

# INTERACTION OF GOLD COMPOUNDS WITH GRAPHITIC CARBONS - NEW FACTS AND MECHANISMS

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## Introduction

The adsorption of the complex gold cyanides is an important industrial application of active carbon adsorbents and has been extensively investigated in the U.S.A. South Africa and Australia. There is still no agreement on the exact mechanism of the gold cyanide adsorption from aqueous solutions (1). One school of thought proposes the adsorption of potassium aurocyanide on the graphitic planes as the driving mechanism (2). Another view represented by M. Adams and C. Fleming (3) is that the aurocyanide ion adsorbs predominantly on polar sites in carbon adsorbents which are invariably produced during the formation of active carbons by oxidation and activation of various carbonaceous materials. This view is broadly supported by E. Papirer et al (4) who stressed that the most desirable polar sites in carbons should have basic properties. The present paper summarises some of the recent study carried out by the authors on the adsorption of potassium gold aurocyanide or graphites and active carbons to obtain more detailed information on its mechanism of interactions with the graphitic adsorbents. Some of this work was recently described by S. Lagerge (5).

## Experimental

The Microscal Mark 4 Flow Adsorption Microcalorimeter (FAMC) used in the work was described previously (6). The work was carried out by using two methodologies: Flow Injection Adsorption Thermodynamics (FIAT) and Flow Equilibrium Adsorption Thermodynamics (FEAT).

Some surface properties of the adsorbents used in this work are given in Table 1. The solvents and reagents used were all Aldrich materials with purities exceeding 99%.

## Results and Discussion

An example of the results obtained by the Flow Injection FIAT method is shown in Figure 1 for active carbon 2. As can be seen, this carbon was quite effective

in irreversibly adsorbing a high proportion of the injected gold compound with the production of gradually decreasing heat effects. The results of a similar series of experiments obtained for all the three active carbons are plotted in Figure 2 and the corresponding molar heats of adsorption in Figure 3. The carbons show very different effectiveness in the removal of the gold solute from solution, and different heats of adsorption.

Cyclic FEAT experiments carried out on the three active carbons and Graphon demonstrate strong adsorption of the  $\text{KAu}(\text{CN})_2$  on all the carbons with varying degrees of irreversibility. The results for all the carbons are given in Table 2. As can be seen the adsorption at room temperature can be clearly divided into irreversible and reversible processes.

The heats of adsorption follow similar trends to the amounts of adsorptions confirming their reversible and irreversible proportions. The shapes of the peaks represent the kinetics of the adsorption process and differential quantities can be obtained from them. Most of the adsorption occurs, however, in the first 30 minutes of the contact and it appears therefore that a relatively short contact time should be sufficient to achieve a substantial degree of the extraction of potassium aurocyanide from dilute aqueous solutions.

The results in Table 2 show that there are considerable variations between the various carbons in their total gold adsorption capacities, but more importantly, in their ability to irreversibly adsorb gold aurocyanide from dilute solutions. It is interesting that the proportion of the strongly adsorbed gold cyanide does not depend on the presence or absence of micropores. The graphitised carbons gave a similar proportion of the strong adsorption to some of the microporous carbons. There is also no direct correlation with the accessible graphite basal planes in the adsorbents given in Table 1 and the proportions of polar surface sites

The comparison of graphite flakes and Graphon shows that the polar sites present in the flakes radically increase the irreversible adsorption. There is also an important fact that the total amount of  $\text{KAu}(\text{CN})_2$  adsorption

is drastically reduced for all the carbons investigated by the presence of 1% of n-butanol in the solution.

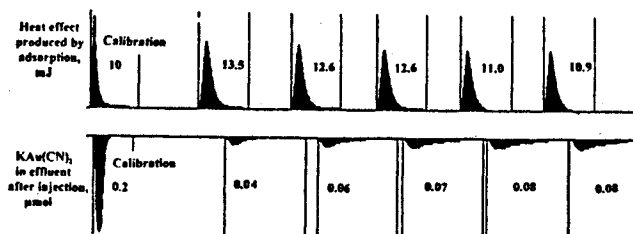
## Conclusions

The adsorption of potassium aurocyanide from water on graphitic carbons is invariably partly irreversible at room temperature. The active sites responsible for the irreversible adsorption are basal planes linked to polar functional groups. The adsorption of  $\text{KAu}(\text{CN})_2$  occurs only on a small percentage of the total surface available in carbon adsorbent irrespective of whether the carbons are microporous or not. Most of the graphitic basal plane surface in carbon adsorbents is inactive for the adsorption of potassium aurocyanide. This applies to irreversible and reversible adsorption. Nevertheless, the fact that blocking of the basal planes by a monolayer of n-butanol drastically reduces the adsorption of gold cyanide indicates that the basal planes constitute an essential element in this adsorption process.

## References

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**Figure 1 Adsorption of  $\text{KAu}(\text{CN})_2$  from 20  $\mu\text{mol}$  0.01 molar solution Aliquots Injected into Water Percolating through a Bed of 10.2 mg of Carbon 2 mixed with 85 mg of PTFE Powder at a rate of 50  $\mu\text{l}/\text{minute}$**



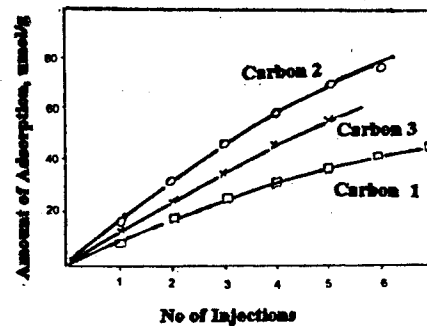
**Table 1. Properties of Carbon Adsorbents**

Adsorbent	BET $\text{N}_2$ S.A. $\text{m}^2 \text{g}^{-1}$	Polar * Surface $\text{m}^2 \text{g}^{-1}$	Accessible** Basal Plane Surface $\text{m}^2 \text{g}^{-1}$
Graphon	85	0.25	85
Graph. Flakes	90	4	93
Carbon 1	1118	24	103
Carbon 2	1135	22	136
Carbon 3	1688	10	179

**Table 2. Results of Adsorption/Desorption Cycles**

Carbon	Total Adsorption			Irreversible Adsorption	
	$\Delta H$ $\text{Jg}^{-1}$	$\Delta A$ $\mu\text{molg}^{-1}$	$\Delta H$ $\text{kJ mol}^{-1}$	$\Delta A$ $\mu\text{mol g}^{-1}$	$\Delta H$ $\text{kJmol}^{-1}$
1	-17.7	404	-44	47	-140
2	-28.5	619	-46	178	-100
3	-21.2	471	-45	162	-28
Graphon	-1.1	41	-27	5	-80
Graph. Flakes	-2.3	34	-68	14	-107

**Figure 2 Flow Injection Adsorption of  $\text{KAu}(\text{CN})_2$  on Active Carbons from Water - 3 min Contact**



**Figure 3 Cumulative Molar Heats of Adsorption of  $\text{KAu}(\text{CN})_2$  on Different Active Carbons**

