**q\_three** = "I want to recycle batteries in minimum cost, so which process should I use? And what are the conditions for that process"

LLM response: To recycle batteries at a minimum cost, you should use the hydrometallurgy process, specifically involving leaching and selective oxidation. The conditions for this process are: pH of 1.0, with 2.0 mol/L of H2SO4, leaching temperature of 100 °C, and leaching time of 2 hours. Additionally, alkaline leaching is required with 1.0 mol/L of Na2CO3 for 2 hours, followed by electrochemical treatment of 0.2 Coulomb/g, and roasting at 800 °C for 1 hour. This process has a total cost of 0.0182.

**q\_four** = "I want to recycle batteries in minimum energy requirement, so which process should I use? And what are the conditions for that process"

LLM response: To recycle batteries with the minimum energy requirement, you should use the solvent extraction process. The conditions for this process are: pH 1.0, temperature of 25 °C, 100 g/L, and a duration of 20 minutes, which requires a total energy of 1857.03 J.

**q\_one** = "I want to recycle lithium ion batteries with at least 95% Rare Earth Elements recovery. Which processes can achieve this?"

LLM response:

Formatted Context: To recycle, the following recycling processes meet the specified criteria:

- Process: roasting-leaching-solvent extraction-electrowinning process

- Efficiency: 98.0%

- Conditions: 400 °C Temperature

- Total Cost: $46.7

- Total Energy: 162366.4 J

- Process: leaching with diluted H2SO4

- Efficiency: 95.0%

- Conditions: 70 °C, diluted H2SO4, 90 °C

- Total Cost: $148.93333

- Total Energy: 71565.08333 J

**q\_five** = "I want to recycle batteries. And I want processes which recovers Indium (In) element as it's an expensive material. What processes & conditions should I use?"

LLM response: To recycle batteries and recover Indium (In), you can use the leaching and precipitation process. The conditions for this process are: pH of 2.0, 1.0 M H2SO4, 1.0 M H2O2, a leaching time of 120 minutes, and a leaching temperature of 80 °C, with a pulp density of 100 g/L. This process has a recovery rate of 98.44%.

**q\_six** = "I want to recycle batteries. And I want processes which can recover Lithium (Li), Cobalt (Co) & Manganeses (Mn) with minimum cost. What processes should I use & it's recovery rate?"

LLM response: To recycle batteries and recover Lithium (Li), Cobalt (Co), and Manganese (Mn) with minimum cost, you can consider the following processes:

1. Hydrometallurgical leaching, roasting: This process can recover Li, Co, and Mn with a recovery rate of 99.99% for Li, Ni, Co, and Mn. The approx. total cost for this process is 0.29787$.

2. Pyrolysis gas reduction by lignocellulosic biomass: This process can recover Lithium with a recovery efficiency of 99.99% and purity of 98.3% at 500 °C. Although the total cost is not the lowest, it is an eco-friendly and energy-saving method.

3. Chemical leaching, solvent extraction, selective precipitation: This process can recover Li, Co, and Mn with leaching efficiencies of almost 100% for Li, 100% for Co, and 94% for Mn. The approx. total cost for this process is 1.82$.

Considering the minimum cost, the Hydrometallurgical leaching, roasting process would be the most suitable option for recovering Lithium (Li), Cobalt (Co), and Manganese (Mn).

**q\_seven** = "I want to recycle batteries. And I want processes which can recover Lithium (Li), Cobalt (Co) & Manganeses (Mn) with minimum cost. What processes should I use & it's recovery rate with process conditions?"

LLM response: To recycle batteries and recover Lithium (Li), Cobalt (Co), and Manganese (Mn) with the minimum cost, you should use the Hydrometallurgical process. This process has a cost of 0.0695 and can recover Li, Co, and other metals. The recovery efficiency of cobalt and nickel are respectively 100% and 99.99%.

The conditions for this process are:

- Type of acid: HCl provides higher leaching efficiency

- Acid concentration: 1–4 mol L−1

- Leaching time: 3–18 h

- Leaching temperature: 25–90 °C

- Solid to liquid ratio: 5% (w/v)

In the nickel and cobalt recovery process, at first the Co(II) in the leaching liquor is selectively oxidized in Co(III) with NaClO reagent to recover Co2O3, 3H2O by a selective precipitation at pH = 3. Then, the nickel hydroxide is precipitated by a base addition at pH = 11.

Another process that can recover Lithium (Li), Cobalt (Co), and Manganese (Mn) is the Hydrometallurgical leaching, roasting process. However, this process has a higher cost of 0.29787.

The conditions for this process are:

- 3:1 mass ratio of ammonium sulfate to lithium battery electrode mixed material

- Roasting temperature of 450 °C

- Roasting time of 30 min

- Leaching time of 20 min

- Leaching temperature of 60 °C

The recovery rates of various valuable metals including Li, Ni, Co, and Mn reached 99.99% for this process.

So, to minimize the cost, the Hydrometallurgical process would be the most suitable option.

**q\_eightv1** = "Can you suggest battery recycling processes which recovers Cobalt (Co) & Lithium (Li) which has minimum energy requirment along with the process conditions?"

LLM response: Solvent extraction is a battery recycling process that can recover Cobalt (Co) and Lithium (Li) with a total energy requirement of 1857.03. The process conditions for this method include a pH of 1.0, a temperature of 25 °C, a concentration of 100 g/L, and a duration of 20 minutes.

**q\_eightv2** = "Can you suggest battery recycling processes which recovers Cobalt (Co) & Lithium (Li) which has minimum energy requirements along with the process conditions & recovery rates?"

LLM response: The solvent extraction process with the name 'solvent extraction' and 'extraction system composed of 0.4 mol/L 2-thenoyltrifluoroacetone (HTTA), 0.4 mol/L trioctylphosphine oxide (TOPO), and ionic liquid (IL) 1-Butyl-3-MethylImidazolium bis (trifluoromethyl sulfonyl) imide' have the minimum energy requirements of 1857.03 and 2168.0088 respectively.

The 'solvent extraction' process has a recovery rate of 97.35% for Co and the process conditions are pH 1.0, 25 °C, 100 g/L, 20 min.

The 'extraction system composed of 0.4 mol/L 2-thenoyltrifluoroacetone (HTTA), 0.4 mol/L trioctylphosphine oxide (TOPO), and ionic liquid (IL) 1-Butyl-3-MethylImidazolium bis (trifluoromethyl sulfonyl) imide' has a recovery rate of 96.52% for Co and the process conditions are O/A = 1/1, 25 °C, reaction time 20 min, and pH = 3.65.

However, the 'mixed acid leaching' process has the highest recovery rate of 99.8% for both Co and Li with process conditions of acetic acid concentration of 1 mol/L, ascorbic acid concentration of 0.1 mol/L, working voltage of 4 V, reaction temperature of 25 °C and reaction time of 70 min, but it has a higher energy requirement of 5373.599167.

It's worth noting that while 'mixed acid leaching' has the highest recovery rate, its energy requirement is significantly higher than the other two processes. Therefore, the choice of process depends on the specific priorities and requirements of the recycling operation.