A Test-Trial of the Ion-Selective Electrode and a Device for the Automatic Measurement of the Concentration of Gold in a Cyanide Solution Using the Ion-Selective Electrode

Victor Vladimirivich Elshin, Aleksey Aleksandrovich Kolodin and Aleksander Evgenievich Ovsyukov

Irkutsk State Technical University, Irkutsk, Russian Federation

Submitted: Sep 12, 2013; Accepted: Nov 5, 2013; Published: Nov 12, 2013

Abstract: The article examines the operation of an automatic device for the continuous measurement of the concentration of gold cyanide complex \([\text{Au(CN)}_2^-]\) ions in a flow-stream, as well as laboratory trials of the measurement ion-selective electrode, which is the device’s sensitive element. The laboratory trials were conducted with a view to identifying the linearity of change in the output characteristic with change in the concentration of dissolved gold in cyanide solutions, as well as the characteristic’s time displacement. The experimental-industrial trials were conducted on eluates from the process of high-temperature coal desorption under the regimen of OAO Yuzhuralzoloto Gruppa Komaniy at the Bereznyakovskaya gold recovery plant.

Key words: Gold %Concentration measurement %Ion-selective electrode %Continuous measurement device %Cyanide solutions

INTRODUCTION

The topicality of the issue of high-precision control of metal content at all stages of the production cycle, from extracting ore to getting the finished product, as well as the issue of ensuring ecological safety for the environment, has necessitated the development of analytical control methods and instruments that possess high sensitivity, precision and productiveness. Control of technological solutions for the concentration of precious metals helps determine the fullness of their transition from ore or the concentrate to the liquid pulp phase, as well as from the pulp solution onto the sorbent and finally, turning them into a product.

Currently, the analysis of technological solutions is mostly conducted using spectral methods and automatic voltammetric analyzers, with high-sensitivity and precision devices employed. Modern production is necessitating increasingly faster methods of control of qualitative indicators in processes, which existing measurement methods, unfortunately, cannot deliver, while the cost of one such measurement will not justify itself. Hence, there is a topicality about the development of measurement devices that would ensure a high speed of obtaining results, sufficient precision and low cost. It is also important to consider the ability to easily and unimpededly build the device into existing systems of automated control of technological processes and having the functionality of diagnostics and transmission of information at a distance.

At present, ionometry [1–4] is one of the most promising solution analysis methods and we have seen a number of technological advances in the area both in Russia [5] and around the world. This method possesses a number of valuable features. It offers a relatively low threshold of detection in addition to its high selectiveness, quickness, the simplicity of its equipment design and the way it performs analysis, etc. Thanks to these features, the method has been successfully employed in determining various ions in solutions with complex compositions [6-9]. However, the abundance and variety of objects getting within the “area of incidence” of ionometry not only necessitates the creation of new ion-selective electrodes (ISE) but warrants further theoretic research.
Such objects are precisely exemplified by cyanide solutions in hydrometallurgy processes, which contain the anion \([\text{Au(CN)}_2^-]\). Control of the concentration of this ion would make it possible to obtain all the necessary information on processes’ progress and make timely amendments to the operation of technological equipment.

**MATERIALS AND METHODS**

This study is a continuation of earlier work [10], which saw two configurations of electrodes built from three types of tertiary and quaternary onium salts. The author has investigated their behavior; obtained the major characteristics of the electrodes using known methods [11]; developed and had a device for automatic measurement of concentrations built, which is equipped with the functionality of automatic calibration and transfer of measured data into the control system.

For new test-trials of the ion-selective electrode, the author selected technological solutions from the plant of the desorption of gold from activated carbons, which were analyzed in the plant’s lab for the concentration of gold, that of sodium cyanide and that of alkali. The analysis results are provided in Table 1.

The test-trial was conducted using graduated 50 ml vessels with continuous mixing. The measurement system consisted of an ion-selective electrode with an attached plasticized membrane sensitive to \([\text{Au(CN)}_2^-]\) ions, a comparison electrode \(\Theta\text{-IM3.1} (\Theta = \text{Auxiliary Laboratory Electrode})\) and a portable ion-meter pX-150. The mixing was performed using an electromagnetic mixer. The solution’s temperature was measured using a Pt100 platinum resistance thermometer. The membrane was made using the following components: the active component – TOAB (tetaoctylammonium bromide): PVC (Polyvinyl chloride): DBP (DIBUTYL PHthalate).

The study’s objective in the first stage was to check the linearity of change in the output characteristic (mV) with change in the concentration of dissolved gold in cyanide solutions, as well as the characteristic’s time displacement. To ensure cleanliness during the experiment, all the samples were kept in one place with a view to keeping the temperatures the same for the solutions.

**Main Part:** The order the experiment was conducted in: solutions 1 through 7 were subjected to measurements in random order and then the experiment was repeated. Thus, there were conducted 8 measurements on each of the 7 solutions. The results are provided in Figure 1.

---

**Table 1: Results of lab sample analysis**

<table>
<thead>
<tr>
<th>Number of sample</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{Au mg/l, lab data})</td>
<td>74,5</td>
<td>133</td>
<td>209</td>
<td>242</td>
<td>366</td>
<td>426</td>
<td>444</td>
</tr>
<tr>
<td>Concentration of (\text{NaCN,}%)</td>
<td>0,009</td>
<td>0,008</td>
<td>0,01</td>
<td>0,01</td>
<td>0,008</td>
<td>0,005</td>
<td>0,01</td>
</tr>
<tr>
<td>Concentration of (\text{NaOH,}%)</td>
<td>0,267</td>
<td>0,416</td>
<td>0,408</td>
<td>0,136</td>
<td>1,728</td>
<td>0,496</td>
<td>1,432</td>
</tr>
</tbody>
</table>

**Place sample was taken**

Plant for desorption of gold from activated carbons

---

Fig. 1: Graphic representation of measuring the output signal (mV) taken on the y-axis from the concentration of the \([\text{Au(CN)}_2^-]\) ion represented in the form of the natural logarithm of concentration \(\text{Ln}(C)\) taken on the x-axis.
Fig. 2: Measuring the concentration of \([\text{Au(CN)}_2^-]\) ions in a flow-stream; the first measurement. The concentration is taken on the y-axis and the volumes of the solutions covered are taken on the x-axis in m/\text{h}.

Fig. 3: Measuring the concentration of \([\text{Au(CN)}_2^-]\) ions in a flow-stream; the second measurement. The concentration is taken on the y-axis and the volumes of the solution covered are taken on the x-axis in m/\text{h}.

The time interval between the first and last measurements was 4 hours. Consequently, the scale displacement on average was 23 mV within 4 hours and 6 mV within 1 hour. Thus, with the steepness of the characteristic equaling 46 mV the measurement error will be about 13% and with the typical time of the process of desorption of gold from activated carbon, which is 1.5 hours, it will be 20% (provided the device is recalibrated once per cycle). Over the measurement period, the solution temperature increased from 23.9°C to 25.5°C, which is due to the operation of the mixing device. The measurement results revealed that a device with such characteristics can pretty much work as an indicator. There are a sufficient number of such indicators available for quick analysis of the nature of a process taking place.

The second stage involved the test-trials of the device for the automatic measurement of the concentration of gold in cyanide solutions [12], which consists of the following components: two vessels for the calibration solutions, a pump, a block of valves, a high-resistance millivolt meter and a block of valves for switching the flow-streams, a measurement cell, a measurement and a comparative electrode. Due to the fact that there is no refrigerator in the technology and solutions measured have a temperature of 70-80°C, a spiral refrigerator cooled externally with running water was placed in front of the device (the cooling system was not provided in the device’s initial configuration).

The device in this condition would not deliver expected results, since temperature stabilization in the measurement cell did not meet the requirements. Nevertheless, several measurements were performed, the results whereof reveal the principal possibility of the device working correctly provided the temperature regimen are observed.

Concurrently with measurements, the selection of samples was conducted, which were sent to the lab for determining the concentration of gold in the solutions.

The measurement data is provided in Figure 2 and Figure 3.

Despite the lack of proper cooling and temperature stabilization, the device reacts to changes in the metal’s concentration in a solution, as the graphs demonstrate.

**CONCLUSION**

The operation of the ion-selective electrode in lab conditions is pretty satisfactory. If the characteristic is displaced by 13% within 1 hour of operation, the inaccuracy can be reduced through timely recalibration.
In taking measurements in a flow-stream, the integrated device demonstrated that it can be used for selective division of the eluate stream into “poor” and “rich” in desorption processes as an indicator device and that higher indicators can be achieved after remediating certain imperfections in the device’s configuration – by implementing more efficient cooling of solutions, in particular.

INFERENCES

The study revealed the viability of the ion-selective method for the in-process monitoring of the concentration of dissolved gold and the efficiency of a device employed on the basis of the method and laid the way for the future improvement of the device’s operational characteristics.

ACKNOWLEDGEMENTS

The work was carried out with financial support (Grant No. 02.G25.31.0075) issued under a decree of the Government of the Russian Federation #. 218 dated 09.04.2010.

REFERENCES