

Some Laboratory Pitfalls in Redside Bayer Chemistry

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Abstract

The vast majority of university students earning a chemistry degree spend very little time on the fascinating world of Bayer chemistry, unfortunately. One of the reasons is probably because it is a constantly evolving and rather complex field, highly dependent on a given plant's liquor properties. From the basics of Bayer liquor potentiometric titration to the counter-intuitive desilication reaction and ubiquitous lime reactions, there are endless possibilities for unexpected behaviors, unknown interferences, and misinterpretations of lab results. This paper will showcase some examples where slight changes in the composition of a plant liquor can impact lab results in the course of a research project on chemical reactions. Also part of the discussion is how some apparently minor modifications in lab procedure can drastically change the obvious result if careful interpretation is not carried out. Intended for the curious developing Bayer chemist to the more seasoned professional, this article contains a series of pitfalls to avoid and tips to remember when dealing with Bayer liquor chemistry.

Keywords: Analysis, Bauxite, Bayer liquor, Bayer process, Chemical reactions.

1. Introduction

Although the first two patents by Karl Josef Bayer [1,2] describing his industrial process to produce alumina from bauxite are 135 years old, the field of Bayer chemistry is still evolving. But while it is a fascinating type of chemistry, not many universities dedicate a significant part of the chemistry curriculum to it, especially in areas of the world where the number of alumina refineries is limited. For many chemists graduating from university, the first encounter with the Bayer process and its family can even be shocking. One rapidly needs to understand that what everybody calls “caustic” is in fact sodium hydroxide, NaOH, even if the concentration is in “grams per liter” written “as Na₂CO₃” or “as Na₂O” (not even using subscript numbers), and not moles per liter like we did learn and use in most chemistry classes. Some things can also be misleading, such as the well-known term “causticity” [3] that one could automatically refer to as “caustic concentration”, until they realise that there's more than meets the eye in this obviously simple terminology.

The young aspiring Bayer chemists then learn that it is not alumina that comes out of the plant, it is “hydrate”, and after asking a few questions they understand that people refer to alumina trihydrate, Al₂O₃·3H₂O, that will go to calcination to “lose water”. Another reason to read and understand that it is dehydroxylation that takes place in the calciner to obtain alumina [4] from aluminium trihydroxide (Al(OH)₃), and not dewatering, dehydration or H₂O evaporation.

Still on the topic of alumina in solution, most of the time reported in g/L Al₂O₃, chemical accuracy will tell that there is actually no alumina in solution, the dissolved species being effectively “sodium aluminate”, i.e., Na⁺[Al(OH)₄]⁻ (and not NaAlO₂). This is where engineers and chemist need to agree on what makes sense and what is practical in the plant on a day-to-day basis.

It usually doesn't take long to figure out that the "alumina-to-caustic" ratio is an important parameter, although the units are not that straightforward at first sight. With some luck, the company uses only one type of unit in all of its facilities. But if we are in the midst of mergers and acquisitions, where companies use A/C ratio, or molar ratio, or RP, things can easily get lost in translation. And once you believe you understand the subtleties of liquor analysis by titration, you find out that dissolved silica can bias the obtained values [5], and that there are various methods including versions "with potassium fluoride (KF)" and "without KF" [6].

Once the liquor concentration units challenge is sorted out, some counter-intuitive chemical reactions tend to get in the way. A low-silica bauxite that may lead to high-silica pregnant liquor being one example (Figure 1), due to differences in kaolin dissolution and desilication product (DSP) precipitation rates, and seed effects [7,8,9,10].

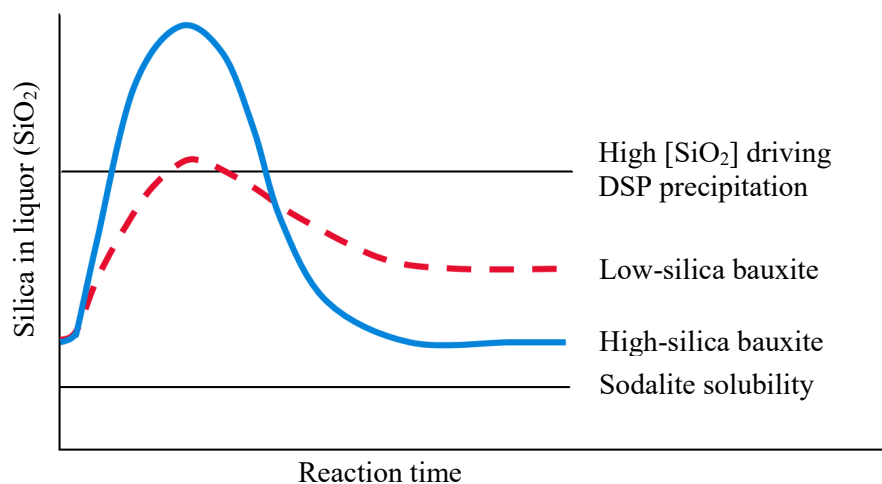


Figure 1. Typical liquor desilication pattern.

But the most striking element remains the ubiquitous calcium: with a solubility of the order of 5 ppm [11], it drives so many reactions and affects so many parts of the process, that lime (CaO) is often referred to as "the *Aspirin*[®] of the Bayer process" (a well-known pun relating to this drug's developer being Bayer, the Germany-headquartered pharmaceutical firm). Calcium is used from phosphorus control in digestion liquor [12,13], to security filtration filter-aid preparation [14,15], liquor causticisation [16], oxalate causticisation [17], and even fine tuning size control in some precipitation circuits [18]. Calcium is simply everywhere and mastering all the aspects of its chemistry in the Bayer process certainly requires a lot of reading [19,20, among others] and a lot of work.

Fortunately enough, there are a few solid references based on rigorous experimental work, that guide our work in the world of Bayer chemistry, among which Oku-Yamada's silica solubility work [21], Rosenberg-Healy's gibbsite solubility model [22], and many more that can be found in Donaldson's and Raahauge's *Essential Readings in Alumina and Bauxite* [23].

This article is not written as a thorough review of Bayer chemistry but is meant to showcase some laboratory work pitfalls one could encounter when learning to play with Bayer liquor chemistry and related analyses that could lead to misinterpretation of results and be further misleading in developing hypotheses and theories.

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