Marks 5

- The pH of a solution can be controlled by adding small amounts of gaseous HCl. Assuming no change in volume, calculate what the pH of the solution must be to just dissolve 1.00 g of NiS suspended in 1.0 L of water.

  Data: $H_2S(aq) \rightleftharpoons 2H^+(aq) + S^{2-}(aq)$ $K = 1.1 \times 10^{-20}\ M^2$

  $K_{sp}(NiS) = 1.0 \times 10^{-22}\ M^2$

For the dissolution $NiS(s) \rightleftharpoons Ni^{2+}(aq) + S^{2-}(aq)$,

$$K_{sp} = [Ni^{2+}(aq)][S^{2-}(aq)].$$

For the acid dissociation, $H_2S(aq) \rightleftharpoons 2H^+(aq) + S^{2-}(aq)$,

$$K = \frac{[H^+(aq)]^2[S^{2-}(aq)]}{[H_2S(aq)]}$$

Combining these two equilibria gives, for the overall reaction,

$$NiS(s) + 2H^+(aq) \rightleftharpoons Ni^{2+}(aq) + H_2S(aq),$$

$$K_{eq} = \frac{[Ni^{2+}(aq)][H_2S(aq)]}{[H^+(aq)]^2} = \frac{K_{sp}}{K} = \frac{1.0 \times 10^{-22}}{1.1 \times 10^{-20}} = 9.1 \times 10^{-3}$$

The formula mass of NiS is (58.69 (Ni) + 32.07 (S)) g mol^{-1} = 90.76 g mol^{-1}. The amount in 1.00 g is therefore,

$$\text{number of moles} = \frac{\text{mass (g)}}{\text{molar mass (g mol}^{-1})} = \frac{1.00\,\text{g}}{90.76\,\text{g mol}^{-1}} = 0.0110\ \text{mol}$$

In the dissolution $NiS(s) \rightleftharpoons Ni^{2+}(aq) + S^{2-}(aq)$, so if 0.0110 mol of NiS(s) completely dissolves in 1.0 L, $[Ni^{2+}(aq)]$ = 0.011 M. From the overall reaction, each mole of NiS which dissolves produces one mole of $H_2S(aq)$ so $[H_2S(aq)]$ = 0.011 M. Hence,

$$[H^+(aq)]^2 = \frac{(0.011\,M)(0.011\,M)}{9.1 \times 10^{-3}} \quad \text{or } [H^+(aq)] = 0.12\ M$$

$$pH = -\log_{10}[H^+(aq)] = -\log_{10}(0.12) = 0.94$$

pH = **0.94**