

The elution of gold from activated carbon using deionized water

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SYNOPSIS

The pretreatment of gold-loaded activated carbon with a relatively strong sodium cyanide solution prior to elution with deionized water at 90 to 125°C has been shown to have a most beneficial effect on the elution of gold. The findings emphasize the important role played by the calcium cation and the hydroxyl anion in effecting efficient elution of gold. The elution of the relatively unstable complexes of silver and base metals with cyanide was also significantly affected by the ratio of the sodium cyanide to sodium hydroxide in the reagents used in the pretreatment stage. It was demonstrated that the use of 0,5 bed volume of a pretreatment reagent comprising 10 per cent sodium cyanide stabilized with 1 per cent sodium hydroxide for safety reasons resulted in a virtually 100 per cent recovery of adsorbed gold, silver, and base metals on subsequent elution with deionized water. The elution procedure takes a relatively short time, about 14 hours at 90°C (7 bed volumes) or 3 hours if pressure elution at 125°C (4 to 5 bed volumes) is used. Because the mechanism of elution after pretreatment entails the shifting of a physical rather than a chemical equilibrium, the higher the gold loading on the activated carbon, the more efficient is the elution procedure. When compared with other elution procedures, the proposed method appears to have several economic advantages.

SAMEVATTING

Daar is aangetoon dat die voorafbehandeling van goudbelaaide geaktiveerde koolstof met 'n betreklike sterk natriumsianied oplossing voor stroping met gedeioniseerde water teen 90-125°C 'n besonder voordelige uitwerking het op die herwinning van goud. Die bevindings onderstreep die belangrike rol wat deur die kalsium katioon en die hidroksiel anioon gespeel word by die verkryging en daarstelling van doeltreffende goudstroping, terwyl die herwinning van die betreklik onstabiele silwer- en basismetale sianiedkomplekse aansienlik aangetas is deur die verhouding van natriumsianied/natriumhidroksied reagent wat gedurende die voorafbehandelingsstadium gebruik is. Dit is aangetoon dat die aanwending van 'n voorafbehandelingsreagent saamgestel uit 'n 0,5 bedvolume 10 persent natriumsianied gestabiliseer met 1 persent natriumhidroksied om veiligheidsredes, ten gevolge gehad het dat feitlik 100 persent van die opgeloste goud, silwer, en basis-metalewaardes teruggevind is. Die stropingsprosedure kan in 'n betreklike kort tyd verrig word t.w. ca 14 uur teen 90°C (7 bedvolumes) of in drie uur as drukherwinning teen 135°C (4 tot 5 bedvolumes) aangewend word. Omdat die meganisme van stroping na voorafbehandeling eerder 'n fisiese as 'n chemiese ewewigsverskuiwing behels, sal bevind word dat hoe hoër die goudbelading op die geaktiveerde koolstof, hoe doeltreffer is die herwinningsprosedure. Wanneer die voorgestelde metode met ander stropingsmetodes vergelyk word, blyk dit dat die voorgestelde metode 'n hele aantal ekonomiese voordele inhou.

Introduction

It has been amply demonstrated that, even on a commercial scale, activated carbon is a most efficient and selective scavenger for gold from gold-plant leach liquors, pregnant slurries, and effluents, the major problem to date being the recovery of the gold from the loaded carbon to allow re-use of the latter. Methods involving expensive and hazardous reagents such as sodium sulphide-sodium sulphite-sodium hydroxide¹, boiling sodium cyanide-sodium hydroxide², pressure leaching at 150°C with sodium cyanide-sodium hydroxide³, and anhydrous ammonia⁴, have all been used but have not proved very attractive. This has perhaps inhibited the wider use of activated carbon as a means for the economic concentration of gold from dilute cyanide solutions. Later work⁵ related to the mechanism of gold adsorption onto activated carbon has shown that both the kinetics and the equilibrium capacity of gold adsorption are dependent on the ionic strength and the presence of the calcium cation, as well as on the hydroxyl anion in the adsorbent medium. It was also demonstrated that, provided the adsorbed gold that initially concentrated on the activated carbon as the calcium aurocyanide complex was converted to either the sodium or potassium complex by a pretreatment stage involving an alkaline metal carbonate-hydroxide reagent, such complexes could be successfully eluted from the carbon with hot

deionized water. The quality of the water used as eluant was shown to have a very definite effect on the efficiency of elution.

As the pretreatment of gold-loaded activated carbon with an alkaline metal carbonate prior to elution with deionized water involved the precipitation of calcium carbonate to effect the elution of either the potassium or sodium aurocyanide complex, the build-up of calcium carbonate on the carbon was at that stage a distinct disadvantage. The poor elution characteristics of the adsorbed silver and base metals due to the instability of such complexes under high pH pretreatment conditions were also indicated. The present investigation was thus carried out in order to optimize the elution of all such adsorbed values from activated carbon using deionized water as the eluant. The pretreatment of loaded activated carbon with a relatively strong solution of sodium cyanide and sodium hydroxide before elution was shown to have considerable promise in this latter regard.

Materials

Type-G210 granulated coconut-shell carbon (0,5 to 2 mm) supplied by Le Carbone South Africa (Pty) Limited was loaded with approximately 0,3 per cent gold from a gold-plant effluent containing about 0,1 g/g gold. The charcoal was then washed with dilute hydrochloric acid to remove any calcium carbonate that had built up on the charcoal. The chemical compositions of the virgin,

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TABLE I

THE COMPOSITION OF ACTIVATED CARBON

Element	Virgin carbon g/t	Loaded carbon g/t	Acid-washed loaded carbon g/t
Na	18 500	4 500	—
K	10 400	1 900	—
Ca	640	14 800	4 100
Mg	300	100	—
Au	0	2 700	2 900
Ag	< 10	45	64
Fe	1 500	1 500	1 600
Ni	10	2 500	2 200
Cu	20	240	90
Co	4	2	—
Zn	120	380	80

loaded, and acid-washed carbon are shown in Table I.

All the other chemicals used in the present investigation were of C.P. grade.

Method

With the aid of a vibrator, 15 g of air-dried, acid-washed carbon (moisture content about 22 per cent) was loaded as a wet slurry at 90°C into a water-jacketed chromatography column (0.9 cm internal diameter by 40 cm long) in series with an LKB 17 000 Minirac fraction collector. Unless otherwise specified, the pretreatment solutions of sodium hydroxide and sodium cyanide were pumped at about 1 bed volume per hour (apparent flow velocity 9.2×10^{-3} cm/s; 1 bed volume = 25 ml) after the column had been drained of surplus water, while the elution flow rates varied from $\frac{1}{2}$ to 2 bed volumes per hour. Up to 12 bed volumes of eluate were collected. Finally, the carbon was removed from the column and, after being oven-dried at 110°C, was analysed and the adsorption activity determined.

The capacity of the eluted carbon for adsorbing gold was evaluated as follows. A given mass of oven-dried carbon was shaken for 17 hours under ambient conditions with 100 ml of approximately 100 g/t gold solution added as potassium aurocyanide in a standard borate buffer of pH 10.0. The slurry was then filtered through Whatman No. 540 filter paper and the filtrate analysed for gold. The degree of gold adsorption occurring at equilibrium was then measured by use of the empirical Freundlich isotherm as previously described⁵.

Results

Pretreatment with Sodium Hydroxide

Fig. 1 illustrates the elution of gold, silver, and nickel from activated carbon pretreated with potassium carbonate-potassium hydroxide as outlined in an earlier study⁵. The recovery of gold was 99.1 per cent in 12 bed volumes. This pretreatment reagent was then compared with the use of an equimolar sodium carbonate-sodium hydroxide reagent, which was shown to have very similar elution characteristics for gold, silver, copper, and nickel (Table II). The use of sodium salts rather than potassium salts would have obvious economic advantages.

As it had already been shown that potassium hydroxide had a markedly beneficial effect on the elution of gold when added to a potassium carbonate pretreatment reagent⁵, it was questionable whether the

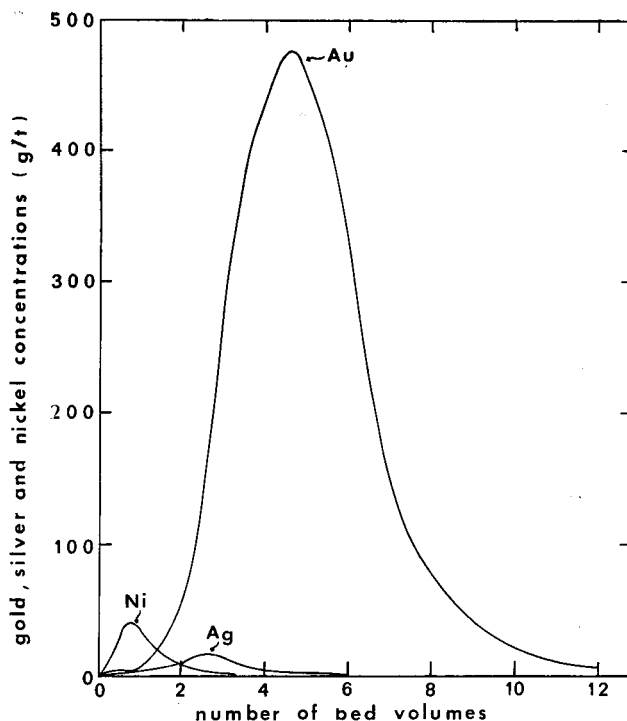


Fig. 1—The elution of gold, silver and nickel from activated carbon after pretreatment with 10 per cent potassium carbonate-5 per cent potassium hydroxide

carbonate or the higher pH (hydroxide) was individually responsible for the efficient elution, or whether a strong hydroxide pretreatment in the absence of added carbonate would suffice.

Fig. 2 (Table II) presents the gold-elution curves for the strong equimolar hydroxide pretreatment reagents of potassium hydroxide, sodium hydroxide, and lithium hydroxide. From these results, it can be seen that, while efficient gold elution can be carried out in the absence of added carbonate, the use of potassium hydroxide is only marginally better than the use of sodium hydroxide, which is significantly better than the use of lithium hydroxide. The elution recovery of gold was 98.6 per cent in 12 bed volumes after pretreatment with 14 per cent sodium hydroxide, but the recoveries of silver, copper, and nickel were poor (Table II).

At this stage in the present investigation, the poor elution characteristics of silver, copper, and nickel were thought to be due, in part at least, to the instability of such cyanide complexes under the prescribed high pH pretreatment conditions. This instability would be reduced considerably by the pretreatment of the carbon with sodium cyanide. Furthermore, such a pretreatment would promote the transformation of the calcium aurocyanide to the sodium form more efficiently than would a carbonate pretreatment, because calcium cyanide is more soluble than either calcium carbonate or calcium hydroxide and would be eluted from the carbon rather than remain as an insoluble precipitate. This early elution of soluble calcium from the system would surely have a very beneficial effect.

Pretreatment with Sodium Cyanide

Figs. 3 to 5 show the corresponding curves for the

elution of gold, silver, and nickel respectively when the loaded activated carbon was pretreated with 10 per cent sodium cyanide containing up to 20 per cent sodium hydroxide. It can be seen that, as the concentration of sodium hydroxide in the pretreatment reagent was decreased, the elution of gold, silver, and nickel all improved, with sharper, more symmetrical peaks and earlier elution profiles in all cases. This improvement in the elution efficiency of all three species as the concentration of sodium hydroxide in the pretreatment reagent

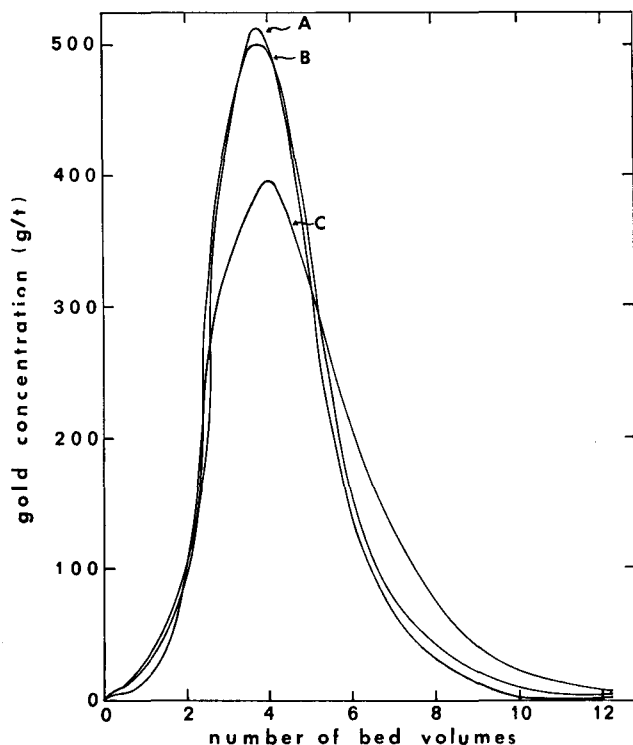


Fig. 2—The elution of gold from activated carbon after pretreatment with equimolar hydroxide reagents
A 10 per cent potassium hydroxide,
B 7 per cent sodium hydroxide
C 4,3 per cent lithium hydroxide

decreased supports the view that, for silver, copper, and nickel (Table II), the stability of the respective cyanide complexes is lower at high pH values. The elution recovery was 99,5 per cent gold, 98,0 per cent silver, 92,3 per cent copper, and 95,5 per cent nickel in 12 bed volumes after the carbon had been treated with 10 per cent sodium cyanide–1,0 per cent sodium hydroxide. A very similar effect was noted when the concentration of the sodium cyanide was increased from 1 to 10 per cent in the presence of 14 per cent sodium hydroxide (Table II).

Effect of Flow Velocity

From Table III it can be seen that the elution of gold, silver, and nickel from activated carbon pretreated with 10 per cent sodium cyanide–1,0 per cent sodium hydroxide is not seriously affected by elution rates within the prescribed experimental parameters. The extraction of gold after seven hours of elution at 1 bed volume per hour was more than 97 per cent, while the recovery of gold after 3,5 hours of elution at 2 bed volumes per hour was 90,8 per cent.

Elution at High Gold Loadings

Type-G215 activated carbon supplied by Le Carbone (Pty) Limited was loaded with between 4 and 6 per cent gold from clarified gold-plant pregnant solutions averaging 8 g/t gold. The loaded carbon was then treated with sodium cyanide–sodium hydroxide reagents and eluted at 90°C as previously described.

Elution curve A (Fig. 6) shows the effect of eluting a loaded carbon (4,0 per cent gold, 600 g/t silver, and 2600 g/t nickel) after pretreatment with 10 per cent sodium cyanide–14 per cent sodium hydroxide. The gold concentration at peak elution was 8500 g/t, with recoveries of 98,4 per cent of the gold, 83,0 per cent of the silver, and over 99,6 per cent of the nickel in 6 bed volumes (Table IV). The recovery of silver was poor owing to the high concentration of sodium hydroxide used (see Table II).

TABLE II

THE EFFECT OF VARIOUS PRETREATMENT PROCEDURES ON THE ELUTION OF GOLD FROM ACTIVATED CARBON
Eluant: Deionized water at 0,5 bed volume per hour and 90°C

Pretreatment reagent	Elution peak concentration, g/t			Recovery after 12 bed volumes, %				Residual carbon activity mg Au/g C
	Au	Ag	Ni	Au	Ag	Cu	Ni	
1 bed volume 10% K ₂ CO ₃ –5% KOH	478	13	43	99,1	80,0	89,0	ca 40	14
1 bed volume 10% KOH	510	8	—	98,9	62,5	78,9	85,3	14
1 bed volume 7% NaOH (equivalent to 10% KOH)	500	10	—	98,1	89,1	86,7	87,8	8
1 bed volume 4,3% LiOH (equivalent to 10% KOH)	390	9	—	97,2	92,2	52,3	86,2	13
1 bed volume 14% NaOH	580	11	—	98,6	65,7	81,2	89,7	13
0,5 bed volume 10% NaCN	940	40	1 600	99,5	98,0	95,6	97,1	13
0,5 bed volume 1% NaOH–10% NaCN	862	37	1 930	99,5	98,0	92,3	95,5	12
0,5 bed volume 5% NaOH–10% NaCN	825	25	1 430	99,1	95,4	91,2	97,4	12
0,5 bed volume 14% NaOH–10% NaCN	820	25	1 350	99,4	92,2	98,9	96,8	13
0,5 bed volume 20% NaOH–10% NaCN	770	23	1 260	99,4	82,9	—	98,2	12
1 bed volume 14% NaOH	580	11	—	98,6	65,7	81,2	89,7	13
0,5 bed volume 1% NaCN–14% NaOH	630	21	1 250	99,4	92,2	—	95,9	13
0,5 bed volume 3% NaCN–14% NaOH	705	28	1 560	99,1	94,9	80,0	96,0	14
0,5 bed volume 5% NaCN–14% NaOH	670	25	1 360	99,4	82,9	84,5	97,1	13
0,5 bed volume 8% NaCN–14% NaOH	740	24	1 560	99,4	86,0	93,4	98,6	13
0,5 bed volume 10% NaCN–14% NaOH	820	25	1 350	99,4	92,2	98,9	96,8	13

Elution curve B (Fig. 6) illustrates the elution of loaded carbon (5,9 per cent gold, 1900 g/t silver, and 6000 g/t nickel) after being pretreated with 12 per cent sodium cyanide-1 per cent sodium hydroxide. The gold concentration at peak elution was 14 400 g/t, with the recovery of 99,8 per cent of the gold, 97,1 of the silver, and 99,9 per cent of the nickel in 6 bed volumes (Table IV). The recovery of silver was significantly better than that shown in curve A because of the lower concentration of sodium hydroxide. Similar elution data are plotted in curve C, which illustrates the elution of gold from activated carbon loaded with 4,1 per cent gold, 1200 g/t silver, and 1700 g/t nickel (Fig. 6). In this series of elution investigations at high gold loadings, the carbon was not washed with acid before the elution, but this omission appeared to have little or no effect on the efficiency of the gold, silver, and nickel elution. (More recent investigations in these laboratories⁷ have shown that the acid washing of loaded carbon has a significantly beneficial effect on the elution of gold and silver.)

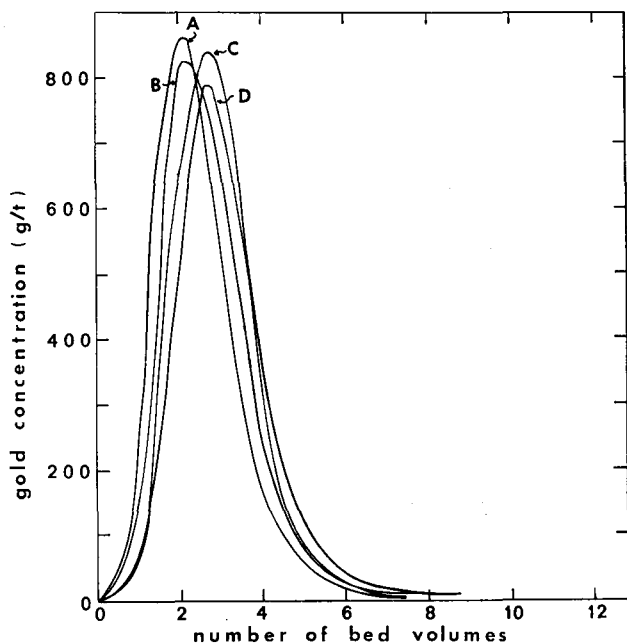


Fig. 3—The elution of gold from activated carbon as a function of the concentration of sodium hydroxide in the pretreatment reagent

- A 1,0 per cent sodium hydroxide-10 per cent sodium cyanide
- B 5 per cent sodium hydroxide-10 per cent sodium cyanide
- C 14 per cent sodium hydroxide-10 per cent sodium cyanide
- D 20 per cent sodium hydroxide-10 per cent sodium cyanide

As the elution of gold with deionized water relies on the displacement of a physical rather than a chemical equilibrium, the higher the initial gold loading on the carbon, the more efficient in terms of gold recovery the elution procedure becomes. This is demonstrated by a comparison of the above results with earlier results at lower gold loadings.

Elution at Higher Temperatures

Earlier findings⁶ had shown that the gold-cyanide complex and particularly the silver-cyanide complex are susceptible to decomposition at high elution temperatures and pressures when potassium carbonate-potassium hydroxide is used in the pretreatment. In the present investigation, loaded carbon was pretreated

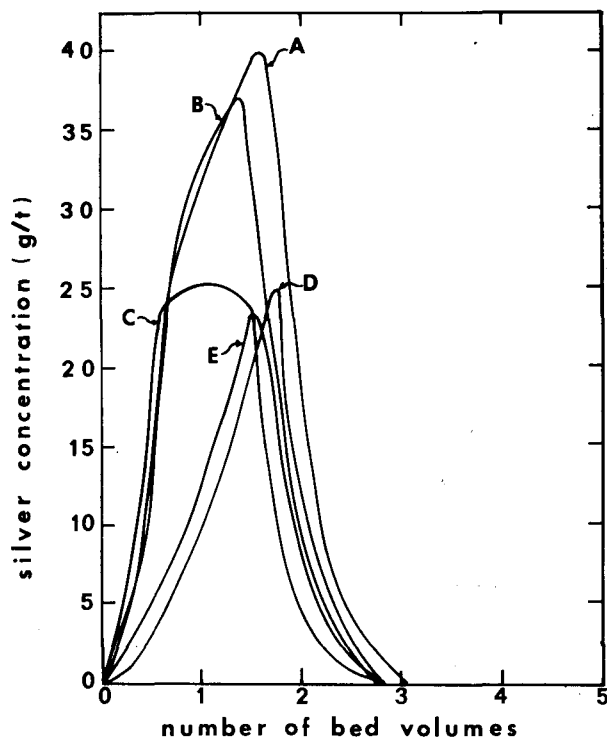


Fig. 4—The elution of silver from activated carbon as a function of the concentration of the sodium hydroxide in the pretreatment reagent

- A 0 per cent sodium hydroxide-10 per cent sodium cyanide
- B 1,0 per cent sodium hydroxide-10 per cent sodium cyanide
- C 5 per cent sodium hydroxide-10 per cent sodium cyanide
- D 14 per cent sodium hydroxide-10 per cent sodium cyanide
- E 20 per cent sodium hydroxide-10 per cent sodium cyanide

TABLE III

EFFECT OF APPARENT FLOW VELOCITIES ON THE ELUTION OF GOLD FROM ACTIVATED CARBON
Pretreatment: 0,5 bed volume of 10 per cent sodium cyanide-1 per cent sodium hydroxide

Elution rates at 90°C	Concentration at elution peak, g/t			Recovery after 7 bed volumes, %				Residual carbon activity, mg Au/g C
	Au	Ag	Ni	Au	Ag	Cu	Ni	
0,5 bed volume/h ($4,9 \times 10^{-3}$ cm/s)	862	37	1 930	99,0	98,0	92,3	95,5	12
1 bed volume/h ($9,2 \times 10^{-3}$ cm/s)	820	34	1 540	97,3	95,4	91,2	96,7	—
2 bed volumes/h ($17,0 \times 10^{-3}$ cm/s)	625	26	1 190	90,8	95,4	83,4	95,2	—

with 10 per cent sodium cyanide-1,0 per cent sodium hydroxide and eluted under pressure at 125°C as previously described⁵. At an elution rate of 1,7 bed volumes per hour involving 4,7 bed volumes of eluate (Table V), 99,2 per cent of the gold and 95,3 per cent of the silver were recovered in an elution time of 3 hours. This can be compared with 14 hours for elution at 0,5 bed volume per hour at 90°C (Table III). From these data, it can be seen that, if time is of major importance, the use of increased elution temperatures can have significant advantages.

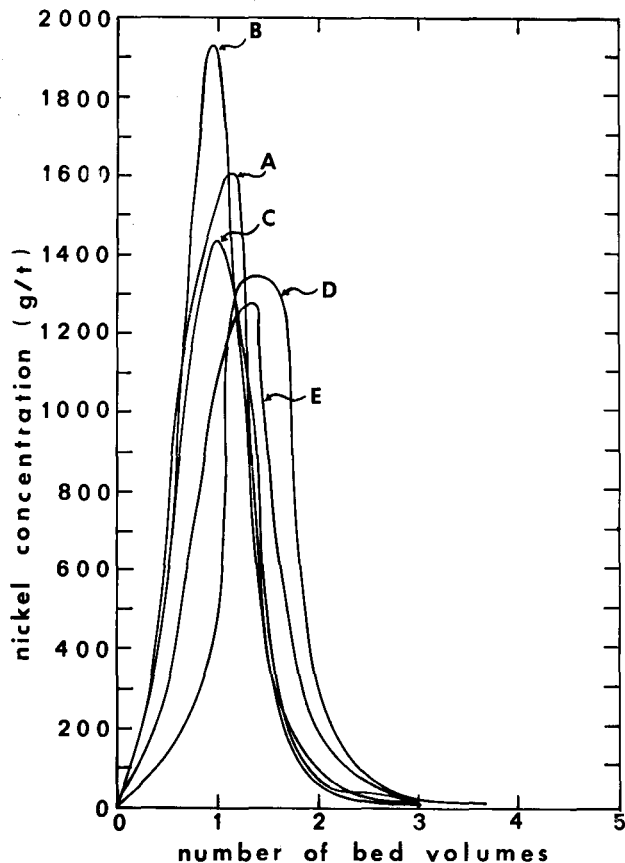


Fig. 5—The elution of nickel from activated carbon as a function of the concentration of the sodium hydroxide in the pretreatment reagent

- A 0 per cent sodium hydroxide-10 per cent sodium cyanide
- B 1,0 per cent sodium hydroxide-10 per cent sodium cyanide
- C 5 per cent sodium hydroxide-10 per cent sodium cyanide
- D 14 per cent sodium hydroxide-10 per cent sodium cyanide
- E 20 per cent sodium hydroxide-10 per cent sodium cyanide

Other Elution Conditions

Figs. 7 to 10 illustrate the elution of gold, calcium, silver, and nickel from loaded carbon by three different sets of conditions: pretreatment with sodium cyanide and sodium hydroxide followed by elution with deionized water at 90°C (condition A), pretreatment with potassium carbonate-potassium hydroxide followed by elution with deionized water at 90°C (condition B), and elution with sodium sulphide-sodium hydroxide⁸ at 65°C (condition C). Further elution details are given in Table VI.

Fig. 7 shows that condition A while being comparable with condition C provides a more efficient elution mechanism (a recovery of 99,0 per cent of the gold in 7 bed volumes) than that provided by condition B. This is due, in part at least, to the mass action effect involved in the replacement of calcium with sodium in the cyanide complexes as previously described. In the cyanide

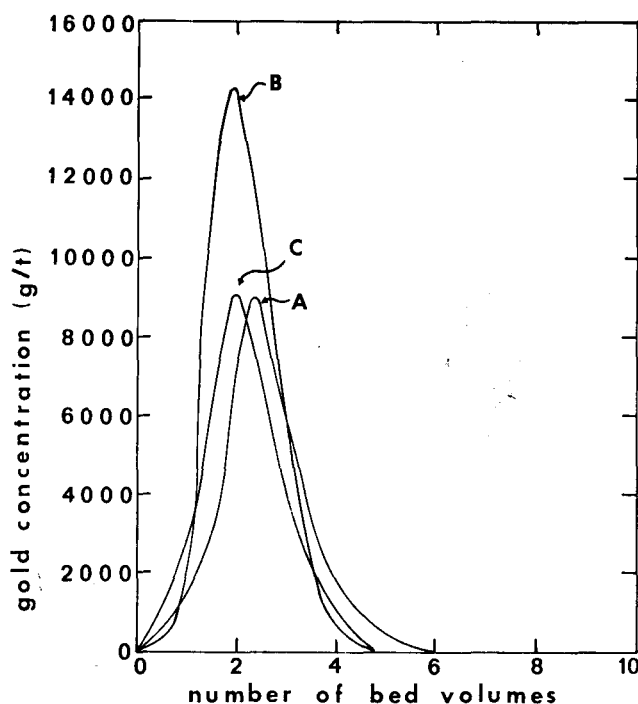


Fig. 6—The elution of gold from activated carbon at high gold loadings

- A 4,0 per cent gold loading, pretreatment with 14 per cent sodium hydroxide-10 per cent sodium cyanide
- B 5,9 per cent gold loading, pretreatment with 1,0 per cent sodium hydroxide-12 per cent sodium cyanide
- C 4,1 per cent gold loading, pretreatment with 1,0 per cent sodium hydroxide-12 per cent sodium cyanide

TABLE IV

ELUTION AT HIGHER GOLD LOADINGS

Eluant: Deionized water at 0,5 bed volume per hour and 90°C

Pretreatment reagent	Original loading, %			Concentration at elution peak, g/t			Recovery after 6 bed volumes, %		
	Au	Ag	Ni	Au	Ag	Ni	Au	Ag	Ni
0,5 bed volume 10% NaCN-14% NaOH ...	4,0	0,06	0,26	8 500	140	970	98,4	83,0	99,6
0,5 bed volume 12% NaCN-1% NaOH	5,9	0,19	0,60	14 000	1 000	3 500	99,8	97,1	99,9
0,5 bed volume 12% NaCN-1% NaOH	4,1	0,12	0,17	8 800	470	720	99,5	91,0	99,3

pretreatment, the calcium is removed efficiently as a soluble product, whereas, in the pretreatment with potassium carbonate, the product is a precipitate of calcium carbonate. The virtually complete removal of calcium as soluble calcium cyanide would appear to have a more beneficial effect on the subsequent elution mechanism. This is well illustrated in Fig. 8, which shows the elution of calcium after the two pretreatments.

Fig. 9 illustrates the elution of silver under the same three sets of conditions as shown in Fig. 7. Again, the pretreatment with sodium cyanide-sodium hydroxide (A) yields significantly better recoveries of silver than does pretreatment B. The poor recoveries of silver after pretreatment B are undoubtedly due to the high concentration of potassium hydroxide used, while the very poor recovery of silver from the elution with sodium sulphide-sodium hydroxide (C) is due to the precipitation of silver sulphide on the carbon. Similarly, Fig. 10 illustrates the elution of nickel under these three sets of conditions and, again, A (pretreatment with sodium cyanide-sodium hydroxide) has very distinct advantages over the other two sets of conditions.

Activity of Eluted Carbon

The virgin activated carbon used in the present investigation had an equilibrium capacity constant, *k*, of 22 mg of gold per gram of carbon. As can be seen from the data presented (Tables II, III, V, VI), the capacity constants of the used carbon after elution was about 8 to 14 mg. Thermogravimetric analysis was carried out on various samples of loaded, virgin, and eluted carbons to determine the losses in mass resulting from the volatile organic constituents present in the

material. It was thought that the organic constituents originating from mine waters were primarily responsible for reducing the activity of the used carbon.

The largest losses in mass in the range 180 to 540°C were recorded for the eluted and loaded carbons. The virgin carbon showed only a small loss in mass in this temperature range, suggesting the presence of organic poisons in the used carbons that are firmly bound to the carbon and that are not easily removed during elution. This strongly suggests that the used carbon should be regenerated by thermal means.

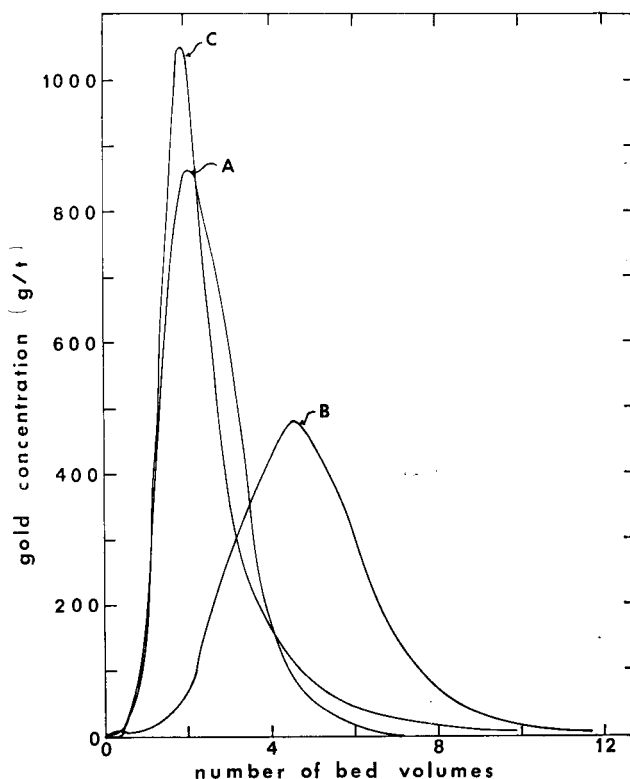


Fig. 7—The elution of gold from activated carbon under three sets of conditions

- A** pretreatment with 10 per cent sodium cyanide-1,0 per cent sodium hydroxide, elution with deionized water at 90°C
B pretreatment with 10 per cent potassium carbonate-5 per cent potassium hydroxide, elution with deionized water at 90°C
C elution with 3 per cent sodium sulphide-3 per cent sodium hydroxide at 65°C

TABLE V

THE PRESSURE ELUTION OF GOLD FROM ACTIVATED CARBON AT 125°C and 200 kPa

Eluant: Deionized water at 1,7 bed volumes per hour

Pretreatment reagent	Recovery after 4,7 bed volumes, %			Residual carbon activity mg Au/g C
	Au	Ag	Ni	
1 bed volume 5%NaCN-10% NaOH	98,8	93,3	98,4	12
1 bed volume 14%NaCN-1% NaOH	99,2	95,3	—	14

TABLE VI

COMPARISON OF THREE DIFFERENT SETS OF ELUTION CONDITIONS

Conditions	Concentration at elution peak, g/t			Recovery after 7 bed volumes, %				Residual carbon activity mg Au/g C
	Au	Ag	Ni	Au	Ag	Cu	Ni	
A 0,5 bed volume 10% NaCN-1% NaOH, followed by deionized water at 0,5 bed volume per hour and 90°C	862	37,0	1 930	99,0	98,5	92,0	95,5	12
B 1 bed volume 10% k ₂ CO ₃ -5% KOH, followed by deionized water at 9,5 bed volumes per hour and 90°C	478	13,0	43	85,0	95,5	89,0	ca 40	14
C 10 bed volumes of 3% Na ₂ S-3% NaOH-½% Na ₂ SO ₃ at 65°C at 2 bed volumes per hour, followed by 10 bed volumes water, followed by 4 bed volumes 5% HNO ₃ , followed by 10 bed volumes water	1 050	0,2	300	94,3	< 10,0	44,5	65,4	10

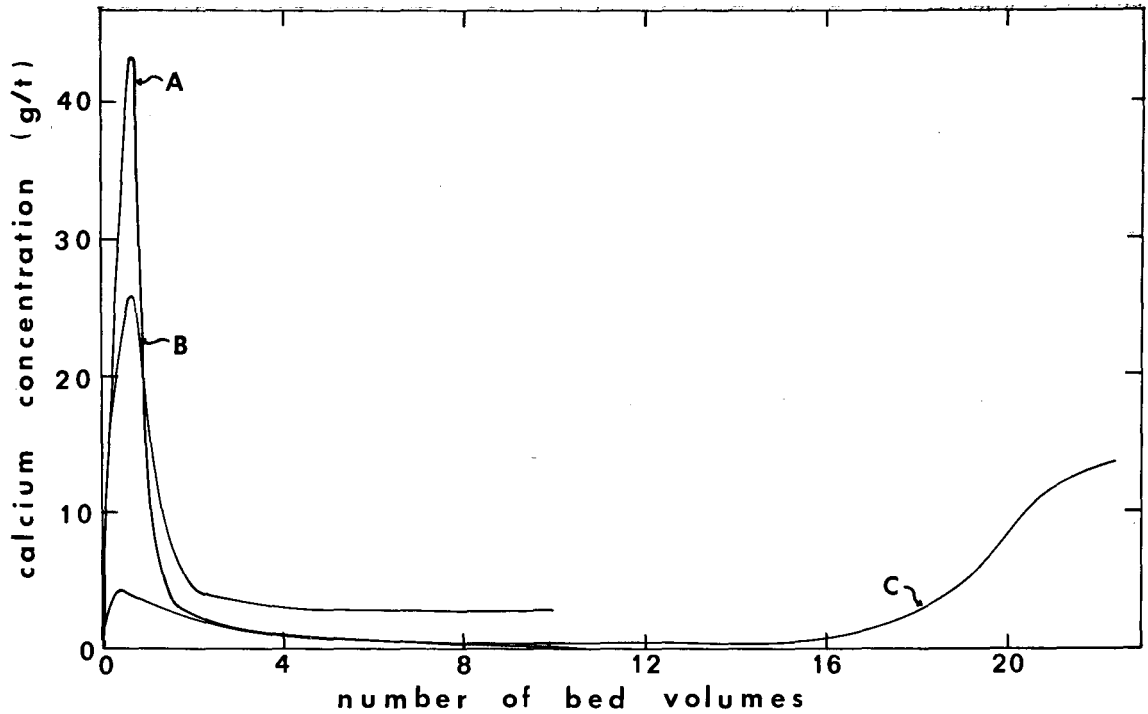


Fig. 8—The elution of calcium from activated carbon after three types of pretreatment
A pretreatment with 10 per cent sodium cyanide, elution with deionized water at 90°C
B pretreatment with 10 per cent sodium cyanide-14 per cent sodium hydroxide, elution with deionized water at 90°C
C pretreatment with 10 per cent potassium carbonate-5 per cent potassium hydroxide, elution with deionized water at 90°C

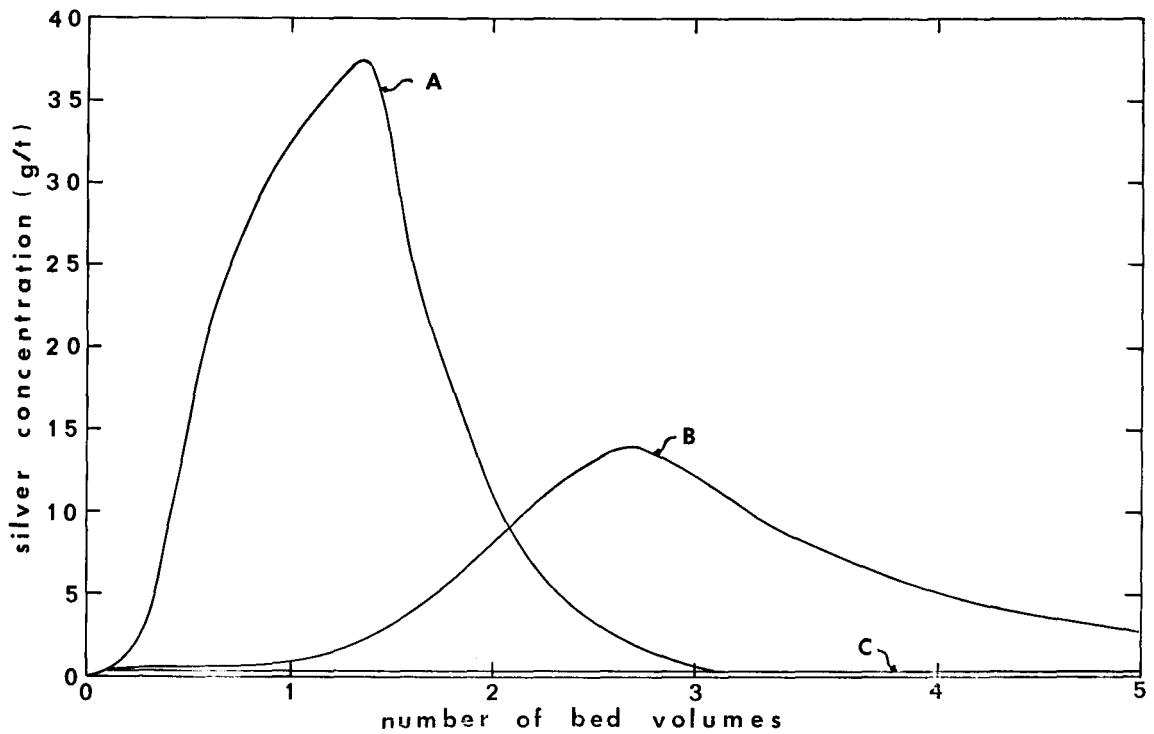


Fig. 9—The elution of silver from activated carbon under three sets of conditions
A pretreatment with 10 per cent sodium cyanide-1,0 per cent sodium hydroxide, elution with water at 90°C
B pretreatment with 10 per cent potassium carbonate-5 per cent potassium hydroxide, elution with deionized water at 90°C
C elution with 3 per cent sodium sulphide-3 per cent sodium hydroxide at 65°C

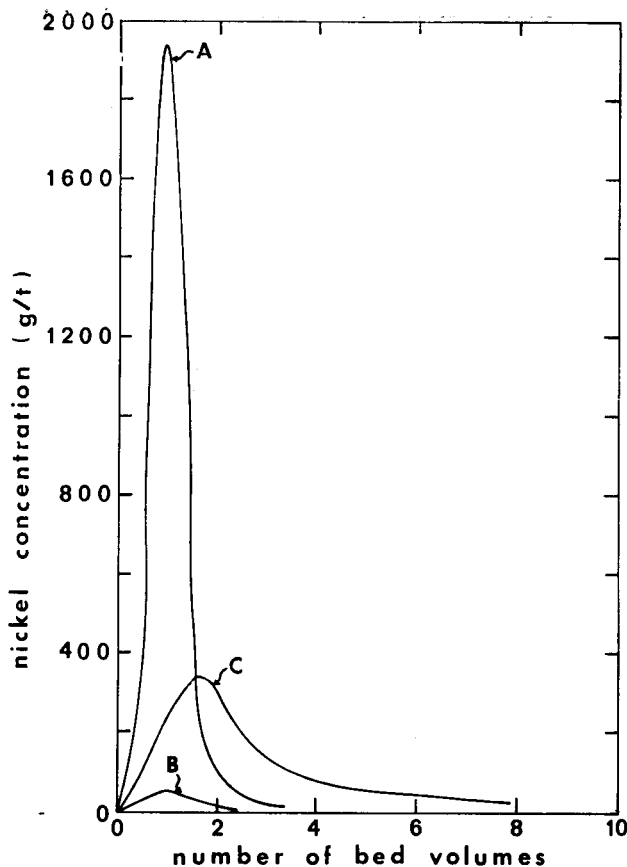


Fig. 10—The elution of nickel from activated carbon under three sets of conditions

- A pretreatment with 10 per cent sodium cyanide-1,0 per cent sodium hydroxide, elution with deionized water at 90°C
- B pretreatment with 10 per cent potassium carbonate-5 per cent sodium hydroxide, elution with deionized water at 90°C
- C elution with 3 per cent sodium sulphide-3 per cent sodium hydroxide at 65°C

Discussion

The present findings regarding the elution of gold, silver, and base metals from activated carbon using deionized water emphasize the important role played by the calcium cation in effecting efficient extraction of gold. Pretreatment of the loaded carbon with relatively strong sodium cyanide has a most beneficial effect on the elution of the otherwise unstable silver and base-metal complexes. As was demonstrated, the use of 0,5 bed volume of pretreatment reagent containing 10 per cent sodium cyanide that had been further stabilized with

1,0 per cent sodium hydroxide for safety reasons, followed by elution with deionized water, results in a virtually 100 per cent recovery of the adsorbed gold, silver, and base-metal values. The elution procedure takes a relatively short time, about 14 hours at 90°C (7 bed volumes) or 3 hours if pressure elution at 125°C (4 to 5 bed volumes) is used. This can be compared with the pressure stripping of gold from carbon³ in 2 to 6 hours at 150 to 160°C using 12 bed volumes of 0,4 per cent sodium hydroxide-0,03 per cent sodium cyanide, or with the 24 to 30 hours required for atmospheric-pressure elution as described by Zadra².

When compared with other elution procedures, the proposed method appears to have several economic advantages. Firstly, there is no precipitation of calcium carbonate or of silver and base-metal sulphides. Such precipitates tend to build up on the carbon with extended use, resulting in carbon poisoning if they are not removed. With regard to reagent costs, the re-use of both regenerated cyanide in an eluate-electrowinning stage and caustic soda in other parts of the gold plant appear to be distinct possibilities. While the cost of deionized water or steam condensate would incur a small additional expenditure, other gold-elution procedures are unlikely to compete in this latter regard. Lastly, because the mechanism of elution after pretreatment entails the shifting of a physical rather than a chemical equilibrium, the efficiency of the elution procedure increases as the amount of loaded gold is increased.

Acknowledgement

The authors are indebted to T. Szendrei for the thermogravimetric analyses, C. G. Schmidt for the pressure-elution data, and the analytical section of Anglo American Research Laboratories for the chemical analyses.

References

1. ZADRA, J. B. U.S. Bureau of Mines, RI 4672. Apr. 1950.
2. ZADRA, J. B., ENGEL, A. L., and HEINEN, H. J. U.S. Bureau of Mines, RI 4843. Feb. 1952.
3. ROSS, J. R., SALISBURY, H. B., and POTTER, G. M. AIME Annual Meeting, Chicago, Feb.-Mar., 1973.
4. NIZAMUTDINOVA, R. A., and CHUVASHEVA, G. L. *Tr. Tsent. n-i gornorazved, in-ta*, vol. 77. 1967, pp. 24-33.
5. DAVIDSON, R. J. *J. S. Afr. Inst. Min. Metall.*, vol. 75, no. 4. 1974, p. 67.
6. SCHMIDT, C. G. Anglo American Research Laboratories, private communication.
7. DUNCANSON, D. Anglo American Research Laboratories, unpublished results.
8. GARNER, A. W. B. Anglo American Research Laboratories, private communication.

Training programmes

The Federation of Societies of Professional Engineers has announced that the following four programmes for engineers-in-training have been accepted in principle by the S.A. Council of Professional Engineers:

UKOR (Electrical Engineers)
 City of Johannesburg (City Engineers, Civil)
 SAPPI (Chemical Engineers)
 Dept of Water Affairs (Civil Engineers).