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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 (circle): Tues aft Tues night Wed Thurs aft Thurs night
Fri

Lab Week (circle): **1** 2

Laboratory Report Form

Experiment 4.

Equilibria

Checklist:

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

Student's Initials BG

Table 1. Observations and Discussion

$$[Cu(H_2O)_4]^{2+} (aq) + 4\ NH_3 (aq) \text{ » } [Cu(NH_3)_4]^{2+} (aq) + 4\ H_2O (l)$$

a) The $CuSO_4$ (aq) solution is dissolved in water creating the solution $Cu(H_2O)_4^{2+}$ (aq) which takes on a translucent light blue colour and a strong odour.

b) The solution almost instantaneously turns a darker blue colour after the addition of NH_3 (aq) which is transparent before being added and has a very strong odour. This is cause by the reaction of $Cu(H_2O)_4^{2+}$ (aq) and NH_3 (aq) which created the solution $[Cu(NH_3)_4]^{2+}$ (aq). Since the reaction is almost instantaneous, the products are favoured.

c) The solution then turns back to the initial colour of light blue after the addition of HCl. This occurs because HCl reacts with NH_3 (aq) to neutralize. According to LeChatelier's principle, the reaction will proceed in the opposite direction to increase the amount of NH_3 (aq) which will minimize the effect of change on the system.

1. After repeating the addition of NH_3 and HCl, the same changes were observed as before. A darker blue colour was observed when NH_3 (aq) was added to the solution. Then, the solution was returned to it's initial light blue colour after the addition of HCl.

$$2AgNO_3 (aq) + Na_2CO_3 (aq) \text{ » } Ag_2CO_3 (s) + 2\ NaNO_3 (aq)$$

d) The Na_2CO_3 (aq) solution is transparent.

e) When $AgNO_3$ (aq) is added to the solution, the solution became a tan, opaque colour with some residue at the bottom of the test tube. This is because when the $AgNO_3$ (aq) and Na_2CO_3 (aq) where added, $AgNO_3$ (aq) is insoluble and left the solution of $NaNO_3$ (aq) which is a tan colour. This will be minimized to effect the change of the reaction, according to LeChatlier's principle. This will reduce the amount up until all the Ag_2CO_3 (s) has disappeared.

$$2\ H^{+}\ (aq)\ +\ CO_3^{2-}\ (aq)\ \gg\ H_2CO_3\ (aq)\ \gg\ H_2O\ (l)\ +\ CO_2\ (g)$$

f) The $NaNO_3$ (aq) solutions becomes transparent and the precipitate dissolves after the addition of HNO3. The solution becomes transparent because the H^+ (aq) of HNO3 reacts with CO_3^{2-} (aq) of $AgNO_3$ (aq) to create the solution H_2CO_3 (aq). The solution then separates to create CO_2 (g) and H_2O (l). The precipitate disappears as the concentration of Na_2CO_3 (aq) is reduced during this reaction. This means the initial reaction:

$$2AgNO_3\ (aq)\ +\ Na_2CO_3\ (aq)\ \gg\ Ag_2CO_3\ (s)\ +\ 2\ NaNO_3\ (aq)$$

will be minimized to effect the change of the reaction, according to LeChatlier's principle. This will reduce the amount up until all of the Ag_2CO_3 (s) has disappeared.

$$Ag^{+}\ (aq)\ +\ Cl^{-}\ (aq)\ \gg\ AgCl\ (s)$$

g) By the addition of HCl, the solution is white and opaque. This occurs because the Ag^+ (aq) of Ag_2CO_3 (s) reacts with the Cl^- (aq) of HCl, which reduces the amount of Ag+ in the reduced solution. According to LeChatlier's principle, the initial reaction:

$$2AgNO_3\ (aq)\ +\ Na_2CO_3\ (aq)\ \gg\ Ag_2CO_3\ (s)\ +\ 2\ NaNO_3\ (aq)$$

will be driven towards the products which minimizes the effects on changes, which gives the opaque colour of the solution.

$$Ag^{+}\ (aq) +\ 2NH_3\ (aq)\ \gg\ [Ag(NH_3)_2]^{+}\ (aq)$$

h) The addition of NH_3 (aq) causes the solution to become transparent. This occurs because the Ag^+ (aq) from the reactants reacts with NH_3 (aq), which according to LeChatlier's principle would reverse the reaction to produce more reactants. Consequently, causing the production of $AgNO_3$ (aq) and Na_2CO_3 (aq), which makes the solution transparent.

$H^+ (aq) + NH_3 (aq) » NH_4^+ (aq)$ 2. When we repeat steps 7 to 9 the changes that occurred earlier are not the same. When HNO_3 (aq) was added, the solution became slightly white and opaque colour. Then, when NH_3 (aq) was added the solutions separated into two, an opaque layer underneath and the other layer was transparent.
$Ag^+ (aq) + I^- (aq) » AgI (s)$ i) The addition of KI, which was transparent, to the solution caused the solution to remain transparent, which is a source of error because it was supposed to separate into three different colours like it did during the step before.
$2Ag^+ (aq) + S^{2-} (aq) » Ag_2S (s)$ j) When Na_2S (aq), which was a slight yellow colour before being added to the solution, was added the transparent solution turned to a light yellow/ brown. This occurred because the solubility constant for Ag_2S (s) is lower than AgI (s), causing the Ag^+ (aq) to react with the S^{2-} (aq) of Na_2S (aq) to form Ag_2S (s) which is the yellow/brown colour observed.

$$CH_3COOH\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + CH_3COO^-\ (aq)$$

k) Adding the universal indicator turned the solution a translucent red colour. Using pH paper, it is indicated that the solution has a pH of 3.0 (medium-dark orange).
l) The pH of each solution is about 3.0 meaning that they are identical.
m) When $NaCH_3COO$ (aq) is added a buffer is created and causes the solution to turn from red to a very light oranges, it also increases the pH from 3.0 to 4.0.
n) The pH measurement by the colour of solution and the pH paper are identical.
o) In distilled water, the universal indicator is a dark yellow colour and has a pH of 7.0.
p) The addition of the acid HCl decreased the pH of the distilled water solution and the buffer solution. The distilled water solution decreased from a pH of 7.0 to 2.0, and the buffer solution decreased from 4.0 to 3.0 (both were light yellow colours).
q) The two pH's are identical considering the colour of the indicator is the same as the colour that is shown on the pH paper.
r) The addition of a base increased the pH of the distilled water solution and barely increased the pH of the buffer solution. The pH of the distilled water solution increased from 7.0 to 13.0 which was a very dark blue colour. The pH of the buffer solution only increased from 4.0 to 5.0.

$4Cl^- (aq) + [Co(H_2O)_6]^{2+} (aq) \gg [CoCl_4]^{2-} (aq) + 6 H_2O (l)$

t) At room temperature, $CoCl_2$ (aq) is red and translucent.
u) When 12.0M HCl is added the solution became a dark blue. This takes place because the concentration of Cl^- (aq) increases when HCl (aq) is added which then forms $CoCl_4^{2-}$ (aq), which is dark purple/blue. This means the reaction is product favoured.
v) Adding water to the solution becomes pink because water increases the concentration of the product, which will push the reaction to the reactants, thus forming more of $Co(H_2O)_6^{2+}$ (aq), which will give the pink colour of $CoCl_2$ (aq).
dd) When the solution is placed in boiling water, it becomes dark purple. This happens as the solution warms because the products are favoured and the solution becomes dark purple. Since the reaction favours products upon addition of heat in the solution, the reaction is endothermic.

$4 Br^- (aq) + [Cu(H_2O)_4]^{2+} (aq) \gg [CuBr_4]^{2-} (aq) + 4 H_2O (l)$

w) The appearance of $CuBr_2$ (aq) is black, glossy, and grainy.
x) After 5 drops of distilled water were added, the solution turned very dark brown, almost black.
y) After 10 drops of distilled water were added (about 15 in total), the solution was dark brown.
z) After 2 mL of water was added, the solution was a translucent light green which means the reactants were favoured.
aa) The solid KBr is white, and grainy.
bb) The solution its dark green with brown residue when adding KBr to a solution of diluted $CuBr_2$ (aq). The addition of KBr increases the concentration of Br^- (aq) and balance the changes to the products which gives it the dark green colour. The residue is produced as a result of the supersaturation of the solution.
cc) By heating the solution, the solution is separated to create two solutions, dark brown and the other is dark green favouring the products.

Calculations:

1. pH of water = 7.0

2. pH of buffer

Ka = 1.8×10^{-5}

$[CH_3COOH]_f = [CH_3COOH]_i \times (V_{CH3COOH}/V_T)$
$= (0.1\ mol/L)\ (10\ drops/20\ drops)$
$[CH_3COOH]_f = 0.05\ mol/L$

$[NaCH_3COOH]_f = [NaCH_3COO]_i \times (V_{NaCH3COO}/V_T)$
$= (0.1\ mol/L)\ (1\ drop/2\ drops)$
$[NaCH_3COOH]_f = 0.05\ mol/L = [CH_3COO^-]$

pH = pKa + log [A]/[HA]
$pH = -\log(1.8 \times 10^{-5}) + \log(0.05M/0.05M)$
pH = 4.70

3. pH of Acid and Water
$H_2O(l) + HCL(aq) \rightarrow H3O^+(aq) + Cl^-(aq)$
$[HCl^-] = [H^+]_f = [H^+]_i\ (V_{HCl}/V_T)$
$= (0.1\ M)\ (5\ drops/25\ drops)$
$[H^+]_f = 0.02\ mol/L$
$pH = -\log[H^+]$
pH = -log(0.02M)
pH = 1.70

The pH of water changes from 7.0 to 1.70 with the addition of HCl.

4. pH of base and water
$H_2O(l) + NaOH\ (aq) \rightarrow Na^+(aq) + OH^-(aq) + H_2O(l)$
$[NaOH] = [OH^-]_f = [OH^-]_i\ (V_{NaOH}/V_T)$
$= (0.1\ M)\ (5\ drops/\ 25\ drops)$
$[OH^-]_f = 0.02M$
$pOH = -\log[OH^-]$
pOH = -log(0.02M)
pOH = 1.7

pH = 14 - pOH

pH = 14 - 1.7
7.0 to 12.3
pH = 12.3

The pH of water changes from
with the addition of NaOH.

5. pH of acid and buffer

$CH_3COO^-(aq) + HCl(aq) \rightarrow CH_3COOH(aq) + Cl^-(aq)$

0.05 mol/L (20 drops/25 drops) = 0.04 mol/L
0.1 mol/L (5 drops/25 drops) = 0.02 mol/L
0.05 mol/L (20 drops/25 drops) = 0.04 mol/L

I	0.04M	0.02M	0.04M	—
C	-0.02M	- 0.02M	+0.02M	—
E	0.02M	0	0.06M	—

pH = pKa + log[A]/[HA]
$pH = -\log(1.8\times10^{-5}) + (0.02M/0.06M)$
pH = 4.3

6. pH of base and buffer

$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COO^-(aq) + Na + H_2O(l)$

0.05 mol/L (20 drops/25 drops) = 0.04 mol/L
0.1 mol/L (5 drops/25 drops) = 0.02 mol/L
0.05 mol/L (20 drops/25 drops) = 0.04 mol/L

I	0.04M	0.02M	0.04M	—
C	-0.02M	- 0.02M	+0.02M	—
E	0.02M	0	0.06M	—

pH = pKa + log[A]/[HA]
$pH = -\log(1.8\times10^{-5}) + (0.06M/0.02M)$
pH = 5.2

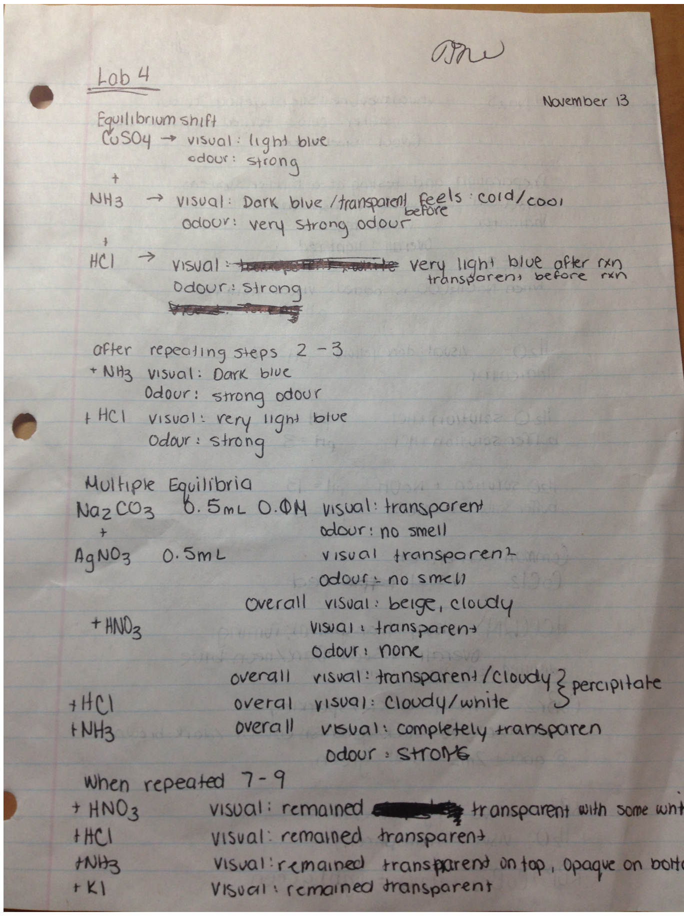
Additional Discussion:

During the experiment, the effect of various factors such as temperature, the common ion effect, and the addition of products or reactants on a system were observed. LeChatlier's principle was used to explain our observations during this lab. In addition, the Henderson-Hasselbalch equation was used to calculate the theoretical pH of the buffers and distilled water which was observed during the experiment. However, the results for the pH's are not the same as the theoretical pH's. This is caused by source of error. A significant source of error is the inaccuracy of the pH papers since they only measure to whole numbers. This causes the data the vary but a lot. For instance, for buffers with NaOH, the experiment has demonstrated that there has been no change in pH. However, after the theory, it changed from 4.0 to 4.3. Both figures rounded to whole numbers, in this case 4.0, which demonstrated no change. Another source of error is if before the experiment, there was residue left in the test tubes or beakers that could have reacted with the solutions. This could explain why some of the pH values could have been drastically different.

Conclusion:

In conclusion, the equilibrium of reactions could be manipulated to favour either the products or reactants. Water underwent a large change in pH when acid and base was added, while the buffer went under little change in pH. The heat pushes the equilibrium towards the products for the endothermic reaction and to the reactants for the exothermic reaction in our lab.

Raw Data:



Lab 4

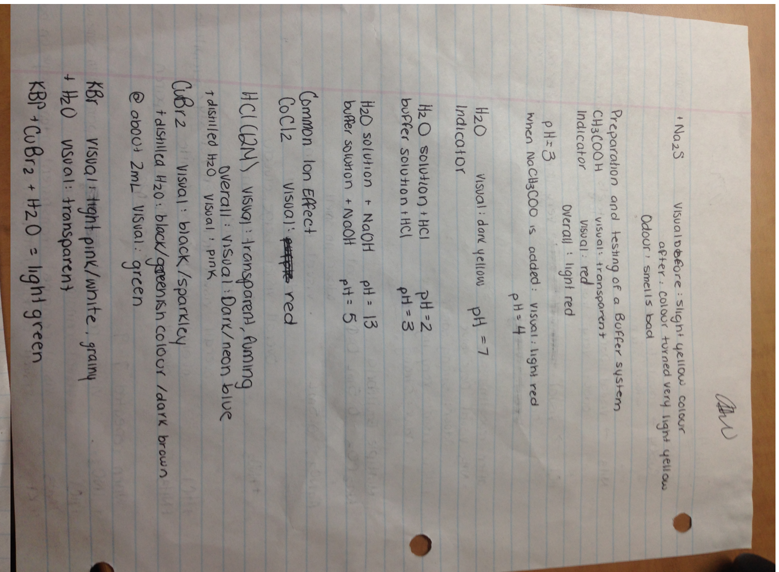
November 13

Equilibrium shift
$CuSO_4$ → visual: light blue
odour: strong
+
NH_3 → visual: Dark blue / transparent before, feels cold/cool
odour: very strong odour
+
HCl → visual: ~~transparent / white~~ very light blue after rxn, transparent before rxn
odour: strong

after repeating steps 2 - 3
+ NH_3 visual: Dark blue
Odour: strong odour
+ HCl visual: very light blue
Odour: strong

Multiple Equilibria
Na_2CO_3 0.5mL 0.0M visual: transparent
odour: no smell
+
$AgNO_3$ 0.5mL visual transparent
odour: no smell
overall visual: beige, cloudy
+ HNO_3 visual: transparent
odour: none
overall visual: transparent/cloudy } percipitate
+HCl overal visual: Cloudy/white
+NH_3 overall visual: completely transparen
odour: strong

when repeated 7 - 9
+ HNO_3 visual: remained ~~[illegible]~~ transparent with some wht
+HCl visual: remained transparent
+NH_3 visual: remained transparent on top, Opaque on botto
+ KI visual: remained transparent



+ Na_2S visual before: slight yellow colour
after: colour turned very light yellow
Odour: smells bad

Preparation and testing of a Buffer system
CH_3COOH visual: transparent
Indicator visual: red
Overall: light red
pH = 3
when $NaCH_3COO$ is added: visual: light red
pH = 4

H_2O visual: dark yellow pH = 7
Indicator

H_2O solution + HCl pH = 2
buffer solution + HCl pH = 3

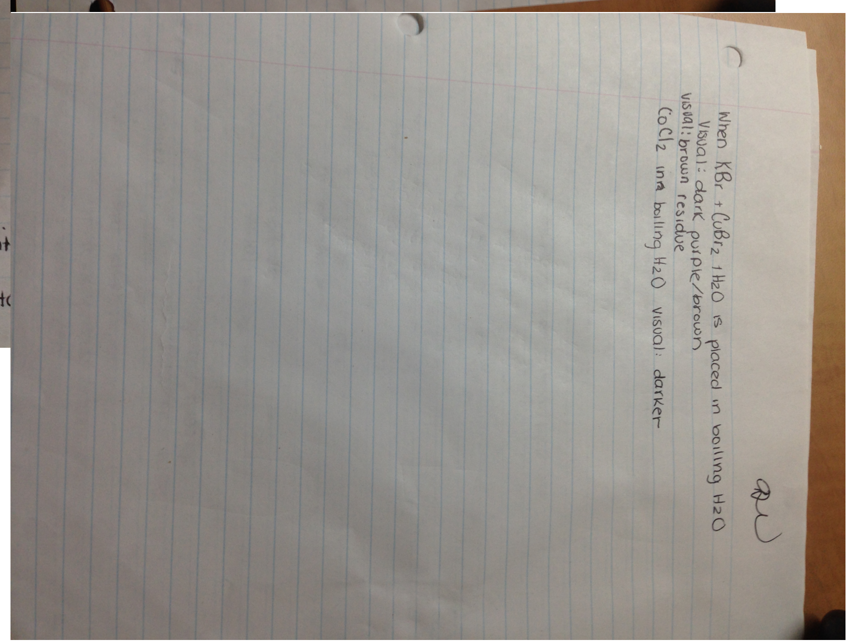
H_2O solution + NaOH pH = 13
buffer solution + NaOH pH = 5

Common Ion Effect
$CoCl_2$ visual: ~~purple~~ red

HCl (12M) visual: transparent, fuming
overall: visual: Dark/neon blue
+ distilled H_2O visual: pink

$CuBr_2$ visual: black/sparkley
+ distilled H_2O: black/greenish colour / dark brown
@ about 2mL visual: green

KBr visual: light pink/white, grainy
+ H_2O visual: transparent
KBr + $CuBr_2$ + H_2O = light green



When KBr + $CuBr_2$ + H_2O is placed in boiling H_2O
Visual: dark purple/brown
visual: brown residue
$CoCl_2$ in a boiling H_2O visual: darker