# Industrial gases and precious metals

By Tony Wheatley, **Sam A. Rushing** on Nov 23, 2010

The global output of new gold in 2009 was 2,572 tonnes, which is about 75% greater than the total for 1970. The top five producing countries back then, led by South Africa, included the then USSR, Canada, US and Australia who together produced 91% of the world's gold output.

In 2009 these five long-term producers accounted for only 37% of the new gold while China, Peru, Indonesia, Ghana and Uzbekistan delivered 29%. As the production base has diversified around the globe, extraction processes have evolved to suit the varying conditions encountered.

South Africa's Bushveld Complex is the main producing area supplying around 59% of the worlds PGM requirements and another significant area is the Norilsk region in Russia that is responsible for 27%, while North America produced about 14% of global output last year.

**Extraction via gases**
By *Tony Wheatley*
The use of oxygen in non-ferrous pyrometallurgy has a history of success dating back to the mid 1960s to raise furnace temperatures and thereby assist in the smelting of metal concentrates.

Using oxygen in processes that previously relied on compressed air obviously increases the operating cost, and can be justified only where it provides greater flexibility of operation or solves the problem of a bottleneck caused by capacity constraints within the process.

More recently the application of oxygen to hydrometallurgical processes for the extraction of precious metals including gold and the platinum group metals has generated significant new demands for oxygen gas that is used as a reactant in many hydrometallurgical processes.

However, oxygen is sparingly soluble in aqueous electrolyte solutions, and the driving force for its mass transfer from the gas to the aqueous phase is also very low. Consequently oxygen can be lost to atmosphere.

The concentration of oxygen in an aqueous medium at ambient pressure can be increased by injecting oxygen through a diffuser which disperses oxygen through the aqueous medium in the form of fine bubbles that dissolve more readily.

**Gold extraction**
Almost universally the chemical recovery of gold from milled slurries uses the cyanide leach process, usually followed by counter current adsorption using in-pulp activated carbon.

Oxygen plays an important role in the leaching of gold in a cyanide solution because the rate of dissolution of gold in cyanide solution is directly proportional to the amount of oxygen present.

A typical gold leach may require at least two oxidation steps: Firstly, pre-aeration to overcome the chemical oxygen and cyanide demand of gangue mineral components such as pyrrhotite or other sulphides; secondly, aeration to provide oxygen for the cyanidation leach reactions.

Where the consumption of oxygen and cyanide by gangue minerals impedes the mechanisms of oxidation and cyanidation of gold, the use of gaseous oxygen from on-site generators or bulk liquid provides distinct advantages including reduced leach time, increased recovery and reduced cyanide consumption that can offset the addition cost.

Conventional mill practice involves the sparging of oxygen or air through the pH adjusted gold leach pulp preferably prior to the addition of cyanide.

The pre-aeration operation not only meets oxygen demand for the oxygen consumers, but also saturates the leach slurry with dissolved oxygen to accelerate the oxidation of gold in the cyanidation circuit. The maximum utilisation of oxygen in the gold mill circuit depends on its solubility in the leach pulp and systems that sparge oxygen into open tanks typically achieve as little as 2-5%, by comparison with in-pipe oxygenation which can achieve 30-80%.

Internationally, the use of oxygen in gold recovery has declined because heap leaching is now used at the majority of large-scale gold mines throughout the world.

**PGM extraction**
The production of pure platinum group metals (PGM) typically starts from residues of the production of gold, copper or nickel production.

The differences in chemical reactivity and solubility of several compounds of the metals under extraction are used to separate them. Each processing step is designed to increase the grade or concentration of the valuable components of the original ore, by reducing the bulk of the products.

The mined ore is crushed and milled in order to obtain smaller rock particles and to expose the minerals which contain the PGM. In a 'froth flotation' process these particles are mixed with water and special re-agents, before air is pumped through the liquid.

As a result bubbles to which the PGM-containing particles adhere are created and they float to the surface. The flotation concentrates undergo smelting and converting, to produce a PGM-containing nickel-copper matte.

The matte is treated hydrometallurgically to separate the base metals from the precious metals. Modern hydrometalurgical processes typically incorporate leach autoclaves in which oxygen under high temperature and pressure is a vital reagent used to extract metals.

Finally, the PGM concentrate is refined to separate the individual precious metals into their pure forms. All of the PGMs' final chemical compounds can ultimately be reduced to the elemental metal using hydrogen.

Nickel production is also closely linked with the separation of PGMs and requires a controlled atmosphere of both nitrogen and hydrogen.

**The role of carbon dioxide**
By *Sam A. Rushing*
There has been a great deal of press these days with respect to the ever-glorious value of gold, and how the investor seeks an ultra-secure economic haven with investments in gold.

By a similar token, the spotlight has been on the subject of rare earths, this being so much of these ultra-precious metal commodities, 17 metallic elements often not spoken of on a daily basis by the mainstream, but essential for the developments in 21st century technologies, such as for computers, smart phones, mega computer storage systems; and the great future in electric cars, is pivotal with the availability and affordability of rare earths.

As for the theme of precious metals, what usually comes to mind is primarily gold, silver, and platinum and other (often) expensive commodities; and now the so-called ultra-precious metals, or rare earths (RE). When considering $CO_2$ and the subject of RE and precious metals, it is interesting to consider carbon dioxide and carbonic acid being generated when treating, processing, and applying to these metals.

Consider the application of ultra-precious metals cerium and palladium used daily which yield $CO_2$ as one of the by-product gases. As for $CO_2$ consumption, $CO_2$ and anhydrous ammonia can be used in the production of ammonium bicarbonate on-site, for in-situ leaching of numerous metallic compounds.

However, what has been most common in true industrial practice found globally, is the recovery of uranium via the application of traditional ammonia and carbon dioxide to produce carbonates of ammonia for solution leaching (ISL), or in-situ leaching.

**Uranium recovery**
When speaking of in-situ leaching (ISL) of various compounds and metals, often uranium, much of this activity has been on somewhat of a roller coaster ride since the early 1960s, when the US and the then Soviet Union endeavored in this practice.

With respect to ISL of uranium, the future remains somewhat of a mixed bag. Those who are largely against this process claim environmental damage and the degradation of public lands.

The early ISL projects sometimes used mineral acids such as sulfuric and nitric. However, since the 1970s essentially all such projects use carbonate solutions; thus engaging the requirement for liquid $CO_2$ on-site – assuming ammonium bicarbonate is the leaching agent. However in some cases sodium bicarbonate is used in this application.

When thinking in terms of sodium bicarbonate, it is interesting to note that merchant $CO_2$ is consumed in places such as the Church & Dwight plants in Ohio and Wyoming, where soda ash is converted to sodium bicarbonate. So $CO_2$ from the merchant sources can often apply, whether this is ammonium bicarbonate produced on-site for the ISL project, or sodium bicarbonate in solution can often be sourced from these plants which use merchant grade $CO_2$ for the production of this commodity.

When thinking in terms of sourcing $CO_2$ for the sodium bicarbonate conversion, the producers generally seek food and beverage product, as the soft drink industry also seeks the high level of purity, therefore the food and beverage related sodium bicarbonate from these merchant sources in the US supplies what one could otherwise consider to be a fully industrial process/product.

Many of the proposed expanded or new ISL projects are slated for sites on Indian reservations, and otherwise protected places such as near the Grand Canyon – all of this has sufficient pressure against such developments by Indian Tribes, and environmentalists. However, both in the US and internationally, there are exceptions to this hard push against uranium solution mining.

As to the controversies, some of the complaints more specifically include acidification of ground waters, even though the bicarbonates can be a buffer if this is the ammonium bicarbonate method – but also can result in a migration of heavy and possibly radioactive metals, disturbance of the ground water table, habitat destruction.

In any event, this discussion concerning uranium is interesting, since it has, and can continue to employ a merchant grade CO2, when some 20% or more of the world's uranium is produced by ISL, rather than conventional methods of mining.

**Gold, RE & other precious metals recovery**

On the subject of mining, gold, for example, has not been commercially mined by ISL. However, tests have taken place in the past for the extraction of gold via this technique, but not with carbonates.

Little progress has occurred using this technology generally due to funding and previous poor results – so something similar to this process may someday be a safer and cleaner means of mining the more common precious metals.

On the subject of ISL applications for the recovery of some of the RE – or ultra-precious metals, including tantalum, niobium, and zirconium – testing began this year in Africa.

Other projects which would use solution mining, and potentially CO2 in the carbonate solutions may soon become a developing or even thriving industry – again the versatility of CO2 is demonstrated by such potential.

There is also the prospect of precipitating RE from the leached by-products found in weathered clays, using ammonium bicarbonate. In such a case, CO2 would be a feedstock for this process.

**Emitting CO2**

This discussion may be turned around, when considering the daily example of employing cerium and palladium – where palladium is softer than platinum, yet resistant to oxidation and high temps and would be found in the auto catalyst.

The catalytic converter would turn otherwise unwanted, and toxic compounds including hydrocarbons, carbon monoxide, and nitrogen oxides to carbon dioxide, water and nitrogen.
Perhaps in the future, significant sums of CO2 will be recovered downstream via many catalytic converters, and sequestered or reused in merchant or friendly settings.

Once again, the gases at large, and particularly CO2 taken in this context, demonstrate the versatile nature of the gas – whether used as a feedstock for processing or a by-product of processes.

The ultimate challenge, however, will be to minimise the emission of CO2 from every process and vent, whereby the global atmospheric levels of CO2 do not pray upon global temperatures.

**About the author**

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