Cyanide tests to show action of common cyanicidas

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THESIS
FOR THE
Degree of Bachelor of Science
IN
MINE ENGINEERING.

SUBJECT:
"Cyanide Tests to Show Action of Common Cyanicides."

CHARLES L. LINTECUM.
JUNE, 1905.
In view of the growing importance of the cyanide process and in that it seems destined to take an important place in the metallurgical treatment of gold and silver ores, the following tests have been taken as a thesis:

It was intended at the outset to deal with varied ores and corroborate or establish any relation existing between such cyanicides as Cu, Bi, Sb, Mn, As, Fe, S and Te and the amount of copper consumed.

This object however, was not fully realized owing to the fact that a large amount of work was done on ores No's. 1, 2, 3 and 4. Those being sulphides of various degrees of oxidation but containing none of the cyanicides above mentioned except Fe and S.

The preliminary work on ores 1, 2, 3 & 4 consisted of:

1. Sampling
2. Assaying
3. Qualitative analysis
4. Acidity Determinations.

1. Sampling

The original lots of ore consisted of about 48 lb each. This was first put through a dodge crusher set at one half inch. Then through Cornish rolls at 3/16 inch.

Sampled to 12# and reduced to 6 mesh

This was then further sampled and reduced on bucking board to various meshes as required.

2. Assaying

The assays of the original ore were made in a pot furnace using one assay ton and ore passing one hundred mesh.
III Qualitative Analysis.

A carefully taken sample from each ore was qualitatively examined by running through the first, second and third groups. The test for Te was made by boiling in $H_2SO_4$ in which case a purple time indicated Te.

Of the above cyanides only Fe and S were found.

IV Acidity Determinations.

Starting with a standard $HCl$ solution of which $1cc = 0.006201 \text{ HCl}$ a standard solution of $NaOH$ of which $1cc = \frac{45.4}{11.5}$ standard $HCl$ was procured.

First added $5cc$ $NaOH$ solution to ten grams of ore and agitated twenty minutes.

The solution was then decanted off and filtered. The tails were thoroughly washed and filtrates added to the corresponding solution.

This was now titrated back with standard $HCl$, using methyl orange indicator.

The difference in acid required to titrate the solution and the acid required to neutralize $5cc$ $NaOH$ = equivalent of standard $HCl$ in ten grams of ore.

<table>
<thead>
<tr>
<th>Ore No.</th>
<th>Acid to titrate back</th>
<th>Equivalent of standard HCl in ore</th>
<th>Equivalent of conc HCl in ore</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.1 cc</td>
<td>13.0 cc</td>
<td>8.682%</td>
</tr>
<tr>
<td>2</td>
<td>18.0 cc</td>
<td>2.1 cc</td>
<td>1.603%</td>
</tr>
<tr>
<td>3</td>
<td>2.8 cc</td>
<td>17.3 cc</td>
<td>10.733%</td>
</tr>
<tr>
<td>4</td>
<td>4.0 cc</td>
<td>16.1 cc</td>
<td>9.933%</td>
</tr>
</tbody>
</table>
Having made the above preliminary tests a series of eight tests was made on each of the four ores in which the mesh was varied.

The first three tests in each series being without preliminary wash. In the fourth test a preliminary H₂O wash was used, in the fifth four washes were added previous to KCNO.

6. KCNO solution being used in all tests.

Ore No.1. Pyrite slightly oxidized containing some silicious gangue.

<table>
<thead>
<tr>
<th>Test</th>
<th>mesh of ore</th>
<th>Time of treatment</th>
<th>Weight of ore</th>
<th>% of ore in tail</th>
<th>Assay of ore in tail</th>
<th>% of KCNO</th>
<th>Grams of KCNO</th>
<th>% of K₂CO₃</th>
<th>Grams Fe in tail</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>14 hrs</td>
<td>56.018</td>
<td>.516</td>
<td>.24</td>
<td>96</td>
<td>1.00</td>
<td>96.06</td>
<td>.08</td>
<td>No wash</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>14 hrs</td>
<td>58.070</td>
<td>.282</td>
<td>.27</td>
<td>58.7</td>
<td>2.00</td>
<td>100.00</td>
<td>.05</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>14 hrs</td>
<td>58.135</td>
<td>.137</td>
<td>.35</td>
<td>81.4</td>
<td>3.00</td>
<td>100.00</td>
<td>.05</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>14 hrs</td>
<td>57.754</td>
<td>.558</td>
<td>.39</td>
<td>90</td>
<td>4.00</td>
<td>100.00</td>
<td>.05</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>14 hrs</td>
<td>58.135</td>
<td>.202</td>
<td>.17</td>
<td>39</td>
<td>5.00</td>
<td>100.00</td>
<td>.05</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>120</td>
<td>14 hrs</td>
<td>58.135</td>
<td>.137</td>
<td>.10</td>
<td>41.1</td>
<td>6.00</td>
<td>100.00</td>
<td>.05</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>140</td>
<td>14 hrs</td>
<td>58.135</td>
<td>.182</td>
<td>.25</td>
<td>56.9</td>
<td>7.00</td>
<td>100.00</td>
<td>.05</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>160</td>
<td>14 hrs</td>
<td>58.135</td>
<td>.182</td>
<td>.28</td>
<td>55.1</td>
<td>8.00</td>
<td>100.00</td>
<td>.05</td>
<td></td>
</tr>
</tbody>
</table>

It will be observed that the extraction decreases as the mesh increases. This might be due either to decreased percolation or to a more rapid consumption of cyanide by the iron salts in the finer mesh.

Since in one, two and three practically all the copper is consumed and in five, six and seven east all, therefore the decrease in extraction with increase of mesh is most probably due to less perfect percolation.
It is difficult to account for the poor extraction in four as it should at least be as good as that in two. However, this may have resulted from a small pellet of gold in the ore of test four.

The lower extraction in eight in which the time was ninety-six hours as against seventy-two hours in the other cases would indicate that the finer mesh gave less perfect contact of ore and solution, resulting in lower extraction.

Ore No. 2 Heavy Pyrite R.P. 7 Assay 92.92 on oz/ton

<table>
<thead>
<tr>
<th>Test</th>
<th>Mesh</th>
<th>Time of Treatment</th>
<th>Weight of Tails</th>
<th>% of ore</th>
<th>Assay of Tails/Tn</th>
<th>% Gold in Tails</th>
<th>% Gold Extracted</th>
<th>Grms of KCN Consumed</th>
<th>% of KCN Consumed</th>
<th>Grms Fe in Filtrate</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>ore</td>
<td>92 hrs</td>
<td>57.945</td>
<td>.387</td>
<td>.40</td>
<td>44</td>
<td>.36</td>
<td>2.960</td>
<td>98.57</td>
<td>.05</td>
<td>No wash</td>
</tr>
<tr>
<td>1.2</td>
<td>30</td>
<td>72 hrs</td>
<td>58.245</td>
<td>.097</td>
<td>.42</td>
<td>46.6</td>
<td>54.4</td>
<td>2.996</td>
<td>99.83</td>
<td>.025</td>
<td>&quot;</td>
</tr>
<tr>
<td>11</td>
<td>80</td>
<td>88.155</td>
<td>.177</td>
<td>.34</td>
<td>59</td>
<td>41</td>
<td>2.996</td>
<td>99.61</td>
<td>99.83</td>
<td>.025</td>
<td>H2O wash</td>
</tr>
<tr>
<td>12</td>
<td>30</td>
<td>57.150</td>
<td>.582</td>
<td>.62</td>
<td>57.4</td>
<td>32.6</td>
<td>2.989</td>
<td></td>
<td></td>
<td></td>
<td>K O H Wash</td>
</tr>
<tr>
<td>14</td>
<td>50</td>
<td>58.000</td>
<td>.312</td>
<td>.31</td>
<td>33.7</td>
<td>65.3</td>
<td>2.946</td>
<td>98.53</td>
<td></td>
<td>.02</td>
<td>2/K O H Sol</td>
</tr>
<tr>
<td>15</td>
<td>80</td>
<td>58.050</td>
<td>.282</td>
<td>.75</td>
<td>61.5</td>
<td>18.5</td>
<td>2.810</td>
<td>93.87</td>
<td></td>
<td></td>
<td>&quot;</td>
</tr>
<tr>
<td>16</td>
<td>100</td>
<td>80</td>
<td>58.050</td>
<td>.32</td>
<td>34.8</td>
<td>65.2</td>
<td>2.816</td>
<td></td>
<td></td>
<td></td>
<td>&quot;</td>
</tr>
</tbody>
</table>

Here again we have the lower extraction on the finer mesh.

Though the KCl consumption increases with fineness of mesh on the ores without the alkali wash, the reverse is true where the alkali wash was used.

This again would indicate that perfect percolation was not obtained on the finer mesh.

Though thirteenth was last it would probably have shown the highest extraction of the series.

Number sixteen shows a higher relative extraction here than did eight the corresponding test in above series.
This is probably due to the fact that the copper consumption was greater in eight and the amount of active copper during the last twenty-four hours was very small.

Ore No. 3. Partially oxidized pyrite containing a large amount of Senclous gangue. R/P 1.8 Assay .24 oz Au/ton

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Mesh time of</th>
<th>Weight of</th>
<th>% of Assay of</th>
<th>% Gold</th>
<th>% Gold</th>
<th>% of KCl</th>
<th>Fe in</th>
<th>Grams of</th>
<th>Grams</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ore treated</td>
<td>ore Tails</td>
<td>Tails in/g of</td>
<td>Extracted</td>
<td></td>
<td></td>
<td></td>
<td>Consumed</td>
<td>Consumed</td>
<td>Filterate</td>
</tr>
<tr>
<td>17</td>
<td>30</td>
<td>72 hrs</td>
<td>57.316</td>
<td>.814</td>
<td>.62</td>
<td>31.6</td>
<td>18.4</td>
<td>2.999</td>
<td>99.93</td>
<td>.0175</td>
</tr>
<tr>
<td>18</td>
<td>50</td>
<td></td>
<td>57.566</td>
<td>.746</td>
<td>.62</td>
<td>81.6</td>
<td>18.4</td>
<td>3.000</td>
<td>100.0</td>
<td>.0175</td>
</tr>
<tr>
<td>19</td>
<td>80</td>
<td></td>
<td>57.380</td>
<td>.752</td>
<td>.75</td>
<td>100.0</td>
<td>0.00</td>
<td>2.999</td>
<td>99.93</td>
<td>.0175</td>
</tr>
<tr>
<td>20</td>
<td>50</td>
<td></td>
<td>56.658</td>
<td>1.674</td>
<td>.37</td>
<td>75.0</td>
<td>25</td>
<td>2.999</td>
<td>99.93</td>
<td>.0175</td>
</tr>
<tr>
<td>21</td>
<td>50</td>
<td></td>
<td>57.170</td>
<td>1.352</td>
<td>.45</td>
<td>35.1</td>
<td>40.9</td>
<td>2.861</td>
<td>95.37</td>
<td>.0175</td>
</tr>
<tr>
<td>22</td>
<td>50</td>
<td></td>
<td>56.056</td>
<td>2.277</td>
<td>.25</td>
<td>30.2</td>
<td>68.8</td>
<td>2.971</td>
<td>97.23</td>
<td>.0165</td>
</tr>
<tr>
<td>23</td>
<td>80</td>
<td></td>
<td>56.900</td>
<td>1.452</td>
<td>.19</td>
<td>23.0</td>
<td>75</td>
<td>2.772</td>
<td>92.40</td>
<td>.0165</td>
</tr>
<tr>
<td>24</td>
<td>100</td>
<td></td>
<td>2.912</td>
<td>97.07</td>
<td>80.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In this series the extraction increases with the fineness of the mesh in contrast-distinction to the two former series.

This being a porous oxidized ore permits of percolation in the finer mesh, while the two former ores being sulphides would tend to pack and not admit of good percolation without vacuum pressure which was not practicable in these tests.

Number twenty shows a higher extraction and a lower cyanide consumption than does eighteen which is of coarse mesh.

This would indicate that the ore contains soluble salt which was dissolved out by the H₂O wash.

Number twenty-four showing a higher relative extraction than the corresponding test in either of the former series and the KCl consumption being greater than in sixteen would indicate that the increased extraction was due to better percolation and also that the Au is in a finer state of division favorable to cyanidation.
ORE NO. 4. OXIDIZED WHITE COMBUSTIBLE RICHICIOUS GANGLUE
R.P. 0 NEUTRAL
ASSAY 48 OZ. AG/TON

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Lash</th>
<th>Time of Treatment</th>
<th>Weight of Tail</th>
<th>% of ore Dissolved</th>
<th>Tails/In.</th>
<th>Gold Assay</th>
<th>% Gold Exacted in Tails</th>
<th>Grams of KCN Consumed</th>
<th>% Of KCN Consumed</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>20</td>
<td>75 hrs</td>
<td>39.52</td>
<td>5.804</td>
<td>45</td>
<td>32.8</td>
<td>67.2</td>
<td>2.0000</td>
<td>99.99</td>
<td>No Wash</td>
</tr>
<tr>
<td>24</td>
<td>20</td>
<td></td>
<td>34.17</td>
<td>3.181</td>
<td>31</td>
<td>23.9</td>
<td>78.1</td>
<td>2.6000</td>
<td>99.99</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>20</td>
<td></td>
<td>32.80</td>
<td>1.182</td>
<td>2.45</td>
<td>25.7</td>
<td>87.3</td>
<td>2.4000</td>
<td>99.99</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>20</td>
<td></td>
<td>36.43</td>
<td>5.182</td>
<td>12</td>
<td>17.9</td>
<td>70.3</td>
<td>2.7000</td>
<td>99.99</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>20</td>
<td></td>
<td>32.00</td>
<td>6.317</td>
<td>26.7</td>
<td>2.4600</td>
<td>99.85</td>
<td>2% K.O.H. Wash</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>20</td>
<td></td>
<td>37.33</td>
<td>1.657</td>
<td>42.4</td>
<td>2.4300</td>
<td>98.37</td>
<td>2% K.O.H. Sol.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>20</td>
<td></td>
<td>32.54</td>
<td>0.00</td>
<td>7.4</td>
<td>2.4710</td>
<td>99.70</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The extractions in twenty-five, twenty-six and twenty-seven are rather erratic. Since the KCN was practically all consumed by the soluble salts the extraction would increase with the length of time required for the consumption of the KCN in each case.

The KCN consumption in twenty-eight is less than in twenty-five, twenty-six and twenty-seven which shows the ore to contain soluble salts that were dissolved out by H2O wash.

In consequence the action is better than in twenty-six.

Numbers twenty-nine, thirty and thirty-one show decrease of extraction as fineness of ore increases.

This is due to the fact that the ore is of a talcy nature and the slices procured by fine grinding were less permeable than when the ore was treated in a coarse condition.

Though number thirty-two shows increased extraction it is most likely due to increased time of leaching.

RESUME.

Relation of KCN Consumed to Salts Dissolved.

There appears to be no relation between the consumption of KCN and the weight of ore dissolved, for it would seem that the KCN consumption should be proportional to the amount of salts dissolved.
This is probably true but not apparent since practically all the KCN is consumed in these tests.

Had there been a sufficient amount of KCN to combine with all the salts that went into solution in each case the KCN consumption would doubtless be proportional to the amount of salts dissolved.

Relation of KCN Consumed to Fe in Solution.

Any ferrous sulphate present in ore is soluble in the solution of ferrous sulphate present.

These are both acted upon by KCN. Potassium ferro cyanide, Prussian blue and probably Potassium ferri cyanide being formed besides other salts mentioned later.

However Potassium Ferrocyanide is the principal salt formed by the following reaction taking place:

$$\text{FeSO}_4 + 6\text{KCN} = \text{K}_4\text{Fe(CN)}_6 + \text{K}_2\text{SO}_4$$

From this it follows that the ratio of Fe dissolved to KCN consumed is 1:7.

Thus $\text{Fe} = 56$ and $6\text{KCN} = 6(39+12+14) = 390$

$\therefore \text{Fe} : 6\text{KCN} = 56 : 390 = 1/7$

Let us next consider whether or not the iron in solution is sufficient to account for the loss of cyanide.

Since $1 \text{Fe} = 7 \text{KCN}$ therefore to get the KCN consumed by Fe multiply the amount of Fe in solution by 7 which will give the corresponding KCN consumed according to the above equation.

A few words here as to method of titration solutions for Fe might be in place before considering the above relation.

A standard solution of $\text{K}_2\text{MnO}_4$ in which 1 cc = .01 grams Fe, was prepared.
The solutions were reduced for titration by Zn in closed flasks as in ordinary titrations.

The reaction taking place in the titration is as follows:

\[ 10 \text{K}_4\text{Fe(CN)}_6 + 2\text{KMnO}_4 + 8 \text{H}_2\text{SO}_4 = 10\text{K}_3\text{Fe(CN)}_6 + 6 \text{K}_2\text{SO}_4 + 2 \text{MnSO}_4 + 8 \text{H}_2\text{O} \]

This disregards KCnS which if present would be determined as indicated on a following page.

The difficulty of titrating was in the formation of a brownish discoloration in the solution before the end point was reached which obscured the end point.

This might have been obviated by using \( \text{K}_3\text{Fe(CN)}_6 \) as an outside indicator. This precaution was not taken however and as a result the first two titrations show the abnormal amount of .09 and 06 grams Fe respectively, corresponding to .63 and .42 grams KCn when as a matter of fact there was only .3 grams KCn in the solutions.

In the subsequent titrations however when the nicety of detecting the end point in the presence of this discoloration had been acquired it will be observed that the Fe in solution is insufficient to account for the KCn consumed.

This in three and four then are .035 grams Fe = .245 grams \( \text{KOH} \) whereas .3 grams are consumed.

In number six where the KCn consumption is less than in three and four the amount of Fe dissolved is greater. This is doubtless due to the conversion of Fe into ferous hydrate by the KOH added in six.

\[ \text{FeSO}_4 + 2\text{KOH} = \text{Fe(OH)}_2 + \text{K}_2\text{SO}_4 \]

In the subsequent titration in no case does the amount of Fe dissolved account for the KCn consumed.
Let us now look to the cause of the KCn consumption in excess of that indicated by the Fe in solution. KCn loss may result from evaporation of HCN.

Thus $\text{KCN} + \text{H}_2\text{O} = \text{HCN} + \text{KOH}$

also $2 \text{KCN} + 2 \text{H}_2\text{O} + 2\text{O} = \text{HCN} + \text{HcnO} + 2\text{KOH}$

This reaction however is generally prevented by the presence of reducing agents in the ore.

These losses are in appreciable and may be disregarded for all practical purposes.

Dilute acids decompose KCn in a similar manner resulting in the evolution of HCN.

Thus $\text{H}_2\text{SO}_4 + 2\text{KCN} = 2\text{HCN} + \text{K}_2\text{SO}_4$

However concentrated acids decompose cyanide forming compounds not belonging to the cyanide group.

Formates and acetates are sometimes formed if the solution be heated above 140 degrees F. resulting in the loss of cyanide.

Loss from this source would not be possible in the above tests since they were all made below eighty degrees F.

The presence of carbonates facilitates the decomposition of KCn. Also CO$_2$ dissolved from the atmosphere evolves HCN in the absence of excess free alkali.

The relation of dissolving CO$_2$ by the solution is about one thousand cc/sq yd/hours in still air and increases to 1200-1300 in strong wind.

The above figures are from tanks above the ground and the rate of absorption may be increased three-four times at ground level or below.
The tension of $CO_2$ also has marked effect. As the air becomes more saturated the tendency if $CO_2$ molecules to go into the solution increases.

**CYANICIDES.**

Though gold and silver are electro positive to other ore constituents the larger surface of the latter oftimes results in the dissolution of larger amounts than of gold and silver impoverishing the solution.

Successive treatment of pyrites results in a constant decrease in dissolving power.

If the solution then be oxidized by standing or the addition of MnO$_2$ its dissolving power is restored.

Besides $K_4FeCN_6$, Prussian blue, and $K_3FeS_4$, there is also formed KCnS, K$_2$S and K$_2$S$_2$O$_3$ in the dissolution of pyrites.

Lowry found that $\frac{1}{2}$ K$_2$S and Na$_2$S in a KCn solution did not decrease its dissolving power.

To prevent these losses McArthur and Ellis patented a desulphurizing process in 1893. It consisted in the addition of lead salt thus precipitating Pb$_4$S$_5$PbS.

Though S combines with cyanide in the presence of an oxidizing agent forming thiocyanate it is not an appreciable loss.

Though lack of time prohibited it the KCnS in the solution might have been determined as follows:

To a portion of the solution acidified with H$_2$SO$_4$ and reduced to the ferrous state Fe$_2$Cl$_3$ was added

This precipitated all $K_4FeCN_6$ as prussian blue which is then filtrated off and the solution titrated for KCnS.
Thus

\[ 10\text{KCNS} + 12 \text{KMnO}_4 + 13 \text{H}_2\text{SO}_4 = 11\text{K}_2\text{SO}_4 + 12 \text{MnSO}_4 + 10 \text{HCN} + 8 \text{H}_2\text{O} \]

Since these ores contain none of the other cyanides except Fe and S which have been considered, further consideration of cyanides will be deferred to the special ores.

**ROASTING FOLLOWED BY CYANIDING.**

Ore number 
one was dead roasted and cyanided with the following results:

<table>
<thead>
<tr>
<th>Weight in Grms.</th>
<th>Gold Assay.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw ore</td>
<td>400</td>
</tr>
<tr>
<td>Roasted ore</td>
<td>339</td>
</tr>
</tbody>
</table>

It is a striking coincidence that the raw and roasted ore assay the same.

This means that the percent of gold lost by volatilization equals the percent by weight lost by ore which is mostly due to loss of S or SO₂

**Ore 50 MESH**

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Assay of Tails/In Roasted ore</th>
<th>Assay of Tails/In Raw Ore</th>
<th>% Gold lost in Tails Roast- ing</th>
<th>% Gold in Extract KCN</th>
<th>% OF Gold Grms</th>
<th>% OF Gold in KCN</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>.03</td>
<td>.026</td>
<td>5.9</td>
<td>15.3</td>
<td>78.8</td>
<td>.209</td>
<td>69.3 KCN Solub.</td>
</tr>
<tr>
<td>34</td>
<td>.032</td>
<td>.027</td>
<td>5.3</td>
<td>15.3</td>
<td>78.4</td>
<td>.542</td>
<td>90.3 1% w</td>
</tr>
<tr>
<td>35</td>
<td>.035</td>
<td>.029</td>
<td>6.9</td>
<td>15.3</td>
<td>77.8</td>
<td>.548</td>
<td>91.3 1% w</td>
</tr>
</tbody>
</table>

A comparison of thirty three with two and six; which are the same ore unroasted shows a consumption of 69.3% KCN in the former against 100% when no preliminary wash was used and 98.97% when an alkali wash was used.

This marked decrease in consumption of KCN is due to the conversion of Fe₂O₃ which does not react with KCN appreciably.
Besides oxidizing Fe to an inactive form roasting also makes the Fe more porous thus insuring better percolation and contact of solution with the Au.

A comparison of these tests with series one shows an increased extraction of about 23% which is about .1 oz/ton.

Though the time of treatment is 120 hours as compared with seventy two hours in series one, the increased extraction cannot be due to this since the KCn was all consumed in 72 hours in the raw ore.

A comparison of 34 and 35 shows no increase of extraction nor of KCn consumption by giving a preliminary alkaline wash.

This might be expected since the acidity of the ore is destroyed in roasting and the Fe2O3 formed is basic.

**STRONG AND WEAK SOLUTIONS.**

Comparing 33 and 34 we find that the percent of KCn consumption in the one half percent solution is less than in the one percent solution but that the Au extraction is practically the same.

Jullian & Smart have made tests on the relative solubility of different substances in solutions of varying strengths.

They conclude that: The same relative solubility of different substances exists with solutions of all strengths within working limit.

Tests 33 and 34 do not conform to this hypothesis for should the solubility of all ore constituents hold the same relative position in each case the amount of Au extracted should be proportioned to the KCn consumed.
Also auriferous ores containing copper have been successfully treated by using very weak solutions (in 1/100%) whereas had a stronger solution been used the copper would have gone into solution and the resultant KCN consumption prohibited the treatment.

This does not agree with the above conclusions of Jullian and Smart. However they are interesting and the following table has been copied and the resultant curves plotted.

<table>
<thead>
<tr>
<th>Order of Solubilities</th>
<th>% of KCN SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc</td>
<td>2</td>
</tr>
<tr>
<td>Gold</td>
<td>116</td>
</tr>
<tr>
<td>Silver</td>
<td>136</td>
</tr>
<tr>
<td>Lead</td>
<td>136</td>
</tr>
<tr>
<td>Copper Pyrites</td>
<td>101</td>
</tr>
<tr>
<td>Charcoal Iron</td>
<td>62.</td>
</tr>
<tr>
<td>Pyrite &amp; Cast Iron</td>
<td>50.</td>
</tr>
<tr>
<td>Galena</td>
<td>25.</td>
</tr>
<tr>
<td>Iron Rust</td>
<td>20.</td>
</tr>
<tr>
<td>Mispickel</td>
<td>19.</td>
</tr>
<tr>
<td>Marcasite</td>
<td>13.</td>
</tr>
<tr>
<td>Efficiency of KCN per unit</td>
<td>.096</td>
</tr>
</tbody>
</table>

At ordinary temperature the pressure of the solution of gold and silver depends on:

1st. The number and velocity of migratory ions and the number of molecules that take part in dissolving the metal.

2nd. The difference of potentials between two parts of the metallic substance in contact with the solution.

The number of ions and the difference of potentials would increase with the strength of the solution while the velocity of the ions would be decreased, due to the viscosity of the stronger solution.
The solubility of O is greater in weak than in strong solutions and since O is necessary in the dissolution of Au and Ag, therefore the solubility of Au and Ag passes through a maximum in passing from weak to strong solutions.

Maclaurin found .25\% to be the solution of maximum dissolving power on gold and silver.

**EFFECT OF Te ON KCN SOLUTION.**

Telluride Ore Assay 1.41 Oz/ton. Treated at 80\% ash, 72 hrs in 3\% KCN Sol.

<table>
<thead>
<tr>
<th>Test</th>
<th>Weight of Ore</th>
<th>Assay of Gold</th>
<th>Gold of KCN Grm. KCN</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>Tails dissolv.</td>
<td>Tails in tail. extract consumed</td>
<td>consumed</td>
<td>50 Grms. of Ore</td>
</tr>
<tr>
<td>36</td>
<td>38.61</td>
<td>.742</td>
<td>.12</td>
<td>95.28%</td>
</tr>
<tr>
<td>37</td>
<td>37.5</td>
<td>.832</td>
<td>.15</td>
<td>95.77%</td>
</tr>
</tbody>
</table>

Te is said not to act directly with cyanide but alkali in the presence of O dissolves Te and its associated S, forming a solution having a reducing action.

The extraction obtained indicated that the KCN was not consumed before the dissolution of the Au. However the high consumption of KCN would lead to the conclusion that Te must here have some action on KCN.

**EFFECTS OF Mn on KCN SOLUTIONS**

In 37 the extraction is less and likewise the consumption of KCN than in 36 where the same ore without addition of MnO2 was used.

One would think that the oxidizing action of MnO2 would tend to neutralize the reducing effect of Te and thus result in a better extraction.

It is probable from a comparison of these results that the MnO2
reacted quickly with the KCN before much of the Au had time to
dissolve, thus leaving a weak solution during the larger part of
treatment.

That the ultimate KCN consumption in 37 is less than in 36 may
be due to the oxidizing action of $\text{MnO}_2$.

### Effect of Co & Ni on KCN Sol.s.

| Test | Mesh | Time of Weight | % of | Assay of | % Gold | % Gold | Grms of | of K
|------|------|----------------|------|----------|--------|--------|---------|------|
| No.  |      |               | Assay of | tails/tn | in extract | Tails in | Disolv. of | K
|      |      |               | ore tails/tr | Orig. ore | Tails ed | Consumed | ore 1 | ore 1 |
| 38   | 30   | 72 hrs        | 55.88   | 2.447   | .18     | 86.7    | 14.3    | .296.00 |
| 39   | 20   |              | 55.91   | 2.423   | .20     | 86.2    | 41.8    | .287.00 |

That the presence of Co and Ni are detrimental to cyaniding is
corroborated by these tests.

In 38 and 39 the same conditions obtained as in 7 and 29
except one assay tone of a 12% Co and Ni ore are substituted for
one assay tone ores one and four, in seven and twenty-nine.

The Co and Ni ore run only a slight trace of Au. This was
neglected in the extraction computation without material error.

In 38 the extraction is 14.3% as compared with 41.9 in seven
and in 39 it is 41.8 as compared with 82.1 in 29.

However the KCN consumption is but slightly greater with the Co
and Ni ore than where all pyrite ore was used.

Therefore the explanation of the decreased consumption must
be that the Co and Ni ore goes into solution and reacts on KCN more
quickly than do the salts of ore one and four, thus leaving the
solution in an impoverished condition for a longer part of the
treatment than when only ore one and four were used.
EFFECT OF Cu ON KCN SOLUTIONS.

Formerly the presence of any appreciable amount of 
Cu in an ore was thought to preclude the use of cyanide.

The ammonia cyanide process has of late been applied to the treatment of auriferous ores containing Cu, Ni and Zn.

It is also claimed that the process is applicable to the treatment of ores containing ferous or other reducing agents when the consumption of KCN is excessive.

When KCN is added to NH₄OH in the presence of cyanide, cupric cyanide CuCl₂ and cupric hydroxide Cu(OH)₂ are formed.

This forms a stable solution and is said to possess oxidizing properties by drawing oxygen from the air.

The percentage of NH₃ used in the solution is equivalent to the percent of Cu in the ore.

In this connection the conclusions of Sulman in a paper read before the British Institute of Mining and Metallurgy may be quoted, which is as follows:

"Owing to the complexity of the reactions it is difficult if not impossible to formulate any such simple chain of reaction as is held to explain the solution of Au by simple alkali cyanides in the presence of O, and that this is still further complicated by the probable formation of other metallic cupro-cupric cyanides, such as those of Fe, etc.

It seems evident however that the broad explanation of the ammonia copper cyanide process is dependent not on the solvent action of KCN upon Au nor of ammonia cyanide, whether combined with copper cyanide or not plus oxygen, but on the formation of ammonia cuproso-cupric cyanides of the cuprammonia type.
These gradually yielding up some portions of their cyanogen contents act as powerful solvents for Au until their limits of stability and solubility are reached without the necessary intervention of oxygen.

When they reach this limit they cease to act as solvents and separate out in crystalline form.

These compounds either in solution or as crystals are broken off on heating with lime or other fixed alkali yielding ammonia and a solution of alkaline or alkaline earth cyanide, whilst the caprosocupric hydrates contaminated with more or less cuprous cyanide are left as a precipitate.

The form in which the Au is dissolved in these reactions therefore also differs from that in the ordinary cyanide process as there is no uncombined alkaline cyanide necessary to be present to produce an alkaline aurocyanide.

The author states that it probable that the Au is converted by recent cyanogen into simple aurous cyanide, which is readily soluble in any slight excess of ammonia and ammonical salts.

Gold and Silver Ore from Argentine Republic carrying 10% Cu Treated 2 A.T. 96 hours in 1% KCN Solution Ore 100 Mesh Assay Au 1/4 oz/ton.

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Assay of Tails/Tn Ore</th>
<th>% Gold in Tails</th>
<th>% Gold Grms of Extract KCN</th>
<th>% of KCN Consumed</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>4.24</td>
<td>93.4</td>
<td>6.6</td>
<td>2998</td>
<td>99.97</td>
</tr>
<tr>
<td>41</td>
<td>2.68</td>
<td>69.03</td>
<td>40.97</td>
<td>2900</td>
<td>96.67</td>
</tr>
</tbody>
</table>

Though the extraction is low in each case the improved extraction with ammonia clearly shows the superiority of the ammonium cyanide process over copper ores.

Though the tabulation shows the KCN consumption not materially
18

lessened in the use of ammonia the titrations were not at all satisfactory.

Having no better information on this point the titrations were made as in the case of simple KCN with AgNO₃ using K.I. indicator.

It is quite probable that the ammonia cuprose-cupric cyanide does not yield up their available cyanogen to AgNO₃ immediately, as does KCN in which case the titration would not show the available cyanide present in the solution.

The method of recovering valuables from the solution in this process consists in boiling the solution in a still, precipitating the metals as oxides and recovering the ammonia by distillation.

The cost of treating solutions is about 20c/ per ton.

FREE MILLING TESTS.

In view of the fact that the cyanide tests on ores Nos. 1, 2, 3, 3 and 4 gave poor results the following free milling tests were made:

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Ore Number</th>
<th>Time of Rotation</th>
<th>Assay of Amalgam</th>
<th>% Gold Extracted</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
<td>1</td>
<td>3 hrs</td>
<td>.2003</td>
<td>47.9</td>
</tr>
<tr>
<td>43</td>
<td>1</td>
<td>9 &quot;</td>
<td>.19 oz</td>
<td>45.2</td>
</tr>
<tr>
<td>44</td>
<td>2</td>
<td>9 &quot;</td>
<td>.84 &quot;</td>
<td>91.3</td>
</tr>
<tr>
<td>45</td>
<td>3</td>
<td>9 &quot;</td>
<td>.55 &quot;</td>
<td>73.3</td>
</tr>
<tr>
<td>46</td>
<td>4</td>
<td>3 &quot;</td>
<td>.22 &quot;</td>
<td>32.8</td>
</tr>
<tr>
<td>47</td>
<td>4</td>
<td>9 &quot;</td>
<td>.42 &quot;</td>
<td>62.6</td>
</tr>
</tbody>
</table>

Each test consisted of two assay tons of ore at one hundred mesh to which ten percent Hg and sufficient H₂O to form a pulp of thick
consistency were added.

The tests were made in glass jars which were placed in a revolving frame, thus insuring perfect contact of amalgam and ore and a uniform basis of comparison.

Ore number one shows a better extraction for three than for nine hours treatment.

This might result from flouring in the latter case and a consequent loss of amalgam on which the percent of extraction is based.

Ore number four, which is of a slimy nature, shows about one hundred percent better extraction for nine hours treatment than for three hours.

This might be expected since the ore being of a slimy nature would not admit of quick contact of amalgam and free ore.

It would be expected that the amalgamation extraction would vary immensely as the cyanide extraction since the course Au not readily dissolved by KON is more liable to amalgamation and vice versa.

This condition would probably obtain were it not for the complication caused by cyanicides, etc. in cyaniding and incrustations of S, greese, etc. which are detrimental to amalgamation.

It would have been instructive to have followed the amalgamation tests by cyaniding the tails. This was not done on account of the difficulty of saving all the tails when separating out the amalgam.

MILL RUN.

Having made the above free milling tests on ores Number one, two, three and four, a mill run was then made on the remaining ore since under normal conditions this would more nearly approach the
results than would be obtained in practice.

Owing to the fact that the ore was reduced to ten mesh before feeding to the battery the result was a too rapid discharge and an overburdening of the plate not giving sufficient time for contact of ore and amalgam.

Test 48  MILL RUN.

<table>
<thead>
<tr>
<th>Ore Number</th>
<th>Pounds of Ore used</th>
<th>Assay oz Au/ton</th>
<th>Total Au in Ore</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>36</td>
<td>.42</td>
<td>.00576 oz</td>
</tr>
<tr>
<td>2</td>
<td>46</td>
<td>.92</td>
<td>.02116</td>
</tr>
<tr>
<td>3</td>
<td>10.8</td>
<td>.75</td>
<td>.00405</td>
</tr>
<tr>
<td>4</td>
<td>38.3</td>
<td>.67</td>
<td>.01273</td>
</tr>
</tbody>
</table>

Since 1 oz Troy 31.110 Mgs.

ASSAY OF AMALGAM FROM CLEAN UP 86.8 Mgs.

Extraction = $\frac{86.8}{1670} = 5.2\%$

The amalgamation plate which was approximately 4' long was prepared as follows:

It was first polished by rubbing with emory cloth. KCN was then applied to remove all stains and impurities.

When the KCN had had sufficient time to dissolve all impurities from the surface it was wiped off clean with waste.

The amalgam was then applied and thoroughly rubbed in. It was then placed in position ready for work.

The results of this run are valueless so far as the adaptibility of the ore to free milling is concerned.

Nevertheless it shows the utility of obtaining accurate results on a commercial scale, using such small amounts of ore.
In conclusion it might be said that the above tests have not been sufficiently exhaustive and complete to draw any broad conclusions as to the method best adapted to the treatment of ores Nos. 1, 2, 3 and 4 as to the relative effect of cyanicides on cyanide solutions.