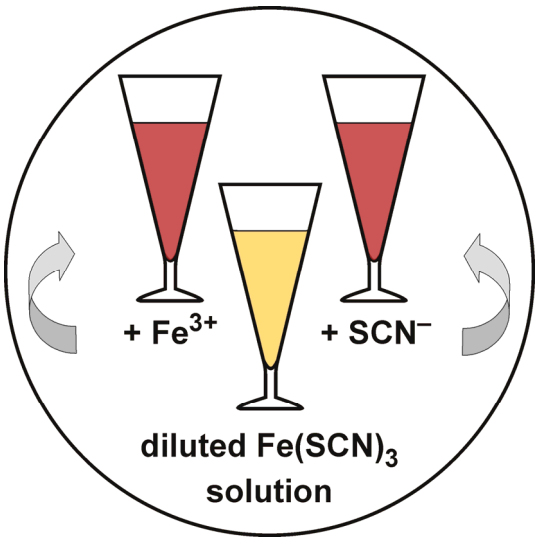
Iron(III) Thiocyanate Equilibrium



Equipment:

large goblet
three smaller goblets
glass rod

Chemicals:

iron(III) nitrate solution (approx. 0.1 M)
ammonium thiocyanate solution (approx. 0.1 M)
deionized water

Safety:

iron(III) nitrate nonahydrate ($Fe(NO_3)_3 \cdot 9\ H_2O$):

H272, H315, H319
P302 + P352, P305 + P351 +P338

ammonium thiocyanate (NH_4SCN):

H332, H312, H302, H412
P273, P302 + P352

It is necessary to wear safety glasses.

Procedure:

10 mL of iron(III) nitrate and 10 mL of ammonium thiocyanate solution are filled in the large goblet. The blood-red mixture is diluted with water until its color changes to pale orange. Subsequently, the solution is divided into three approximately equal parts. The solution in the first small goblet is then treated with 20 mL of excess iron(III) solution, that in the third with 20 mL of excess thiocyanate solution.

Observation:

The color gets again blood-red in both cases. The second goblet acts as reference.

Explanation:

Between iron hexaquo complex cations and thiocyanate anions on the one hand and the blood-red iron thiocyanate complex on the other hand exists an equilibrium which can be described by the following simplifying conversion formula (reaction equation):

$$[Fe(H_2O)_6]^{3+} + 3\ SCN^- \rightleftarrows [Fe(H_2O)_3(SCN)_3] + 3\ H_2O.$$

The application of the mass action law results in

$$\overset{\circ}{K}_c = \frac{c([Fe(H_2O)_3(SCN)_3])}{c([Fe(H_2O)_6]^{3+}) \cdot c(SCN^-)^3}.$$

Water as solvent is treated as pure substance; therefore, it does not appear in the formula.

Dilution with water lowers the concentration of the complex, but also the concentrations of the free ions. Therefore, the denominator will decrease much faster than the numerator. Because the quotient is a constant, the so-called equilibrium constant $\overset{\circ}{K}_c$, the numerator also has to decrease: The equilibrium is displaced towards the reactant side, i.e. some iron thiocyanate complex has to decompose again into iron hexaquo complex cations and thiocyanate anions. The pale orange color of the resulting solution is caused by the iron hexaquo complex.

The addition of excess iron(III) ions, however, results in an increase of the denominator. More iron thiocyanate complex has to be formed in order to use up this extra reactant (along with the other reactant thiocyanate) and re-establish the equilibrium. Similarly, the addition of excess thiocyanate also causes a shift of the equilibrium to the product side.

Disposal:

The solutions are poured in a special jar for hazardous waste disposal.