9: Aqua regia - chemical leaching of gold

Aqua regia was invented by Iranian alchemist Abu Musa Jabir ebn Hayyan about 800 A.D. This followed from his discovery of hydrochloric acid upon mixing common salt with sulphuric acid.

Aqua regia is a mixture of three to four volumes of concentrated hydrochloric acid to one volume of concentrated nitric acid. It is a corrosive, fuming, aggressive liquid and must only be used by a trained chemist following strict precautions in a properly equipped laboratory or outside space, and only after a hazard analysis has been prepared.

Neither of the acids in aqua regia can dissolve gold, but in combination are very aggressive in dissolving gold.

The fuming and yellow colour of aqua regia are due to the reaction of nitric acid HNO_3 with hydrogen chloride form water H_20 plus two chemicals that are yellowish and volatile - nitrosyl chloride NOCl and chlorine Cl_2. The newly-formed nitrosyl chloride decomposes to nitric oxide NO and chlorine.

Nitric acid HNO_3 is a powerful oxidizer, which will actually dissolve a virtually undetectable amount of gold, forming gold ions (Au^{3+}).

$$Au_{solid} + 3NO_3^-{}_{aq} + 6H^+{}_{aq} = Au^{3+}{}_{aq} + 3NO_2{}_{gas} + 3H_2O_{liquid}$$

Hydrochloric acid HCl supplies chloride ions (Cl^-) in large amounts which attack the gold to produce chloraurate anions $AuCl_4^-$ in solution:

$$Au^{3+}{}_{aq} + 4Cl^-{}_{aq} = AuCl_4^-{}_{aq}$$

This is an equilibrium reaction favouring formation of chloraurate anions. It results in a removal of gold ions from solution and allows further oxidation of gold by the nitric acid, and so more gold is dissolved. In addition, gold may be oxidized by free chlorine in the aqua regia.

Operation

This text is based on recovering gold from scrap by Shor International www.shorinternational.com.

The two acids mix quietly – avoid splashes, protect eyes and work in the open or under a fume hood. Both acids emit acrid fumes. No heat is evolved when mixing but the aqua regia at once starts to emit chlorine gas slowly for several days. Never stopper an aqua regia bottle for chlorine may build up and explode it. The aqua regia is used immediately, or days or weeks later.

Typically 1-2 kilos of scrap are put in an empty 6-litre Ehrlenmeyer flask under a fully ventilated fume hood, or outside. The aqua-regia is added slowly, such as drop-by-drop from a bottle set on a shelf above the reaction flask.

Dangerous fumes of nitrogen oxides are generated; being heavier than air they require either a very good fume hood, or for the process to be done outside.

When bubbling ceases and no more brown fumes are produced then a little hydrochloric acid is added. A further spurt of activity may occur if the original hydrochloric acid has been exhausted. When reaction has ceased, the pregnant solution is poured off into a glass or plastic container, leaving the solid residue in the reaction vessel.

The process is repeated with more aqua regia until no bubbling or brown fumes are seen, even if the reaction vessel is gently warmed and gently agitated. All the gold has now been dissolved.

The contents of the reaction vessel are vacuum filtered, and the gold precipitated from the pregnant solution as described in www.shorinternational.com.

Adoption by placer gold miners

Aqua regia is rarely, if ever, used by placer gold miners. A few recreational miners do use aqua regia but it has not become popular [44].

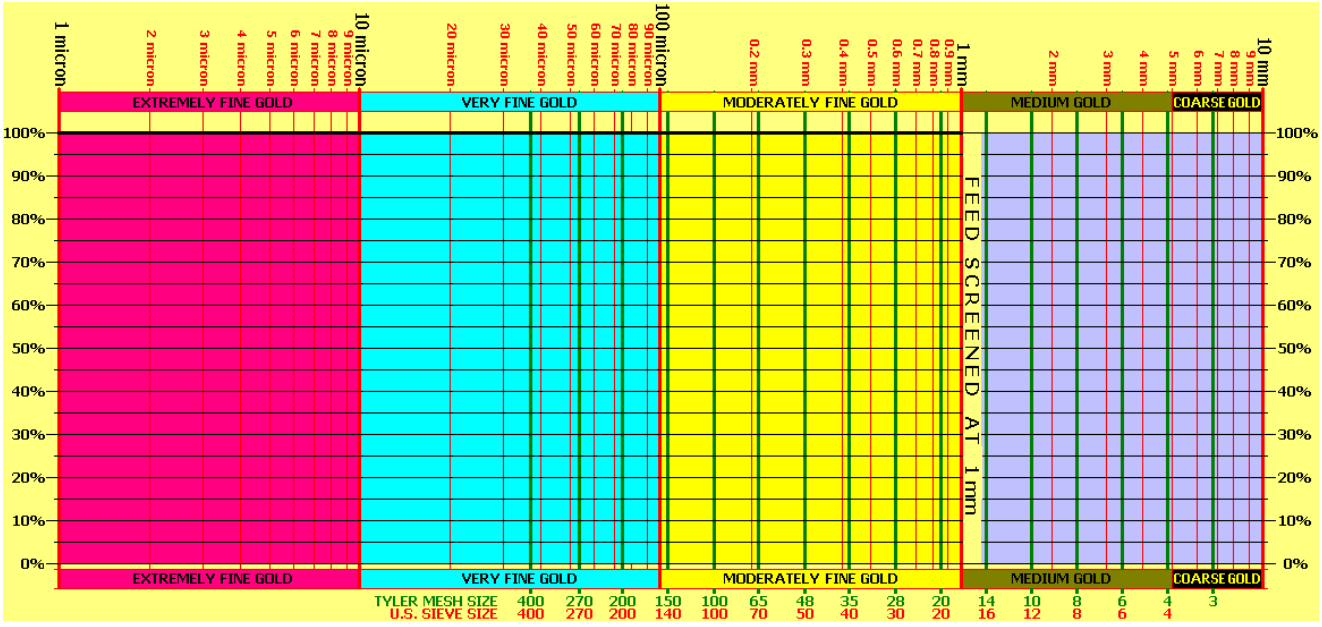

Figure 24. GOLD RECOVERY BY AQUA REGIA LEACHING

Aqua regia can dissolve (leach) 90-100% of gold even as large as 1mm, but is too aggressive for mining use. (compiler: Robin Grayson)