**MERTALOR, gold extraction**

Sastanak sa ljudima iz Metalora je super prosao. Trebace im dosta toga od nas. nasli smo za njih novu i n ajinteresantniju aplikaciju za masovnu proizvodnju zlata. To mozemo i u Makedoniji I Srbiji da primenimo.

Metalor ima poseban department za razvoj strateskih i novih tehnologija… treba da se vidimo i da pricamo i da ti sve pokazem. Vazno je. Bitno je. To je novi i veliki posao. Treba da imamo vise partnera i klijenata u ovom poslu. Ne samo Metalor.

Zanima ih i atomizacija zlata, ali najveci biznis je ono sto vec imaju, a to je gold enrichment + refinement + extraction... to je jedan isti proces i sve se dogadja sa nasim MMM vibratorom. Treba da sto pre patentiramo sve oko toga. Imaju proizvodnju u Kini.

Radi se o sledecem: Koristi se aqua regia rastvor koji polako rastvara zlato, platinu I druge metale. Ultrazvukom se taj process ubrzava 100 do 1000 puta… MMM ultrazvucni pretvaraci su odlicni za te primene… Tehnologija nije komplikovana… Treba da se patentira… Lako se primenjuje… To sam rafdio sa fabrikom Precinox… bez NDA…

Aqua regia for gold

**Aqua Regia** is a mixture of two acids, hydrochloric acid and nitric acid. ... But if you can put **gold** into solution that contains both acids, then it can react, and in fact, can indeed dissolve **gold** – which is why **Aqua Regia** is also known as 'royal water.”5 août 2014

**Aqua regia** ([/ˈreɪɡiə, ˈriːdʒiə/](https://en.wikipedia.org/wiki/Help%3AIPA/English); from [Latin](https://en.wikipedia.org/wiki/Latin), lit. "regal water" or "king's water") is a [mixture](https://en.wikipedia.org/wiki/Mixture) of [nitric acid](https://en.wikipedia.org/wiki/Nitric_acid) and [hydrochloric acid](https://en.wikipedia.org/wiki/Hydrochloric_acid), optimally in a [molar](https://en.wikipedia.org/wiki/Molar_concentration) ratio of 1:3.[[note 2]](https://en.wikipedia.org/wiki/Aqua_regia#cite_note-2) Aqua regia is a yellow-orange (sometimes red) fuming liquid, so named by [alchemists](https://en.wikipedia.org/wiki/Alchemy) because it can dissolve the [noble metals](https://en.wikipedia.org/wiki/Noble_metal), [gold](https://en.wikipedia.org/wiki/Gold) and [platinum](https://en.wikipedia.org/wiki/Platinum), though not all metals.

## Applications

Aqua regia is primarily used to produce [chloroauric acid](https://en.wikipedia.org/wiki/Chloroauric_acid), the [electrolyte](https://en.wikipedia.org/wiki/Electrolyte) in the [Wohlwill process](https://en.wikipedia.org/wiki/Wohlwill_process) for refining the highest quality (99.999%) gold.

Aqua regia is also used in [etching](https://en.wikipedia.org/wiki/Chemical_milling) and in specific [analytic procedures](https://en.wikipedia.org/wiki/Analytical_chemistry). It is also used in some laboratories to clean [glassware](https://en.wikipedia.org/wiki/Laboratory_glassware) of [organic compounds](https://en.wikipedia.org/wiki/Organic_compound) and metal particles. This method is preferred among most over the more traditional [chromic acid](https://en.wikipedia.org/wiki/Chromic_acid) bath for cleaning [NMR tubes](https://en.wikipedia.org/wiki/NMR_tube), because no traces of paramagnetic [chromium](https://en.wikipedia.org/wiki/Chromium) can remain to spoil spectra.[[1]](https://en.wikipedia.org/wiki/Aqua_regia#cite_note-3) While chromic acid baths are discouraged[[*according to whom?*](https://en.wikipedia.org/wiki/Wikipedia%3AManual_of_Style/Words_to_watch#Unsupported_attributions)] because of the [high toxicity of chromium](https://en.wikipedia.org/wiki/Chromium_toxicity) and the potential for explosions, aqua regia is itself very corrosive and has been implicated in several explosions due to mishandling.[[2]](https://en.wikipedia.org/wiki/Aqua_regia#cite_note-4)

Due to the reaction between its components resulting in its [decomposition](https://en.wikipedia.org/wiki/Aqua_regia#Decomposition_of_aqua_regia), aqua regia quickly loses its effectiveness (yet remains a strong acid), so its components are usually only mixed immediately before use.

While local regulations may vary, aqua regia may be disposed of by careful neutralization, before being poured down the sink. If there is contamination by dissolved metals, the neutralized solution should be collected for disposal.[[3]](https://en.wikipedia.org/wiki/Aqua_regia#cite_note-5)[[4]](https://en.wikipedia.org/wiki/Aqua_regia#cite_note-6)

## Chemistry

### Dissolving gold



Pure gold precipitate produced by the aqua regia chemical refining process

Aqua regia dissolves [gold](https://en.wikipedia.org/wiki/Gold), though neither constituent acid will do so alone, because, in combination, each acid performs a different task. Nitric acid is a powerful oxidizer, which will actually dissolve a virtually undetectable amount of gold, forming gold [ions](https://en.wikipedia.org/wiki/Ion) (Au3+). The hydrochloric acid provides a ready supply of chloride ions (Cl−), which react with the gold ions to produce tetrachloroaurate(III) [anions](https://en.wikipedia.org/wiki/Anion), also in solution. The reaction with hydrochloric acid is an equilibrium reaction that favors formation of chloroaurate anions (AuCl4−). This results in a removal of gold ions from solution and allows further oxidation of gold to take place. The gold dissolves to become [chloroauric acid](https://en.wikipedia.org/wiki/Chloroauric_acid). In addition, gold may be dissolved by the chlorine present in aqua regia. Appropriate [equations](https://en.wikipedia.org/wiki/Chemical_equation) are:

Au + 3 HNO
3 + 4 HCl ↽ − ⇀ {\displaystyle {\ce {<=>>}}} [AuCl
4]−
+ 3 [NO
2] + [H
3O]+
+ 2 H
2O

or

Au + HNO
3 + 4 HCl ↽ − ⇀ {\displaystyle {\ce {<=>>}}} [AuCl
4]−
+ [NO] + [H
3O]+
+ H
2O.

If the aqua regia solution only contains gold, solid [tetrachloroauric acid](https://en.wikipedia.org/wiki/Tetrachloroauric_acid) may be prepared by boiling off excess aqua regia, and removing residual nitric acid by repeatedly heating with hydrochloric acid. That step reduces nitric acid (see [decomposition of aqua regia](https://en.wikipedia.org/wiki/Aqua_regia#Decomposition_of_aqua_regia)). If elemental gold is desired, it may be selectively reduced with [sulfur dioxide](https://en.wikipedia.org/wiki/Sulfur_dioxide), [hydrazine](https://en.wikipedia.org/wiki/Hydrazine), [oxalic acid](https://en.wikipedia.org/wiki/Oxalic_acid), etc.[[5]](https://en.wikipedia.org/wiki/Aqua_regia#cite_note-ullgold-7) The [equation](https://en.wikipedia.org/wiki/Chemical_equation) for the reduction of gold by sulfur dioxide is:

2 AuCl−
4 (aq) + 3 SO
2(g) + 6 H
2O (l) → 2 Au (s) + 12 H+
(aq) + 3 SO2−
4(aq) + 8 Cl−
(aq).

### Dissolving platinum

Similar equations can be written for [platinum](https://en.wikipedia.org/wiki/Platinum). As with gold, the oxidation reaction can be written with either nitric oxide or nitrogen dioxide as the nitrogen oxide product:

Pt (s) + 4 NO−
3 (aq) + 8 H+ (aq) → Pt4+ (aq) + 4 NO2 (g) + 4 H2O (l)

3Pt (s) + 4 NO−
3 (aq) + 16 H+ (aq) → 3Pt4+ (aq) + 4 NO (g) + 8 H2O (l).

The oxidized platinum ion then reacts with chloride ions resulting in the chloroplatinate ion:

Pt4+ (aq) + 6 Cl− (aq) → PtCl2−
6 (aq).

Experimental evidence reveals that the reaction of platinum with aqua regia is considerably more complex. The initial reactions produce a mixture of chloroplatinous acid (H2PtCl4) and nitrosoplatinic chloride ((NO)2PtCl4). The nitrosoplatinic chloride is a solid product. If full dissolution of the platinum is desired, repeated extractions of the residual solids with concentrated hydrochloric acid must be performed:

2Pt (s) + 2HNO3 (aq) + 8 HCl (aq) → (NO)2PtCl4 (s) + H2PtCl4 (aq) + 4 H2O (l)

and

(NO)2PtCl4 (s) + 2 HCl (aq) ⇌ H2PtCl4 (aq) + 2 NOCl (g).

The chloroplatinous acid can be oxidized to [chloroplatinic acid](https://en.wikipedia.org/wiki/Chloroplatinic_acid) by saturating the solution with chlorine while heating:

H2PtCl4 (aq) + Cl2 (g) → H2PtCl6 (aq).

Dissolving platinum solids in aqua regia was the mode of discovery for the most dense metals, [iridium](https://en.wikipedia.org/wiki/Iridium) and [osmium](https://en.wikipedia.org/wiki/Osmium), both of which are found in platinum ore and will not be dissolved by the acid, instead collecting on the base of the vessel.

* 

A [platinum Soviet commemorative coin](https://en.wikipedia.org/wiki/Commemorative_coins_of_the_Soviet_Union#Platinum_coins) being dissolved in aqua regia.

* 
* 

4 days later.

### Precipitating dissolved platinum

As a practical matter, when platinum group metals are purified through dissolution in aqua regia, gold (commonly associated with PGMs) is precipitated by treatment with [iron(II) chloride](https://en.wikipedia.org/wiki/Iron%28II%29_chloride). Platinum in the filtrate, as hexachloroplatinate(IV), is converted to [ammonium hexachloroplatinate](https://en.wikipedia.org/wiki/Ammonium_hexachloroplatinate) by the addition of [ammonium chloride](https://en.wikipedia.org/wiki/Ammonium_chloride). This ammonium salt is extremely insoluble, and it can be filtered off. Ignition (strong heating) converts it to platinum metal:[[6]](https://en.wikipedia.org/wiki/Aqua_regia#cite_note-8)

3 (NH4)2PtCl6 → 3 Pt + 2 N2 + 2 NH4Cl + 16 HCl

Unprecipitated hexachloroplatinate (IV) is reduced with elemental [zinc](https://en.wikipedia.org/wiki/Zinc), and a similar method is suitable for small scale recovery of platinum from laboratory residues.[[7]](https://en.wikipedia.org/wiki/Aqua_regia#cite_note-9)

### Reaction with tin

Aqua regia reacts with [tin](https://en.wikipedia.org/wiki/Tin) to form [tin(IV) chloride](https://en.wikipedia.org/wiki/Tin%28IV%29_chloride), containing tin in its highest oxidation state:

4 HCl + 2 HNO3 + Sn → SnCl4 + NO2 + NO + 3 H2O

### Reaction with other substances

It can react with [iron pyrite](https://en.wikipedia.org/wiki/Pyrite) to form [nitric oxide](https://en.wikipedia.org/wiki/Nitric_oxide):

FeS2 + 5 HNO3 + 3 HCl → FeCl3 + 2 H2SO4 + 5 NO + 2 H2O

## History



The fox in Basil Valentine's Third Key represents aqua regia, *Musaeum Hermeticum*, 1678

Aqua regia was first mentioned in the works of [Islamic alchemists](https://en.wikipedia.org/wiki/Alchemy_and_chemistry_in_medieval_Islam) such as [Muhammad ibn Zakariya al-Razi](https://en.wikipedia.org/wiki/Muhammad_ibn_Zakariya_al-Razi) (854-925),[[8]](https://en.wikipedia.org/wiki/Aqua_regia#cite_note-10) and then later mentioned in a work of [Pseudo-Geber](https://en.wikipedia.org/wiki/Pseudo-Geber) (ca. 1300).[[9]](https://en.wikipedia.org/wiki/Aqua_regia#cite_note-Principe_2012-11) The third of [Basil Valentine](https://en.wikipedia.org/wiki/Basil_Valentine)'s keys (ca. 1600) shows a dragon in the foreground and a fox eating a rooster in the background. The rooster symbolizes gold (from its association with sunrise and the sun's association with gold), and the fox represents aqua regia. The repetitive dissolving, heating, and redissolving (the rooster eating the fox eating the rooster) leads to the buildup of chlorine gas in the flask. The gold then crystallizes in the form of [gold(III) chloride](https://en.wikipedia.org/wiki/Gold%28III%29_chloride), whose red crystals were known as dragon's blood.[[*citation needed*](https://en.wikipedia.org/wiki/Wikipedia%3ACitation_needed)] The reaction was not reported again in the chemical literature until 1890.[[9]](https://en.wikipedia.org/wiki/Aqua_regia#cite_note-Principe_2012-11)

[Antoine Lavoisier](https://en.wikipedia.org/wiki/Antoine_Lavoisier) called aqua regia nitro-muriatic acid in 1789.[[10]](https://en.wikipedia.org/wiki/Aqua_regia#cite_note-12)

When [Germany invaded Denmark](https://en.wikipedia.org/wiki/Operation_Weser%C3%BCbung) in World War II, Hungarian chemist [George de Hevesy](https://en.wikipedia.org/wiki/George_de_Hevesy) dissolved the gold [Nobel Prizes](https://en.wikipedia.org/wiki/Nobel_Prize) of German physicists [Max von Laue](https://en.wikipedia.org/wiki/Max_von_Laue) (1914) and [James Franck](https://en.wikipedia.org/wiki/James_Franck) (1925) in aqua regia to prevent the Nazis from confiscating them. The German government had prohibited Germans from accepting or keeping any Nobel Prize after jailed peace activist [Carl von Ossietzky](https://en.wikipedia.org/wiki/Carl_von_Ossietzky) had received the Nobel Peace Prize in 1935. De Hevesy placed the resulting solution on a shelf in his laboratory at the [Niels Bohr Institute](https://en.wikipedia.org/wiki/Niels_Bohr_Institute). It was subsequently ignored by the Nazis who thought the jar—one of perhaps hundreds on the shelving—contained common chemicals. After the war, de Hevesy returned to find the solution undisturbed and precipitated the gold out of the acid. The gold was returned to the Royal Swedish Academy of Sciences and the Nobel Foundation. They re-cast the medals and again presented them to Laue and Franck.[[11]](https://en.wikipedia.org/wiki/Aqua_regia#cite_note-13)[[12]](https://en.wikipedia.org/wiki/Aqua_regia#cite_note-14)

**Gold extraction** refers to the processes required to extract [gold](https://en.wikipedia.org/wiki/Gold) from its [ores](https://en.wikipedia.org/wiki/Ore). This may require a combination of [comminution](https://en.wikipedia.org/wiki/Comminution), [mineral processing](https://en.wikipedia.org/wiki/Mineral_processing), [hydrometallurgical](https://en.wikipedia.org/wiki/Hydrometallurgy), and [pyrometallurgical](https://en.wikipedia.org/wiki/Pyrometallurgy) processes to be performed on the ore.[[1]](https://en.wikipedia.org/wiki/Gold_extraction#cite_note-1)

[Gold mining](https://en.wikipedia.org/wiki/Gold_mining) from alluvium ores was once achieved by techniques associated with [placer mining](https://en.wikipedia.org/wiki/Placer_mining) such as simple gold panning and sluicing, resulting in direct recovery of small gold nuggets and flakes. Placer mining techniques since the mid to late 20th century have generally only been the practice of artisan miners. [Hydraulic mining](https://en.wikipedia.org/wiki/Hydraulic_mining) was used widely in the [Californian](https://en.wikipedia.org/wiki/California) [gold rush](https://en.wikipedia.org/wiki/Gold_rush), and involved breaking down alluvial deposits with high-pressure jets of water. Hard rock ores have formed the basis of the majority of commercial gold recovery operations since the middle of the 20th century where [open pit](https://en.wikipedia.org/wiki/Open_pit) and or [sub-surface mining](https://en.wikipedia.org/wiki/Sub-surface_mining) techniques are used.

Once the ore is mined it can be treated as a whole ore using a [dump leaching](https://en.wikipedia.org/wiki/Dump_leaching) or [heap leaching](https://en.wikipedia.org/wiki/Heap_leaching) processes. This is typical of low-grade, oxide deposits. Normally, the ore is crushed and agglomerated prior to heap leaching. High grade ores and ores resistant to [cyanide](https://en.wikipedia.org/wiki/Cyanide) leaching at coarse particle sizes, require further processing in order to recover the gold values. The processing techniques can include grinding, concentration, roasting, and pressure oxidation prior to cyanidation.

**Gold recovery from printed circuit boards**

A typical PCB comprises 40% metals, 30% plastics and 30% ceramics,[5,10](https://pubs.rsc.org/en/content/articlehtml/2020/ra/c9ra07607g#cit5) with the metal fraction comprising 10–27% Cu, 2–8% Al, 1–4% Pb, 1–8% Fe, 1–6% Sn, 0.2–3.6% Ni, 0.1–1.5% Zn and <0.1% precious metals.[25–30](https://pubs.rsc.org/en/content/articlehtml/2020/ra/c9ra07607g#cit25) These data were typically obtained by milling the waste PCBs and then leaching the powder with aqua regia (a 1![[thin space (1/6-em)]]():![[thin space (1/6-em)]]()3 mixture of nitric and hydrochloric acid), or alternatively hydrochloric acid followed by aqua regia. The levels of precious metals in electronic waste vary considerably, from 10–1600 ppm of Au, 200–20![[thin space (1/6-em)]]()000 ppm of Ag, and 5–970 ppm of Pd, but in most cases exceed those expected in conventionally mined ores; a rich gold-containing ore is typically 0.0018 wt% (18 ppm) of gold and a typical silver bearing ore contains 0.085% (85 ppm) of silver.[31](https://pubs.rsc.org/en/content/articlehtml/2020/ra/c9ra07607g#cit31) It is also apparent that the concentration of precious metals found in electronic waste is dependent on the age of the device; the thickness of gold contacts halved from ca. 1.0 μm in devices manufactured in the 1980s to 0.6–0.3 μm for those made in the 2000's.[11](https://pubs.rsc.org/en/content/articlehtml/2020/ra/c9ra07607g#cit11)

**Pre-separation treatment of e-waste**

The processing of e-waste typically begins with a manually intensive dismantling phase, during which circuit-board components and the lithium battery are removed for recycling elsewhere ([Fig. 1](https://pubs.rsc.org/en/content/articlehtml/2020/ra/c9ra07607g#imgfig1)). The PCBs are subsequently graded according to their metal![[thin space (1/6-em)]]():![[thin space (1/6-em)]]()plastic ratio and shredded, typically into 1.0 cm2 pieces. The shredded PCBs need to be separated into metallic (ferrous and non-ferrous), and non-metallic (polymer and ceramic) components and a broad range of methods have been identified for this purpose, including mechanical crushing, followed by separation using gravity, electrical conductivity and magnetism, as well as delamination using organic solvents.

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|  | **Fig. 1** Overview of st |  |