Answer on Question #77466, Chemistry / Inorganic Chemistry

The reaction
Co 2+ + 6NH3 => [Co(NH3)6]2+

has an equilibrium constant of 5.0 x 10^4. Solutions were mixed so that the initial concentration of the cobaltous ion was 0.127M and the ammonia was 1.80M. What are the equilibrium concentrations of all three species in the reaction?

Solution

$Co^{2+} + 6NH_3 \leftrightarrow [Co(NH_3)_6]^{2+}$

$$K_c = \frac{[Co(NH_3)_6]^{2+}}{[Co^{2+}][NH_3]^6}$$

The equilibrium constant $K_c = 5.0 \cdot 10^4$ is large, so we should start with as much product as possible. Co^{2+} is a limiting reactant($c(Co^{2+})$=0.127M, $c(NH_3)$ should be 0.127·6 = 0.762, but the concentration of NH_3 is 1.8M).

If all of 0.127 M of Co^{2+} reacts to form product the concentrations would be:

$[Co^{2+}]$ = 0.127-0.127 =0 M

$[NH_3]$= 1.8-0.127·6= 1.038 M

$[Co(NH_3)_6]^{2+}$ = 0.127 M

Using these “shifted” values as initial concentrations with x as the free Co^{2+} ion concentration at equilibrium gives the following ICE table:

	Co^{2+}	+ $6NH_3$	$\leftrightarrow$ $[Co(NH_3)_6]^{2+}$
Initial concentration (M)	0	1.038	0.127
Change (M)	+x	+6x	-x
Equilibrium concentration (M)	x	1.038+6x	0.127-x

Since we are starting close to equilibrium, x should be small so that

1.038+6x ≅ 1.038 M

0.127-x ≅ 0.127 M

$$K_c = \frac{(0.127 - x)}{x(1.038 + 6x)^6} \cong \frac{0.127}{x \times 1.038^6} = 5.0 \times 10^4$$

x= $2.031 \cdot 10^{-6}$

Select the smallest concentration for the 5% rule.

$$\frac{2.031 \times 10^{-6}}{0.127} \times 100\% = 1.599 \times 10^{-3}\%$$

This value is much less than 5%, so the assumptions are valid.

The concentrations at equilibrium are:

$[Co^{2+}]$= x = $2.031 \cdot 10^{-6}$ M

$[NH_3]$ = 1.038+6x = $1.038+6 \cdot 2.031 \cdot 10^{-6}$= 1.038 M

$[Co(NH_3)_6]^{2+}$ = 0.127 –x = $0.127-2.031 \cdot 10^{-6}$ = 0.127 M

By starting with the maximum amount of product, this system was near equilibrium and the change (x) was very small. With only a small change required to get to equilibrium, the equation for x was greatly simplified and gave a valid result well within the 5% error maximum.

Answer: $[Co^{2+}]$= $2.031 \cdot 10^{-6}$ M

$[NH_3]$ = 1.038 M

$[Co(NH_3)_6]^{2+}$ = 0.127 M

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