98.9% for lithium (Li) and 97.4% for manganese (Mn) under conditions of 70 °C, a reaction time of 120 minutes, and a 2:1 molar ratio of components.

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### Q110: What recovery efficiencies are achieved for cobalt and nickel using a pressure leaching process?

\*\*A110:\*\* The pressure leaching process achieves recovery efficiencies of 99.2% for cobalt (Co) and 98.7% for nickel (Ni) under conditions of 1 MPa pressure, 150 °C temperature, and a reaction time of 60 minutes.

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### Q111: What are the leaching efficiencies for lithium and cobalt using ascorbic acid as a reducing agent?

\*\*A111:\*\* Leaching efficiencies of 97.1% for lithium (Li) and 95.4% for cobalt (Co) are achieved using 1 M ascorbic acid, a solid-to-liquid ratio of 20 g/L, and a reaction time of 90 minutes at 60 °C.

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### Q112: What is the recovery efficiency of manganese using a reductive leaching process with sulfur dioxide?

\*\*A112:\*\* Manganese recovery efficiency is 96.5% using reductive leaching with sulfur dioxide at 0.1 MPa SO2 partial pressure, a reaction temperature of 80 °C, and a leaching time of 120 minutes.

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### Q113: How effective is solvent extraction in separating cobalt from nickel in a spent LIB leachate?

\*\*A113:\*\* Solvent extraction achieves a separation efficiency of 98.4% for cobalt (Co) from nickel (Ni) using 0.5 M Cyanex 272 at an organic-to-aqueous phase ratio of 2:1 and a pH of 5.5.

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### Q114: What are the recovery rates for lithium and cobalt in a high-temperature pyrolysis process?

\*\*A114:\*\* High-temperature pyrolysis achieves recovery rates of 95.7% for lithium (Li) and 92.3% for cobalt (Co) at 700 °C with a residence time of 30 minutes.

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### Q115: What is the recovery efficiency of lithium using CO2 precipitation from a spent LIB leachate?

\*\*A115:\*\* The recovery efficiency of lithium is 97.9% using CO2 precipitation at a pH of 10.5, a CO2 flow rate of 0.1 L/min, and a reaction time of 45 minutes.

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### Q116: How effective is biochar in adsorbing heavy metals from spent LIB leachates?

\*\*A116:\*\* Biochar achieves adsorption efficiencies of 94.6% for cobalt (Co) and 92.8% for nickel (Ni) at a dosage of 5 g/L, a contact time of 120 minutes, and a temperature of 25 °C.

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### Q117: What are the leaching efficiencies for lithium and cobalt using a sulfuric acid-ascorbic acid mixture?

\*\*A117:\*\* Leaching efficiencies of 99.2% for lithium (Li) and 98.5% for cobalt (Co) are achieved using 1.5 M H2SO4 and 0.2 M ascorbic acid at 75 °C with a reaction time of 2 hours.

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### Q118: What recovery efficiencies are achieved for nickel and manganese using a glycine-based leaching process?

\*\*A118:\*\* The glycine-based leaching process achieves recovery efficiencies of 96.3% for nickel (Ni) and 94.7% for manganese (Mn) under conditions of 1 M glycine, a solid-to-liquid ratio of 25 g/L, and a reaction temperature of 60 °C.

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### Q119: How effective is ultrasonic-assisted leaching in recovering lithium and cobalt from spent LIBs?

\*\*A119:\*\* Ultrasonic-assisted leaching achieves recovery efficiencies of 97.8% for lithium (Li) and 96.4% for cobalt (Co) at a frequency of 40 kHz, a reaction time of 45 minutes, and a leaching temperature of 50 °C.

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### Q120: What are the leaching efficiencies for lithium and cobalt using a tartaric acid-based process?

\*\*A120:\*\* The tartaric acid-based process achieves leaching efficiencies of 98.4% for lithium (Li) and 96.7% for cobalt (Co) under conditions of 1 M tartaric acid, a solid-to-liquid ratio of 20 g/L, and a reaction time of 60 minutes at 70 °C.

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### Q121: What recovery efficiencies are achieved for lithium and manganese using sodium bisulfate as a leaching agent?

\*\*A121:\*\* Sodium bisulfate achieves recovery efficiencies of 96.5% for lithium (Li) and 94.8% for manganese (Mn) under conditions of 0.8 M NaHSO4, a solid-to-liquid ratio of 30 g/L, and a reaction temperature of 85 °C.

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### Q122: How effective is the electrochemical precipitation method for cobalt recovery?

\*\*A122:\*\* The electrochemical precipitation method achieves 98.7% cobalt (Co) recovery at a current density of 10 mA/cm², a pH of 5, and a reaction time of 90 minutes.

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### Q123: What are the leaching efficiencies for nickel and cobalt using formic acid?

\*\*A123:\*\* Leaching efficiencies of 97.9% for nickel (Ni) and 96.3% for cobalt (Co) are achieved with 1.5 M formic acid, a solid-to-liquid ratio of 25 g/L, and a reaction temperature of 80 °C for 120 minutes.

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### Q124: What recovery efficiencies are achieved for lithium and cobalt using ammonium chloride roasting?

\*\*A124:\*\* Ammonium chloride roasting achieves recovery efficiencies of 98.2% for lithium (Li) and 97.5% for cobalt (Co) at a roasting temperature of 400 °C and a reaction time of 2 hours.

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### Q125: How effective is hydrazine in enhancing manganese leaching efficiency?

\*\*A125:\*\* Hydrazine enhances manganese (Mn) leaching efficiency to 99.1% under conditions of 0.5 M H2SO4, 0.1 M N2H4, a solid-to-liquid ratio of 20 g/L, and a leaching time of 60 minutes at 70 °C.

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### Q126: What is the lithium recovery efficiency using oxalic acid precipitation?

\*\*A126:\*\* Oxalic acid precipitation achieves a lithium (Li) recovery efficiency of 99.4% at a pH of 7.5, a reaction temperature of 50 °C, and a reaction time of 30 minutes.

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### Q127: What are the leaching efficiencies for lithium and cobalt using a hydrochloric acid system with hydrogen peroxide?

\*\*A127:\*\* Leaching efficiencies of 98.7% for lithium (Li) and 96.8% for cobalt (Co) are achieved with 2 M HCl, 1 vol.% H2O2, and a leaching temperature of 75 °C for 90 minutes.

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### Q128: How efficient is selective separation of cobalt from nickel using a Cyanex 272 system?

\*\*A128:\*\* Selective separation achieves 99.2% cobalt (Co) extraction from a nickel-cobalt solution at pH 4.8 with a Cyanex 272 concentration of 0.3 M.

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### Q129: What is the efficiency of manganese recovery using a pyrometallurgical process?

\*\*A129:\*\* Manganese (Mn) recovery efficiency is 97.6% using a pyrometallurgical process at 850 °C with a residence time of 2 hours.

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### Q130: What recovery efficiencies are achieved for lithium and cobalt using a citric acid and hydrogen peroxide mixture?

\*\*A130:\*\* The citric acid and hydrogen peroxide mixture achieves recovery efficiencies of 99.1% for lithium (Li) and 98.4% for cobalt (Co) under conditions of 1.5 M citric acid, 1 vol.% H2O2, and a leaching temperature of 70 °C for 2 hours.

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### Q131: What are the recovery efficiencies for nickel and cobalt using a bioleaching method?

\*\*A131:\*\* The bioleaching method achieves recovery efficiencies of 89.4% for nickel (Ni) and 91.7% for cobalt (Co) using \*Acidithiobacillus thiooxidans\* at a temperature of 30 °C and a reaction time of 14 days.

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### Q132: How efficient is hydrogen peroxide as a reductant in recovering manganese and cobalt?

\*\*A132:\*\* Hydrogen peroxide achieves recovery efficiencies of 97.8% for manganese (Mn) and 98.6% for cobalt (Co) under conditions of 2 vol.% H2O2, a leaching temperature of 60 °C, and a reaction time of 90 minutes.

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### Q133: What recovery efficiencies are achieved for lithium and nickel using ammonium bicarbonate?

\*\*A133:\*\* Ammonium bicarbonate achieves recovery efficiencies of 95.5% for lithium (Li) and 92.8% for nickel (Ni) under conditions of 1.2 M NH4HCO3, a reaction temperature of 65 °C, and a leaching time of 2 hours.

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### Q134: What is the leaching efficiency of cobalt using an ammonia-based leaching solution?

\*\*A134:\*\* The leaching efficiency of cobalt (Co) is 94.6% using an ammonia-based leaching solution with a concentration of 1 M NH3, a solid-to-liquid ratio of 20 g/L, and a leaching temperature of 50 °C for 120 minutes.

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### Q135: How effective is a deep eutectic solvent (DES) in recovering lithium and cobalt?

\*\*A135:\*\* The DES composed of choline chloride and ethylene glycol achieves recovery efficiencies of 96.7% for lithium (Li) and 93.5% for cobalt (Co) under conditions of 60 °C, a leaching time of 2 hours, and a DES-to-solid ratio of 3:1.

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### Q136: What recovery efficiencies are achieved for manganese and cobalt using oxalic acid precipitation?

\*\*A136:\*\* Oxalic acid precipitation achieves recovery efficiencies of 98.9% for manganese (Mn) and 97.2% for cobalt (Co) under conditions of 1.5 M oxalic acid, a reaction temperature of 70 °C, and a reaction time of 90 minutes.

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### Q137: How efficient is the recovery of rare earth elements using a two-stage leaching process?

\*\*A137:\*\* The two-stage leaching process achieves recovery efficiencies of 99.5% for neodymium (Nd) and 99.3% for dysprosium (Dy) using 2 M HNO3 at 80 °C with a reaction time of 2 hours.

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### Q138: What is the efficiency of selective lithium recovery using electrolysis?

\*\*A138:\*\* Electrolysis achieves a selective lithium recovery efficiency of 94.5% under a current density of 5 mA/cm², an electrolyte temperature of 25 °C, and a reaction time of 4 hours.

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### Q139: How effective is acetic acid in leaching lithium and cobalt from spent LIBs?

\*\*A139:\*\* Acetic acid achieves leaching efficiencies of 97.2% for lithium (Li) and 96.4% for cobalt (Co) under conditions of 1.5 M acetic acid, a solid-to-liquid ratio of 20 g/L, and a leaching time of 90 minutes at 75 °C.

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### Q140: What recovery efficiencies are achieved for lithium and manganese using an ultrasonic-assisted leaching process?

\*\*A140:\*\* The ultrasonic-assisted leaching process achieves recovery efficiencies of 99.1% for lithium (Li) and 98.6% for manganese (Mn) under conditions of 40 kHz frequency, a leaching temperature of 60 °C, and a reaction time of 60 minutes.

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Q141: How effective is sodium carbonate roasting in recovering lithium and cobalt from spent batteries?

A141: Sodium carbonate roasting achieves recovery efficiencies of 96.4% for lithium (Li) and 94.2% for cobalt (Co) under conditions of 800 °C, a roasting time of 2 hours, and a 1:1.5 ratio of cathode material to Na2CO3.

Q142: What is the efficiency of manganese recovery using a DES composed of lactic acid and urea?

A142: The DES system composed of lactic acid and urea achieves manganese (Mn) recovery efficiency of 97.8% under conditions of 60 °C, a DES-to-solid ratio of 3:1, and a reaction time of 90 minutes.

Q143: How efficient is the separation of lithium from magnesium using selective crystallization?

A143: Selective crystallization achieves a lithium (Li) separation efficiency of 93.7% from magnesium (Mg) at 25 °C using a lithium-to-magnesium molar ratio of 2:1 in the solution.

Q144: What recovery efficiencies are achieved for nickel and cobalt in a mixed acid leaching process?

A144: The mixed acid leaching process achieves recovery efficiencies of 97.9% for nickel (Ni) and 96.8% for cobalt (Co) using 1.5 M H2SO4 and 0.5 M HCl at a leaching temperature of 75 °C for 90 minutes.

Q145: How effective is pyrolysis in recovering metals from LiNiCoMnO2 cathode material?

A145: Pyrolysis achieves recovery efficiencies of 95.2% for lithium (Li), 92.6% for nickel (Ni), and 91.8% for cobalt (Co) at 700 °C with a residence time of 1 hour.

Q146: What are the leaching efficiencies for lithium and manganese using sulfuric acid and oxalic acid as a mixed leaching agent?

A146: The mixed leaching agent achieves leaching efficiencies of 98.4% for lithium (Li) and 96.7% for manganese (Mn) under conditions of 1 M H2SO4, 0.5 M oxalic acid, and a reaction temperature of 80 °C for 2 hours.

Q147: What is the recovery efficiency of lithium using reverse osmosis filtration in brine recycling?

A147: Reverse osmosis filtration achieves a lithium (Li) recovery efficiency of 96.5% with a water flux of 30 L/m²·h at 25 °C and an applied pressure of 5 MPa.

Q148: How effective is the solvent extraction process in separating rare earth elements from spent magnets?

A148: Solvent extraction achieves a separation efficiency of 98.9% for neodymium (Nd) and 97.5% for praseodymium (Pr) using 1.5 M D2EHPA at a pH of 3.5 with a 1:1 organic-to-aqueous phase ratio.

Q149: What recovery efficiencies are achieved for lithium and cobalt using citric acid-assisted leaching in spent LIBs?

A149: Citric acid-assisted leaching achieves recovery efficiencies of 99.3% for lithium (Li) and 98.7% for cobalt (Co) under conditions of 2 M citric acid, a reaction temperature of 60 °C, and a leaching time of 1 hour.

Q150: What is the efficiency of zinc recovery using ammonium chloride leaching from spent alkaline batteries?

A150: Ammonium chloride leaching achieves a zinc (Zn) recovery efficiency of 95.6% at a leaching temperature of 75 °C, a solid-to-liquid ratio of 20 g/L, and a reaction time of 120 minutes.