Factors affecting the position of equilibrium practical

Aim

This experiment is carried out to determine how the equilibrium position of the chemical reaction of the solution Fe (SCN) (aq) 2 +

with its iron (III) ion, Fe (aq) 3 +

and thiocyanate ion, SCN (aq) –

shifts when the factors such as concentration and temperature are varied.

Introduction

Chemical reactions that continue until one of the reactants is completely used up are said to have proceeded to completion as the reactions stop and the reactants which are not in excess will be converted completely into the products. However, most chemical reactions do not proceed to completion. Chemical reactions, specifically reversible reactions, have the tendency and resilience to alter its condition to achieve the state of equilibrium. The system is said to be in chemical equilibrium when the rates of the forward and backward reactions are balanced, which are equal. The relative concentrations of the reactants and the products in an equilibrium mixture is described as the equilibrium position. Changes in experimental conditions (stress) such as concentration, pressure, temperature and catalyst may disturb the chemical equilibrium, hence cause shifting in equilibrium position that more or less of the desired product is produced. The Le Chatelier's principle is the principle introduced and implemented to determine the direction or shift of the position of equilibrium in order to counteract the experimental variables present in the reaction as well as relieve the effect of the stress.

In this experiment, we will investigate the equilibrium reaction between the

$Fe(aq)^{3+}$

, iron(iii) ion and $SCN(aq)^{-}$

, thiocyanate ion. The equilibrium reaction of this experiment can be shown by the following equation:

$Fe(aq)^{3+} + SCN(aq)^{-}$

$\rightleftharpoons Fe(SCN)(aq)^{2+}$

(pale yellow) (colourless)(red)

The product of this reaction, $Fe(SCN)(aq)^{2+}$

is a complex ion that imparts an intense, blood-red color of the solution. Thus, the intensity of the solution determines the amount of $Fe(SCN)(aq)^{2+}$

. Part A of this experiment investigates the effect of concentration on the position of equilibrium, which then followed by Part B, how the temperature changes affect the position of equilibrium.

Equipment and Safety

Submitted to *“ Preparation for Practical 3– Factors Affecting the Position of Equilibrium”.*

Method / Procedure

Refer to the procedure provided on the Moodle, *Factors Affecting the Position of Equilibrium Practical.*

Results

Data Presentations:

The aqueous equilibrium between the ions $Fe_{(aq)}^{3+}$ and $SCN_{(aq)}^{-}$

in $Fe(SCN)_{(aq)}^{2+}$

can be shown as below:

$Fe_{(aq)}^{3+} + SCN_{(aq)}^{-}$

$\rightleftharpoons Fe(SCN)_{(aq)}^{2+}$

(pale yellow) (colourless) (red)

<u>Part A: Concentration Changes</u>

Table 1: The effect of concentration changes on the aqueous equilibrium after one drop of 0. 1 M $Fe(NO_3)_{3(aq)}$, $KSCN_{(aq)}$, $NaF_{(aq)}$, $AgNO_{3(aq)}$

or equal volume of water is being added

Test Tube	Test Added	Colour Changed to	Equilibrium shifted
A	0 . 1 M of Fe (NO 3) 3 (aq)	Reddish-orange	Forward (shift to the right)
B	0 . 1 M of KSCN (aq)	Dark orange/ orange-pink	Forward (shift to the right)
C	0 . 1 M of NaF (aq)	Pale yellow	Backward (shift to the left)
D	0 . 1 M of AgNO 3 (aq)	Cloudy yellow (white precipitate)	Backward (shift to the left)

E	*Equal volume of water*	Pale yellow (nearly transparent yellow)	Backward (shift to the left)
F	*Control group*		

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

(pale yellow) (colourless) (red)

Part B: Changes in Temperature

Table 2: The effect of temperature changes (hot and cold) on the aqueous equilibrium after placing the test tubes in hot water and ice water

Test Tube	Water Temperature	Colour Changed to	Equilibrium shifted
1	Hot, 373K	Pale yellow	Backward (shift to the left)
2	Cold, 276K	Dark orange	Forward (shift to

the right)

Control group

$Fe^{3+}_{(aq)} + SCN^{-}_{(aq)}$

F $\rightleftharpoons Fe(SCN)^{2+}_{(aq)}$

(pale yellow) (colourless)

(red)

Data Analysis and Discussion

1. The results of Part A and Part B have already tabulated in the data presentation session.
2. Observations

Part A: Concentration Changes

Test Tube A

Based on the result recorded, it can be observed that a reddish-orange colour appears after adding one drop of 0.1 M $Fe(NO_3)_{3(aq)}$

.

Explanation:

Control group $Fe^{3+}_{(aq)} + SCN^{-}_{(aq)}$

$\rightleftharpoons Fe(SCN)^{2+}_{(aq)}$

(pale yellow) (colourless) (red)

Ionic equation of $Fe(NO_3)_3$ aq : $Fe(NO_3)_3$ aq → $Fe(aq)^{3+}$ + $3NO_3(aq)^-$

The $Fe(aq)^{3+}$

ion produced from $Fe(NO_3)_3$ aq

causes the concentration of $Fe(aq)^{3+}$

ion, which is the reactant of the solution $Fe(SCN)(aq)^{2+}$

to increase. As the concentration of $Fe(aq)^{3+}$

ion (the reactant) is increased, according to Le Châtelier’s principle, the equilibrium position will shift in the direction that tends to reduce the concentration of $Fe(aq)^{3+}$

ion (the reactant) of the reaction. Thus, the final equilibrium position of the equation $Fe(aq)^{3+} + SCN(aq)^-$

$\rightleftharpoons Fe(SCN)(aq)^{2+}$

will shift forward to the right. This is because, by doing so, some of the reactant will be used up, hence the concentration of $Fe(SCN)(aq)^{2+}$

increases, causes the colour to intensify, the solution appears in reddish-orange colour.

Test Tube B

Based on the result recorded, it can be observed that an orange-pink/dark orange colour appears after adding one drop of 0 . 1 M of KSCN (aq)

.

Explanation:

Control group $Fe_{(aq)}^{3+} + SCN_{(aq)}^{-}$

$\rightleftharpoons Fe(SCN)_{(aq)}^{2+}$

(pale yellow) (colourless) (red)

Ionic equation of $KSCN_{(aq)}$: $KSCN_{(aq)} \rightarrow K_{(aq)}^{+} + SCN_{(aq)}^{-}$

The $SCN_{(aq)}^{-}$

ion produced from $KSCN_{(aq)}$

causes the concentration of $SCN_{(aq)}^{-}$

ion, which is the reactant of the solution $Fe(SCN)_{(aq)}^{2+}$

to increase. As the concentration of $SCN_{(aq)}^{-}$

ion (the reactant) is increased, according to Le Châtelier’s principle, the equilibrium position will shift in the direction that tends to reduce the concentration of $SCN_{(aq)}^{-}$

ion (the reactant) of the reaction. Thus, the final equilibrium position of the equation $Fe_{(aq)}^{3+} + SCN_{(aq)}^{-}$

$\rightleftharpoons Fe(SCN)_{(aq)}^{2+}$

will shift forward to the right. This is because, by doing so, some of the reactant will be used up, hence the concentration of $Fe(SCN)_{(aq)}^{2+}$

increases, causes the orange-pink/dark orange colour of the solution to intensify.

Test Tube C

Based on the result recorded, it can be observed that a pale yellow colour appears after adding one drop of 0.1 M of $NaF_{(aq)}$

.

Explanation:

Control group $Fe_{(aq)}^{3+} + SCN_{(aq)}^{-}$

$\rightleftharpoons Fe(SCN)_{(aq)}^{2+}$

(pale yellow) (colourless) (red)

Ionic equation of $NaF_{(aq)}$: $NaF_{(aq)} \rightarrow Na_{(aq)}^{+} + F_{(aq)}^{-}$

Overall equation :

$Fe(SCN)_{(aq)}^{2+} + NaF_{(aq)} \rightarrow NaSCN_{(aq)} + FeF_6^{3-}{}_{(aq)}$

After 0.1 M of $NaF_{(aq)}$

is added to the solution $Fe(SCN)_{(aq)}^{2+}$

, it will dissociate into $Na_{(aq)}^{+}$

and $F^{-}_{(aq)}$

. $Na^{+}_{(aq)}$

reacts with $SCN^{-}_{(aq)}$

from the $Fe(SCN)^{2+}_{(aq)}$

to form $NaSCN_{(aq)}$

and $Fe^{3+}_{(aq)}$

reacts with $F^{-}_{(aq)}$

to form $FeF_6^{3-}{}_{(aq)}$

, leading to a reduction of concentration of $SCN^{-}_{(aq)}$

and $Fe^{3+}_{(aq)}$,

which are the reactants of the system. The $NaSCN_{(aq)}$

formed is a pale yellow liquid, which is the result of our final solution. Hence, according to Le Châtelier's principle, the equilibrium position is shifted backward to the left because the system is trying to compensate for the lost or removed $SCN^{-}_{(aq)}$

and $Fe^{3+}_{(aq)}$

ion when they react with the $NaF_{(aq)}$

added. By shifting the equilibrium position backward, the concentration of $SCN_{(aq)}^{-}$

and $Fe_{(aq)}^{3+}$

ion are restored, then the concentration of the backward reaction increases again, which is indicated by the fact that the colour of the solution in test tube C becomes pale yellow.

Test Tube D

Based on the result recorded, it can be observed that a cloudy yellow colour appears after adding one drop of 0.1 M of $AgNO_{3(aq)}$

.

Explanation:

Control group $Fe_{(aq)}^{3+} + SCN_{(aq)}^{-}$

$\rightleftharpoons Fe(SCN)_{(aq)}^{2+}$

(pale yellow) (colourless) (red)

Ionic equation of $AgNO_{3(aq)}$: $AgNO_{3(aq)} \rightarrow Ag_{(aq)}^{+} + NO_{3(aq)}^{-}$

Overall equation :

$Fe(SCN)_{(aq)}^{2+} + AgNO_{3(aq)} \rightarrow AgSCN_{(s)} + Fe(NO_3)_3$ a q)

After 0.1 M of $AgNO_{3(aq)}$

is added to the solution $Fe(SCN)_{(aq)}^{2+}$

, it will dissociate into $Ag_{(aq)}^{+}$

and $NO_{3(aq)}^{-}$

. $Ag_{(aq)}^{+}$

draws off $SCN_{(aq)}^{-}$

from the $Fe(SCN)_{(aq)}^{2+}$

to form $AgSCN_{(s)}$

which is a solid, leading to a reduction of concentration of $SCN_{(aq)}^{-}$,

which is the reactant of the system. The product, $AgSCN_{(s)}$

indicates that white precipitate is formed, causes the cloudiness observed in test tube D. In accordance with the Le Châtelier's principle, the decrease in the concentration of $SCN_{(aq)}^{-}$

ion leads to the decrease in the concentration of $Fe(SCN)_{(aq)}^{2+}$

of the overall equation. The equilibrium position is shifted backward to the left as the system is trying to compensate for the lost or removed $SCN_{(aq)}^{-}$

ion when it reacts with $AgNO_{3(aq)}$

. By shifting the equilibrium position backward, the concentration of $SCN_{(aq)}^{-}$

is restored, then the concentration of the backward reaction increases again, and that is the reason why we observed cloudy or milky yellow of the final solution in test tube D.

Test Tube E

Based on the result recorded, it can be observed that a pale and nearly transparent yellow colour appears after adding equal volume of water.

Explanation:

Control group $Fe^{3+}_{(aq)} + SCN^{-}_{(aq)}$

$\rightleftharpoons Fe(SCN)^{2+}_{(aq)}$

(pale yellow) (colourless) (red)

Ionic equation of $H_2O_{(l)}$: $H_2O_{(l)} \rightarrow H^{+}_{(aq)} + OH^{-}_{(aq)}$

In test tube E, the addition of equal volume of water will increase the volume of the final solution and cause decrease in the concentration of the $Fe(SCN)^{2+}_{(aq)}$, $Fe^{3+}_{(aq)}$

and $SCN^{-}_{(aq)}$

respectively, but it has no effect on the initial amounts (moles and number of particles) of the ions as $n = CV$

. As the solution is diluted, in accordance with the Le Châtelier’s principle, the equilibrium position will shift towards the side which has a greater number of particles, means that the equilibrium position is shifted backward to the left. Therefore, the colour of the solution in test tube E is faded compared to the initial colour and appears to be pale and nearly transparent yellow.

Part B: Changes in Temperature

Test Tube 1

Based on the result recorded, it can be observed that a dark orange colour appears after the test tube is immersed in a beaker of ice-water.

Explanation:

Control group $Fe(aq)^{3+} + SCN(aq)^{-}$

$\rightleftharpoons Fe(SCN)(aq)^{2+}$

(pale yellow) (colourless) (red)

As the temperature decreases, the intensity of the colour of the solution is higher, which appears dark orange, indicating that the equilibrium position shift forward to the right as there are more product, $Fe(SCN)(aq)^{2+}$

than reactants, $Fe(aq)^{3+}$

and $SCN(aq)^{-}$

. In accordance with the Le Châtelier’s principle, the equilibrium shifts in such a way that the temperature increases again by favouring the exothermic reaction, which heat is released. More $Fe(aq)^{3+}$

and $SCN(aq)^{-}$

are converted into $Fe(SCN)_{(aq)}^{2+}$

at such low temperature. Hence, this also means that the equilibrium constant, K_c

changes as well, K_c

will decrease as more product $Fe(SCN)_{(aq)}^{2+}$

is formed than the reactants $Fe_{(aq)}^{3+}$

and $SCN_{(aq)}^{-}$

.

<u>Test Tube 2</u>

Based on the result recorded, it can be observed that a pale yellow colour appears after the test tube is immersed in a beaker of hot water.

Explanation:

Control group $Fe_{(aq)}^{3+} + SCN_{(aq)}^{-}$

$\rightleftharpoons Fe(SCN)_{(aq)}^{2+}$

(pale yellow) (colourless) (red)

As the temperature increases, the intensity of the colour of the solution is lower, resulting in pale yellow, indicating that the equilibrium position shift backward to the left as there are more reactants, $Fe_{(aq)}^{3+}$

and $SCN_{(aq)}^{-}$

than product, $Fe(SCN)_{(aq)}^{2+}$

. In accordance with the Le Châtelier's principle, the equilibrium shifts in such a way that the temperature decreases again by favouring the endothermic reaction, which heat is absorbed. More $Fe(SCN)_{(aq)}^{2+}$

ions are converted into $Fe_{(aq)}^{3+}$

and $SCN_{(aq)}^{-}$

at such high temperature. Hence, this also means that the equilibrium constant, K_c

changes as well, K_c

will increase as more reactants $Fe_{(aq)}^{3+}$

and $SCN_{(aq)}^{-}$

are formed than the product $Fe(SCN)_{(aq)}^{2+}$

.

3. Improvements

a) Repeat Part A and Part B of the experiment several times then compare the results recorded so that the accuracy and the reliability of the results will increase.

b) We should use a pipette to fill the test tubes to one-third of its volume with the solution of $Fe(SCN)_{(aq)}^{2+}$

instead of determining or estimating the volume by human sight. Estimating the volume of $Fe(SCN)_{(aq)}^{2+}$

by human sight without an equipment will result in a higher or lower volume, cause the results lacking of accuracy.

4. Green Chemistry

One of the principles of green chemistry implemented was waste prevention. We prioritize the waste prevention in order to avoid unnecessary and unwanted wastage during and after the experiment. For instance, we should measure the exact volume of solution $Fe(SCN)_{(aq)}^{2+}$

that is needed to be used for Part A and Part B of the experiment rather than wasting by pouring out an excess volume of it and resulting in wastage. Besides that, we consider the hazards of the chemicals used before the experiment such as the $AgNO_{3(aq)}$,

which is a strong oxidizer that can cause skin irritation and burning. Besides that, $Fe(NO_3)_3$ aq

is a corrosive liquid as well that can cause eye irritation once our eyes are exposed to it. A lower concentration which is 0. 1 M

is used for both $AgNO_{3(aq)}$

and $Fe(NO_3$