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Adsorption of zinc ion (Zn^{2+}) on manganese (IV) oxide (MnO_2) in a leclanche dry cell

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ABSTRACT

This work was carried out to study the adsorption of zinc nitrate $(Zn(NO_3)_2)$ on manganese (IV) oxide (MnO_2) in a leclanche dry cell. The aim of the study is to optimize the process for the adsorption of zinc ion on MnO_2 in a leclanche dry cell using a second order factorial method. Potentiometric titration method was the adsorption method used. Considering the temperature effect on electric surface charge, pH respond during titration, concentration effect on adsorption and surface charge and the nature of cation, results obtain show that adsorption is inversely proportional to temperature, in other words, as temperature of cation increases, the adsorption capacity on MnO_2 decreases at a given concentration. Also at a given temperature adsorption capacity increases as the concentration of the adsorbent increases. The highest adsorption capacity was observed at 0.1M for Zn^{2+} at $28^{\circ}C$.

Key words: Adsorption, zinc nitrate (Zn(NO₃)₂), manganese (IV) oxide, potentiometric, concentration, adsorbent.

INTRODUCTION

An electrochemical cell is a device designed to produce electrical energy as the primary output product with the cell itself undergoing a chemical transformation (reaction). Conversely, in cell some chemical reaction can be made to occur through ionic mechanism by passing electric energy into the cell (as a form of secondary input). The latter is an electrochemical cell called an electrolytic cell while the former is called the galvanic cell.

This work is focused on the galvanic cell and attempt to provide detail analysis of the adsorption of cation that has influenced the cell's life span. Adsorption is a process that occurs when a gas or liquid solute accumulates on the surface of a solid or a liquid (adsorbent), forming a film of molecules or atoms (the adsorbate). The galvanic cell can further be classified into primary cell, secondary cell and fuel cells. One common division of batteries distinguishes two types: primary (disposable) and secondary (rechargeable). Primary batteries are designed to be used once only because they use up their chemicals in an effectively irreversible reaction while secondary can be recharge because the reactions are reversible. The area of study is centered around the primary cell also known as the Leclanche cell. The Leclanche or dry cell consist of a positive electrode of finely divided carbon and manganese (IV) oxide packed around carbon rod terminal which is placed in between the cell and the negative pole of zinc, Zn, which makes up the case of the cell. The electrolyte consist of moist mixture of ammonium chloride (NH₄Cl), manganese (IV) oxide MnO₂, zinc chloride ZnCl₂, and a porous inner filter which occupy the space between the paper-line zinc Zn container and the graphite (carbon) rod.

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The primary cells are cells which once the electrolyte has been consumed, further chemical action is impossible and the electrolyte cannot be regenerated by reversing the electric current through the cell as is always the case with electrolytic cell. This is due to locally familiar phenomenon called polarization [1].

Polarization in dry cells (primary cells) is corrected by Manganese (IV) oxide MnO_4 . However, it has been discovered that the rate at which hydrogen bubbles is produced in the cell is much faster than the rate at which the manganese (IV) oxide which act as the depolarizer absorbs it from the electrolyte.

Experiment (potentiometric titration) reveals that some cations which add to the cell enhance the performance of MnO_2 thereby increasing the life-span of the dry cell [2].

The method of factorial experimental design forces data to be orthogonal. This method allows one to determine the relative importance of each input variable and thus to develop a parsimonious model, one that includes only the most important variables and effects [3].

Electric charge is the quantity of electric charge that flows in an electric circuit or that accumulates on the surface dissimilar non-metallic substances that are rubbed together vigorously. Electric charges are either positive or negative and are considered in any system, which is whether chemical or nuclear reaction, the net electrical charge is constant [4]. Thus the surface electric charge is

 $E=nF\theta \ 1.1$

Where

E is the surface electric charge (cmol/cm²) n is the number of ionic charge of the substance F is Faraday's constant i.e. 96500C Θ is the adsorption (mol/cm²)

Electrochemistry is the science dealing with the chemical changes accompanies the passage of an electric current, or the reverse process in which a chemical reaction is used as source of energy to produce an electric current as in the battery. Electric conduction occurs through the motion of charged particles. The charged particles maybe electrons or ions, which are electrically, charged atoms, molecules or molecules aggregates [5]. The overall reaction in a zinc-carbon cell can be represented as:

 $Zn(s) + 2 MnO_2(s) + 2 NH_4^+ (aq) \rightarrow Mn_2O_3(s) + Zn (NH_3)_2^{2+} (aq) \dots 1.2$

In 1866, Georges Leclanché invented a battery that consisted of a zinc anode and a manganese dioxide cathode wrapped in a porous material, dipped in a jar of ammonium chloride solution. The manganese dioxide cathode had a little carbon mixed into it as well, which improved electrolyte conductivity and absorption [6]. In 1887 Carl Gassner patented a variant of the Leclanché cell which came to be known as the dry cell because it did not have a free liquid electrolyte. Instead, the ammonium chloride was mixed with Plaster of Paris to create a paste, with a bit of zinc chloride added in to extend the shelf life. The manganese dioxide cathode was dipped in this paste, and both were sealed in a zinc shell which also acted as the anode [7].

The zinc-carbon battery (as it came to be known) is still manufactured today.

In parallel, in 1887 Frederick Louis Wilhelm Hellesen's developed his own dry cell design. It has been claimed that Hellesen's design preceded that of Gassner [8].

The aim of this work is to optimize the process for the adsorption of Zn ion on MnO_2 in a Leclanche dry cell battery using a second order factorial method.

The objectives of this research work are: To improve the rate of Zn ion adsorption on MnO_2 , To improve the efficiency of MnO_2 as a depolarizer, To increase the life-span of a Leclanche dry cell battery, To increase the rate of removal of hydrogen bubbles in a Leclanche dry cell.

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MATERIALS AND METHODS

2.1 MATERIAL

The materials used consist of the materials for the adsorption from solution experiment for the determination of specific area of manganese dioxide (MnO_2) and that used for the potentiometric titration. These materials include reagents and apparatus (equipment).

These materials includes manganese dioxide (MnO_2), sodium hydroxide (NaOH), acetic acid (CH_3COOH), phenolphthalein, zinc nitrate ($Zn(NO_3)_2$), nitrogen gas, 250 ml beaker, 250 ml Erlenmeyer flask with stopper, 50 ml burette, 100 ml titration conical flask, funnel, analytical balance, 25 ml pipette, spatula, wash glass, fine porosity filter paper, pH meter, (3071), hot/plates magnetic stirrer, magnetic follower, weighing balance, 50 ml burette, 25 ml pipette, 100 ml beaker, 250 ml beaker, 250 ml conical flask, 250 and 500 mls measuring cylinders, 500 ml volumetric flask, nitrogen gas and regulator, tripod stand and damp, and thermometer.

The aim of this research work is to optimize the process for the adsorption of Zn ion on MnO_2 in a Leclanche dry cell battery using a second order factorial method.

The objectives of this work are: To improve the rate of Zn ion adsorption on MnO_2 ; To improve the efficiency of MnO_2 as a depolarizer; To increase the life-span of a Leclanche dry cell battery; To increase the rate of removal of hydrogen bubbles in a Leclanche dry cell.

2.2 METHOD

2.2.1 Procedure for Determination of surface area of MnO₂

Seven cleaned and dried 250ml Erlenmeyer flask were filled with 100ml of acetic acid each. The concentration were ranging from 0.015m, 0.03m, 0.06m, 0.09m, 0.12m, 0.15m and the seventh flask contained 0.015 acetic and serve as control. 2g of manganese (IV) oxide (MnO_2) was weighed and put into the six flasks. The entire seven flasks were then stopped with plastic or rubber cork and each flask was shaken intermittently and after 30 minutes were put into a water bath at 25^oC to stand for 24hours. After 24 hours, the equilibrium was reached. The solution was filtered into seven separate conical flasks; precaution was taken against adsorption of the acid by the acid by the filter paper by decanting the first 10ml from each flask.

Two 25ml of each decanted solution was titrated against 0.1m sodium hydroxide solution using phenolphthalein as an indicator. The concentrations of the acetic acid solutions were calculated, the numbers of moles present before and after adsorption were calculated and the difference obtained. The values were used to calculate values for C/N, tables 3.1 to 3.2, and a plot of C/N against C shown in appendix A was drawn. The slope of the straight line obtained was calculated and used for the calculation of the adsorption area of manganese (IV) oxide (MnO₂).

2.2.2 Procedure for Potentiometric titration

A 100ml beaker was cleaned and rinsed with distilled water, a 50ml of 1m lead nitrate $(Zn(NO_3)_2)$ was measured with a 50ml pipette and transferred into the beaker, the magnetic follower was washed and rinsed and placed into this beaker to provide a continuous stirring.

This was then placed on the magnetic stirrer. The indicator with a built in reference electrode hanging from the clamp of the retort stand was adjusted to sit in the liquid in this beaker. The nozzle of the nitrogen gas cylinder was dipped into the solution. Furthermore a burette filled with 0.1m of sodium hydroxide (NaOH) solution was also placed such that it tip was directly pointed to the solution in the 100ml beaker.

The magnetic stirrer was turned on as the nitrogen gas valve is opened. Nitrogen gas flows into the liquid to remove oxygen from the solution being stirred. It is noticed by the bubbling within the fluid.

The pH meter connected to the electrode fluctuated and final figure is read when it stabilizes. After a while the reading of the stabilized pH meter without a titrant (NaOH) was recorded. Subsequently 0.5ml of the titrant (NaOH) was added from the burette and the pH meters reading recorded after 60 seconds when the indicator electrode has reached a constant value. The 0.5ml increment and the corresponding pH readings were recorded for a total of 10.00ml additions when no significant change was observed in the pH reading. At the end both thee magnetic stirrer and the pH meter were turnoff and the solution mixture discarded.

The process was repeated after the pH meter was stabilized with distilled water, this time 2g of manganese (IV) oxide (MnO_2) was added to the titrant $[Zn(NO_3)_2]$ and the entire process repeated for various concentrations of the titrant (1, 0.1, 0.01. and 0.001m) at two different temperature (28°C&30°C) for with and without MnO₂. The temperature was elevated with the aid of pH meter.

The whole procedure was also repeated using zinc nitrate $[Zn(NO_3)_2]$ solution for various concentration (1, 0.1, 0.01, and 0.001m) at two different temperatures (28°C and 30°C) both for with and without manganese (iv) oxide (MnO₂).

The volumetric readings of 0.1m NaOH and their corresponding pH reading for all the classes of titration carried out were tabulated in tables 3.3 and 3.4.

RESULTS

The experimental data and data analysis obtained are shown below.

 Table 3.1 Result from the titration of 0.1M NaOH versus Various concentration of acetic acid

Initial concentration of acetic acid(M)	0.015	0.03	0.06	0.09	0.12	0.15
Volume of acetic acid(M)	25	25	25	25	25	25
Volume of 0.1M NaOH (ml) (Average titre)	0.8	5.01	15.9	23.70	33.40	41.60

 Table 3.2 Concentration and number of moles adsorbed, Derived from Table 3.1

$C_1(M)$	0.015	0.03	0.06	0.09	0.12	0.15
С	0.0032	0.0200	0.0636	0.0948	0.1336	0.1664
$N = C - C_1$	-0.0118	-0.279	0.0036	0.0048	0.0136	0.0164
C/N	-0.27118	-0.214	17.667	19.75	9.824	10.1463

3.1 Result of titration of NaOH versus Zn(NO₃)₂

	1M Zn($NO_3)_2$	0.1M Zn	$(NO_3)_2$	0.01M Zn	$(NO_3)_2$	0.001M Z	n(N0 ₃) ₂
Volume of NaOH	Without	With	Without	With	Without	With	Without	With
(ml)	MnO ₂							
		·		pH Re	eading			-
0.0	8.04	7.59	8.77	7.78	9.12	7.94	9.15	7.88
0.5	9.86	8.35	10.54	8.41	10.84	8.83	10.93	9.13
1.0	10.08	8.86	10.78	8.64	10.98	9.17	11.11	9.66
1.5	10.18	9.15	10.89	8.95	11.08	9.31	11.21	9.70
2.0	10.27	9.42	10.95	9.05	11.17	9.45	11.26	9.97
2.5	10.35	9.48	11.02	9.34	11.21	9.59	11.34	10.18
3.0	10.37	9.51	11.06	9.36	11.24	9.85	11.36	10.31
3.5	10.40	9.75	11.09	9.67	11.27	9.89	11.40	10.42
4.0	10.43	9.90	11.12	9.80	11.30	10.12	11.44	10.49
4.5	10.47	9.97	11.15	9.98	11.32	10.24	11.46	10.54
5.0	10.52	10.01	11.20	10.06	11.34	10.30	11.49	10.59
5.5	10.55	10.08	11.22	10.18	11.36	10.42	11.51	10.63
6.0	10.58	10.14	11.24	10.26	11.40	10.45	11.53	10.67
6.5	10.61	10.18	11.26	10.30	11.43	10.48	11.55	10.72
7.0	10.63	10.23	11.29	10.33	11.46	10.52	11.58	10.75
7.5	10.66	10.25	11.32	10.40	11.48	10.57	11.60	10.78
8.0	10.68	10.27	11.33	10.44	11.50	10.60	11.62	10.81
8.5	10.70	10.30	11.36	10.48	11.52	10.64	11.63	10.84
9.0	10.72	10.32	11.38	10.50	11.54	10.66	11.65	10.86
9.5	10.74	10.38	11.40	10.52	11.56	10.68	11.67	10.87
10.0	10.76	10.40	11.42	10.55	11.57	10.71	11.69	10.89

Table 3.3 $Zn(NO_3)_2$ solution with and without MnO_2 at $28^{0}C$

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Table 3.4 $\text{Zh}(100_{3})_2$ solution with and without WhO_2 at 50 C								
	1M Zn($NO_3)_2$	0.1M Zn	$(NO_3)_2$	0.01M Zn	$(NO_3)_2$	0.001M Z	n(N0 ₃) ₂
Volume of NaOH	Without	With	Without	With	Without	With	Without	With
(ml)	MnO ₂							
				pH Re	eading			
0.0	7.29	7.19	8.69	8.13	9.16	8.30	9.17	8.52
0.5	9.28	8.29	10.60	9.52	11.06	10.30	10.79	9.38
1.0	10.07	9.42	10.95	10.27	11.25	10.84	11.08	10.28
1.5	10.25	9.84	11.13	10.76	11.43	11.10	11.25	10.82
2.0	10.38	10.03	11.24	10.98	11.52	11.27	11.35	10.95
2.5	10.47	10.17	11.32	11.08	11.59	11.34	11.44	11.12
3.0	10.60	10.30	11.40	11.20	11.66	11.42	11.50	11.28
3.5	10.68	10.33	11.45	11.27	11.72	11.49	11.57	11.36
4.0	10.72	10.38	11.50	11.36	11.75	11.56	11.63	11.44
4.5	10.76	10.42	11.56	11.39	11.79	11.62	11.67	11.49
5.0	10.80	10.45	11.59	11.46	11.82	11.64	11.72	11.52
5.5	10.84	10.50	11.61	11.49	11.86	11.67	11.76	11.56
6.0	10.89	10.55	11.64	11.52	11.88	11.72	11.80	11.61
6.5	10.91	10.59	11.67	11.54	11.90	11.75	11.83	11.65
7.0	11.00	10.64	11.70	11.59	11.92	11.78	11.87	11.69
7.5	11.03	10.68	11.73	11.61	11.95	11.80	11.89	11.73
8.0	11.06	10.72	11.76	11.64	11.96	11.82	11.90	11.76
8.5	11.09	10.76	11.79	11.66	11.98	11.84	11.92	11.79
9.0	11.12	10.79	11.81	11.69	11.99	11.86	11.94	11.81
9.5	11.15	10.84	11.83	11.72	12.01	11.87	11.96	11.83
10.0	11.18	10.86	11.85	11.75	12.03	11.89	11.98	11.84

Table 3.4 $Zn(NO_3)_2$ solution with and without MnO_2 at $30^{0}C$

3.2 Result of Adsorption and Electric Surface Charge Data.

Table 3.5 Results of 1M $Zn(NO_3)_2$ at 28°C

P ^H	Change in volume(Δ)ml	Adsorption capacity(0)mol/cm ²	Electric surface charge(E) cmol/cm ²
8.0	0.35	5.201 x 10 ⁻⁸	1.003 x 10 ⁻²
8.5	0.55	8.173 x 10 ⁻⁸	1.577 x 10 ⁻²
9.0	1.10	1.634 x 10 ⁻⁸	3.153 x 10 ⁻³

Table 3.6 Results of 1M Zn(NO₃) at 30°C

P ^H	Change in volume(ΔV) ml	Adsorption capacity(0) mol/cm ²	Electric surface charge(E)
9.0	0.31	4.606 x 10 ⁻⁹	8.889 x 10 ⁻⁴
9.5	0.41	6.093 x 10 ⁻⁸	1.175 x 10 ⁻²
10.0	0.80	1.188 x 10 ⁻⁸	2.292 x 10 ⁻³

Table 3.7 Results of 0.1M Zn (NO₃) at 28° C

pH	Change in volume(ΔV)ml	Adsorption capacity(0) mol/cm ²	Electric surface charge(E) cmol/cm ²
9.0	1.80	2.675 x 10 ⁻⁸	5.162 x 10 ⁻³
9.5	3.15	4.681 x 10 ⁻⁸	9.034 x 10 ⁻³
10.0	4.65	6.910 x 10 ⁻⁸	1.33 x 10 ⁻³

Table 3.8Results of 0.1M Zn (NO3) at 30°C

pН	Change in volume(Δ) ml	Adsorption capacity(0) mol/cm ²	Electric surface charge(E) cmol/cm ²
9.0	0.25	3.715 x 10 ⁻⁹	7.169 x 10 ⁻⁴
9.5	0.25	3.715 x 10 ⁻⁹	7.169 x 10 ⁻⁴
10.0	0.50	7.430 x 10 ⁻⁹	1.433 x10 ⁻³

Table 3.9 Results of 0.01M Zn $(NO_3)_2$ at 28°C

pН	Change in volume(Δv) ml	Adsorption capacity(0) mol/cm ²	Electric surface charge(E) cmol/cm ²
9.0	0.8	1.188 x 10 ⁻⁸	2.292 x 10 ⁻³
9.5	2.29	3.403 x 10 ⁻⁸	6.567 x 10 ⁻³
10.0	3.65	5.424 x 10 ⁻⁸	1.046 x 10 ⁻²

pН	Change in volume(ΔV) ml	Adsorption capacity(θ) mol/cm ²	Electric surface charge(E)cmol/cm ²
9.5	0.21	3.120 x 10 ⁻⁹	6.021 x 10 ⁻⁴
10.0	0.20	2.972 x 10 ⁻⁹	5.735 x 10 ⁻⁴
10.5	0.31	4.606 x 10 ⁻⁹	8.889 x 10 ⁻⁴

Table 3.10 Results of 0.01M Zn $(NO_3)_2$ at 30°C

Table 3.11 Results of 0.001M Zn $(NO_3)_2$ at $28^{\circ}C$

pН	Change in volume(ΔV) ml	Adsorption capacity(0) mol/cm ²	Electric surface charge(E)cmol/cm ²
9.5	0.50	7.430 x 10 ⁻⁹	1.433 x 10 ⁻³
10.0	0.60	8.916 x 10 ⁻⁹	1.720 x 10 ⁻³
10.5	0.81	1.203 x 10 ⁻⁹	2.321 x 10 ⁻³

Table 3.12 Results of 0.001M Zn $(NO_3)_2$ at 30 °C

pН	Change in volume(ΔV) ml	Adsorption capacity(0) mol/cm ²	Electric surface charge(E)cmol/cm ²
9.5	0.70	1.040 x 10 ⁻⁸	2.007 x 10 ⁻³
10.0	1.85	2.749 x 10 ⁻⁸	5.305 x 10 ⁻³
10.5	3.90	5.795 x 10 ⁻⁸	1.118 x 10 ⁻²

Table 3.13 General Design Matrix for Second Order Factorial Method Using Temperature, Concentration, and pH as Factors and Adsorption Capacity as Response.

S/N	Temperature(°C)	Concentration(M)	pН	Adsorption capacity(0)mol/cm ²
1	+	+	+	R ₁
2	-	+	+	\mathbb{R}_2
3	+	_	+	R ₃
4		_	+	R4
5	+	+		R ₅
6	-	+	-	R_6
7	+	_		R ₇
8		_		R ₈

Table 3.14 Factorial design data analysis for Zn (NO₃)₂ solution

S/N	Temperature(°C)	Concentration(M)	pН	Adsorption capacity(0) mol/cm ²
1	30	1.00	10.0	1.188 x 10 ⁻⁸
2	28	1.00	10.0	1.634 x 10 ⁻⁸
3	30	0.001	10.0	5.795 x 10 ⁻⁸
4	28	0.001	10.0	1.203 x 10 ⁻⁸
5	30	1.00	9.5	4.606 x 10 ⁻⁹
6	28	1.00	9.5	5.201 x 10 ⁻⁸
7	30	0.001	9.5	1.40 ×10 ⁻⁸

3.3 Factorial fit of adsorption (Θ) for Zn (NO₃)₂ Estimated effect for adsorption (Θ)

Term	Effect
Constant	$\Theta_{\rm o} = -7.4350 \ {\rm x} \ 10^{-10}$
Temperature	$\Theta_1 = -7.435 \ge 10^{-10}$
Concentration	$\Theta_2 = 5.9385 \text{ x } 10^{-9}$
pH	$\Theta_3 = -2.51885 \times 10^{-8}$
Temperature*concentration	$\Theta_{12} = 2.14735 \text{ x } 10^{-8}$
Temperature*pH	$\Theta_{13} = -2.01365 \times 10^{-8}$
Concentration * pH	$\Theta_{23} = -1.5 \ge 10^{-12}$
Temperature * concentration* pH	$\Theta_{123} = -6.006006 \times 10^{-8}$

Estimated coefficient for adsorption (Θ)

Term	Coefficient
Constant	$a_0 = 1.13016 \text{ x } 10^{-5}$

Temperature(X_1)	$a_1 = -4.06514 \times 10^{-7}$
Concentration (X_2)	$a_2 = 1.51486 \ge 10^{-6}$
pH(X ₃)	$a_3 = -1.19331 \times 10^{-6}$
Temperature*concentration(X_1X_2)	$a_{12} = -2.51551 \times 10^{-8}$
Temperature*pH (X_1X_3)	$a_{13} = 4.29500 \text{ x } 10^{-8}$
Concentration* $pH(X_2X_3)$	$a_{23} = -8.04524 \times 10^{-8}$
Temperature*concentration*pH($X_1X_2X_3$)	$a_{123} = 0.0000$

Model equation for adsorption of $Zn (NO_3)_2$ is :

$$\begin{split} \Theta_{\text{Zn(NO3)2}} = 1.13016x\ 10^{-5} - 4.0651\ x\ 10^{-7}X_1 + 1.51486\ x\ 10^{-6}X_2 + 1.19331\ x\ 10^{-6}X_3 - 2.5155\ x\ 10^{-8}X_1X_2 + 4.29500\ x\ 10^{-8}X_1X_3 - 8.04524\ x\ 10^{-8}X_2X_3\ [9-10] \end{split}$$





Fig:3.1 Main effects plot for adsorption



Fig: 3.2 Interaction plot for adsorption

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Fig: 3.3 cube plot for adsorption

DISCUSSION

3.4.1 pH response during titration.

During the titration, the following observations were deduced;

As the titration proceeds, as more volumes of the titrant were added, the pH solution tends to alkalinity which was because base was use to carry out the adsorption.

For any given amount of zinc ion and lead ion in solution with or without MnO_2 , it was observe that the pH value without is always higher than that of with.

3.4.2 Effect of concentration on adsorption of Zn²⁺

Adsorption at certain pH values of Zn^{2+} increases with concentration, this shows that high concentration result to high adsorbates and vice versa

The maximum value of adsorption obtained for Zn^{2+} is 6.910 x 10^{-8} mol/cm² at 28°C and at 0.1M solution of the cat ion. When this adsorption value is compare to that obtained (1.634 x 10^{-8} mol/cm²) at 28°C for 1M solution of the cat ion, it was found that the latter is at pH of 9.0 while the former is at pH of 10.0 as shown in table 3.7 and 3.5.

3.4.3 Effect of Temperature on adsorption of Zn²⁺

The effect of temperature on adsorption of Zn^{2+} is high and maximum adsorption occurs at 30°C.

3.4.3 Nature of adsorption of cation.

The best way of achieving a higher electric charge and a better output voltage in dry cell is the adsorption of Zn^{2+} . From the data of analysis obtained, 0.1M of solution of Zn^+ cation in the adsorption process is more effective due to it higher adsorption capacity when compare to other concentrations of Zn^{2+} at 28°C. The Zn^{2+} has a maximum value of adsorption at lower concentration of 0.1M at both temperatures (28°C and 30°C).

3.4.4 Optimized result.

From the factorial design analysis of zinc nitrate, the main effect plot for adsorption shows that as temperature increases, the adsorption of Zn^{2+} decreases, also as concentration increases, the adsorption of Zn^{2+} decreases, also as pH value increases, the adsorption of Zn^{2+} increases.

Effect of interaction of factor plot shows that all factors (concentration, temperature and pH) as an opposite effect on adsorption of Zn^{2+} .

CONCLUSION

The pH response of the cation (Zn^{2+}) without MnO₂ is higher than pH with MnO₂. As the concentration gradually diluted, the adsorption capacity of the cation (Zn^{2+}) decrease at certain P^H. Adsorption is inversely proportional to temperature, in order words, as the temperature of cation (Zn^{2+}) increases, the adsorption capacity decreases at a given concentration, also, at a given temperature adsorption capacity increases as the concentration of the adsorbent increases.

The production of Leclanche dry cell will give more efficiency using MnO_2 as depolarization when blended with 0.1 M Zn^{2+} to enhance its surface charge.

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Fig: Graph of surface area determination