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PLEASE NOTE: If ANY of the above information is UNCLEAR or not provided, your grade will NOT be recorded!!

Lab Day (F)

Lab Week (even)

Lab time (2:30)

Laboratory Report Form

Experiment 2.

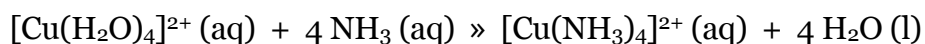
Equilibria

Checklist:

- **Raw Data Sheet written in pen, signed by TA and attached**
- **Completed Report Form attached**

Student's Initials O.A

Table 1. Observations and Discussion



Observations:

(a) A light blue, transparent liquid with low viscosity is observed. This is because when CuSO_4 is added to water, a copper-water complex is formed.

(b) NH_3 is a transparent, colourless liquid with a very strong smell. When 2 drops of the NH_3 is added to the copper-water complex, the solution becomes dark blue.

Discussion:

This happens because when NH_3 is added, which is a base, it neutralizes the Copper which is the conjugate acid from the CuSO_4 salt. The new salt that is formed appears dark blue in the water. In addition, the initial concentration of the product is zero, therefore the products are favoured and the reaction happens very fast. This is based on Le Chatelier's principle which states that if you add more reactants, the reaction will be pushed to make more products.

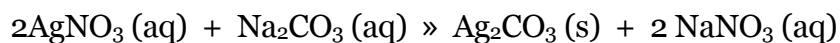
Observation:

(c) HCl (1M) is a transparent, colorless and odorous liquid. After adding 25 drops of HCl the solution turns to a whitish-blue opaque liquid. When 6 more drops were added, it started to turn into a transparent light blue liquid, similar to the one in (a).

Discussion:

The reason the solution turned back into a transparent light blue liquid is because the HCl is a very strong acid that easily gets rid of H^+ ions. These H^+ ions displace the Copper and pair with the NH_3 . Therefore, the copper-water complex is formed again. To support this, according to Le Chatelier's principle, adding more products, which is the acid in this case, will shift the equilibrium towards the reactants.

1) After repeating steps 2 and 3, the exact same changes were observed.



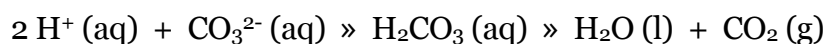
observations:

(d) Na_2CO_3 is a transparent and colourless liquid and so is AgNO_3 .

(e) When 0.5 mL of 0.01 M Ag_2CO_3 is added to 0.5 mL of 0.1 M Na_2CO_3 in a test tube, the solution turns into a creamy-beige and opaque solution.

Discussion:

The products are favoured in this reaction since the initial concentration of products is zero. And according to Le Chatelier's principle the forward reaction is favoured so that products can be formed. This type of reaction is called a double-displacement reaction.

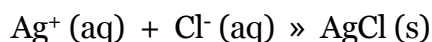


Observation:

(f) HNO_3 is a transparent and colourless liquid. After adding 5 drops of HNO_3 , the creamy-beige opaque solution turns into a transparent and colourless solution.

Discussion:

HNO_3 is a strong acid and it gets rid of H^+ ions easily. Therefore the concentration of H^+ increases. According to Le Chatelier's principle, when the concentration of the reactants increase, which is H^+ in this case, the reaction shifts towards the products and form, in this case, H_2O and CO_2 , which results in a transparent and colourless solution.

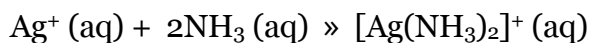


observation:

(g) When 6 drops of 0.1 M HCl was added to the previous solution, the solution turned white and opaque.

Discussion:

This occurs because Cl^- is a weak conjugate base of HCl , and it reacts with the cation Ag^+ to form a silver salt, which results in the white, opaque solution. To support this, Le Chatelier's principle states that when the concentration of reactants increase, which is HCl in this case, it shifts the equilibrium towards the products side.

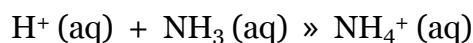


observation:

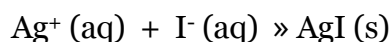
(h) After adding 12 drops of NH_3 , the solution turns half white at the bottom and clear on top, but turns completely colourless and transparent when it was swirled.

Discussion:

Just like the Cl^- , the NH_3 is a weak base that reacts with the cation Ag^+ to form $[\text{Ag}(\text{NH}_3)_2]^+$, which results in the colourless and transparent solution. Again, Le Chatelier's principle states that if we add more reactants (NH_3), the products side is favoured.



(2) When steps 7 and 9 are repeated, the same changes occur (when HNO_3 is added, solution turns white and opaque as NH_3 is removed, when NH_3 added, solution turns clear and colourless).

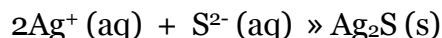


Observation:

(i) When 46 drops of KI, which is a colourless and transparent solution, is added, the solution turns white and opaque except for a little portion at the bottom that remained transparent and colourless.

Discussion:

The iodine ion paired with the Silver cation to form a solid precipitate which is observed as the white stuff in the solution.

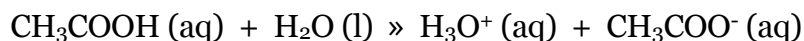


Observation:

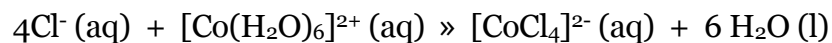
(j) After adding 3 drops of Na_2S the top part of the solution that was white turns into a brownish-grey colour that is translucent.

Discussion:

This happens because the Na_2S disassociates into two separate ions and the S^{2-} ion reacts with the Ag^+ cation to form Silver Sulphide, which results in the brownish grey colour. According to Le Chatelier's principle, as the reactants are being added in, the equilibrium shifts and favours the products.



- (k) CH_3COOH is a transparent and colourless solution, When it is placed in a well and 3 drops of universal indicator is added, the outcome is a red and transparent solution with a slightly vinegary smell.
- (l) The PH was tested by adding drops from the wells onto the PH paper and comparing it to the chart. The Ph was found to be 3, which appeared as orange on the PH paper.
- (m) Adding 10 drops of NaCH_3COOH , which is a transparent and colourless solution, to each of the wells containing the buffer, causes the solution to turn orange.
- (n) When the PH was tested, an orange colour appeared on the PH paper with was a bit lighter than the pervious one, this indicated a PH of 4.
- (o) Distilled water is then added to two DIFFERENT wells along with 3 drops of universal indicator. The solution looked red and transparent. This color corresponds to around a 2 or 2.5 pH .When the PH was measured, the drops from this well turned the Ph paper to orangish-yellow which is about a PH of 5.
- (p) When HCl is added to the well containing the buffer the solution turned to darker orange. When HCl is added to the well containing the distilled water, the solution turned more red than it was before.
- (q) After the addition of HCl, the well with the buffer measured a PH of 2, it turned the PH strip to a light red. The well with the water measured a PH of about 1.5, which turned up on the indicator as darker red.
- (r) NaOH is a transparent and colourless solution. When NaOH was added to the well containing the buffer, the solution turned to a light orange colour. When the NaOH was added to the well containing the water, the solution turned into a purple colour.
- (s) After adding NaOH, the well containing the buffer measured a PH of 4, meanwhile the well containing the distilled water measured a PH of 11.
3. SEE CALCULATIONS SECTION



Observation:

(t) CoCl_2 is a purplish-red and transparent solution.

(u) After adding 4 drops of 12M HCl, which is a transparent and colourless solution with a very strong smell and fumes observed coming out of the bottle, to the CoCl_2 solution, the solution turns blue as the first 2 drops are poured then it turns purple after 4 drops and after it is swirled.

Discussion:

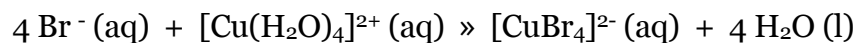
This occurs because HCl dissolves into a cation (H^+) and an anion (Cl^-), the anion then reacts with CoCl_2 to form $[\text{CoCl}_4]^{2-}$. To support this, Le Chatelier's principle states that with the addition of reactants the equilibrium is shifted towards the products.

Observation:

(v) Adding 5 drops of distilled water, the solution turns reddish-pink.

Discussion:

This step shows that increasing the concentration of water, a product, pushes the reaction back towards the reactant side in accordance to Le Chatelier's principle and encourages the formation of the cobalt-water complex.



Observation:

(w) CuBr₂ is a sparkly, shiny, charcoal coloured solid observed in powder form.

(x) After adding 5 drops of distilled water to the CuBr₂, a brownish-black solution is observed with bits of CuBr₂ still there.

(y) After adding 10 more drops of distilled water, the solution turns brown, then light green when it is swirled.

Discussion:

After the addition of water, the reaction seems to be in a bit of a balance, there is some particles of copper-water complex and some of CuBr₄. There is not enough of either to push it fully towards one side or the other. According to Le Chatelier's principle, an increase in reactants will push the reaction further towards the product side and vice versa.

Observation:

(z) After adding 25 more drops of distilled water to make the total volume of water added 2ml, the solution turns turquoise and translucent.

Discussion:

The concentration of water, which is a product, is going up as more water was added, and according to the Le Chatelier's principle, the reaction will be pushed towards the left side favouring the reactants, therefore the copper-water complex and the bromine spectator ion is present.

(aa) KBr (solid) is observed as brownish white crystals that are clumped and of different sizes. After 17 drops of water, the KBr dissolves and produces a colourless and transparent solution.

(bb) When the solution from step 25 (z) is added to KBr the solution turns to light green.

(cc) When the test tube from the previous step is heated, it turns into a yellowish-dark green solution that is opaque.

(dd) CoCl₂ is placed into a clean test tube and heated, it changed from purplish red at room temperature to a darker purplish red. There was no huge change that happened.

Calculations:

pH of pure water= 7.0

pH of buffer:

$C_{iCH_3COOH}=0.1\text{mol/L}$ $C_{iNaCH_3COO}=0.1\text{mol/L}$

$K_{aCH_3COOH}=1.8\times 10^{-5}$

5 Drops = 0.25ml,

$V_i = 10$ drops $CH_3COOH = 0.5\text{ml}$

$V_f=10$ drops $CH_3COOH + 10$ Drops $NaCH_3COO + 5$ drops $NaOH$ OR 5 drops HCl

= 25 drops = 1.25ml

$C_f=C_i(V_i/V_f)$

$C_f=(0.1\text{ mol/L})(0.0005\text{L}/0.00125\text{L})$

$C_f= 0.04\text{ mol/L}$

$pH = pK_a + \log [A^-]/[HA]$

$pH = pK_a + \log [0.04]/[0.04]$

$pH=pK_a+\log 1$

$pH=pK_a+0$

$pH = pK_a = -\log K_a$

$pH = -\log(1.8 \times 10^{-5})$

$pH= 4.74$

pH of Water + Acid

$$C_{\text{HCl}} = 0.1 \text{ mol/L}$$

$$C_f = C_i(V_i/V_f)$$

$$C_f = (0.1 \text{ mol/L})(0.00025\text{L}/0.00125\text{L})$$

$$C_f = 0.02 \text{ mol/L HCl}$$

$$\text{pH} = -\log[\text{H}^+]$$

$$\text{pH} = -\log[0.02]$$

$$\text{pH} = 1.70$$

pH of Water + Base

$$C_{\text{NaOH}} = 0.1 \text{ mol/L}$$

$$C_f = C_i(V_i/V_f)$$

$$C_f = (0.1 \text{ mol/L})(0.0005\text{L}/0.00125\text{L})$$

$$C_f = 0.02 \text{ mol/L NaOH}$$

$$\text{pH} = 14 - (-\log[\text{OH}^-])$$

$$\text{pH} = 14 - (-\log[0.02])$$

$$\text{pH} = 14 - 1.70$$

$$\text{pH} = 12.3$$

pH Buffer+ Acid:

$C_{\text{CH}_3\text{COOH}} = 0.4 \text{ mol/L}$ $C_{\text{CH}_3\text{COO}^-} = 0.4 \text{ mol/L}$

$C_{\text{HCl}} = 0.02 \text{ mol/L}$ $K_{\text{aCH}_3\text{COOH}} = 1.8 \times 10^{-5}$

	HCl	+	CH ₃ COO ⁻ →	CH ₃ COOH
I	0.02		0.04	0.04
C	-0.02		-0.02	+0.02
E	0		0.02M	0.06M

$$\text{pH} = \text{pK}_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

$$\text{pH} = \text{pK}_a + \log \frac{[0.02]}{[0.06]}$$

$$\text{pH} = \text{pK}_a + \log 0.33$$

$$\text{pH} = 4.74 + (-0.481486)$$

$$\text{pH} = 4.26$$

pH Buffer+Base

$C_{\text{CH}_3\text{COOH}} = 0.04 \text{ mol/L}$ $C_{\text{CH}_3\text{COO}^-} = 0.04 \text{ mol/L}$

$C_{\text{NaOH}} = 0.02 \text{ mol/L}$ $K_{\text{aCH}_3\text{COOH}} = 1.8 \times 10^{-5}$

	NaOH	+	CH ₃ COOH →	CH ₃ COO ⁻
I	0.02		0.04	0.04
C	-0.02		-0.02	+0.02
E	0		0.02M	0.06M

$$\text{pH} = \text{pK}_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

$$\text{pH} = \text{pK}_a + \log \frac{[0.06]}{[0.02]}$$

$$\text{pH} = \text{pK}_a + \log 3$$

$$\text{pH} = 5.22$$

Final pH changes

pH of water+acid – pH of water

$$\begin{aligned}\text{Change} &= 1.70 - 7 \\ &= -5.3\end{aligned}$$

pH of water+base – pH of water

$$\begin{aligned}\text{Change} &= 12.3 - 7 \\ &= 5.3\end{aligned}$$

pH of buffer+acid – pH of buffer

$$\begin{aligned}\text{Change} &= 4.26 - 4.74 \\ &= -0.48\end{aligned}$$

pH of buffer+base – pH of buffer

$$\begin{aligned}\text{Change} &= 5.22 - 4.74 \\ &= 0.48\end{aligned}$$

Conclusion:

According to the Le Chatelier's Principle, changing the concentrations of products or reactants can influence the equilibrium by shifting to the side opposite to where there was a concentration increase. For the section, Multiple Equilibria, the equilibrium was seen to be shifted in various ways, all depending on which compounds were added to what side. If reactants were added, the equilibrium shifted towards the products side and vice versa. In the section Buffers, the change of pH of water and buffer when acid was added were - 5.3 and -0.48 respectively. For the changes in pH when base was added to water and buffer, it was calculated to be 5.3 and 0.48 respectively. This demonstrates that buffers are quite effective in terms of stabilizing pH as the changes in pH compared to when acid or base were added to water was roughly 11 times smaller. In the section Common Ion, it is seen that if there is an addition of a common ion in the reactant side, the equilibrium will shift towards the product side and vice versa, also in accordance with Le Chatelier's principle. Finally, for Temperature effect, when heat was added to the reactants, the equilibrium shifted towards the products and vice versa. This is especially true in showing that if the reaction is endothermic, the reaction will shift towards the product side, and if it is exothermic, it will result in an equilibrium shift to the reactant side.

Preparation and testing of a buffer.

CH_3COOH - ~~colorless~~ ^{Transparent}, colorless, not strong vinegar like smell

Universal indicator - Red, translucent.

well 1: $\text{PH} = 3$ well 2: $\text{PH} = 3$

$\text{CH}_3\text{COOH} + \text{Universal indicator}$ - Bright red, translucent, weak vinegar smell

NaCH_3COOH - Transparent, colorless

Add NaCH_3COOH to $\text{CH}_3\text{COOH} + \text{universal indicator}$

↓ turns more orange, still transparent, same colour.

well 1 = $\text{PH} = 4$

well 2 = $\text{PH} = 4$ [acidic and conjugate base]

~~Add distilled water + ~~3 drops~~ universal indicator.~~

~~turns more red.~~

~~PH well 1 = 2 PH well 2 = 2~~

Universal indicator + distilled water

↓ Red, acidic around 2

$\text{PH} = 5$

Add HCl - Strong smell, transparent, colorless

well containing buffer turns near orange darker orange

well containing water turns more red.

PH buffer well = 2

PH water well = 1.5

Add NaOH - clear

well containing buffer turns ^{light} orange $\text{PH} = 4$

well containing water turns purple $\text{PH} = 11$
 HCl

multiple equilibria

AgNO_3 - transparent colorless

Na_2CO_3 - transparent colorless

Add both together 10 drops each

= Creamy beige, opaque

Add HNO_3

= Solid precipitate formed, then solution turned clear

Add ~~10~~ 0.1M HCl

Solution turns white, opaque

Add NH_3 12 drops

white precipitate settles at the bottom then

solution turns clear when it is ~~mixed~~ swirled

repeat step 7 ~~10 drops of HNO_3 are added~~ ~~turns white / translucent~~ ~~change~~

repeat step 8 Add NH_3 , white precipitate ~~settles~~ settles at the bottom / ~~solution becomes clear~~ ~~when swirled~~ bottom white top clear.

Add KI - turns most of the clear part of the solution white, leaves a little clear part between it and the white precipitate.

Add Na_2S 3 drops

turns the top white part to ~~dark grey~~ brownish grey.

Common ion effect

COCl_2 - Purplish red, translucent

Add HCl (12M) - strong odor

after 4 drops it turned blue and fumes were coming out of the HCl bottle, when the plate was shaken, it turned purple.

Adding distilled water.

the mixture turns reddish pink, charcoal

CuBr_2 - sparkly, shiny black powder

5 drops of water - brownish black solution with bits of CuBr_2

10 more drops - turned brown - then turns ^{light} green when swirled. CuBr_2 disappears.

added 25 more drops to be 2ml - solution turns turquoise

KBr - Brownish white crystals

17 drops of water dissolves KBr & transparent colorless

Add KBr to the solution on (25) in a test tube

- solution turned light green

Temperature effect.

28. test tube from 22 turns yellowish dark green

29. EOCl_2 heated in boiling water

- color got darker.

Equilibrium shift

CuSO_4 - light blue, transparent

Adding NH_3 - very strong smell 1-2 drops

solution turns dark blue

Adding HCl (1M) 25 drops

solution turns whitish-blue, opaque

STEP 2 repeat - made it dark blue again

STEP 3 repeat - solution turned very light blue, transparent

