

**Question 37****(18 marks)**

A chemist was asked to develop a method of recycling used cathodes from a new type of lithium battery. The cathodes were a mixture of lithium cobalt oxide ( $\text{LiCoO}_2$ ) and manganese (Mn). Each cathode contained 57.29% cobalt by mass.

Preliminary trials showed that the used cathodes would dissolve completely if enough sulfuric acid was added and if enough time was allowed. The chemist decided to conduct detailed trials to see how the sulfuric acid concentration affected the rate at which the used cathodes dissolved.

Each trial was performed in a sealed, oxygen-free reactor using 5.00 L of sulfuric acid and 0.531 kg of used cathodes. Trials were also performed in the presence of  $\text{Fe}^{2+}$  ions to see if these ions had a catalytic effect. All trials lasted for 15 minutes with the reactor solutions then analysed for their concentrations of  $\text{Li}^+$ ,  $\text{Co}^{2+}$ ,  $\text{Mn}^{2+}$  and, where relevant,  $\text{Fe}^{2+}$ .

The results of the  $\text{Co}^{2+}$  and  $\text{Fe}^{2+}$  analyses are summarised in the following table.

Trial	Initial solution composition		Solution composition after 15 minutes	
	$\text{H}_2\text{SO}_4$ ( $\text{mol L}^{-1}$ )	$\text{Fe}^{2+}$ ( $\times 10^{-1} \text{ mol L}^{-1}$ )	$\text{Co}^{2+}$ ( $\times 10^{-1} \text{ mol L}^{-1}$ )	$\text{Fe}^{2+}$ ( $\times 10^{-1} \text{ mol L}^{-1}$ )
1	1.37	0.00	4.24	0.00
2	3.01	0.00	4.92	0.00
3	5.91	3.31	7.20	3.29
4	7.40	0.00	5.94	0.00
5	8.80	0.00	6.96	0.00
6	8.80	6.62	9.95	6.61

- (a) (i) Which trial number(s) will allow the chemist to investigate the relationship between the sulfuric acid concentration and the amount of cobalt extracted? (1 mark)

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- (ii) Use collision theory to explain the effect of acid concentration on the rate at which the used cathodes dissolved. (3 marks)

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- (b) Do  $\text{Fe}^{2+}$  ions catalyse the dissolution of cobalt in sulfuric acid? Justify your answer. (3 marks)

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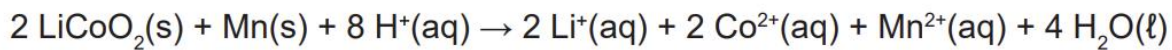
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- (C)

The dissolution reaction is:



(7 marks)

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- (d) Calculate the percentage, by mass, of lithium in a used cathode. Give your answer to the appropriate number of significant figures. (4 marks)

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