

CHARACTERIZATION OF ACTIVATED CARBONS FOR THE EXTRACTIVE METALLURGY OF GOLD

ALTININ METALURJİK KAZANIMINDA AKTİF KARBONUN KULLANILMASI

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Keywords : Surface Area, Adsorption, Aurocyanide Anion, Loading
Capacity, Pollutant Ions.

ÖZET

Bu çalışmada Au (CN)⁻ kompleksinin soğurulması için aktif karbon kullanılmıştır.

Alü ayn aktif karbon numunesi kullanılarak bunların soğurma performansları tespit edilmiş, soğurma kapasitesi ve kinetiği her numunenin fiziksel ve kimyasal özellikleriyle karşılaştırılmıştır.

ABSTRACT

This work presents a study of characterization of activated carbons for the adsorption of Au (CN)⁻ complex.

A comparative study of six samples of activated carbons, three Brazilian and three produced out of Brazil was made in order to determine their qualification for a performance in adsorption circuits in the extractive metallurgy of gold. The adsorptive capacity and the kinetics of adsorption were compared to the physical and chemical properties of each one. The influence of pollutant ions on the kinetics and loading capacity of aurocyanide anion was also determined.

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1. INTRODUCTION

Among the most important application of activated carbon, the extractive metallurgy of gold in the stage of aurocyanide complex $\text{Au}(\text{CN})_2^-$ adsorption can be mentioned. The surface area, that depends on the diameter of the pore, is the most important property of the activated carbon.

The activated carbon has been used for a long time in the recovery of gold through cyanide solutions from lixiviation, but the mechanism with which the carbon adsorbs gold is still undetermined and there are many theories and different opinions about it (QUISPE and SAMPAIO, 1992). The goal of this work was to characterize 3 brazilian carbons and three foreign ones, aiming their utilization in adsorption circuits in the extractive metallurgy of gold and to number the individual effects on the loading capacity of gold brought about by the most common ionic pollutants which belong to cyanide lixiviation. In industrial solutions, such as silver, copper, iron, thiocyanate, cyanide, etc. The ionic interaction was considered a significant factor in the kinetics of gold adsorption. After testing 6 samples of activated carbon one of them was chosen to measure: the effects of pollutants, the effects of stabilizing cations (Ca^{2+} , Na^+ , and K^+), pH, temperature and velocity of agitation on the kinetics and loading capacity.

2. EXPERIMENTAL PROCEDURE

2.1 Materials

2.1.1 Samples of Activated Carbon

The 6 samples of activated carbon were identified by the letters from A to F, being A, B and C foreign carbons and D, E and F brazilian ones. The granulometric fractions provided by manufacturers in ASTM mesh were: A, B and E:

8 x 16 (2,36 x 1,18 mm); **C: 6 x 12** (3,35 x 1,70 mm); **D and F: 6 x 16** (3,35 x 1,18 mm).

2.1.2 Reagents

All the reagents utilized in order to prepare solutions were of analytical grade, deionized water was used and as pH modifiers HCl and NaOH 0.1 N were used as well.

2.2 Methodology

The activated carbons utilized in the tests were homogenized and quartered until aliquotes of 20 g were obtained. For moisture analysis, proximate analysis and pH, these aliquotes of 20 g were ground to 100% -50 mesh (ASTM, 1991). For Iodine Number and Loading Capacity the carbons were ground to 100% -325 mesh (ASTM, 1991; CALGON, 1983). In the remaining tests the carbons were used in the size they were provided by the manufacturers. In order to determine the resistance of the carbons to abrasion the method of the "Companhia Vale do Rio Doce" (CVRD) was applied. According to this method the loss caused by abrasion should be less than 2%. The degree of gold adsorption occurring at equilibrium was measured using of the empirical Freunlich Isotherm (CHEREMISINOFF P. N., et al, 1980). For all the tests of kinetics of adsorption 1 g of dry sample of granular activated carbon was mixed during 8 hours with 1700 ml of a solution with 5mg/l of gold in a batch reactor with baffles. The agitation was adjusted to 900 rpm. After 2, 4, 6 and 8 hours, aliquotes of 10 ml were taken and the amount of gold was analysed by atomic absorption. The ionic effect on the aurocyanide adsorption caused by the most common poluants ions from industrial solutions of gold cyanidation was measured. The variables which were mantained constant for each test were: volume of the solution, weight of the activated carbon, temperature and agitation. The ionic solutions were prepared with deionized water. The used solution of gold

was a buffer of borate in pH 10, with different initial concentrations of gold.

3. RESULTS AND DISCUSSIONS

3.1 Physical Properties and Chemical Characteristics

Table I. Physical properties and chemical characteristics of adsorption of the activated carbons (*)

Activated Carbon	FC %	VM %	ASH X	MOIST. X	AP. DENS. g/cc	HARDNESS X	ABRASION X	IODINE No. mg 12/g AC	pH VALUE	
									suspension	filtrate
A	92,49	5,79	1,72	4,02	0,50	91,70	2,43	1110	9,50	9,00
B	90,40	6,34	3,26	2,83	0,50	98,00	1,88	1200	9,60	9,30
C	91,88	6,36	1,76	3,65	0,47	98,00	1,60	1230	9,50	9,10
D	82,99	10,55	6,46	4,29	0,50	98,00	2,65	850	9,00	8,40
E	86,48	7,86	5,66	8,55	0,50	95,00	3,80	1000	6,50	6,40
F	88,21	9,64	2,15	6,74	0,45	97,00	2,82	881	9,30	8,90

(*) the proximate analysis was carried out on dry basis.

3.2 Loading Capacity

Table II. Values of the Isotherm of the Activated Carbon A

pH	Grams of Carbon (M)	Cone, of gold in equilib. (C)		mg Adsorbed (X)	Carbon Loading X/M
		mg/l	mg		
10	Soluc. cabeça	100,00	10,000		
	0,4000	0,90	0,090	9,910	24,78
	0,3000	3,62	0,362	9,638	32,13
	0,2000	14,20	1,420	8,580	42,90
	0,1003	45,00	4,500	5,500	54,8

The isotherms of the other activated carbons are figured out in the same way. Table III shows the coordinates of the experimental and calculated isotherms, fitted by the least-squares method. The fitted isotherms are presented in Fig. 1 and table IV presents the results of loading capacity.

Tabela III. Isotherm Coordinates Plotted in Fig. 1

Activated Carbon	[Au]eq. C	mg Au ads./g a. c. XM exp.	mg Au ads./g a. c. XM calc.	R Squared	Standard error est. de XM
A	0,90	24,78	24,60	0,999	0,006
	3,62	32,13	32,49		
	14,20	42,90	42,70		
	45,00	54,84	53,78		
B	1,40	24,65	24,27	0,995	0,014
	4,52	31,83	32,15		
	16,00	42,00	43,55		
	43,00	56,38	55,21		
C	2,30	24,43	24,52	0,987	0,018
	7,00	31,00	31,33		
	23,50	38,25	40,89		
	51,00	49,00	48,49		
D	3,20	24,20	24,87	0,893	0,031
	11,20	29,60	29,27		
	29,00	35,50	33,12		
	65,50	34,50	36,82		
E	9,00	22,75	24,06	0,876	0,033
	16,20	27,93	26,90		
	34,50	32,75	31,06		
	67,00	33,00	35,23		
F	9,50	22,63	22,71	0,901	0,026
	21,00	26,33	25,99		
	37,50	31,25	28,68		
	69,00	31,00	31,81		

Table IV. Results of the Loading Capacity

Activated Carbon	K-value KgAu/t	1/n	Maximum Capacity of the Adsorbent (X/M) _∞
A	25	0,20	63
B	22	0,24	68
C	20	0,22	56
D	21	0,13	39
E	16	0,19	38
F	15	0,17	34

3.3 Kinetics of Adsorption

It has been showed in tests of batch adsorption that the rate in which the gold gets out of the solution can be described as a first order process for short periods of time, less than 12 hours, (NICOL et al, 1984; FLEMING et al, 1984).

The kinetics model is described by:

$$dC_c/dt = kC_s \quad [1]$$

In which: C_c and C_s are the respective concentrations of gold in the carbon and in the solution, at time t in mg/kg and K is the kinetics constant of first order. From [1] and from the mass balance equation at any time in the batch reactor we have:

$$\ln C^0_s/C_s = M_c/M_s kt \quad [2]$$

in which C^0_s is the concentration of gold in the solution at time 0 in mg/kg. All the kinetics tests were analysed through the equation [2]. Table V presents a comparison of the results of loading capacity and kinetics. Fig. 2 shows the kinetics results of the tested carbons.

Table V. Comparison of the Results of Loading and Kinetics

Carvão Ativado	Cte. Cinética h ⁻¹	K-value kgAu/t	1/n
A	590	25	0.20
B	828	22	0.24
C	776	20	0.22
D	200	21	0.13
E	147	16	0.19
F	212	15	0.17

4. EFFECT OF THE POLUANT IONS

Metallic copper and silver were individually dissolved in cyanide of potassium until solutions with different initial concentrations of cyanide, copper and silver were obtained. Then a buffer solution, pH 10, with initial concentration of 10 mg Au/l was added. Fig. 3 shows that gold adsorption is extremely diminished in 200 ppm of Cu, whereas there is almost no reduction in gold adsorption in solutions with 100 ppm of copper. It can be concluded, as it was shown by FLEMING and NICOL, that in low ratios of free cyanide and copper, the $\text{Cu}(\text{CN})_2^-$ complex is adsorbed by carbon, whereas in high ratios the $\text{Cu}(\text{CN})_3^{2-}$ and $\text{Cu}(\text{CN})_4^{3-}$ complexes are formed and the adsorption on carbon is not significative. Fig. 4 presents the results, where the adverse effect of silver in gold adsorption is shown. It can be also noticed that a silver/gold ratio of 2:1 has a pronounced effect on decreasing gold adsorption.

The individual dissolution of ferrocyanide of potassium and thiocyanate of potassium in deionized water produced iron and thiocyanate pollutant solutions. From Fig. 5 it can be concluded that the iron pollutant does not practically present any noticeable effects on gold loading for the established levels; the curves are similar. Fig. 6 presents the results and shows that the SCN^- is not as hazardous as the copper and silver pollutants, although some decrease in the loading happened. Fig. 7 shows that the high concentration of cyanide inhibits the adsorption and in Fig. 8 it can be seen that the addition of 0,067 M of calcium ions has great influence on the kinetics of gold adsorption, if it is compared to the presence of three-time-higher concentrations of sodium and potassium ions, which do not improve the loading. The solution without ions has a slower kinetics, what leads to the conclusion that these cations, especially the calcium, make the complex $\text{Ca}[\text{Au}(\text{CN})_2]_2$ stable (formation of pair ion) promoting the kinetics and the loading. Fig. 6 shows that the adsorption capacity diminishes with the pH increase,

despite the presence of 200 ppm de Na added as sodium chloride. The decrease of the k-value can be inferred to the competition between the OH⁻ and the Au(CN)₂⁻ in the adsorption on the carbon surface area.

The loading capacity at 30, 40 and 60 °C was measured. The results are shown in Fig. 10, where the adsorption's tendency of increasing with the decrease of the temperature in a linear variation can be observed, proving that the adsorption is an exothermic reaction. Fig. 11 clearly presents that the kinetics constant increases notoriously with the increase of the agitation for diluted solutions. The same does not occur for high gold concentrations.

5. CONCLUSIONS

The characterization of the carbons showed that the brazilian ones present minor indices than the imported carbons, therefore, their use get compromised for CIP and CIL adsorption circuits. However they could be used in CIC circuits.

Considering the typical conditions of the industry such as dilute solutions and alkaline environments, the significative presence of copper and/or silver in the cyanide solutions from gold ores have remarkable influence on the rate of adsorption and in the final extraction of gold. The remaining poluants have minor effect.

The effect of the pH, free cyanide and temperature are the most important variables which affect gold adsorption and loading.

ACKNOWLEDGEMENTS

The authors would like to thank Ana Maria dos S. da Silva, Daniela Veek dos Santos e Luciane F. de Souza for their helping in the laboratory tests. Acknowledgement is also

led to Angela R. Stainki for her helping in the translation of this article into English.

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Fig. 1: Isotherms of Aurocyanide Adsorption on Activated Carbon

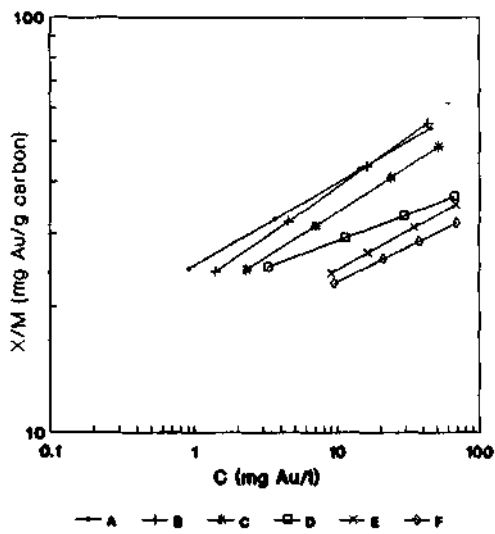


Fig. 2: Kinetics of Adsorption

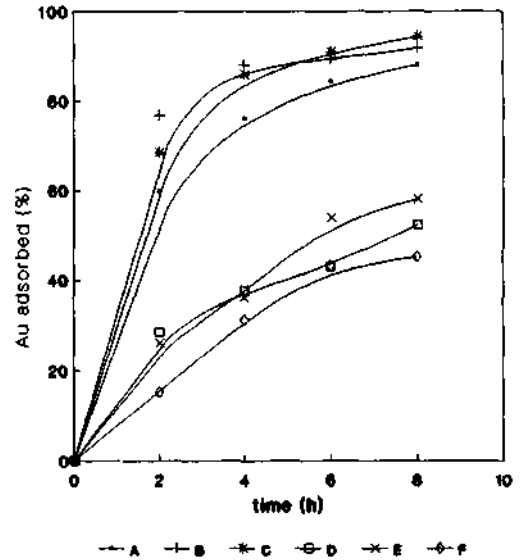


Fig. 3: Effect of Copper on Aurocyanide Adsorption

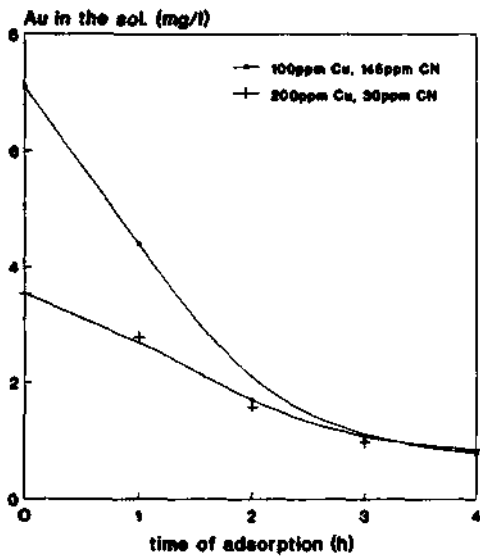


Fig. 4: Effect of Silver on Aurocyanide Adsorption

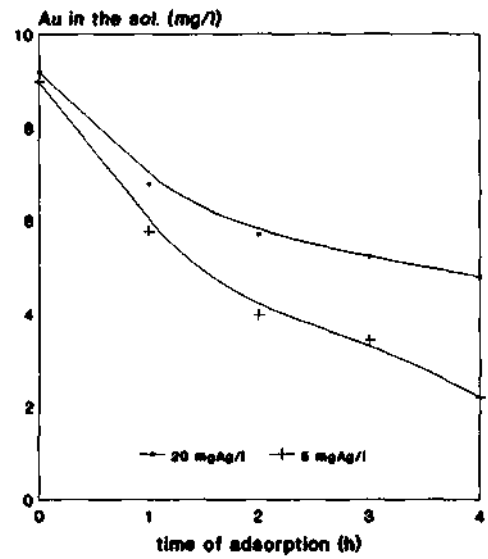


Fig. 5: Effect of Iron on Aurocyanide Adsorption

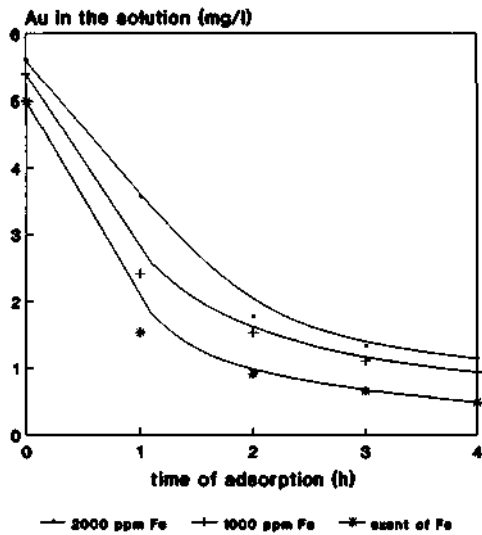


Fig. 6: Effect of Thiocyanate on Aurocyanide Adsorption

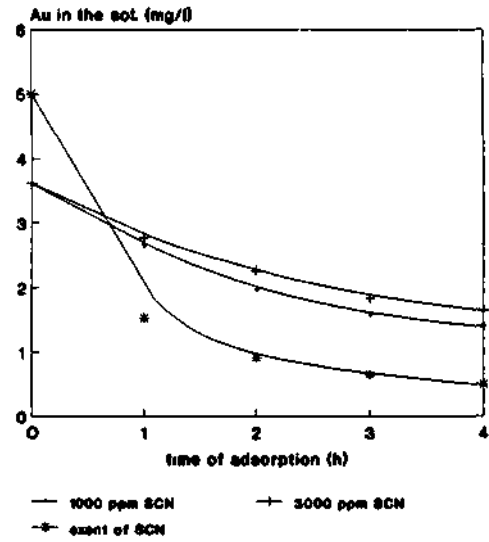


Fig. 7: Effect of Cyanide on Aurocyanide Adsorption

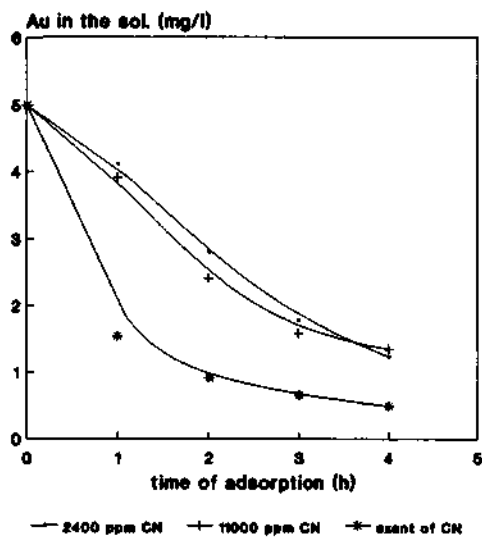


Fig.8: Effect of Ca, K, and Na on Aurocyanide Adsorption

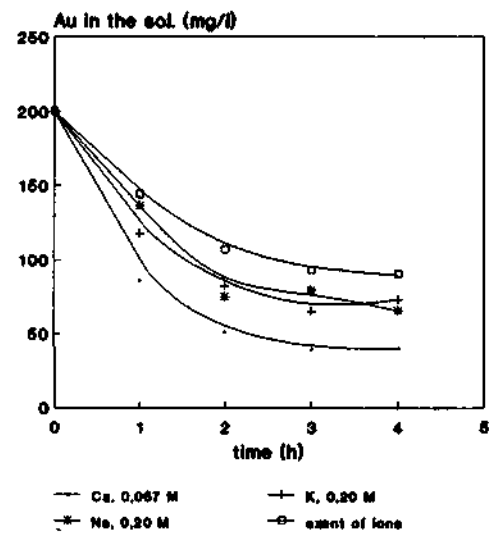


Fig. 9: Effect of pH on Gold Adsorption
In Presence of 2000 ppm Na

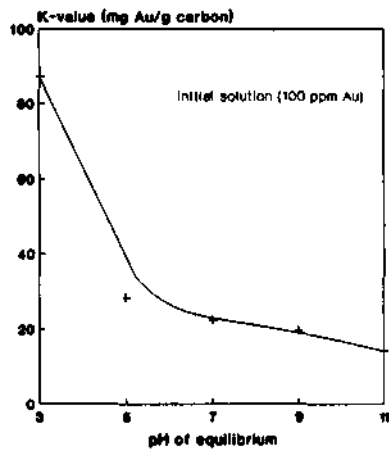


Fig. 10: Effect of Temperature
initial Buffer Solution 100 ppm Au

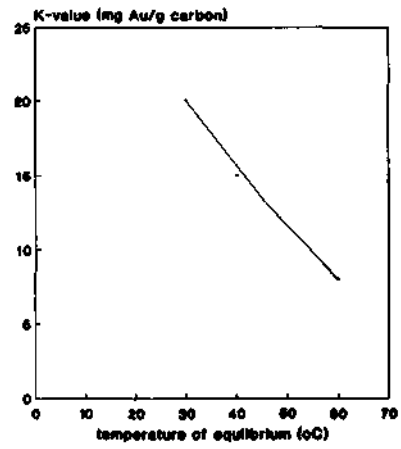


Fig. 11: Effect of stirring on the
Kinetics of Adsorption

