TOXIC METAL IONS ADSORPTION ON BAGASSE FLY ASH

A
Report on
Loboratory project submitted for the partial fulfilment of the Degree of

MASTER OF PHILOSOPHY
IN
CHEMISTRY (Industrial Methods of Chemical Analysis)

By
RASHMI

DEPARTMENT OF CHEMISTRY
UNIVERSITY OF ROORKEE
ROORKEE - 247 667 (INDIA)
JULY - 1998

CANDIDATE'S DECLARATION

I here by certify that the work which is being presented in the thesis entitled, **"TOXIC METAL IONS ADSORPTION ON BAGASSE FLY ASH "** in partial fulfilment of the requirement for the award of the Degree of Master of Philosophy submitted in the Department of Chemistry of the University is an authentic record of my own work carried out during period from Jan, 1998 to July 1998 under the Supervision of **Dr. K.C.Gupta**, Assistant Professor, Department of Chemistry, University of Roorkee, ROORKEE.

The matter embodied in this thesis has not been submitted by me for the award of any other degree.

Rashmi
(RASHMI)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

KCGupta

Date 9th : July 1998
Place : Roorkee

Dr. K.C.Gupta
Assistant Professor
Department of Chemistry
University of Roorkee
Roorkee - 247 667 (U.P.)

CL Sharma
Prof. & Head
Chemistry Deptt.
University of Roorkee
Roorkee-247 667 (U. P.)

ACKNOWLEDGEMENT

No word can articulate my deep sense of gratitude to my mentor, **Dr. K.C. Gupta,** Assistant Professor, Department of Chemistry, University of Roorkee for his meticulous guidance, moral support, stimulating encouragement, tireless effort and constant attention through out my project work.

I am also indebted to pay my Sincere thanks to Dr. C.L.Sharma, professor and Head of Chemistry Department, University of Roorkee, Roorkee for Providing necessary facilities.

I'm also thankful to Mr. Abdul Haq. and Mr. V.P.Sexana for providing technical assistance in the analysis of the samples.

Above all I also feel Lucky to have cherish, forbearence, immutable encourgement recevied from my parents continsousely.

Last but not the least, It gives me fabulous delectation to thank Mr. Sanjeev who instilled in me courage, confidence, Patiences, firm determination for fulfilling my tasks.

So special thanks goes to Mr. Sanjeev who give me inspiration to do my work sincerely.

(RASHMI)

CONTENTS

ABSTRACT

Adsorption is an efficient and widely used technique for the treatment and recovery of the metal ion from the waste water. The bagasse fly ash has currently created an interest among the various workers to use it as an adsorbent for various metal ions. In this dissertation, an effort has been made to study the adsorption behavior of Pb(II) and Cd(II) ions on bagasse fly ash which is a by product of a sugar industry.

Experimental observations are collected at different initial metal ion concentration, pH variations, temperature variations, contact time variations and at different weight of the fly ash and result are suitably interpreted.

An increasing trend in uptake amount of the metal ions on increasing the initial concentration of the metal ion at fixed pH and temperature has been obrserved.

On increacing the pH of the medium, the uptake amount the of metal ion by the bagasse fly ash has also shown an increasing trend. There was maximum uptake of metal ions at pH-7 which clearly indicated that bagasse fly ash can be used efficiently in neutral media.

Effect of temperature on adsorption of metal ions has suitably explained and data were used to calculate various thermodynamic parameters, such as ΔG, ΔH and ΔS. There was a decrease in the value of free energy change (ΔG)during adsorption of Pb (II) ion and Cd(II) ions on bagasse fly ash which suggested for the feasibility and spontaneity of the adsorption process.

The metal ion uptake has increased on increasing the weight of the adsorbent but the efficiency of the adsorbent has decreased on increasing the weight of the adsorbent.

The experimental data have been fitted well in Langmuir's adsorption isotherm from which adsorption parameter K_1 and K_2 have been calculated.

INTRODUCTION

&

LITERATURE SURVEY

INTRODUCTION

Due to the rapid industrialization and exhausted exploitation of the natural resources, the qualities of environment has deteriorated to such an extent that the healthy survival of the mankind on the earth has become a challenge. If this state of the affairs is allowed to continue, it will prove to be a monstrous problem. Various kinds of the pollutants creating special concern to the society to search out some remedial measures to combat this problem of environmental and ecological imbalance, water is an essential commodity for the human lives, animals and other vegetation. Various industries discharging pollutants in the rivers, fresh water reservoirs, causing scarcity of potable water on earth. Among the various techniques used for the seperation of inorganic and organic pollutants, the adsorption process has been supposed to be an easy and economical. In this technique the properties and the cost of the adsorbent plays an important role and there is a continuous demand to search out an adsorbent which would be an efficient and easy to be regenerated.

The litrature survey describes the various kind of adsorbents of common use under different experimental conditions. The following section gives an account of the efforts made by various workers to remove pollutants from the waste water using different adsorbents.

LITERATURE REVIEW

Removal of heavy metal pollutants at high concentration from water can be readily accomplished by chemical precipitation or electrochemical methods. At low concentration, the removal of such pollutants is more effective by ion exchange or adsorption on solid adsorbent such as activated carbon. The adsorption techonology is currently being used extensively for the removal of organic and inorganic micro pollutants from aqueous phase. The use of carbon adsorption for the direct treatment of liquid industrial waste water is relatively a recent practice and has been successfully utilised for the reclamation of Organic chemicals [1], phenols [2], pesticides [3,4], humic substance [5], Clays [6], Anions [7], Dyes [8], etc. Activated carbon has been used for the removal of complexes. Joachim and Heinrich [9,10,11] proposed the kinetics of adsorption of activated carbons for single solute, multisolute systems and for natural organic material.

In 1971 Sigworth and Smith [12] suggested a correlation of solution pH and the adsorption of inorganics by activated carbons. Later on they proposed a basis of classification of the heavy metals, according to their adsorption potential on activated carbons. Their adsorption characteristics are much influenced by the presence of complexing agents, pH, valency and ionic forms of the metals. Reed and Arunachalm [13] used the granular activated carbon columns for Pb(II) removal. Activated carbon has also been used as an adsorbent for Pb(II). Adsorption capacity of carbon was maximum at pH 2.2 and was not affected by surface area and particles size. Rowely et. al. [14] used shredded rubber from old automobiles tyres for the removal of metal ions. Coal fly ash was suggested by Sen and De et. al. [15] for the removal of Hg(II). Different adsorbents, both natural and synthetic have been used for the purpose of adsorption. Some natural adsorbents of routine use are clay zeolites, fly ash etc. and synthetic adsorbents are activated carbons, polymeric adsorbents and many synthetic ion exchangers.

Adsorption by granular activated carbon is an efficient and cost effective measure for contaminated ground water.

In 1970 synthetic carbonaceous adsorbent was developed for the treatment of potable water. This adsorbent has 3 to 4 times more capacity for removal of trichloroethene (TCE) than the granual activated carbon [16]

Roberts [17] has described in details the use of GAC columns in potable water treatment plants. Coupat and Lalancetle [10] treated cyanides, phosphates, organic matters such as oil, dyes and water containing heavy metals such as Hg(II), Cd(II), Zn(II), Cu(II), Fe(III), Ni(II), Cr(VI); Ag(II) and Pb(II) effectively after a crude settling by contacting with peat mass sphagnum moss peat [19] which is oligotropic in nature and has been used effectively to remove Cr(VI) from aqueous solution. The process is pH dependent and the optimum range of pH was 1.5-3.0.

Bark of various species of coniferous trees have also been employed to scavenge heavy metal ions. Adsorption of ions of Cd, Zn, Hg, Co, Mn, Ni metals on bark of various species has been studied [20].

Alves et al [21] studied the removal of trivatent chromium in tannery waste water by using Pinus sylvestris bark.

Removal of Cr (VI) from waste water with coconut husk fibres (CHF) and palm pressed fibres (PPF) was studied [22]. Range of pH for effective Cr (VI) removal was 1.5-5 CHF and 1.5-3 for PPF. Adsorption capacity of CHF and PPF was 20 and 14 mg/g. Adsorption of Cadmium by two powdered carbons (PACs) was investigated in single and binary systems. Both PACs were effective in removal of Cd(II) from solution [23].

Removal of heavy metal ions by cotton is reported by Narder and Parvathy [24]. They succeeded in scavenging Cd(II) ions from aqueous solution effectively within the pH range of 4-7. Churchill and Walters [25] prepared bacterial cell surface for the sorption of heavy metals. Adsorption studies of Cd(II), Ni(II) and Zn(II) ions by ungranulated blast furnace slag have been reported by Dimitrova [26] and the effect of pH was investigated Navasivayam and Rangnathan [27] used the hydroxides of iron (III) and chromium (III) for removal of Pb(II) from the waste water and adsorption parameters have been optimised. Parameters studied include agitation time, pH temperature and Pb(II) concentration.

Quantitative removal of Pb(II) was observed at pH $\geq$ 7.0 . Desorption of Pb(II) from Pb coaded adsorbent was 56% at 4. pH.

Activated carbon prepared from peanut hulle, an agricultural waste by product has been tried for the adsorption of Cd(II) from synthetic waste water by Navasivayam and Periasamy [28].

Vasudevan [33] studied the treatment of Cr(III) and Ni(II) in waste water by using aquatic plants such as Salvinia and Spirodila within concentration range of 1.0-8.0 ppm. The percentage removal of these metal ions was observed to be 56-96% and 18-72% after the first 2 and 14 days respectively. Removal rate for a single group solution and mixed group solution was 35-83%. Recent studies have shown that adsorption of Cr(VI) on suitable adsorbent may be an alternate inexpensive technique to remove/recover the Cr(VI) from the waste water. Various types of activated carbons obtained from low cost material such as coconut shell, coconut jute, tea leaves and rice husk have been in use for the removal / recovery of Cr(VI) from the aqueous phase.

In India sugar industry is the second largest agrobased industry and produces large amount of pollutants particularly in terms of suspended solids, organic matter, mud, bagasse, and bagasse fly ash, and air pollutants.

Amount of bagasse fly ash generated from bagasse fired boiler varies widely from boiler to boiler depending upon the efficiency of the boilers. It is estimated that bagasse fly ash obtained from the sugar industry is an order of 0.64 million tonnes per annum.

Current studies reported in the literature have suggested that bagasse fly ash can be an efficient adsorbent for the treatment of organic and inorganic pollutants released in the waters by various industries.

Among the various adsorbents like activated carbon, coal fly ash, peat, wood, lignites and agricultural residues, the bagasse fly ash seems to be a cheaper substitute for the treatment of industrial liquid wastes. Recently activated carbon used as an adsorbent is costly and get lost 10-15% during its regeneration after adsorption. Bagasse fly ash has been used for the removal of COD from sugar mill effluent [34] [35].

Prabhu et. al [34] have applied bagasse fly ash for the removal of Zn(II) ions from the waste water. They have observed an increasing trend in percent removal of Zn(II) ion on increasing the amount of adsorbent.

I.D. Mall et. al. [35] have made comparative studies for the removal of COD and color from sugar mill effluent using bayasse fly ash, activated carbon and concluded that bagasse fly ash is comparable to activated carbon in its adsorptive properties, hence recomonded bagasse fly ash to be a good substitute of activated carbon. Srivastava et. al. [36] have used the bagasse fly ash for the removal of 2,4,6 trinitrophenol at different pH, concentration of phenol, amount of adsorbent and in presence of surfactants. Adsorption data were fitted in Langmuir and Freundlich's isotherms. Thermodynamic data have been calculated to explain the feasibility of the process.

Mahadev et al [35] have used the bagesse fly ash for the removal of resorcinol from the industrial effluents. The adsorption behavior of fly ash was compared with activated carbon. Bagasse fly ash has been used by Mishra et al [39] for the treatment of sugar mill and distillary mixed effluents. Srivastava et. al [37] have further used bagasse fly ash for the treatment of waste water. In view of the current applications of the bagasse fly ash in treatment of industrial waste water, an attenpt has been made to under take a detail studies for the adsorption of toxic metal ions, Pb(II) and Cd(II) on bagasse fly ash.

EXPERIMENTAL

EXPERIMENTAL

A. **REAGENTS** - All the reagents used in this project work were of analytical grade chemicals unless otherwise stated. Stock solutions of two metal ions, namely lead and cadmium were prepared in double distilled water using their salts $Pb(NO_3)_2$ and $3CdSo_4.8H_2O$ respectively.

B. **INSTRUMETATION** - To follow the adsorption of Cd(II) and Pb(II) ions on bagasse fly ash, the following equipments were used during experimental work.

1. pH-meter (Model-CL-46 Toshniwal)
2. Thermostatic Water bath
3. Atomic Absorption Spectrophotometer (Model-PERKIN ELMER-3100)
4. Metaller weighing balance
5. Heating mental

C. METHODOLOGY -

(i) PREPARATION OF FLY ASH SAMPLES.

Bagasse fly ash was used as an adsorbent to study the adsorption of lead(II) and cadmium(II).

Bagasse fly ash was obtained from local sugar industry, "The Ganga Sugar Industry at Devband". Bagasse fly ash was first of all sieved to the mesh size of 50-60 to obtained bagasse fly ash particles of similar size. These bagasse fly ash particles were treated with 1% solution of hydrogen peroxide to remove all the adhering organic particulates and other impurities, subsequently bagasse fly ash was washed repeatedly with distilled water and dried at 90°C in a vacuum oven.

(ii) <u>ESTIMATION OF THE METAL IONS</u> -

Metal ions were estimated using atomic absorption spectrophotometer. The collected filterates of Pb(II) and Cd(II) metal ions were analysed to find out the actual amount of the metal ions adsorbed during the process.

(iii) <u>ADSORPTION STUDIES</u> -

To prepare the solution of desired concentration, the calculated quantity of salts was dissolved in doubly distilled water. After preparation of stock solution of the Pb(II) and Cd(II) ions, the calibration curves were drawn to find out the concentration of the metal ion present in the unknown solution. Subsequently adsorption experiments were performed using batch technique. 0.5g of the dried fly ash was kept into the stoppered conical flasks, containing solution of metal ions of known concentration at room temperature. Concentration of metal ion was varied from 50ppm to 200ppm. for studying the effect of initial concentration of the metal ions on adsorption.

Adsorption experiments were also carried out at different pH and different temperatures. The conical flask containing metal ion and bagasse fly ash was kept for 24 hours to attain the equilibrium conditions of adsorption. After adsorption, the content of the conical flack has filtered and filterate was analysed to find out the amount of metal ions adsorbed during adsorption process. The concentration of the metal ions in the solution was determined using atomic absorption spectrophotometer. Experiment were also conducted at different temperature to evaluate the theromdynamic parameters and to explain the feasibility of adsorption process.

The effect of pH on adsorption of metal ion has been studied by changing the pH of the medium from 3-7. The pH of the medium was maintained by using dilute hydrochloric acid and alkali.

The effect of amount of bagasse fly ash on adsorption has also been studied by deffrent amount of adsorbent at constant concentration of metal ion, pH and temperature.

(iv) KINETIC STUDIES -

Kinetic studies for the uptake of metal ions have also been undertaken in order to have an understanding of the mechanistic aspects of the process. The experiments for both the metal ions were performed using batch technique in which known amount of the adsorbent and adsorbate solutions were continuously shaken together and withdrawn periodically from the reaction vessel.

A number of conical flasks containing a definite volume of metal ion solution (50ml) of known concentration were placed in a thermostatic water bath. After attaining a pre-set temperature a known amount of the adsorbent (0.5 g) was added into each conical flask. After predicided interval of time, the solutions of specified conical flask was removed from the adsorbent and analysed to determine the uptake amount of Pb(II) and Cd(II) metal ions. The final reading for maximum adsorption was recorded at 24 hrs.

RESULTS
AND
DISCUSSION

RESULTS AND DISCUSSION

CHRACTERISATION OF THE BAGASSE FLY ASH

Bagasse fly ash was stable in water, metal ion solutions, in acids, bases and commonly used organic solvents. The ash was very light with a bulk density of arround 244 Kg m^{-3} with a moisture content of 8.11. The volatile matter was repoted to be 22.46 and combustible matter arround to be 22.46 The silica (12.37%) is a major constituent of fly ash. Alumina 6.84% and calcium is 0.03%.

Silica and alumina contents of the bagasse fly ash are very low as compared to the coal fly ash. The x-ray diffractogram of the bagasse fly ash suggest the nature which is mainly due to the presence of Silica as major amorphous constituent (fig-23).

The other compositonal parameters of the fly ash are shown in the following table

Parameter	*Bagasse*
Bulk density, Kg/m^3	244
Moisture	8.11
Ash	30.74
Volatile matter	22.46
Combustible matter	69.26
Surface area, m^2/g	410.00

Chemical analyses	*Bagasse*
Silica %	12.37
Alumina %	6.84
Calcium %	0.03
M-alkalinity %	0.80
P-alkalinity %	0.10

ADSORPTION STUDIES -

The hydogen peroxide treated and sieved bagasse fly ash was used to study the adsorption of Cd(II) an Pb(II) metal ions, at constant pH, temperature and weight of adsorbent. These metal ions are toxic in nature and discharged oftenly in the environment by various industries. This study may be a step to understand the techniques of separation of these metal ions from the industrial waste using bagasse fly ash. To optimize the physical conditions of maximum separation of metal ion, the effect of following parameters was studied and discussed in the following sections.

EFFECT OF INITIAL CONCENTRATION OF Pb (II) AND Cd (II) IONS ON ADSORPTION ON BAGASSE FLY ASH

The experimiental data collected at various initial concentration of Pb(II) and Cd(II) ions at constant pH, temperature are given in tables 1 and 7 indicated clearly that uptake amount of metal ions has increased on increasing the initial concentration of the metal ion. However, the rate of uptake of metal ions at high concentration became slightly low due to the non-availability of the adsorption sites corresponding to the metal ions present in the solution. The oxides of the aluminium and silica are potential adsorption sites for the metal ions on the surface of the bagasse fly ash. The comparison of uptake amount of the metal ions clearly indicated that the lead ions are preferentialy adsorbed more in comparison to cadmium ion. These expermiental data were fitted well in the Langmuir adsorption model as clear from the figures 1 and 12.

From these plots values of adsorption constants K_1 and K_2 are calculated and given in tables 1 and 7 respectively. The value of maximum adsorption constant K_2 found to be more for Pb(II) ion which may be due to strong interaction of Pb(II) ions with the bagasse fly ash.

EFFECT OF PH ON ADSORPTION OF METAL IONS ON BAGASSE FLY ASH

To analyse the effect of hydrogen ion concentration on adsorption behavior of Pb(II) and Cd(II) ions on bagasse fly ash, the pH of the medium was varied from 3-7 and adsorption data were collected. The evaluation of adsorption data have clearly indicated that the metal ion uptake has increased on increasing the pH of the medium, this may be because of deprotonation of the bagasse fly ash. These data are given in tables 2 and 8.and shown, graphically in figures 2-5 and 13-16. The value of adsorbed amount (x) and maximum adsorption capacity (K_2) have increaced on increasing the pH of the medium. This clearly suggested that bagasse fly ash can be used for the subtantial separation of the metal ions from neutral medium.

EFFECT OF TEMPERATURE ON ADSORPTION OF METAL IONS ON BAGASSE FLY ASH

To determine the thermodynamic parameters of adsorption and to study the feasibility of the adsorption of these metal ions on bagasse fly ash, the adsorption data have been collected as a function of temperature variation and reported in tables 3-4 and 9-10 and shown graphically in figures 6-8 and 17-19. Observation of these data have clearly indicated that maximum adsorption capacity (K_2) has increased on increasing the temperature. The value of adsorption constant K_1 has shown a decreasing order in case of Pb(II) metal ions which suggested Pb(II) ions adsorption to be an exothermic one. The value of K_1 found to be in increasing order in case of Cd(II) ions on increasing temperature, clearly suggested to assume an endothermic nature of adsorption of Cd(II) ions on bagasse fly ash. The negative value of free energy parameter (ΔG) has clearly suggested the feasibility of adsorption of both metal ions on bagasse fly ash under normal experimental conditions. The values of $\Delta H, \Delta G \, and \, \Delta S$ are shown in tables 4 and 10. The entropy change during adsorption of both metal ions was found to be positive which suggested for configurational variation in metal ion association at the surface of bagasse fly ash during adsorption process.

These thermodynamic parameter as discussed above have been calculated by fitting the adsorption data in equations 1-3.

(v) THERMOCYNAMIC PARAMETERS OF THE ADSORPTION

(ΔG, ΔH and ΔS)

The thermodynamic parameters of the adsorption were determined by using the following equations .

$$\Delta G = - RT \ln K \qquad (I)$$

$$ln \frac{K_2}{K_1} = \frac{\Delta H}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \qquad (II)$$

$$\Delta G = \Delta H - T\Delta S \qquad (III)$$

EFFECT OF TIME VARIATION ON ADSORPTION OF METAL IONS ON BAGASSE FLY ASH

To understand the dynamics of metal ions during adsorption, the data have been collected as a function of time variation at constant pH, temperature, weight of the fly ash and initial concentration of metal ions. The metal ion adsorption has increased on increasing the contact time of metal ion with the bagasse fly ash. The maximum uptake was observed at 24 hrs., and beyond this time no substantial increase in the percent uptake was observed. These time variation data were fitted well in first order rate equation which clearly suggested that adsorption of these metal ions follows first order rate kinetics. The value of the first order rate constant has been determined from the slope of the graph plotted between log (Ce-x) Vs time as shown in figures 9-10 and 20-21. The values of first order rate constant is given in tables 5 and 11. This clearly suggested that to increase the maximum adsorption of metal ions, the contact time should have been increased. The following equation was used to calculated first order rate constant of adsorption.

$$k = \frac{1}{t} In \frac{a}{(a-x)} \qquad \text{(IV)}$$

EFFECT OF WEIGHT OF ADSORBENT (BFA) ON METAL ION ADSORPTIONS

To understand the effect of weight variation of adsorbent, experiments have been carried out by taking different initial weights of the bagasse fly ash at constant pH, temperature and initial metal ion concentration. The data given in tables 6 and 12 and in figures 11 and 22 have clearly indicated an increasing trend of adsorption on increasing the weight of the adsorbent. The value of adsorption constant K_2 found to be decreased on increasing the weight of the adsorbent. Which is due to the decrease in net available surface of the adsorbent on increasing the weight of the adsorbent. However, overall amount adsorbed (x) has shown an increasing trend. This suggested that there is a clear increase in percent uptake of metal ion on increasing the amount of adsorbent but the efficiency has decreased on increasing the weight of the adsorbent. These observations indicated that adsorbent should be used in continuous stirring and flowing conditions than the column and bed conditions.

CONCLUSSION

CONCLUSSION

Bagasse fly ash can be a suitable substitute for the activated carbon and other adsorbents for the adsorption of toxic metal ions under normal experimental conditions. This will also be an effort to utilize the sugar industry waste, for the treatment of industrial effluent and the recovery of adsorbed metal ions.

It would be useful, if adsorptions studies of mixed metal ions is also made to identify the selectivity of the bagasse fly ash for the commonly discharged toxic metal ions.

TABLES

Table - 1 Effect of Initial Concentration of Pb(II) Ions on Adsorptions on BFA

Amount of adsorbent = 0.5 g
Particle Size = 40-60 Mesh
Temp = 25°C
pH = 7
Equilibrium time = 24 hrs.

Initial concentration of Pb(II) Ci (ppm)	**Equilibrium Concentration of Pb(II) Ce (ppm)**	**Amount of Pb(II) ions adsorbed (x) (ppm)**	**Value of adsorption constant K_2 (gg-1)**	**value of adsorption constant. K_1**
50	2.65	47.35	0.37	62.27
100	8.20	91.80		
150	21.30	128.70		
200	44.60	155.40		

Table - 2 Effect of pH on Pb(II) Ion Adsorptions on BFA

Amount of adsorbent = 0.5 g
Particle Size = 40-60 Mesh
Temp = 25°C
Equilibrium time = 24 hrs.

pH	Value of adsorption constant K_2 (gg^{-1})	Value of adsorption constant K_1	x (ppm)
3	0.157	227.48	78.5
5	0.271	1537.515	120.8
7	0.353	74.549	177.5

Table - 3 Effect of Temperature on Pb(II) Ion Adsorption on BFA

Amount of adsorbent = 0.5 g

Particle size = 40-60 Mesh

pH = 5

Equilibrium time = 24 hrs.

Temperature (°C)	Value of adsorption constant K_2 (gg^{-1})	Value of adsorption constant K_1
20	0.128	434.028
35	0.229	272.950
40	0.327	254.940

Table - 4 Thermodynamic Parameters of Pb (II) Ion Adsorption on BFA

ΔH / $Jmol^{-1}$	ΔS / J $K^{-1}mol^{-1}$	ΔG / KJ mol^{-1}
-4.145	50.487	-14.797

`Table -5 Effect of Time Variation on adsorption of Pb (II) Ion on BFA

Amount of adsorbent = 0.5 g

Particle size = 40-60 Mesh

pH = 7

Temp. = 25° C

Initial concentration = 200 PPM

Time (min.)	Ce (ppm)	x (ppm)	Rate constant of Adsorption k
0	200	0	
120	98.8	101.2	
240	75.8	124.2	6.737×10^{-3} min $^{-1}$
360	72.8	127.2	
1440	44.6	155.7	

Table - 6 Effect of Weight of Adsorbent (BFA) on Pb(II) Ion Adsorption

Particle size = 40-60 Mesh

pH = 7

Temp. = 25° C

Equilibrium Time = 24 hrs.

Initial concentration = 500 PPM

Weight of adsorbent (g)	x (ppp)	K_2 (gg^{-1})
0.25	78.2	0.540
0.50	155.4	0.365
1.00	312.0	0.268
1.25	391.1	0.157

Table -7 Effect of Initial Concentration of Cd (II) Ions on Adsorption on BFA

Amount of adsorbent = 0.5 g.
Particle size = 40-60 Mesh
Temp. = 25 ° C
pH = 7
Equilibrium time = 24 hrs.

Initial Concentration of Cd(II) ion Ci (ppm)	Equilibrium Concentration of Cd(II) ion Ce (ppm)	Amount of Cd(II)ion adsorbed x (ppm)	Value of Adsorption Constant K_2 (gg^{-1})	Value of Adsorption Constant K_1
50	24.02	25.98	0.15	47.94
100	60.49	39.51		
150	103.24	46.76		
200	149.50	50.50		

Table - 8 Effect of pH on Adsorption of Cd(II) Ion on BFA

Amount of adsorbent = 0.5 g
Particle size = 40-60 Mesh
Temp. = 25° C
Equilibrium time = 24 hrs.

pH	Value of Adsorption Constant K_2 (gg^{-1})	Value of Adsorption Constant K_1	x (ppm)
3	0.13	11.43	11.51
5	0.14	21.85	25.01
7	0.15	47.94	39.51

Table -9 Effect of Temperature on Cd(II) Ion Adsorption on BFA

Amount of adsorbent = 0.5 g

Particle size = 40-60 Mesh

pH = 5

Equilibrium time = 24 hrs.

Temp. (° C)	Value of Adsorption Constant K_2 (gg^{-1})	Value of Adsorption Constant K_1
30	0.041	87.108
35	0.047	88.650
40	0.052	96.154

Table - 10 Thermodynamic Parameters of Cd(II) Ions Adsorption on BFA

$\Delta H/Jmol^{-1}$	$\Delta S/J\ K^{-1}mol^{-1}$	$\Delta G/KJ\ mol^{-1}$
7791.865	62.862	-11.255

Table - 11 Effect of Time Variation on Asorption of Cd(II) Ions on BFA

Amount of adsorbent = 0.5 g
Particle size = 40-60 Mesh
pH = 7
Temp. = 25°C
Initial Concentration = 200 PPM

Time (min.)	Ce (ppm)	x (ppm)	Rate constant k (min^{-1})
0	200.0	0.0	11.162×10^{-3}
120	143.2	56.2	
240	129.3	70.7	
360	125.5	74.5	
480	124.0	76.0	

Table -12 Effect of Weight of Adsorbent on Cd (II) Ion Adsorptions on BFA

Particle Size = 40-60 Mesh
pH = 7
Temp. = 25 °C
Equilibrium time = 24 hrs.
Initial Concentration = 500 ppm

Weight of adsorbent (g)	x (ppm)	K_2 (gg^{-1})
0.25	27.8	0.298
0.50	50.2	0.152
1.00	96.1	0.071
1.25	119.9	0.045

FIGURES

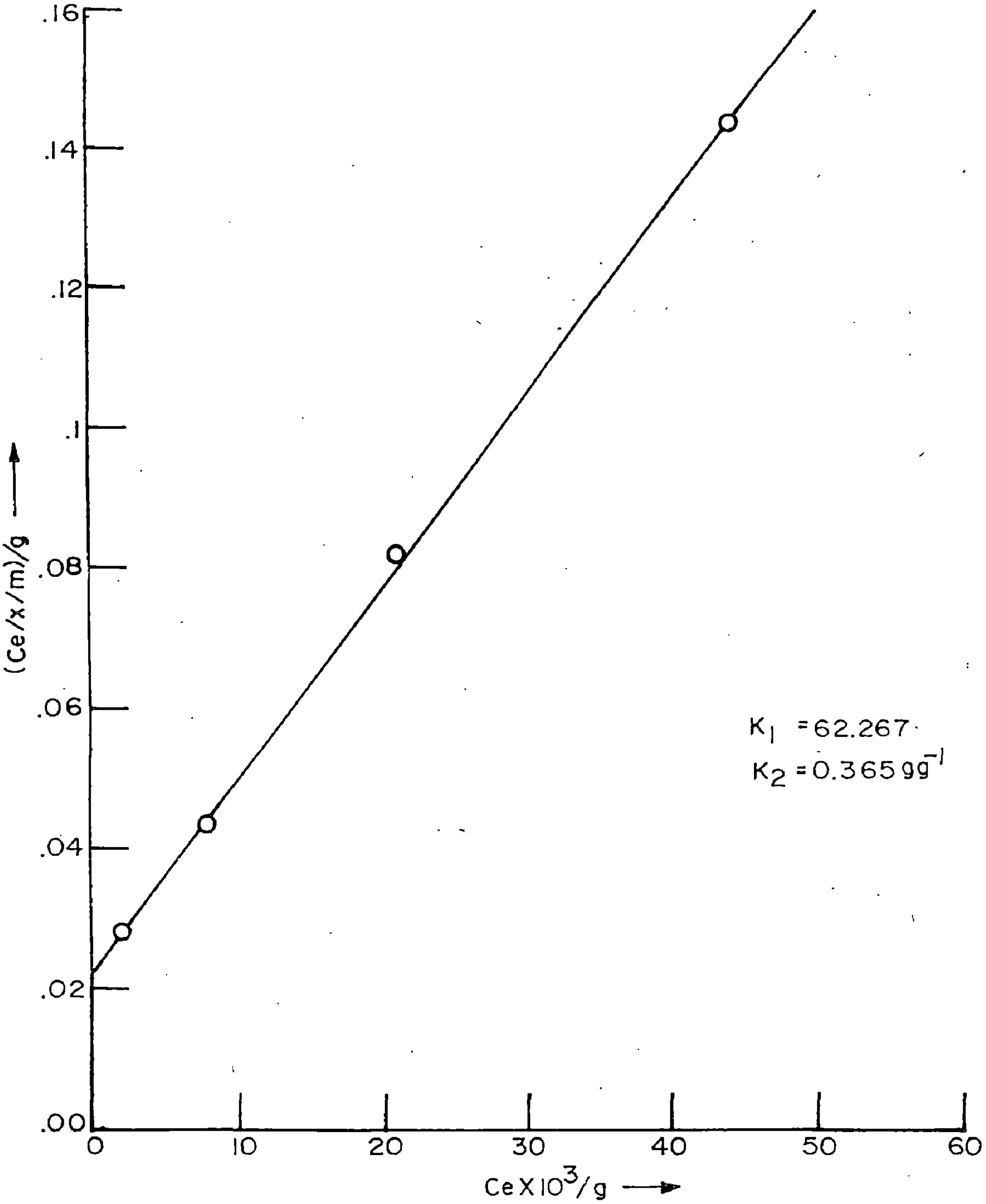

Figure - 1 Effect of initial concentration of Pb (II) ions on adsorption on BFA

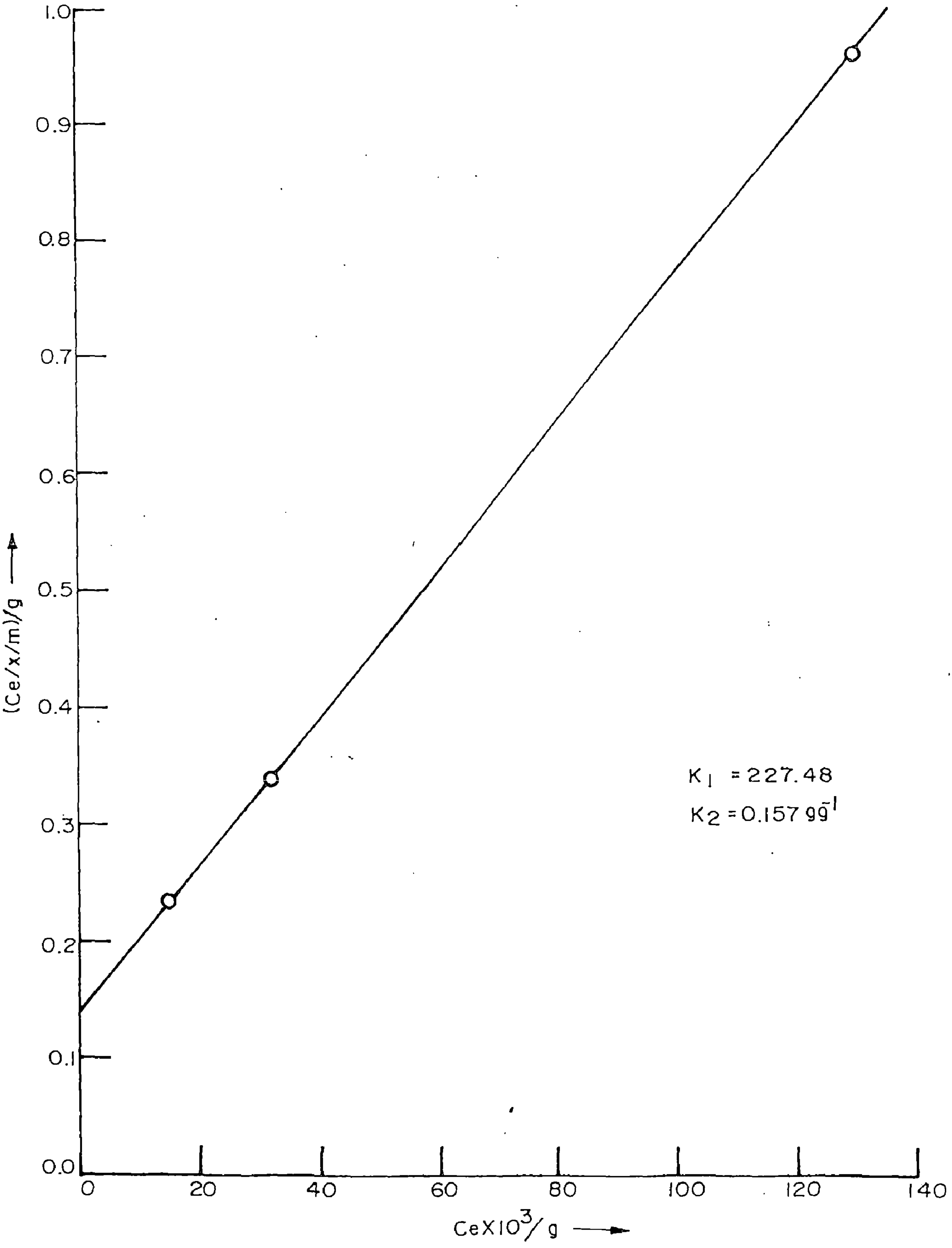

Figure -2 Effect of pH on Pb(II) ions adsorption on BFA at pH-3

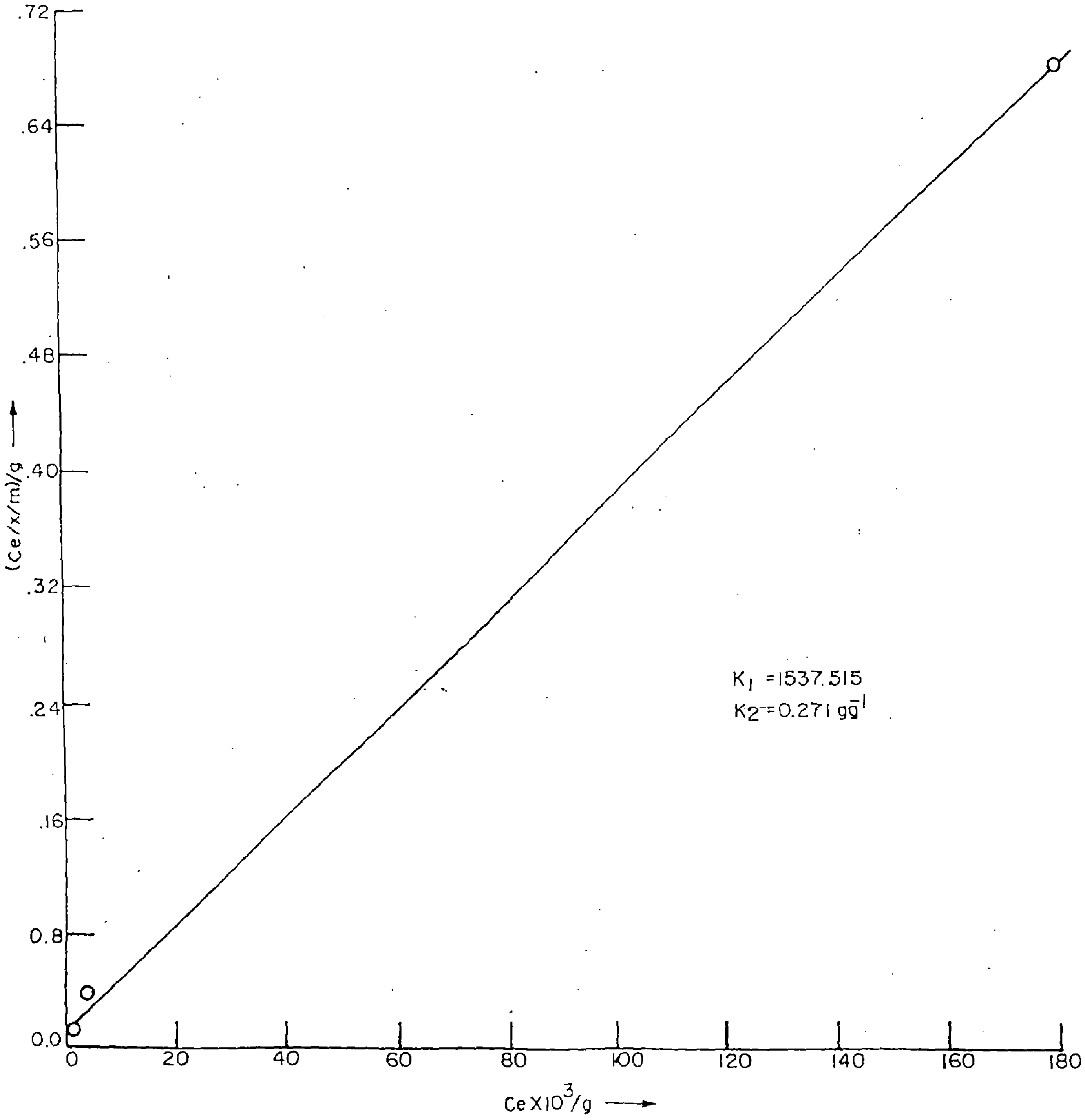

Figure -3 **Effect of pH on Pb(II)** ions adsorption on BFA at pH-5.

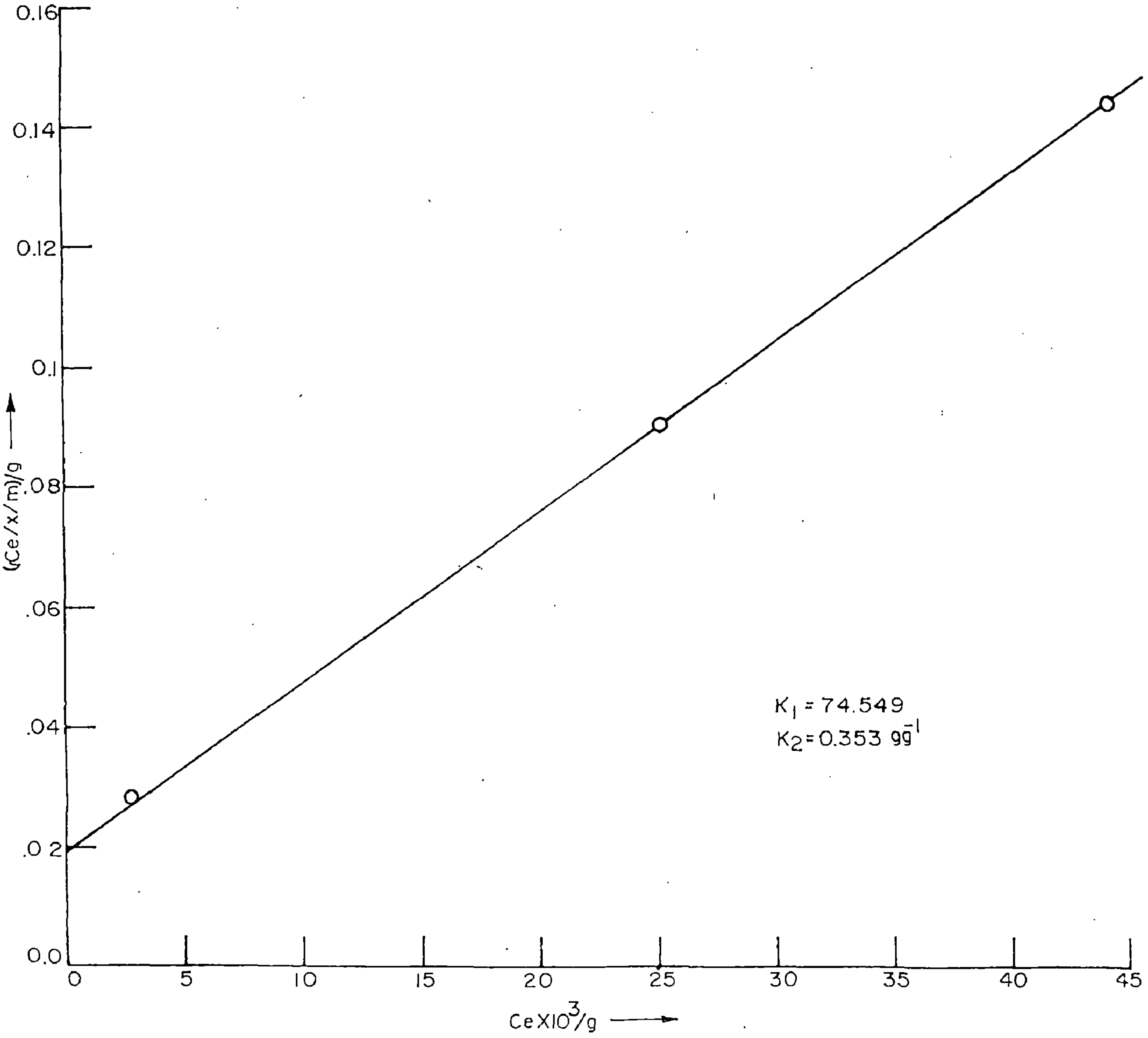

Figure -4 Effect of pH on Pb(II) ions adsorption on BFA at pH-7.

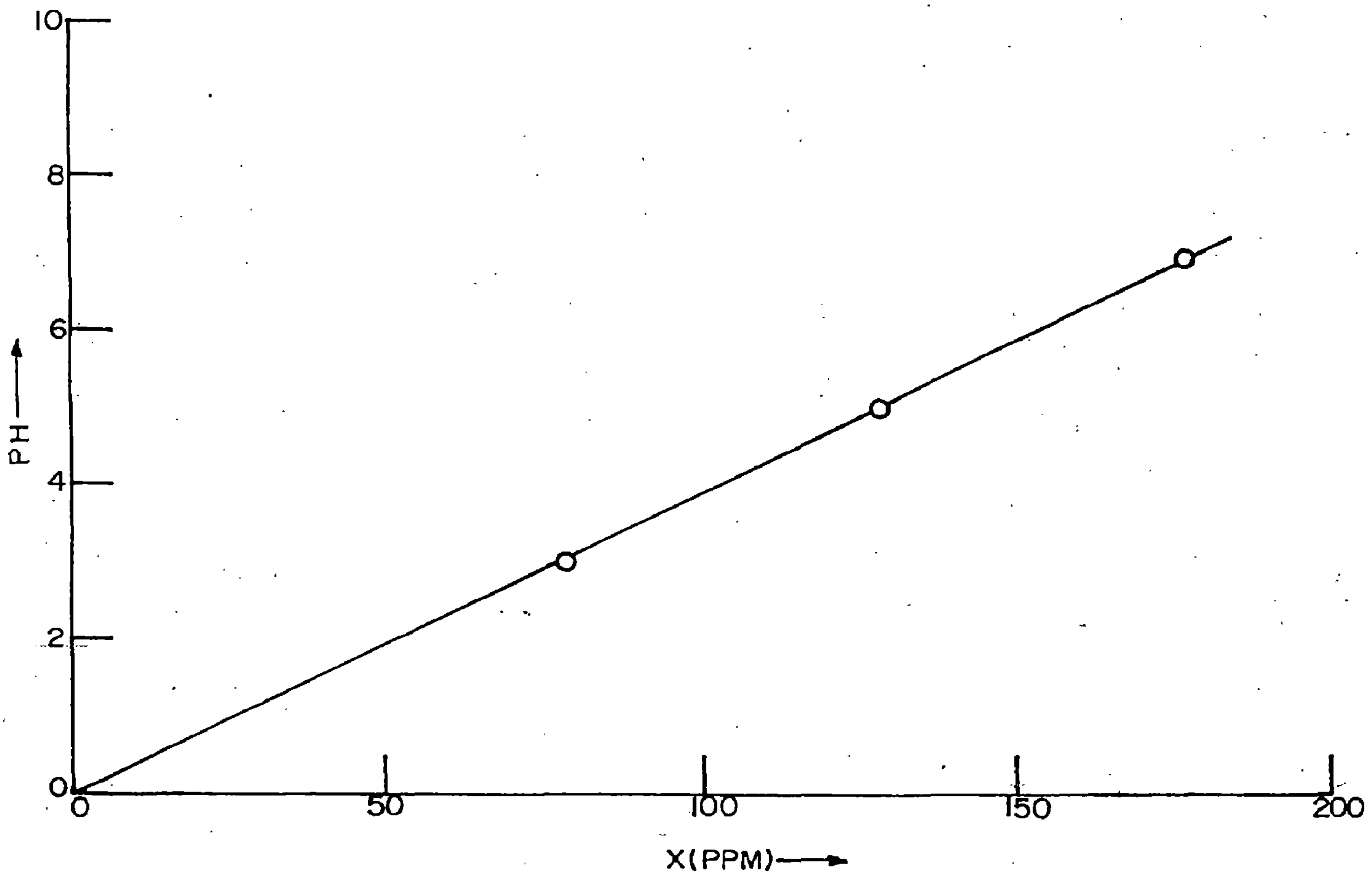

Figure -5 Effect of pH on Pb(II) ions adsorption on BFA.

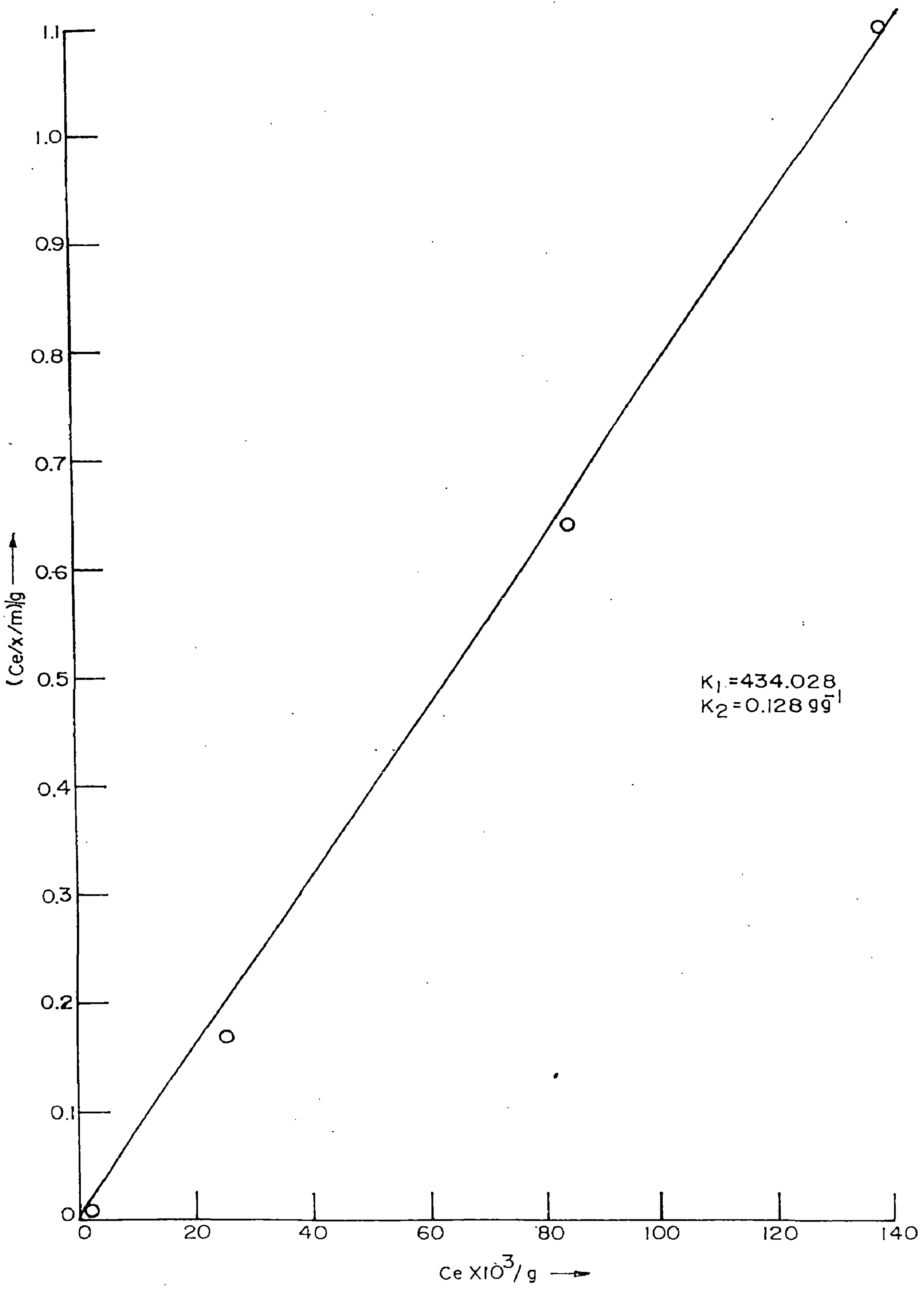

Figure -6 Effect of Temperature on Pb(II) ions adsorption on BFA at 20⁰C.

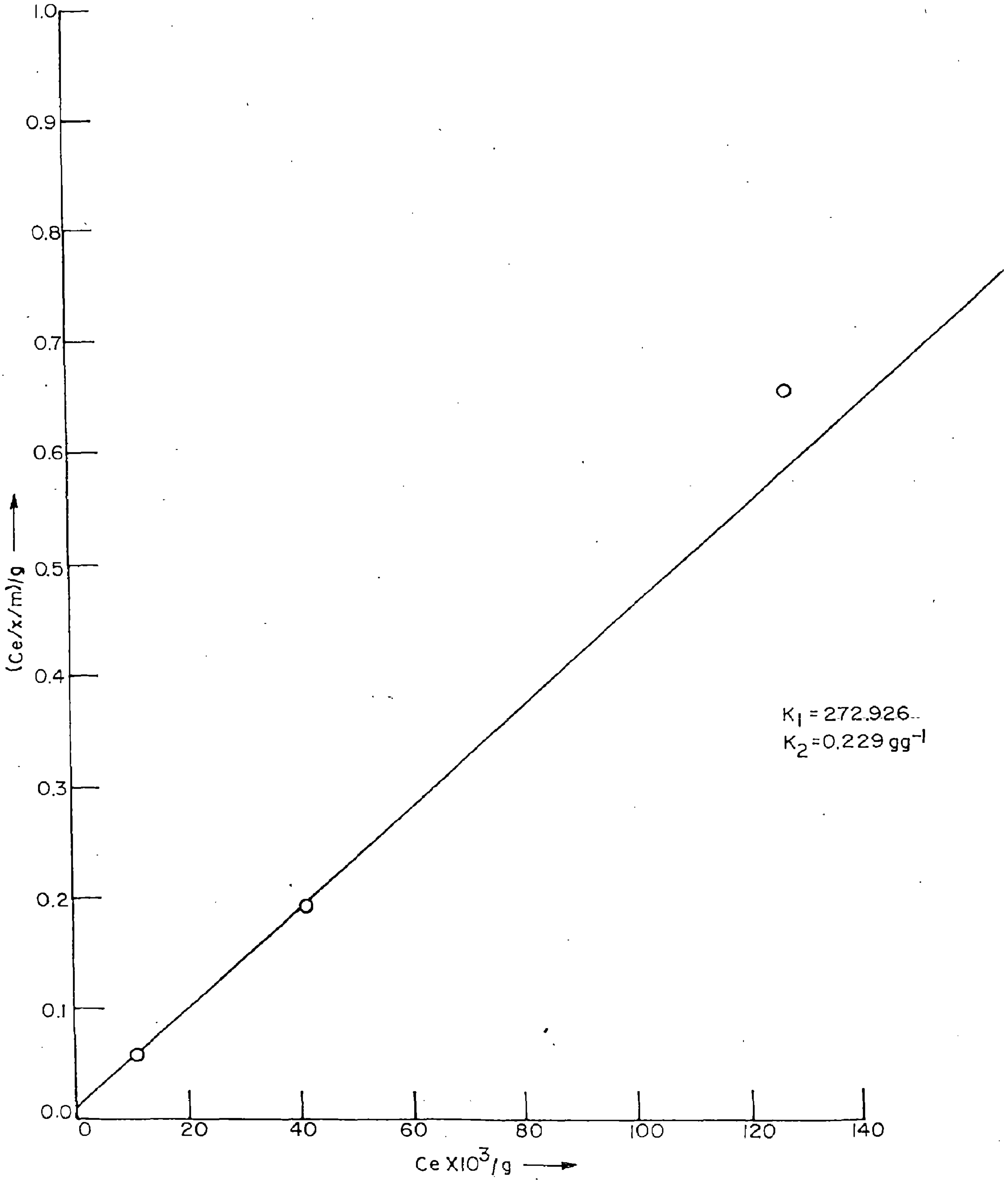

Figure-7 Effect of Temperature on Pb(II) ions adsorption on BFA at 35⁰C.

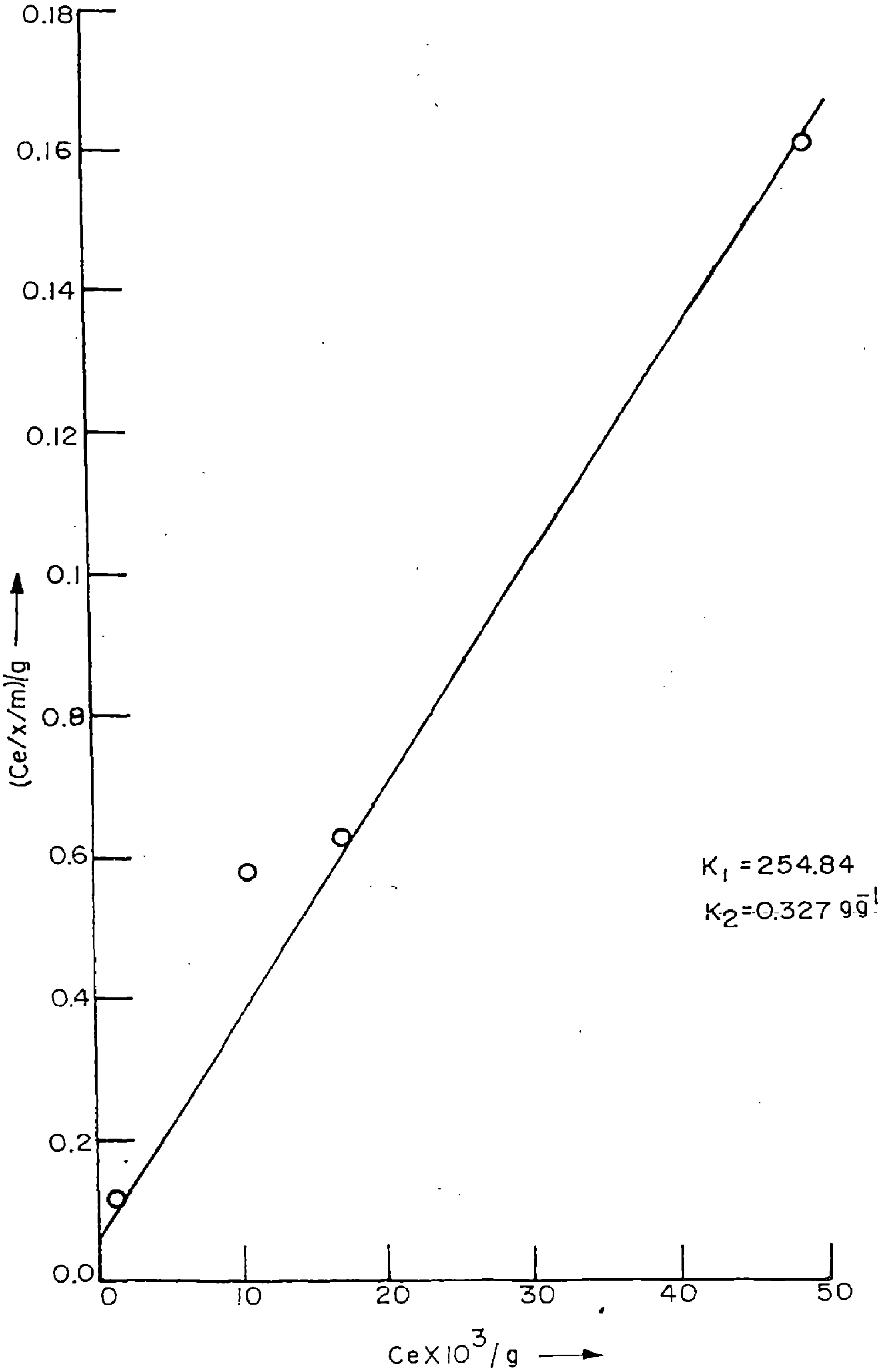

Figure-8 Effect of Temperature on Pb(II) ions adsorption on BFA at 40°C.

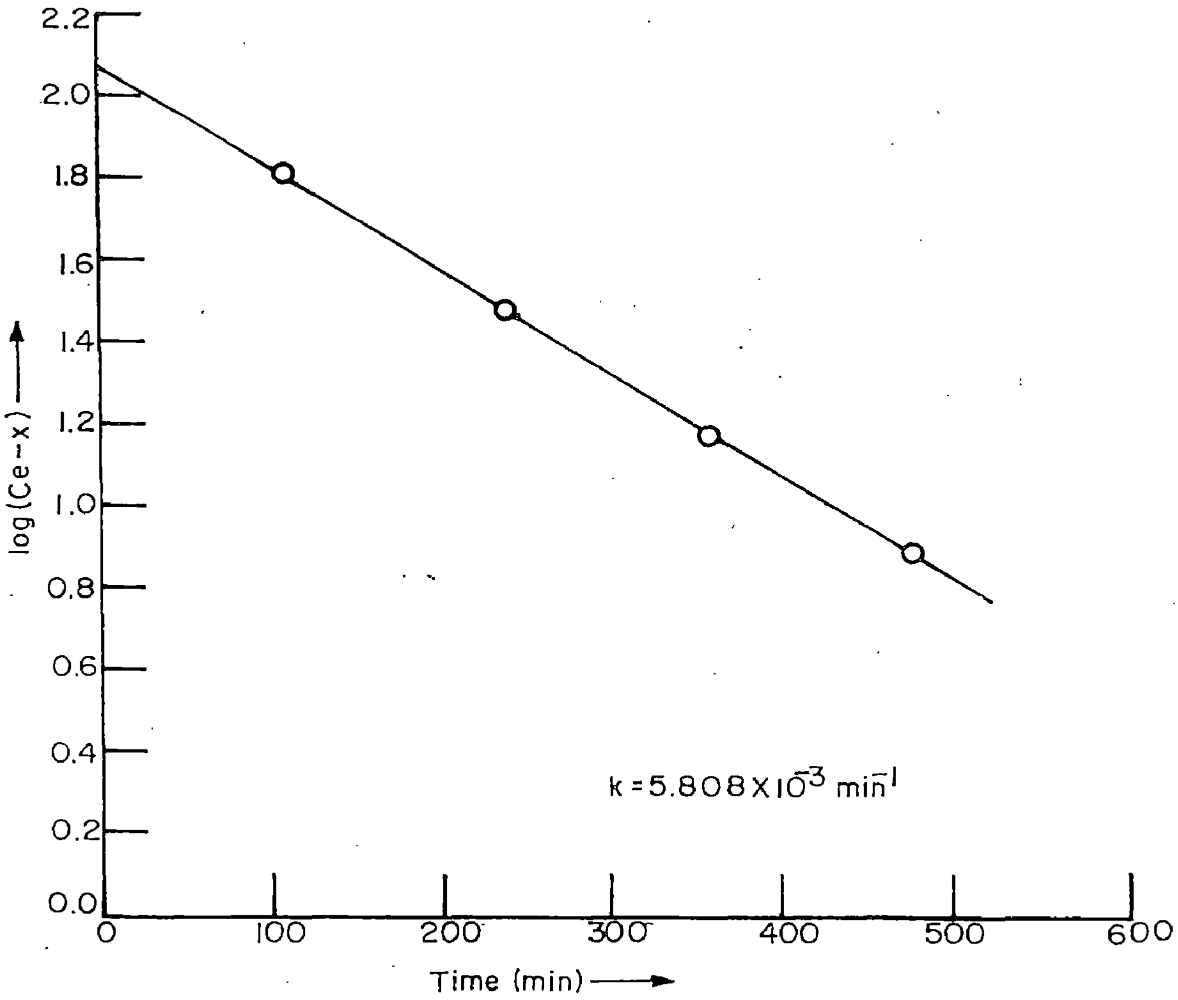

Figure -9 Effect of Time variation adsorption of Pb(II) ions on BFA.

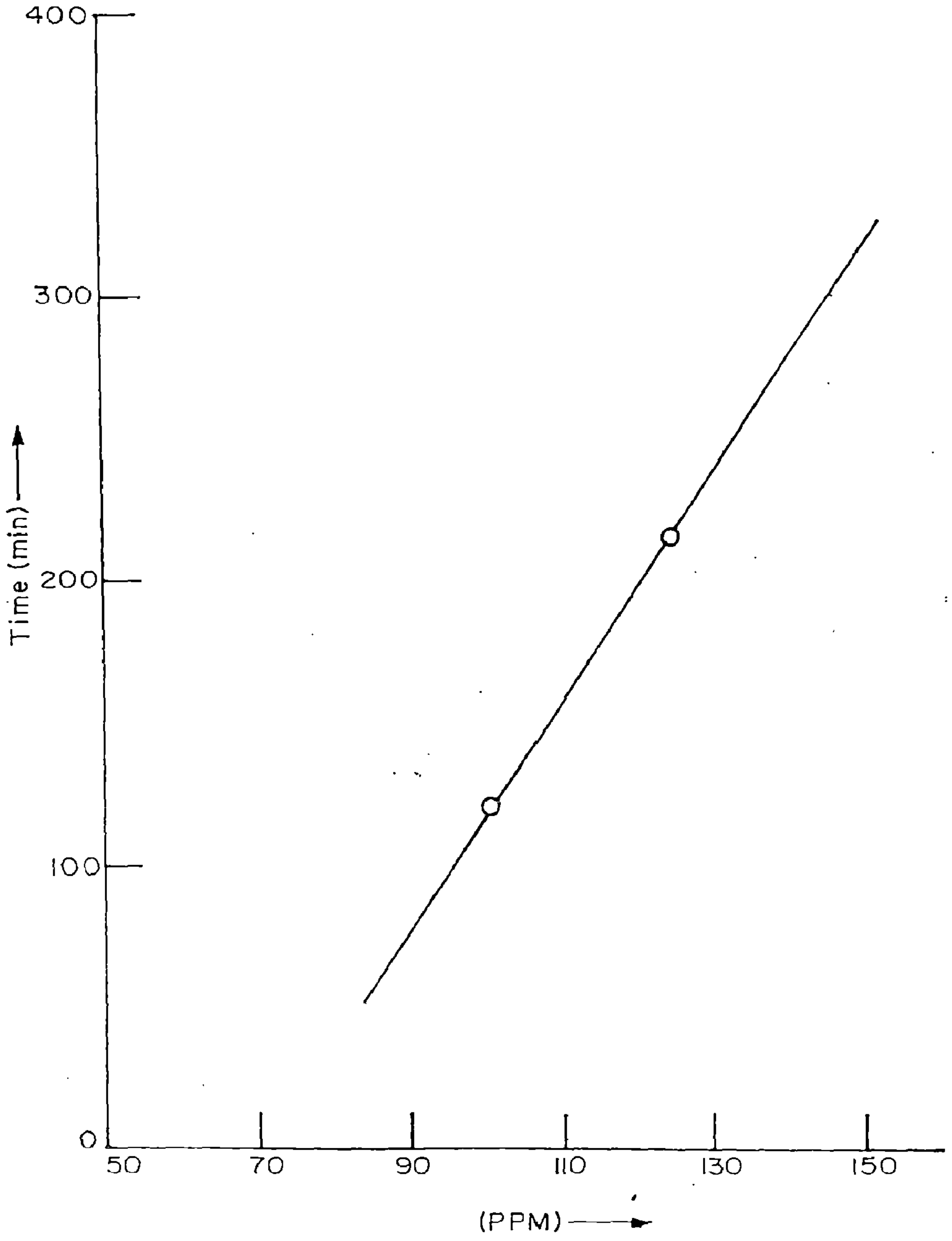

Figure -10 Effect of Time variation on adsorption of Pb(II) ions on BFA.

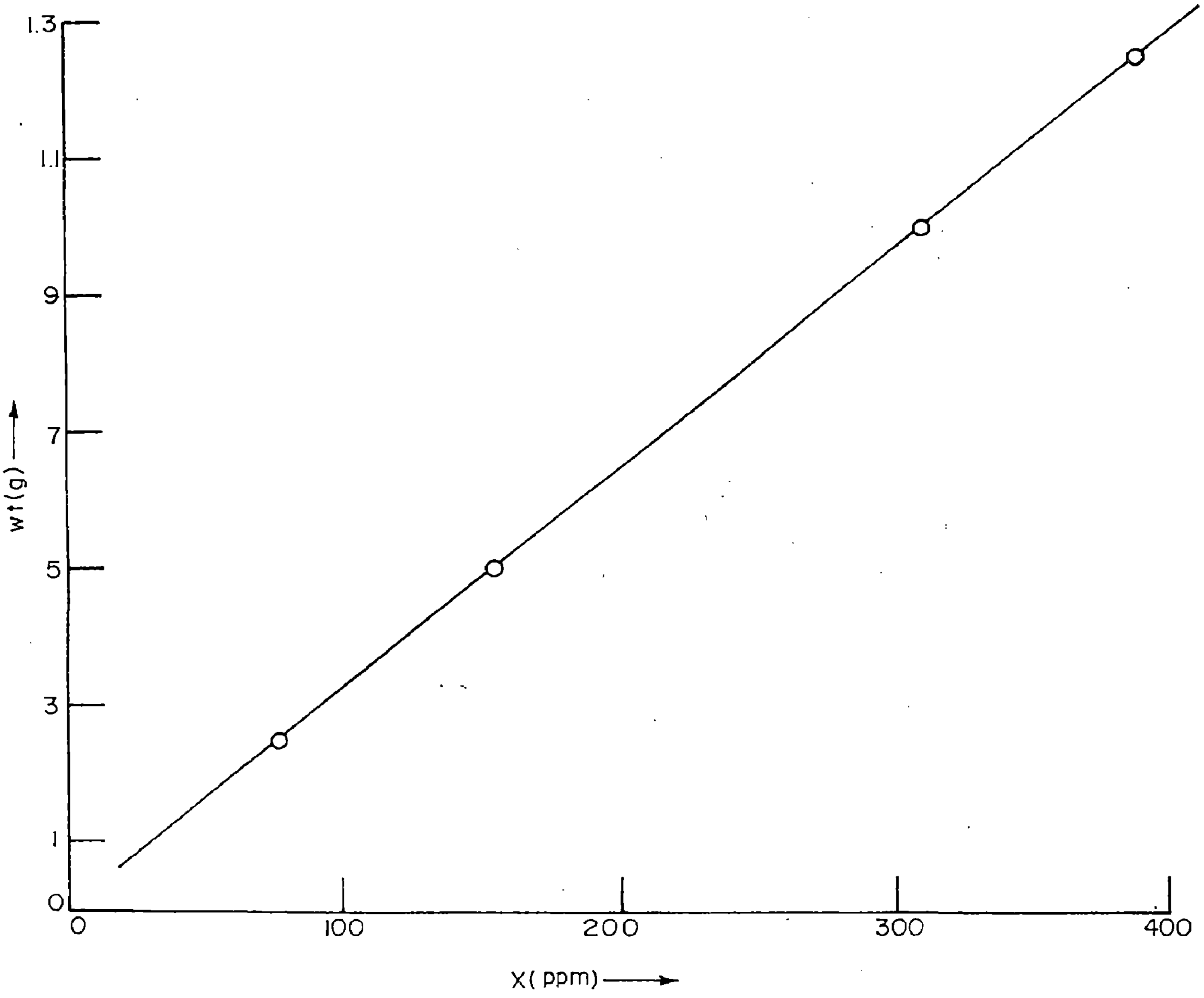

Figure -11 Effect of Weight variation of adsorbent (BFA) on Pb(II) ions adsorption

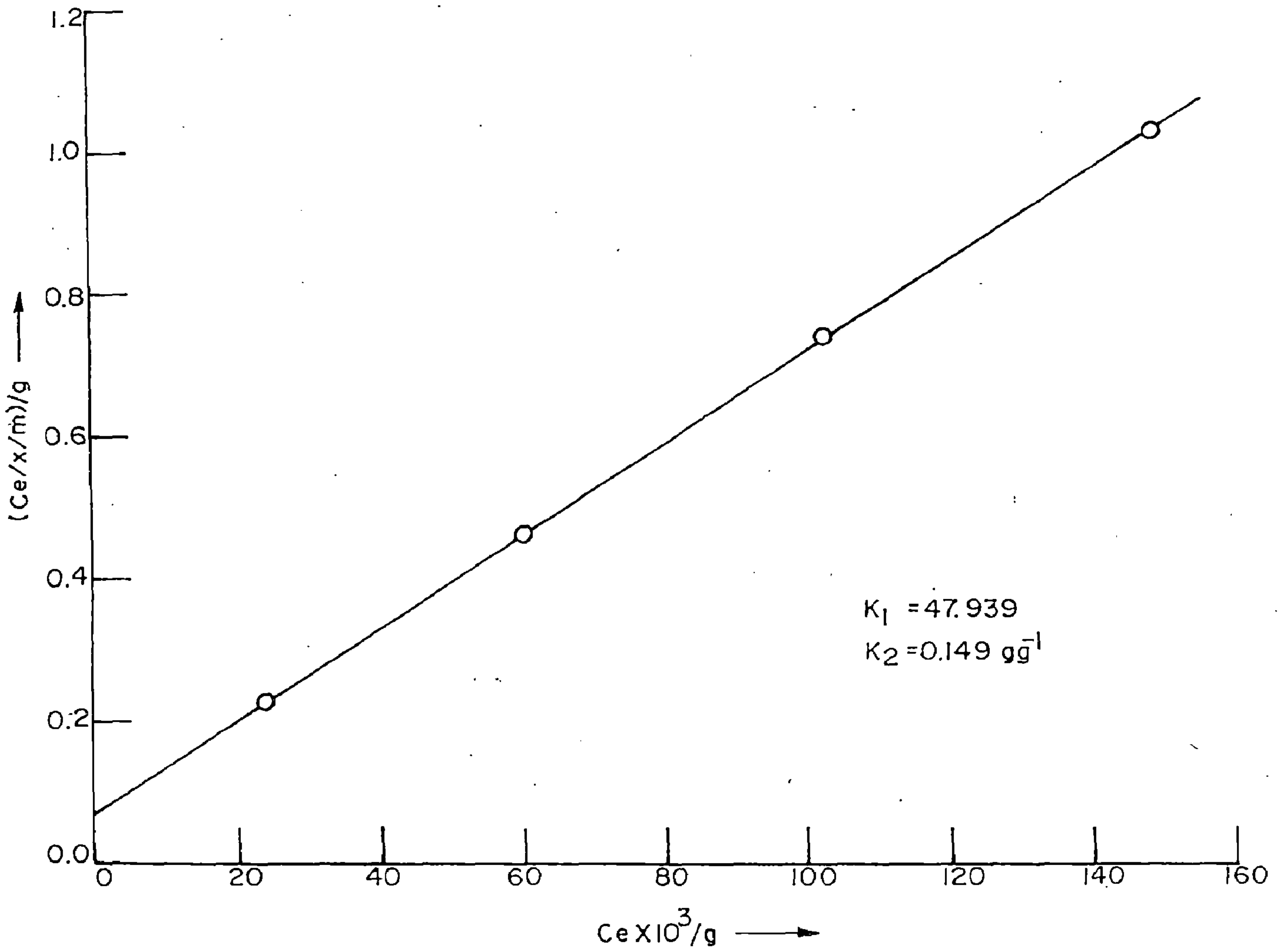

Figure -12 Effect of Initial concentration of Cd(II) ions on adsorption on BFA.
and -15 Effect of pH on Cd(II) ions adsorption on BFA at pH-7.

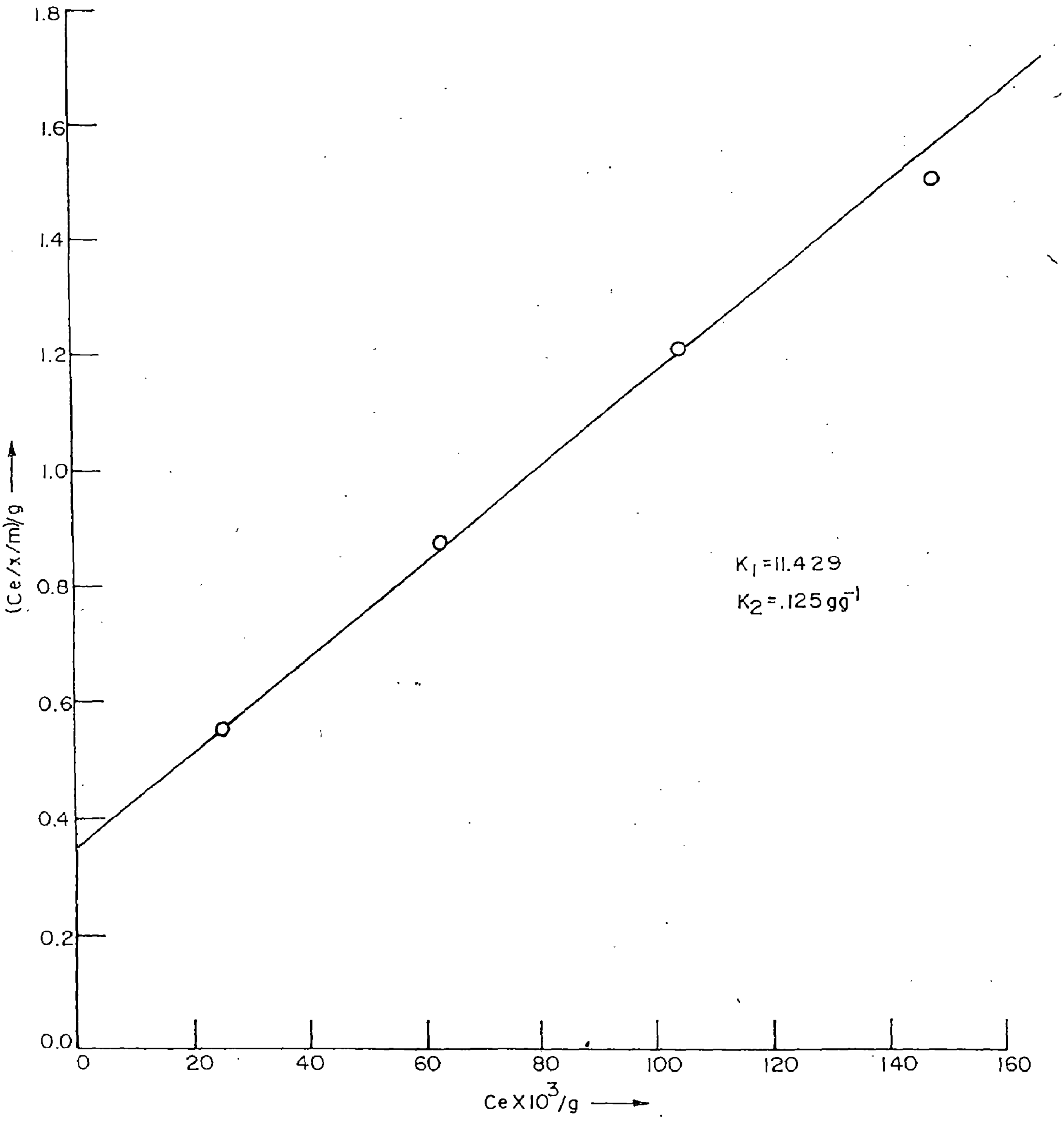

Figure -13 Effect of pH on Cd(II) ions adsorption on BFA at pH-3.

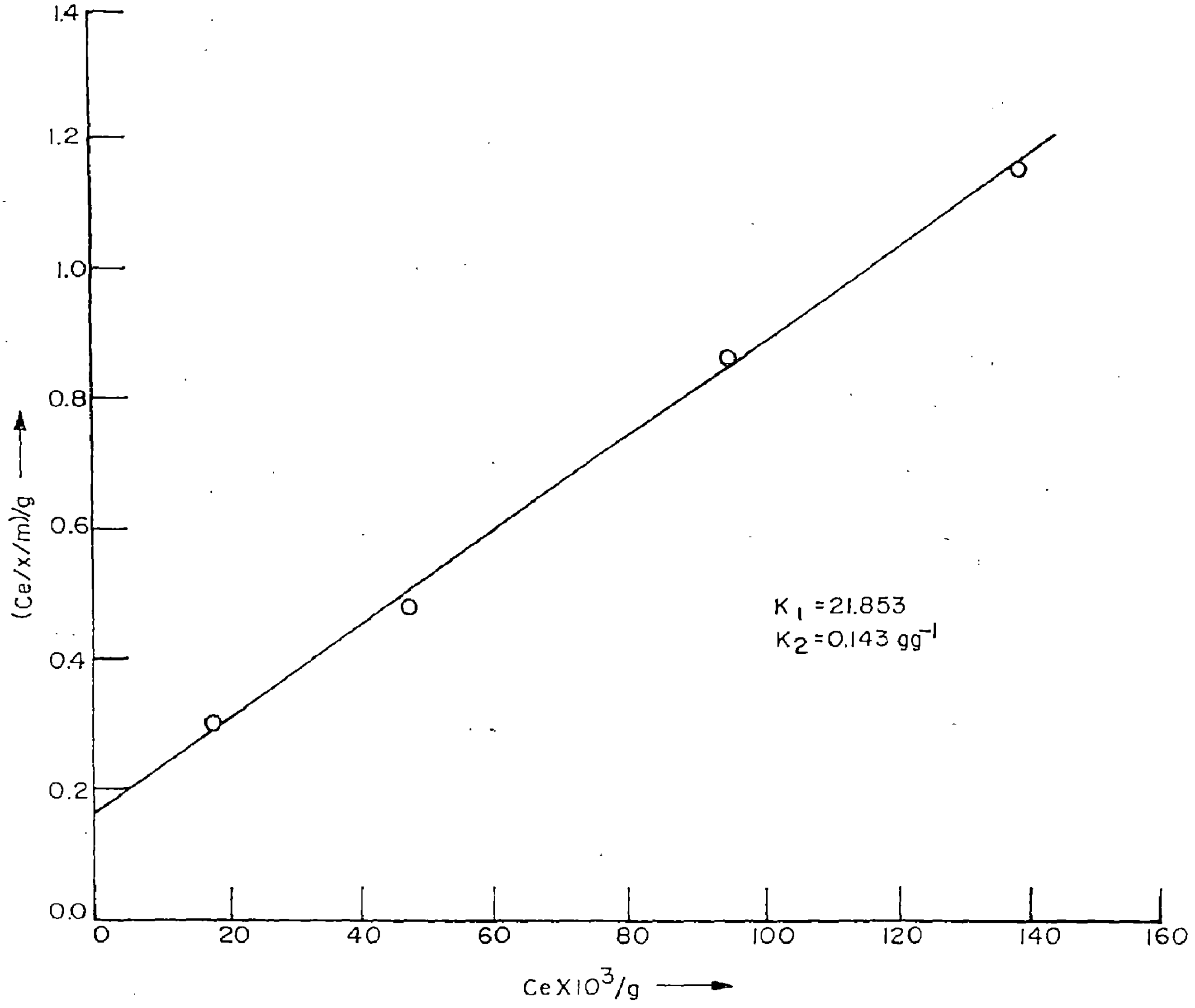

Figure-14 Effect of pH on Cd(II) ions adsorption on BFA at pH-5.

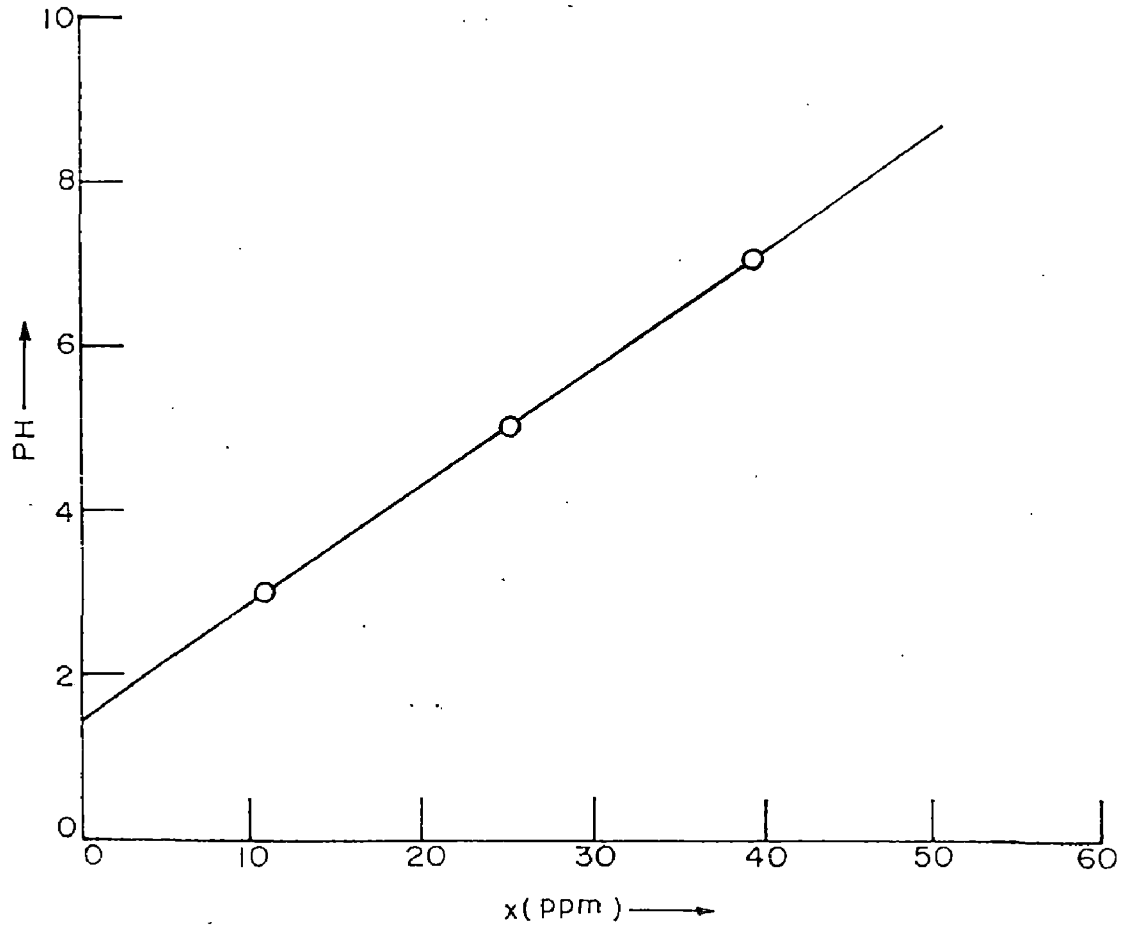

Figure-16 Effect of pH on Cd(II) ions adsorption on BFA.

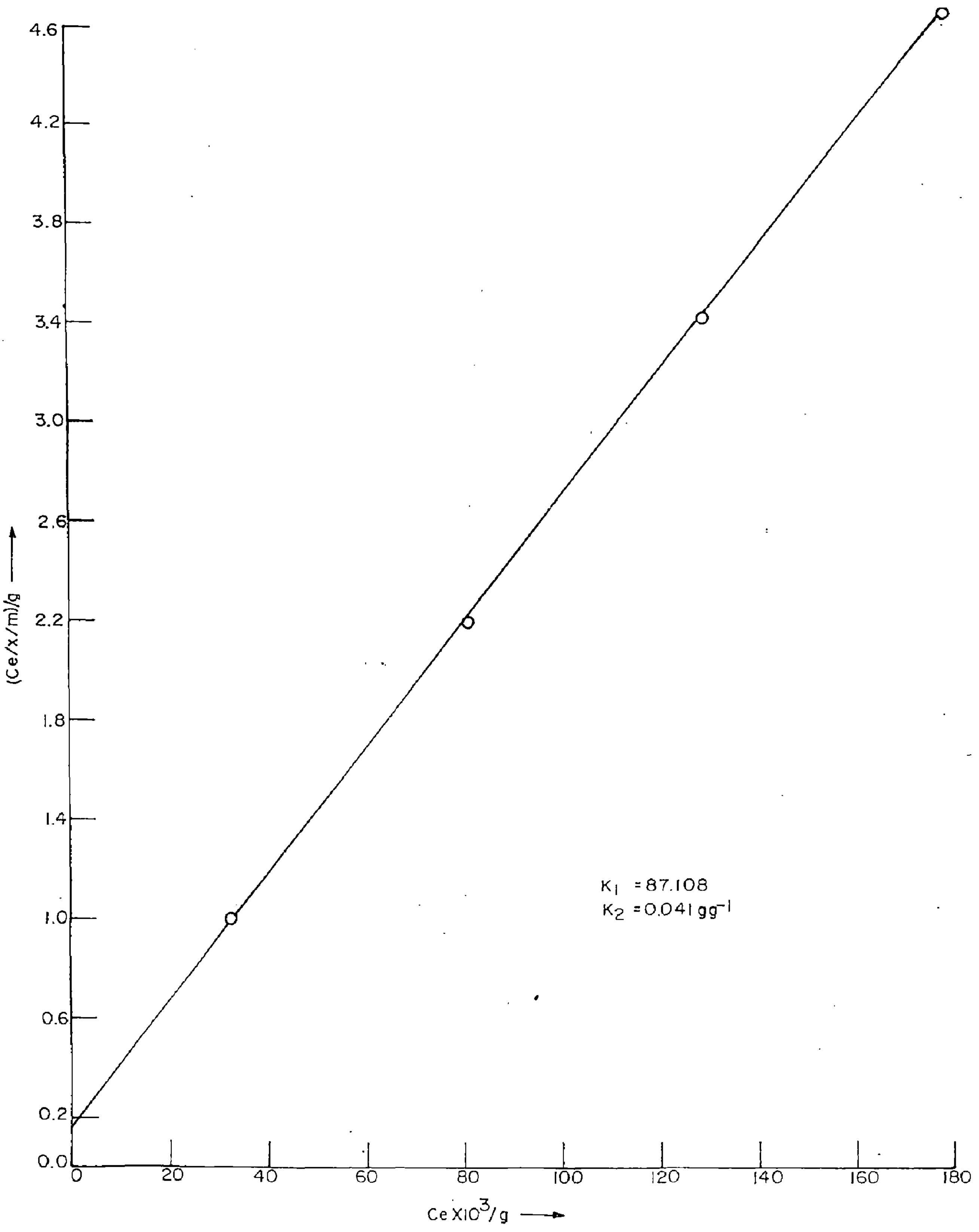

Figure-17 Effect of Temperature on Cd(II) ions adsorption on BFA at 30^{0}C.

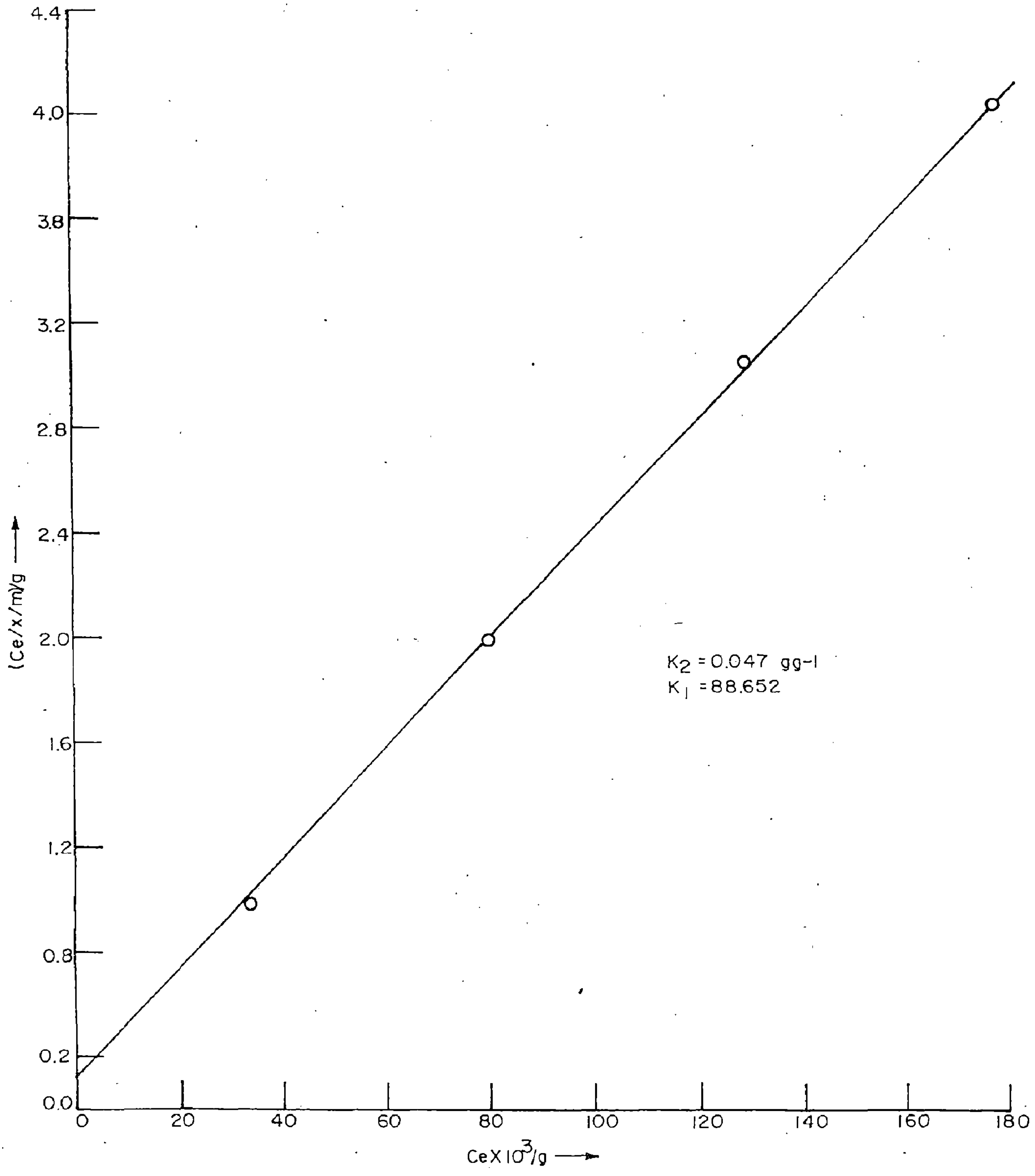

Figure-18 Effect of Temperature on Cd(II) ions adsorption on BFA at 35^{0}C.

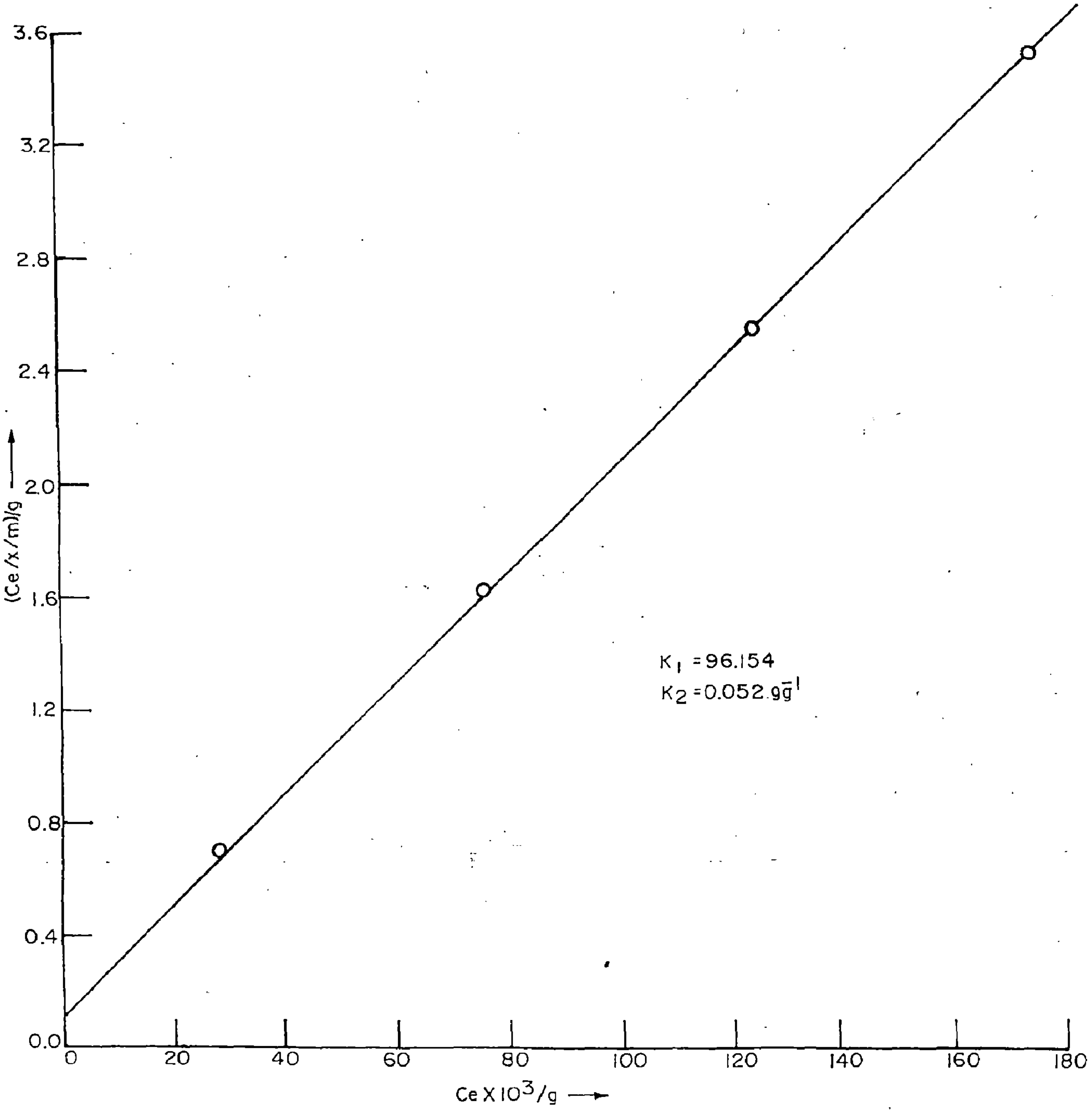

Figure-19 Effect of Temperature on Cd(II) ions adsorption on BFA at 40^0C.

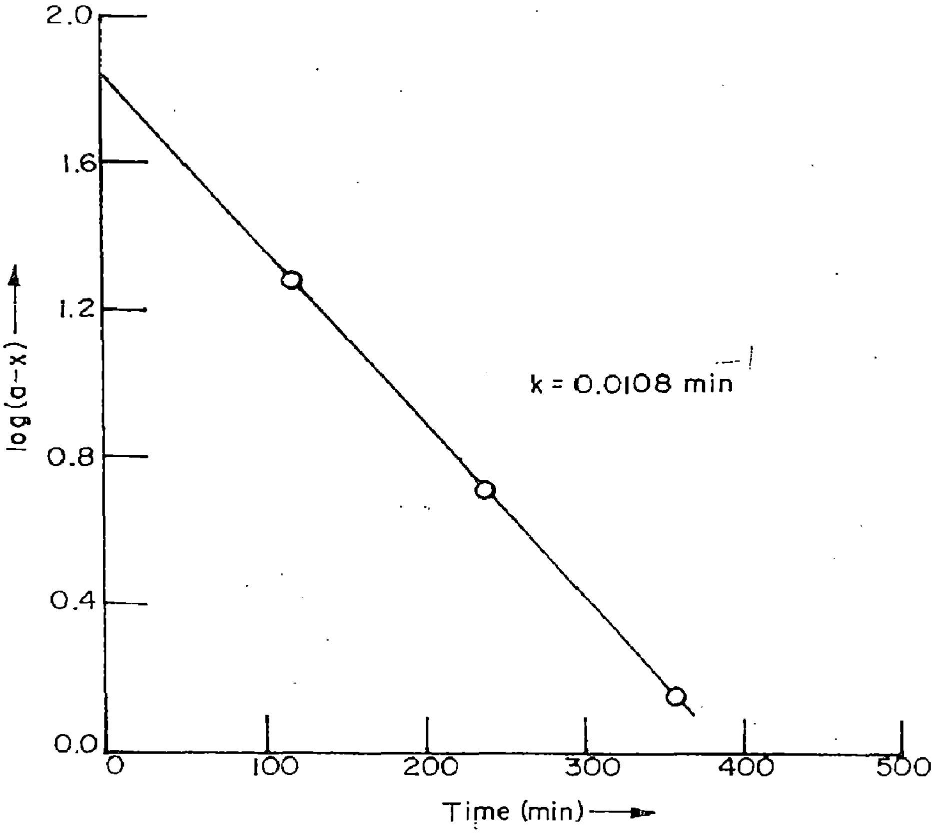

Figure-20 Effect of Time variation on Cd(II) ions on adsorption on BFA.

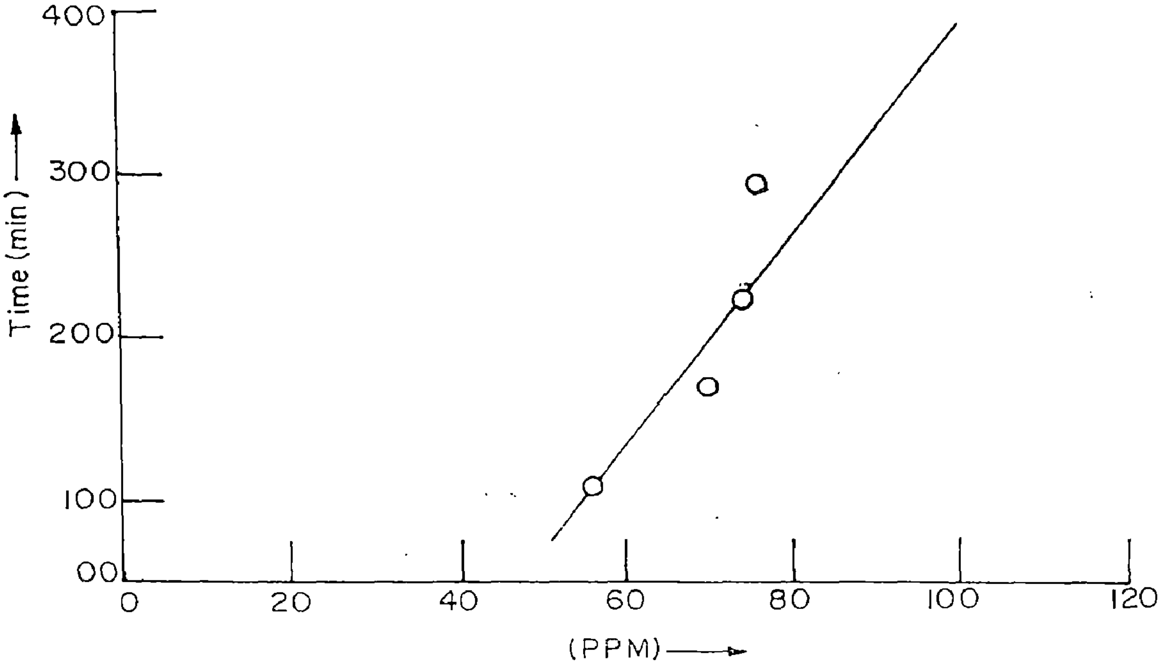

Figure-21 Effect of Time variation on Cd(II) ions adsorption on BFA.

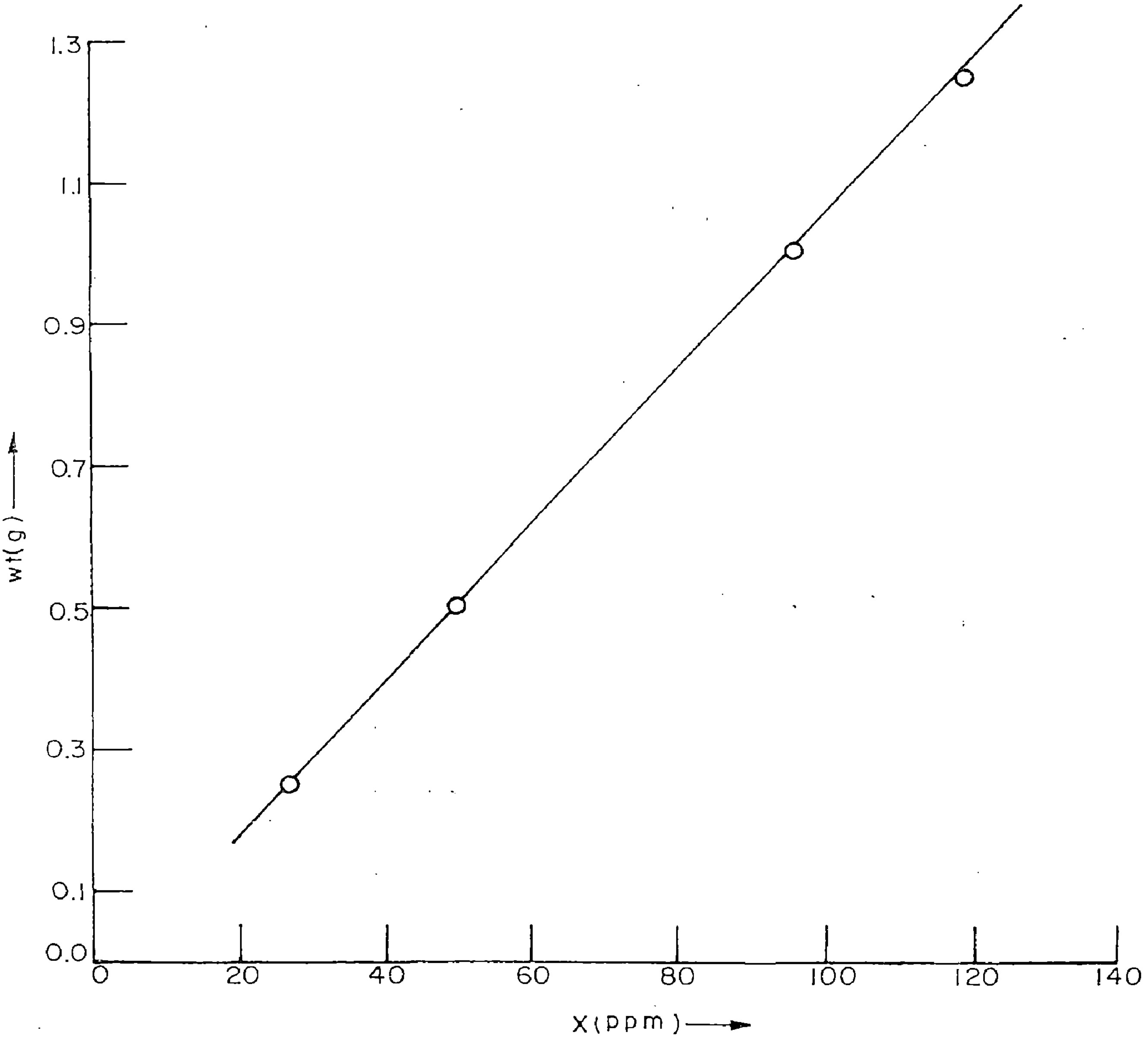

Figure-22 Effect of Weight variation of adsorbent (BFA) on Cd(II) ions adsorption.

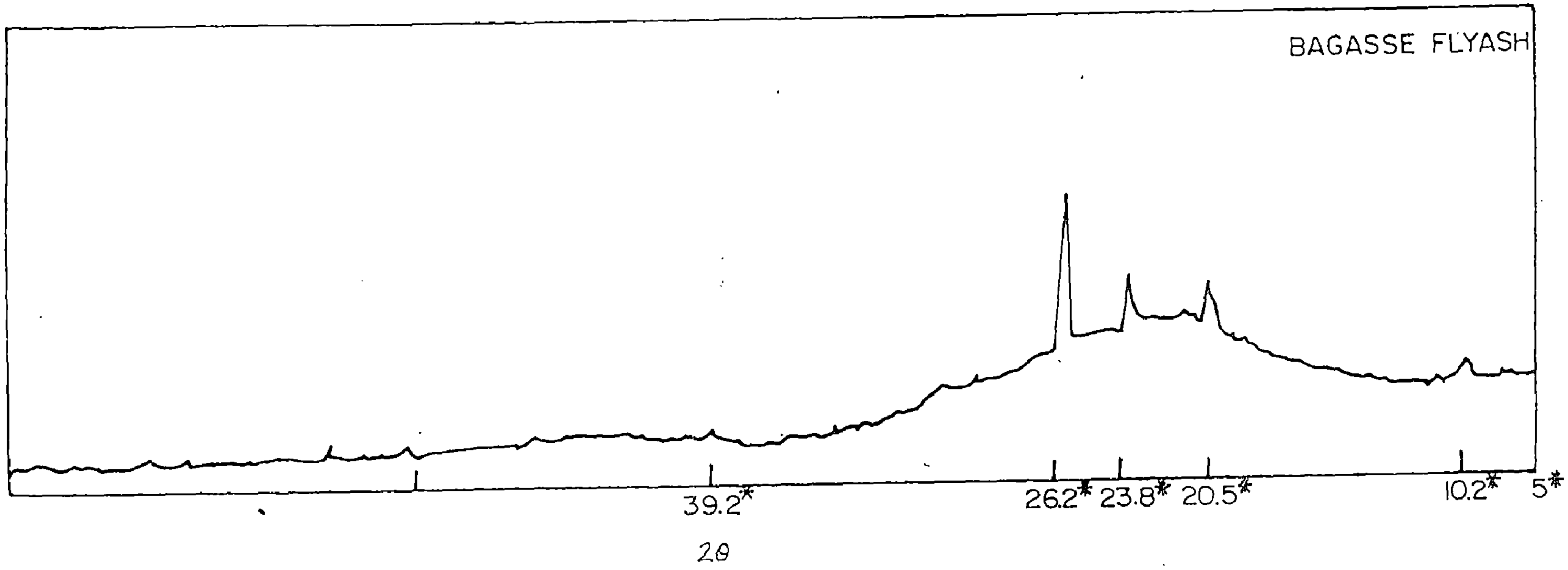

Figure-23 X-ray diffractogram of bagasse fly ash.

REFERENCES

REFERENCES

1. M.C.Anne sini, F. Gironi, M.Ruzzi and C.Tomei, water Res. 21, 567 (1981)
2. Y. chen-Yu and P.C.Singir, J.Environ. Engg. (ASCE)110, 978 (1984)
3. E.H.Smith, water Res. 25, 125 (1991)
4. T.F.Speth, J.Environ. Engg. (ASCE), 119, 1139 (1993)
5. M.C.Lee, J.C.Crittendan, V.C.Soneyink and M.Ali, J.Environ. Engg. (ASCE)109, 63 (1983)
6. N.Narkis and B.B.David, water Res.,19, 815 (1985)
7. S.Saha, water Res., 27, 1347 (1993)
8. G.Mckay and B.Alduri, Ind. Engg. Chem. Res., 30, 385 (1991)
9. J.Felting and Heinrich, J.Environ. Engg. (ASCE) 113, 764 (1987)
10. J. Fetling and Heinrich, J.Environ. Engg. (ASCE)113, 180 (1987)
11. Fetting and Heinrich, J.Environ. Engg. (ASCE), 113, 795 (1987)
12. E.A.Sigworth and S.B.Smith, J Am. Water Wks. Assoc. 64, 306-391 (1972)
13. B.E. Reed and S.Arunachalam, J.Environ Engg.(ASCE) 3-4, 416-436 (1994)
14. A.G.Rowley, F.M.Husband and A.B. Cunningham, water Res., 18, 981 (1984)
15. A.K.Sen and A.K.De, water Res.,21, 885 (1987)
16. D.W.Hand, J.A.Herlevich, D.L.Perram and J.C.Crittenden, J.Am. water wks. Assoc.-86 7-12 (1994).
17. V.Roberts, M.P.Cornel and R.S.Summers. J.Environ. Engg., (ASCE),3, 891, (1985)
18. B.Coupal and M.J.Lolan and Cetle, water Res., 10, 1071 (1976)
19. C.F.Forster and D.C. Sharma, water Res., 27, 120 (1993)
20. K.Seki, N.Saito and M.Aoyama, R.Shikenjoho, 6, 10 (1992) CA 119:31908.

21. M.M.Alves, J.M.Castan Keira, MC.S. percira and L.A.T.Varconcelos, water Res. 27, 1333 (1993)

22. W.T.Tan, S.T. Ooi and C.K.Lee, Environ Technol. 14(3) 277 (1993); CA 119; 552752

23. B.E.Reed and M.R.Maturumto, J.Environ. Engg.(ASCE), 119, 332 (1993)

24. P.A.Nader and B. Parvathy; IAWPC. Tech. Annual 9, 176, 1982; CA 100; 215224

25. S.A.Churchill, J.V.Watters and P.F.Churcill. J.Environ. Engg (ASCE) 10, 206 (1995)

26. S.V.Dimitrova; water Res., 31, 228 (1996)

27. C.Namasivayam and K.Rangnathan, Ind.Engg. Chem. Res., 34 869 (1995)

28. K. Periasamy and C.Navnasivayam, Ind.Engg. Chem. Res., 33, 317 (1994)

29. D.P.T. Blackmore, J.Ellis and P.J.Riley, water Res.,30 2512 (1996)

30. S.Saha, water Res., 27, 1347 (1993)

31. O.J.Hao and C.P.Huang, J. Environ. Engg. (ASCE) 112 (1-6) 1054 (19986)

32. I.D.Mall, I.M.Mishra, Ind. Engg. Chemi. Res. 39(2) 115-119 (1994)

33. R.K.Srivastava, S.K.Gupta, K.D.P. Nigam and P.Vasudevan, water Res.,28(5-8) 1631 (1994)

34. P.V.Prabhu, M.S.N.Swamy and T.S.Raju, Indian association water pollution control, 8, 46, (1981)

35. I.D.Mall, N.Mishra and I.M.Mishra, Rescarch and Industry Vol. 39,150 (1994)

36. S.K.Srivastava, V.K.Gupta and D.Mohan, Indian J. Chem. Tech. 2(6), 333 (1995)

37. S.K.Srivastava, V.K.Gupta and I.S.Yadav, Fresenius Envison Bull. 4,550, (1995)

38. S.M. Mahadev, I.D.Mall, B.Prasad, I.M. Mishra, of Institution of Engineers, 206-220 (1996)

39. I.D.Mall, V.Kumar, I.M.Mishra, Meeting of Institution of Engineers, 1995 Nov. 9-10.