$$\begin{cases} m\left(KAl(SO_4)_2 \cdot 12\,H_2O\right) = 11,4\,g \\ V = 0,100\,l \\ K_h(Al^{3+}) = 1,40 \cdot 10^{-5} \\ K_a(HSO_4^-) = 1,26 \cdot 10^{-2} \end{cases} \qquad M\left(KAl(SO_4)_2 \cdot 12\,H_2O\right) = 474,2\,g/mol$$

a) $KAl(SO_4)_2 + H_2O \rightarrow K^+ + Al^{3+} + 2\,SO_4^{2-}$
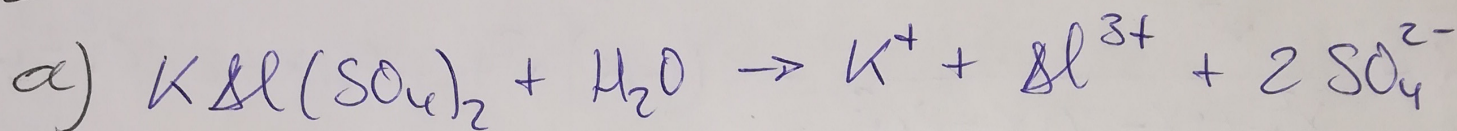
$$C_i = \frac{n}{V(l)} = \frac{m}{M \cdot V(l)} = \frac{11,4}{474,2 \cdot 0,100} = 0,240 \; mol/l$$

$$Al^{3+} + H_2O \rightleftharpoons AlOH^{2+} + H^+$$
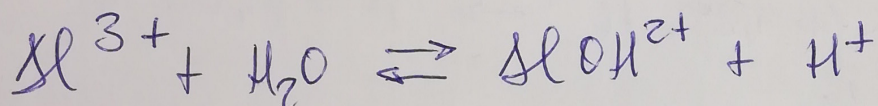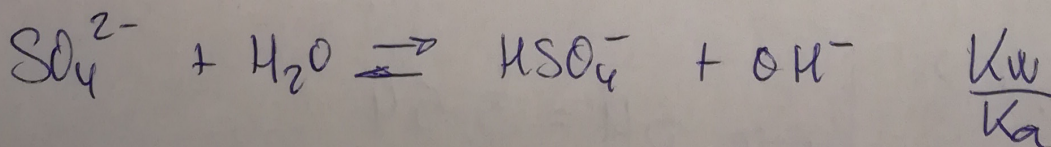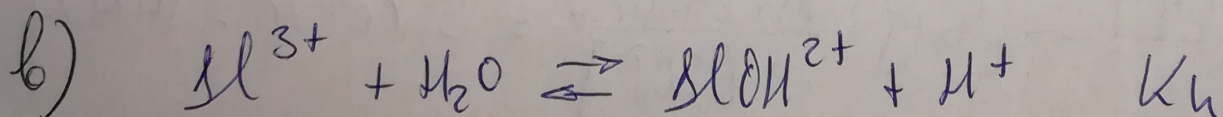
$$K_h = \frac{[AlOH^{2+}][H^+]}{[Al^{3+}]} = \frac{x^2}{C_i - x} \qquad \begin{bmatrix} C_i \gg 100 \cdot K_h \\ C_i - x \cong C_i \end{bmatrix}$$

$$x = \sqrt{K_h \cdot C_i} = \sqrt{1,40 \cdot 10^{-5} \cdot 0,240} = 1,83 \cdot 10^{-3} \; mol/l$$

$$x = [H^+] \rightarrow pH = -\log[H^+] = -\log(1,83 \cdot 10^{-3})$$

$$\underline{\underline{pH = 2,74}}$$

b) $Al^{3+} + H_2O \rightleftharpoons AlOH^{2+} + H^+ \qquad K_h$

$\quad\;\; SO_4^{2-} + H_2O \rightleftharpoons HSO_4^- + OH^- \qquad \dfrac{K_w}{K_a}$

$$\frac{K_h \cdot K_w}{K_a} = \frac{[AlOH^{2+}][HSO_4^-][H^+][OH^-]}{[Al^{3+}][SO_4^{2-}]}$$

$$\frac{K_h}{K_a} = \frac{[AlOH^{2+}][HSO_4^-]}{[Al^{3+}][SO_4^{2-}]} = \frac{x^2}{(C_i-x)(2C_i-x)}$$

Donde $K = \dfrac{K_h}{K_a} = \dfrac{1,40 \cdot 10^{-5}}{1,26 \cdot 10^{-2}} = 1,11 \cdot 10^{-3}$

$$K = \frac{x^2}{x^2 - C_i x - 2C_i x + 2C_i^2} \rightarrow (1-K)x^2 + 3KC_i x - 2KC_i^2 = 0$$

$$x^2 + 8 \cdot 10^{-4} x - 1,29 \cdot 10^{-4} = 0$$

Donde $(8 \cdot 10^{-4})^2 \ll 4 \cdot 1,29 \cdot 10^{-4} \rightarrow x = \sqrt{1,29 \cdot 10^{-4}}$

$x = 1,13 \cdot 10^{-2}$ mol/l

$[AlOH^{2+}] = [HSO_4^-] = 1,13 \cdot 10^{-2}$ mol/l

$[Al^{3+}] = C_i - x = 0,240 - 1,13 \cdot 10^{-2} = 0,289$ mol/l

$[SO_4^{2-}] = 2C_i - x = 0,480 - 1,13 \cdot 10^{-2} = 0,469$ mol/l

$$K_h = \frac{[AlOH^{2+}][H^+]}{[Al^{3+}]} \rightarrow [H^+] = \frac{K_h [Al^{3+}]}{[AlOH^{2+}]} = 2,84 \cdot 10^{-4} \text{ mol/l}$$

$$K_a = \frac{[SO_4^{2-}][H^+]}{[HSO_4^-]} \rightarrow [H^+] = \frac{K_a [HSO_4^-]}{[SO_4^{2-}]} = 3,00 \cdot 10^{-4} \text{ mol/l}$$

$pH = 3,52$

$pH = 3,55$ $\Big| \rightarrow \underline{\underline{pH = 3,54}}$

The figure shows % formation relative to Al (y-axis, 0 to 100) versus pH (x-axis, 4.0 to 7.5) for various aluminium species: Al^{3+}, $Al(OH)^{2+}$, $Al(OH)_2^+$, $Al(OH)_3(s)$, $Al_{13}(OH)_{32}^{7+}$, and $Al(OH)_4^-$.