Effect of concentration changes on equilibrium yields

Part 1: Effect of concentration changes on equilibrium yields

THEORY

The solution of $Fe(SCN)^{2+}$ with which you have been supplied contains the ions Fe^{3+} , SCN^- and $Fe(SCN)^{2+}$ at equilibrium according to the equation :

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

(pale yellow) (colourless) (blood red)

The intense, blood-red colour of the solution is due to the presence of the $Fe(SCN)^{2+}(aq)$ ion. The colour of the solution in each test-tube, when viewed down the tube, is a measure of the concentration of $Fe(SCN)^{2+}(aq)$ in the tube. If the volumes are the same in each tube, then the colour can also be used as a measure of the amount, in mol, of $Fe(SCN)^{2+}(aq)$ in the tubes. By noting how the intensity of this colour changes, it is possible to deduce the effect of each of the tests on the equilibrium. For instance, if the colour deepens, the amount of $Fe(SCN)^{2+}(aq)$ ions has increased and the amount of the $Fe^{3+}(aq)$ and $SCN^-(aq)$ ions must have simultaneously decreased since they are used up to form more $Fe(SCN)^{2+}(aq)$. The equilibrium would be described as having a net forward reaction (the position of equilibrium would have ' shifted to the right').

In tests A to E the amount, in mol, of $Fe^{3+}(aq)$ or $SCN^-(aq)$ ions present in the solution is initially changed as follows:

In Test A addition of $Fe(NO_3)_3$ increases the amount of Fe^{3+}.

In Test B addition of KSCN increases the amount of SCN^-.

In Test C addition of NaF decreases the amount of Fe^{3+} because F^- ions react with Fe^{3+} ions to form FeF_6^{3-}

In Test D addition of $AgNO_3$ decreases the amount of SCN^- because Ag^+ ions react with SCN^-ions to form a white precipitate of AgSCN.

In Test E addition of water has no effect on the initial amounts of the two ions, but affects the concentration of ALL components in the mixture.

Refer to Chemistry 2, Chapter 9, for a discussion of the effects of changes in conditions on equilibria.

PROCEDURE and RESULTS

1 Fill each of six semi-micro test-tubes to 1/3 of its volume with $Fe(SCN)^{2+}$ (aq) solution. Check that the liquid in each tube has the same intensity of colour when you look down the tube using a white tile or sheet of paper as a background. If necessary, add more solution so that the liquid in each tube is the same colour. Label the tubes A to F.

2 Using test-tube F for the purposes of comparison, perform each of the tests described in the table and record the change that occurs in the colour of the solution when viewed down the tube.

Test-tube Test Colour change

A 1 drop of $Fe(NO_3)_3$ added

B 1 drop of KSCN added

C 1 drop of NaF added

D 1 drop of $AgNO_3$ added

E Equal volume of water added

F None No change

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

(pale yellow) (colourless) (blood red)

Test Tube

A

B

C

D

E

Test

Add

$Fe(NO_3)_3$

Add

KSCN

Add

NaF

Add

$AgNO_3$

Add

H_2O

Initial effect on …

[Fe^{3+}]

INCREASES

[SCN^-]

[Fe^{3+}]

[SCN^-]

[Fe^{3+}]

Change in colour

Change in

[$Fe(SCN)^{2+}$]

Consequent change in [Fe^{3+}] and [SCN^-]

Comparison of final concentration of the ion with the initial concn.

[Fe^{3+}]

GREATER

[SCN-]

[Fe3+]

[SCN-]

[Fe3+]

Comparison of final amount (mol) of the ion with the initial amount

n (Fe3+)

GREATER

n (SCN-)

n (Fe3+)

n (SCN-)

n (Fe3+)

Direction of the shift in equilibrium

ï‚®

RIGHT

Draw graphs showing the changes in concentration due to the change in the position of equilibrium in each of the tests A to E (the graph for Test A has been drawn as an example).

Note :

Parts of graphs showing system at equilibrium should be horizontal lines

Changes in concentration should be approximately in proportion

Concentrations at new position of equilibrium must not go above/below the original values

TEST A

SCN-

Fe(SCN)2+

Fe3+

Concentration

Time

Initial

Equilibrium

Final

Equilibrium

TEST B

Concentration

Time

Initial

Equilibrium

Final

Equilibrium

SCN-

Fe(SCN)2+

Fe3+

TEST C

Concentration

Time

Initial

Equilibrium

Final

Equilibrium

SCN-

Fe(SCN)2+

Fe3+

TEST D

Concentration

Time

Initial

Equilibrium

Final

Equilibrium

SCN-

Fe3+

Fe(SCN)2+

TEST E

Concentration

Time

Initial

Equilibrium

Final

Equilibrium

$Fe(SCN)^{2+}$

SCN^-

Fe^{3+}

Part 2 : Effect of changes in volume on a gaseous equilibrium

THEORY

The syringe contains the gases nitrogen dioxide (NO_2) and dinitrogen tetroxide (N_2O_4) in equilibrium

:

$N_2O_4(g)$ 2 $NO_2(g)$

(colourless) (dark brown)

N_2O_4 is a colourless gas, whilst NO_2 is a dark brown gas. Consequently, changes in the concentration of NO_2 can be monitored by observing changes in the intensity of the colour of the gas mixture. In this way, shifts in the position of equilibrium can be identified. In this experiment the temperature of the mixture is constant so the value of the equilibrium constant, K, is unchanged. The effect of a change in volume on gaseous equilibria is described in Chemistry 2, Chapter 9.

PROCEDURE

Test 1

Hold a syringe containing a mixture of NO_2 gas and N_2O_4 gas in equilibrium and rapidly withdraw the plunger, holding it in position once you have done so. Note and record the change which occurs in the intensity of the brown colour the instant the volume is increased and the change in colour which occurs a moment later.

(You may need to do the test a few times in order to identify both of these changes.)

Observations :

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Test 2

Hold the syringe securely, this time firmly holding the sealed end of the syringe. Rapidly push in the plunger to decrease the volume of gas. Hold the plunger in the new position. Again, note and record the change which occurs in the intensity of the brown colour the instant the volume is decreased and the change that occurs a moment later.

(You may need to do the test a few times in order to identify both of these changes.)

Observations :

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QUESTIONS

1. Write an expression for the equilibrium constant, K, for the reaction being investigated.

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2. For Test 1 :

a) Account for the initial colour change in terms of the instantaneous change in concentration of NO2.

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b) What does the subsequent change in colour tell us about the concentration of NO_2 ?

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c) Complete the following explanation of the effect of the increase in volume on the equilibrium.

The increase in volume initially causes the concentration of NO_2 to …………………………….. and the concentration of N_2O_4 to ………………………………. The concentration fraction is ……………………… than the equilibrium constant, K, and the system is no longer at equilibrium. To regain equilibrium the concentration fraction must ……………………………….

The concentration of NO_2 must ………………………………. while the concentration of N_2O_4 must ………………………………………..

There is a shift in equilibrium to the ………………………… causing the amount of NO_2 to ……………………….. and the amount of N_2O_4 to …………………………………..

3. For Test 2:

Use Le Chatelier’s Principle to explain the change in equilibrium observed when the plunger was pushed in and the volume of the gas mixture decreased.

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Part 3: Effect of temperature on equilibrium mixtures

THEORY:

According to Le Chatelier's principle, a temperature change of an equilibrium mixture will elicit a response by the equilibrium mixture, so as to partially oppose the change. The effect on the concentration of the equilibrium components, and hence on the equilibrium constant, depends on whether the reaction is exothermic or endothermic, and on the direction of the temperature change.

Refer to Heinemann Chemistry Two, Chapter 9, for further discussion of the effect of temperature change on chemical equilibrium.

PROCEDURE AND RESULTS

A. N2O4 (g) 2NO2 (g) ; endothermic. (Note : N2O4 is colourless and NO2 is brown)

Carefully place one of the stoppered test-tubes containing an N2O4 / NO2 gas mixture in a beaker of hot water for about one minute, holding the stopper firmly in place. Place the other tube in a beaker of ice water.

Remove the tubes from the hot water and ice-water and immediately compare the intensities of the brown colour in the tubes. Record your observations.

Hot water ………………………………………………………………………………………

Cold water………………………………………………………………………………………

B. $Fe^{3+}(aq) + SCN^-(aq)$ $Fe(SCN)^{2+}(aq)$; exothermic. (Red colour is due to $Fe(SCN)^{2+}$)

Half-fill two semi-micro test-tubes with $Fe(SCN)^{2+}$ solution.

Place one test-tube in a beaker of ice water. Place the other test-tube into a beaker of very hot water.

Compare the colour of the mixtures in the two test-tubes. Record your observations.

Hot water …………………………………………………………………………………

Cold water…………………………………………………………………………………

C. $H_3PO_4(aq)$ $H_2PO_4^-(aq) + H^+(aq)$; exothermic (Methyl violet indicator)

(Green – Blue – Violet as pH increases)

Pour 1M orthophosphoric acid (H_3PO_4), into each of two semi-micro test-tubes, to a depth of about 3 cm. Add one drop of methyl violet indicator to each test-tube.

Place one test-tube in a beaker of ice water. Place the other test-tube into a beaker of very hot water. Record the colour of the indicator in each of the two test-tubes.

Hot water …………………………………………………………………………………

Cold water…………………………………………………………………………………

Note the acidity of each solution. Methyl violet indicator is yellow in solutions with a high concentration of H+ (aq) (low pH) and its colour changes through green to blue and to violet as the H+ (aq) concentration reduces (ie with increasing pH).

QUESTIONS

In Part A, the brown colour in the test-tubes supplied is due to the presence of nitrogen dioxide (NO2) gas.

How does the concentration of nitrogen dioxide in the equilibrium mixture change as the temperature is increased?

What does your experiment indicate happens to the value of the equilibrium constant, K, for this reaction as the temperature increases? Explain.

Describe (using Le Chatelier's principle) how the equilibrium position has shifted.

In Part B, the red colour is caused by the ion Fe(SCN)2+.

How does the concentration of Fe(SCN)2+ ions in the equilibrium mixture change as the temperature is increased?

What does this indicate about the value of the equilibrium constant, K, for this reaction as the temperature increases? Explain.

Describe (using Le Chatelier's principle) how the equilibrium position has shifted..

Account for your observations in Part C of this experiment (H3PO4 (aq))