Experiment 34

A Quantitative Study of Equilibrium

INTRODUCTION

In Experiment 33, you learned how to change an equilibrium reaction. But when you apply a stress, by how much will the equilibrium change? This would be a vital piece of information if you were running an industrial process.

In this experiment, you will look for patterns in the concentrations of the ions present in the following equilibrium reaction:

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq).$$

Remember, only the product ion has a colour but you can calculate the other two concentrations from your data.

PROBLEM

How are the concentrations of the ions in an equilibrium reaction related?

APPARATUS AND MATERIALS

Per pair of students:

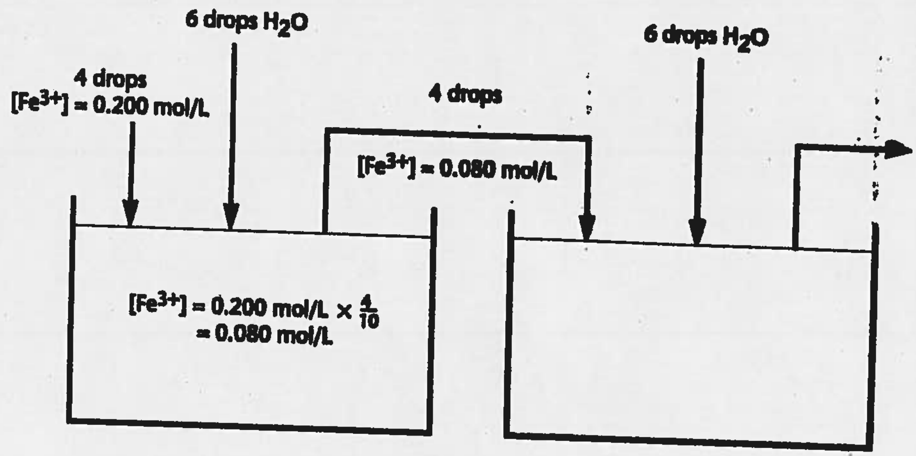
1 96-well plate
5 1-mL micro-tip pipettes
dropper bottles of:
  0.200 mol/L solution of iron(III) nitrate
  0.002 00 mol/L solution of potassium thiocyanate
  distilled water

SAFETY

Iron(III) nitrate solution is corrosive. However, in the concentration used here, it presents little risk. Wash any spills off your skin and clothing.

PRELAB ASSIGNMENT

1. Read the Procedure. Copy and continue the sample flow chart below, to show the dilutions of the Fe^{3+} solution. Draw the chart large enough to include the calculations for the concentration of the Fe^{3+} ions in each well, as shown below.

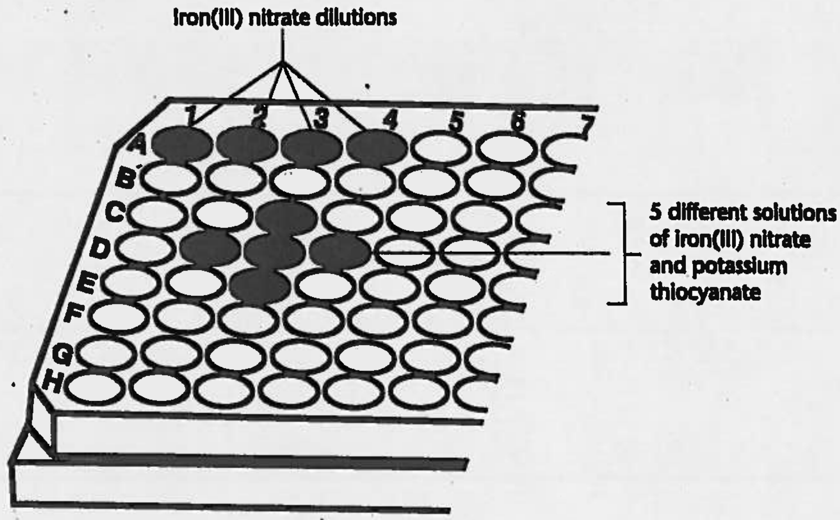


2. Make a table like the one below to record your observations.

Well	Initial		Drops of Reference	Equilibrium		
	$[Fe^{3+}(aq)]$	$[SCN^{-}(aq)]$		$[Fe^{3+}(aq)]$	$[SCN^{-}(aq)]$	$[FeSCN^{2+}(aq)]$
D3						
C3						
D4						
E3						
D2						

PROCEDURE

1. In a 96-well plate, place 5 drops of potassium thiocyanate solution in each of wells C3, D2, D3, D4, E3 as in the diagram on the next page.



2. Add 5 drops of iron(III) nitrate solution to well D3. This is your reference solution.
3. Place 6 drops of distilled water in each of wells A1 to A4 as shown in the above diagram.
4. In well A1, add 4 drops of iron(III) nitrate solution.
5. With a clean pipette, draw up the solution from well A1 to mix it. Return it to the well. Draw up the solution a second time and try to avoid drawing up air bubbles.
6. Add 5 drops of the solution from well A1 to well C3. Add 4 drops of the solution from well A1 to well A2. Discard any remaining solution. Wash the pipette.
7. Repeat Step 5 for well A2. Add 5 drops of the solution from well A2 to well D4, and 4 drops of the solution from well A2 to well A3.
8. Repeat Step 5 for well A3. Add 5 drops of the solution from well A3 to well E3, and 4 drops of the solution from well A3 to well A4.
9. Repeat Step 5 for well A4. Add 5 drops of the solution from well A4 to well D2. The five solutions should be arranged like a five on a die with the reference solution in the centre.
10. Draw up all the reference solution in well D3 into a clean pipette. Replace the solution in well D3, drop by drop.
11. Record the number of drops in well D3 when the colour of its solution matches that of the solution in well D2 (dilution 4).
12. Continue to add drops of solution in well D3. Record the number of drops as each reference colour matches those in wells E3, D4, and C3.

ANALYSIS

1. Calculate the initial $[Fe^{3+}(aq)]$ and $[SCN^{-}(aq)]$ when they are mixed in each of wells D3, C3, D4, E3, and D2. Record the results in the table.

2. Calculate the equilibrium $[FeSCN^{2+}(aq)]$ by comparing the number of drops of the reference solution that had the same colour as each of the four dilutions.

3. Using the equilibrium equation, find how much $Fe^{3+}(aq)$ and $SCN^{-}(aq)$ were used up, and thus their equilibrium concentrations.

4. Look for a relationship among these four sets of equilibrium data. Set up a table for the four dilutions and evaluate the following expressions for each dilution. Put your answers in the table.

$$\frac{[FeSCN^{2+}(aq)]}{[Fe^{3+}(aq)] + [SCN^{-}(aq)]} \qquad \frac{[Fe^{3+}(aq)][Fe^{2+}SCN(aq)]}{[SCN^{-}(aq)]} \qquad \frac{[FeSCN^{2+}(aq)]}{[Fe^{3+}(aq)][SCN^{-}(aq)]}$$

5. Using the values you found for each dilution, find the ratio of the largest value to the smallest value. Which of the three expressions gives you the most consistent value?

Optional: A spreadsheet program on a computer would be helpful with your calculations.

EXTENSION

1. What is the equilibrium expression for each reaction?

(a) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

(b) $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

(c) $H_2CO_3(aq) \rightleftharpoons H^{+}(aq) + HCO_3^{-}(aq)$

2. In general, what is the relationship between the concentrations of the reactants and the concentrations of the products in an equilibrium reaction?