Indian Institute of Technology Jammu
Department of Chemical Engineering

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EXPERIMENT #6

pH titration to study the buffering activity of a given Carbonate – Bicarbonate Buffer

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EXECUTIVE SUMMARY	(05)	______
INTRODUCTION/OBJECTIVES/SCOPE/PROCEDURE	(25)	______
RESULTS & DISCUSSION	(40)	______
a) Data analysis and interpretation of information		
b) Presentation of relevant information (including results on graphical, tabular or equation forms)		
CONCLUSIONS	(05)	______
REFERENCES	(05)	______
APPENDIX		
a) Original data, sample calculations, BioCOSHH	(05)	______
GENERAL COMPLETENESS		
a) Conciseness and neatness	(05)	______
VIVA-VOCE	(10)	______
TOTAL	(100)	______

FEEDBACK SHEET

भारतीय प्रौद्योगिकी संस्थान जम्मू
INDIAN INSTITUTE OF TECHNOLOGY JAMMU

EXECUTIVE SUMMARY :-

This experiment intended to investigate the buffering activity of a given carbonate-bicarbonate buffer solution using pH titration with a prepared and standardized 0.1N HCl solution. We put 100 mL of a particular buffer solution into a beaker for pH titration. Then, each time, we poured 1 mL of a prepared HCl solution into the beaker containing the buffer solution and kept track of the results. pH readings and changes in pH were taken until the buffer solution's pH reached a stable acid condition.

INTRODUCTION :-

A buffer is an aqueous solution that can resist significant changes in pH levels upon adding a small amount of acid or alkali. Each buffer is characterized by a set 'capacity', which is defined as the quantity of strong acid or base that must be added to change the pH of one liter of the solution by one pH unit. In other words, buffer capacity is the amount of acid or base that can be added before the pH begins to change significantly[1].
A buffer range is the specific pH range in which a buffer effectively neutralizes the added acid or base while maintaining a nearly constant pH. The capacity and range of a particular buffer ensure that the added small amount of acid/base is neutralized and the chemical reaction keeps going without giving a wrong outcome for the experiment/process. Simply put, a buffer is a mixture of a weak acid and its conjugate base or a weak base and its conjugate acid[1].

Buffer solution characteristics:
The pH value does not change when the solution is kept for a long period. Dilution does not affect the pH of the solution. Even a modest amount of a strong acid or a strong base does not affect its pH[2].
We used a carbonate-bicarbonate buffer system in our experiment, which might include carbonic acid and bicarbonate. H CO 2 3 is a weak acid, while HCO3 is a bicarbonate anion, which is the conjugate base. In this is the case, the following is the reaction equation:-

$$CO_2 + H_2O \rightleftarrows H_2CO_3 \rightleftarrows HCO_3^- + H^+$$

Buffering capacity:
Buffer capacity quantifies the ability of a solution to resist changes in pH by either absorbing or desorbing H+ and OH- ions. When an acid or base is added to a buffer system, the effect on pH change can be large or small, depending on both the initial pH and the capacity of the buffer to resist change in pH[3].
Buffer capacity (β) is defined as the moles of an acid or base necessary to change the pH of a solution by 1, divided by the pH change and the volume of the buffer in liters; it is a unitless number. A buffer resists changes in pH due to the addition of an acid or base through the consumption of the buffer. As long as the buffer has not been completely reacted, the pH will not change drastically. The pH change will increase (or decrease) more drastically as the buffer is depleted: it becomes less resistant to change[3].

OBJECTIVE :-

To study the buffering activity of a given Carbonate-Bicarbonate Buffer by titrating it with a standardized 0.1N HCl.

SCOPE :-

We can create and standardize 0.1N HCl using a prepared 0.1N Na_2CO_3 solution and Phenolphthalein as an indicator in this experiment. We can compare the observed and theoretical values of the HCl concentration used in the titration. Also, by producing a graph between the volume of standardized 0.1N HCl added and the pH reading, we may assess the buffering activity of a given buffer solution.

REQUIREMENTS :-

HCl (Sigma Aldrich 37% V/V pure stock solution, ACS Reagent), Na_2CO_3(Sigma Aldrich, ACS Reagent), Deionised water, Phenolphthalein(sigma aldrich, ACS reagent), 0.2M Carbonate-Bicarbonate Buffer, pH meter (HANNA edge pH, made in Romania), magnetic stirring motor (REMI 5 MLH PLUS), magnetic stirring bar, 25mL burette with a least count of 0.1mL, funnel, measuring cylinders and beakers, analytical weighing balance, watch glass.

PROCEDURE :-

Preparation of 0.1N Na_2CO_3 :

We took 50 ml of distilled water in a beaker(we marked it as beaker 'A'). Then 0.265g of Na_2CO_3 powder was taken (weighed using an analytical weighing balance), and put it into the beaker containing 50 ml distilled water and mixed them.

Preparation of 0.1N HCl :

We took 300ml of distilled water in a beaker(we marked it as beaker 'B'). Then we added 2.5ml of 37% (V / V) HCl in the same beaker with the help of a measuring cylinder.

Standardization of 0.1N HCl :

We took three beakers, and in each beaker, we added 10ml of prepared 0.1N HCl solution from beaker 'B' with the help of a measuring cylinder. Then we added 2-3 drops of Phenolphthalein to each of the three beakers. After that, we filled the burette with the prepared 0.1N Na_2CO_3 solutions from beaker 'A'. Then we titrated the HCl solution in the three beakers. The color was changed from colorless to pink. We took the readings of the Na_2CO_3 used in each titration. Using those readings, we calculated the experimental value of the concentration of HCl solution.

pH titration of the given 0.2M carbonate bicarbonate buffer:

We used a clean burette and filled it with 0.1N HCl from Beaker 'B'. Then we took 100 mL of carbonate bicarbonate buffer solution to another beaker (marked as beaker 'C'). The pH meter probe was then cleaned in distilled water and gently wiped with tissue paper. It didn't need to be calibrated because it had already been calibrated for our experiment. The pH of the buffer solution in beaker 'C' was tested and recorded. We placed the magnetic stirring bar into the beaker C and put that beaker onto the magnetic stirring motor. The pH meter probe was then carefully put into the beaker 'C', and the stirring motor was set to 150 rpm. Then we titrated the buffer solution in beaker 'C' with HCl in the burette. We noted the pH readings after adding 1ml of HCl solution until pH was stable in the acid region.

RESULTS & DISCUSSION:-

Standardization of HCl solution:

Vol. of 0.1 N HCl (mL)	Vol. of 0.1N Na2CO3 solution used (mL)	Average vol. of Na2CO3 used (ml)
10	10.1	10.166
10	10.2	
10	10.2	

Table 1: Titration Observations of HCl solution with Na_2CO_3 solution

Let
N1 = Normality of HCl
V1 = Volume of HCl used = 10mL
N2 = Normality of Na2CO3 used = 0.1N
V2 = Volume of Na2CO3 used = 10.166mL

From N1V1 = N2V2,
N1 = (0.1*10.166)/10
= 0.10166 N
N1 ≈ 0.1N

Table 2: pH titration of the given 0.2M carbonate bicarbonate buffer

Vol. of 0.1 N HCl added (ml)	pH reading	Change in pH reading
0	10.79	0
1	10.78	0.01
2	10.77	0.02
3	10.76	0.03
4	10.75	0.04
5	10.74	0.05
6	10.73	0.06
7	10.72	0.07
8	10.71	0.08
9	10.7	0.09
10	10.69	0.1
11	10.68	0.11

12	10.67	0.12
13	10.66	0.13
14	10.65	0.14
15	10.64	0.15
16	10.63	0.16
17	10.62	0.17
18	10.61	0.18
19	10.6	0.19
20	10.59	0.2
21	10.58	0.21
22	10.57	0.22
23	10.56	0.23
24	10.55	0.24
25	10.54	0.25
26	10.53	0.26
27	10.52	0.27
28	10.51	0.28
29	10.5	0.29
30	10.49	0.3
31	10.48	0.31
32	10.47	0.32
33	10.46	0.33
34	10.45	0.34
35	10.44	0.35
36	10.43	0.36
37	10.42	0.37
38	10.41	0.38
39	10.4	0.39
40	10.39	0.4
41	10.38	0.41
42	10.37	0.42
43	10.36	0.43
44	10.35	0.44
45	10.34	0.45
46	10.33	0.46
47	10.32	0.47

48	10.31	0.48
49	10.3	0.49
50	10.29	0.5
51	10.28	0.51
52	10.27	0.52
53	10.26	0.53
54	10.25	0.54
55	10.24	0.55
56	10.23	0.56
57	10.22	0.57
58	10.21	0.58
59	10.2	0.59
60	10.19	0.6
61	10.18	0.61
62	10.17	0.62
63	10.16	0.63
64	10.15	0.64
65	10.14	0.65
66	10.14	0.65
67	10.13	0.66
68	10.12	0.67
69	10.11	0.68
70	10.1	0.69
71	10.1	0.69
72	10.09	0.7
73	10.08	0.71
74	10.07	0.72
75	10.06	0.73
76	10.06	0.73
77	10.05	0.74
78	10.04	0.75
79	10.03	0.76
80	10.03	0.76
81	10.02	0.77
82	10.01	0.78
83	10	0.79

84	9.99	0.8
85	9.98	0.81
86	9.98	0.81
87	9.97	0.82
88	9.96	0.83
89	9.95	0.84
90	9.95	0.84
91	9.94	0.85
92	9.93	0.86
93	9.93	0.86
94	9.92	0.87
95	9.91	0.88
96	9.9	0.89
97	9.89	0.9
98	9.89	0.9
99	9.88	0.91
100	9.87	0.92
101	9.87	0.92
102	9.86	0.93
103	9.85	0.94
104	9.84	0.95
105	9.84	0.95
106	9.83	0.96
107	9.82	0.97
108	9.81	0.98
109	9.81	0.98
110	9.8	0.99
111	9.79	1
112	9.78	1.01
113	9.77	1.02
114	9.77	1.02
115	9.76	1.03
116	9.75	1.04
117	9.74	1.05
118	9.74	1.05
119	9.73	1.06

120	9.72	1.07
121	9.71	1.08
122	9.7	1.09
123	9.7	1.09
124	9.69	1.1
125	9.68	1.11
126	9.67	1.12
127	9.67	1.12
128	9.66	1.13
129	9.65	1.14
130	9.64	1.15
131	9.63	1.16
132	9.63	1.16
133	9.62	1.17
134	9.62	1.17
135	9.61	1.18
136	9.6	1.19
137	9.59	1.2
138	9.58	1.21
139	9.57	1.22
140	9.57	1.22
141	9.56	1.23
142	9.55	1.24
143	9.54	1.25
144	9.53	1.26
145	9.53	1.26
146	9.52	1.27
147	9.51	1.28
148	9.5	1.29
149	9.49	1.3
150	9.48	1.31
151	9.48	1.31
152	9.47	1.32
153	9.45	1.34
154	9.45	1.34
155	9.45	1.34

156	9.44	1.35
157	9.43	1.36
158	9.41	1.38
159	9.4	1.39
160	9.39	1.4
161	9.38	1.41
162	9.37	1.42
163	9.37	1.42
164	9.36	1.43
165	9.34	1.45
166	9.32	1.47
167	9.3	1.49
168	9.29	1.5
169	9.28	1.51
170	9.26	1.53
171	9.24	1.55
172	9.22	1.57
173	9.2	1.59
174	9.19	1.6
175	9.18	1.61
176	9.17	1.62
177	9.15	1.64
178	9.13	1.66
179	9.12	1.67
180	9.1	1.69
181	9.08	1.71
182	9.05	1.74
183	9.02	1.77
184	9	1.79
185	8.98	1.81
186	8.96	1.83
187	8.94	1.85
188	8.92	1.87
189	8.87	1.92
190	8.85	1.94
191	8.81	1.98

192	8.79	2
193	8.78	2.01
194	8.75	2.04
195	8.7	2.09
196	8.67	2.12
197	8.63	2.16
198	8.58	2.21
199	8.46	2.33
200	8.39	2.4
201	8.34	2.45
202	8.29	2.5
203	8.23	2.56
204	8.12	2.67
205	7.93	2.86
206	7.73	3.06
207	7.57	3.22
208	7.45	3.34
209	7.36	3.43
210	7.29	3.5
211	7.26	3.53
212	7.17	3.62
213	7.09	3.7
214	7.04	3.75
215	6.93	3.86
216	6.88	3.91
217	6.82	3.97
218	6.78	4.01
219	6.76	4.03
220	6.72	4.07
221	6.69	4.1
222	6.65	4.14
223	6.61	4.18
224	6.6	4.19
225	6.6	4.19
226	6.6	4.19
227	6.6	4.19

228	6.59	4.2

On plotting the data given in Table 2 on the graph, we get the pH titration curve of the given carbonate – bicarbonate buffer as shown in Fig 1 below.

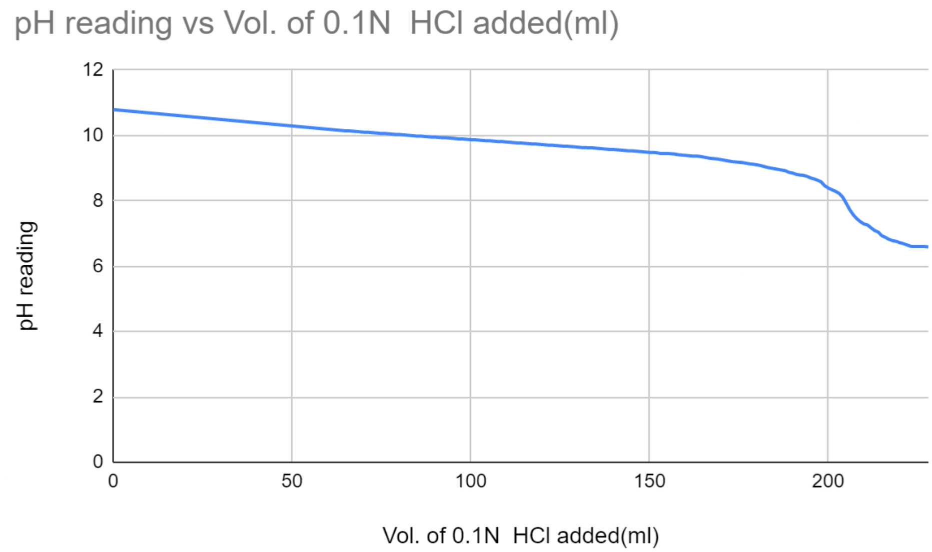

Fig 1: pH Titration Curve of the carbonate – bicarbonate buffer

The change in pH after adding 1 mL of HCl solution is merely 0.01, as seen in the data table (Table 2) above. The pH changes by 0.1 after adding 10 mL of HCl solution and changes to 0.5 after adding 50 mL of HCl solution. The pH changes by 0.92 after adding 100 mL of HCl solution. These are the minor pH changes as compared to the volume of acid added. This demonstrates that the carbonate-bicarbonate buffer solution can withstand a significant pH fluctuation and thus has a high buffering capacity.
The graph (Figure 1) shows that the change in pH is relatively small compared to the addition of H+ ions because carbonate ions and bicarbonate ions are in equilibrium (i.e., bicarbonate and carbonic acid.) As the curve moves out of the buffer zone, the pH decreases significantly because if we supply strong acids over a long period, the extra protons will get free within a certain limit.

Buffering capacity(β)

$$\beta = \frac{\Delta n}{\Delta pH}$$

Δn = number of moles of an acid or a base added per liter of buffer solution
ΔpH = change in pH

Let the volume of HCl added = 199mL
Then, number of moles of HCl added = 0.0199 mols
Volume of the buffer solution added = 0.1L
Δn = 0.0199/0.1 = 0.199 mol/L
ΔpH = 2.18 pH units

Therefore,

$$\beta = 0.199/2.33$$
$$= 0.0854$$

CONCLUSIONS:-

We were able to standardize the 0.1N HCl solution successfully. pH titration allowed us to study the action and behavior of the carbonate-bicarbonate buffer solution. The pH of the carbonate-bicarbonate buffer solution was 10.79 at first, indicating an alkaline buffer. On adding HCl solution to the buffer, the pH drops slowly at first. However, pH drops faster after adding 199ml of acid, as shown in both the graph (Fig 1) and the data table (Table 2). Thus we may conclude from the above experiment that carbonate-bicarbonate solution has a good buffering capacity and can resist changes even when small amounts of acid are present. Also, we were able to observe some brisk effervescence of CO2 .

RECOMMENDATIONS:-

Place the pH probe in the beaker with extreme caution to avoid damaging the electrode with the stirring bar. Wait for the pH meter reading to stabilize before taking it. A proper calibration of the equipment measuring the pH of the solution is one recommendation.

REFERENCES:-

1. https://westlabblog.wordpress.com/2017/03/29/what-is-a-buffer-and-how-does-it-work/
2. https://thefactfactor.com/facts/pure_science/chemistry/physical-chemistry/buffer-solution/9059/
3. https://research.cbc.osu.edu/reel/research-modules/environmental-chemistry/methods/buffer-capacity/#:~:text=Buffer%20capacity%20(%CE%B2)%20is%2

APPENDIX:-

BioCOSHH Risk Assessment (Attached)
Material Safety Data Sheet (MSDS)
1. 0.1N HCl (Attached)
2. 0.1N Na_2CO_3(Attached)
3. Phenolphthalein (Attached)