Question 40 **(22 marks)**

A chemist was developing a new method for extracting lithium metal from ores rich in the mineral lepidolite. The procedure being proposed by the chemist is as follows:

Step 1	crush and grind the ore
Step 2 (Leach)	add sulfuric acid to the crushed ore to dissolve lepidolite (and other soluble ore constituents)
Step 3	add reagents to the leach solution that will precipitate unwanted soluble species
Step 4	recover lithium as lithium carbonate.

In a test of Step 2, performed by the chemist, 5.0 L of sulfuric acid, which was in excess, was added to a crushed and ground sample of a lepidolite-containing ore.

The leach solution was analysed and found to contain sulfate ions and hydrogen ions from the sulfuric acid and the ions stated in the table below.

Ions present	**Concentration**
Li^+	2.13 g L^{-1}
Rb^+	1.30 g L^{-1}
$A\ell^{3+}$	1.86 g L^{-1}
Fe (as Fe^{2+} and Fe^{3+})	1.27 g L^{-1}

The chemist tried to remove the rubidium and aluminium ions from the leach solution by cooling the solution to 5.00 °C so as to precipitate them as rubidium alum, $RbA\ell(SO_4)_2$. The equation is shown below.

$$Rb^+(aq) + A\ell^{3+}(aq) + 2\,SO_4^{2-}(aq) \rightarrow RbA\ell(SO_4)_2(s)$$

The chemist found that, while all of the Rb^+ precipitated, there was a considerable quantity of $A\ell^{3+}$ ions still dissolved in the leach solution.

(a) Calculate the concentration of $A\ell^{3+}$ ions remaining in the 5.0 L of leach solution. Give your answer in grams per litre (g L^{-1}) to the appropriate number of significant figures. (9 marks)

To remove the remaining $A\ell^{3+}$ ions from the leach solution, the chemist added 2.63 L of a 0.0550 mol L^{-1} K_2SO_4 solution, with the result being the precipitation of potassium alum as shown in the equation below.

$$K^+(aq) + A\ell^{3+}(aq) + 2\ SO_4^{2-}(aq) \rightarrow KA\ell(SO_4)_2(s)$$

The sulfate ions remained in excess due to the initial addition of sulfuric acid.

(b) Was sufficient K_2SO_4 solution added to precipitate all of the $A\ell^{3+}$ ions remaining in the leach solution? Justify your answer with relevant calculations. (4 marks)

The final purification step was the removal of iron from the leach solution. To do this the chemist added a suitable oxidant (1.00 mol L^{-1} hydrogen peroxide) to convert all of the Fe^{2+} ions to Fe^{3+} ions. The chemist then added excess sodium hydroxide solution to precipitate all of the iron (now present as Fe^{3+} ions) as $Fe(OH)_3$. This precipitate, and the alum precipitates formed earlier, were removed by filtration.

(c) Write a balanced overall equation to show the conversion of Fe^{2+} to Fe^{3+} by hydrogen peroxide. (3 marks)

The leach solution, now free from rubidium, aluminium and iron, was heated and evaporated to dryness, yielding a lithium-rich residue. The residue was further treated to produce lithium carbonate suitable for use in lithium-ion battery manufacture, with the mass of lithium carbonate recovered being equal to 46.7 g.

(d) Calculate the percentage yield of lithium carbonate, Li_2CO_3, based on the theoretical amount that should have been recovered. Use the concentration of $Li^+(aq)$ in the table on page 42. (6 marks)