Gold Allergy: Differentiating Myth from Reality

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ABSTRACT: The ionisation of elemental gold is essential to induce contact allergy and to elicit allergic contact dermatitis (ACD). It is understandable that gold when present in a solution as a soluble or complex ion may cause contact dermatitis. However, keeping the electrochemical nobility of gold in mind, it is not clear how metallic gold or gold alloys present in jewellery and similar products would react with body sweat at a rate sufficient to elicit an allergic reaction in gold-sensitised people. Notably, experiments in vitro with simulated sweat/salt solutions have concluded little to no gold ion formation. Defining the role of gold in contact allergy has certainly become a major challenge for dermatologists, as the evaluation of data presented in the literature regarding the release of gold in sweat, is not conclusive.

Less than two decades after gold was named 'Contact Allergen of the Year' by the American Contact Dermatitis Society, the research carried out at the AnchorCert Analytical Laboratory of the Birmingham Assay Office, has now conclusively proven that, provided conditions are favourable, gold articles, both in **plated & un-plated** category, can react with bodily fluids such as sweat and release soluble gold ions which can potentially induce allergic contact dermatitis in gold-sensitised individuals.

During current research, we observed that the gold plating of gold-plated articles tends to react with artificial sweat and produce soluble gold ions when it is not in perfect uncharged equilibrium with its substrate, due to the difference in electrode potential. Soldered/ welded assemblies of non-plated jewellery items introduce the macro potential difference between solder and gold base alloy which could also cause the release of gold ions into sweat.

Gold, due to its nobility, hinders the production of significant amounts of soluble gold ions. If the quantum of gold release will be above or below the threshold limit required to trigger an allergic reaction in gold sensitised individuals, will depend on the size of potential difference which in turn depends on the size of macro defects.

In this paper, we provide an overview of the literature concerning gold allergy and gold release data from various gold alloys and gold-plated materials, including those, where gold release in sweat was conclusively detected & measured by ICP-OES technique.

We are continuing broader studies, conducted more rigorously, which are needed to firmly answer the questions raised in this paper regarding the condition & mechanism of gold dissolution in bodily fluids.

1. BACKGROUND

Gold metal was declared 'Contact Allergen of the Year' in 2001 by the American Contact Dermatitis Society (ACDS). This was puzzling information as we had always viewed gold as an element which is inert and therefore difficult to solubilise in body fluids (sweat, saliva, tissue, etc.). Given its high resistance to corrosion, it was difficult to comprehend its capability to release soluble gold ions in body fluids which, in our opinion, were essential for its ability to serve as an allergen and cause an allergic reaction to the human skin.

Dr Joseph F. Fowler, JR., M.D., a leading Dermatologist and expert on the Metal-induced Allergic Contact Dermatitis (MACD) field has done a tremendous amount of work on patch testing and metal-induced skin allergy including several papers on allergy due to gold. Dr Fowler presented a paper on Gold Allergy at the European Society of Contact Dermatitis (ESCD) Congress held in 2016 in Manchester, UK. In his view, gold should have been the allergen of the decade, century, and perhaps, the millennium, as patch test data from around the world were showing that gold is among the most common allergens in routine testing. Prevalence of gold allergy data as provided by Dr Fowler is shown in table 1 below.

Table 1

Prevalence of Gold Allergy[1]		
Report	**Patient Screened (N)**	**Positive to Gold (%)**
Sweden, 1994	823	8.3%
N. Ireland, 1995	278	4.6%
England, 1996	100	13.0%
Germany, 1997	872	5.1%
Portugal, 1997	2,853	0.8%
Scotland, 1997	373	2.1%
NACDG, 1998-2004	15,800	9.9%
Singapore, 1998	345	6.4%
Israel, 2000	406	8.4%
Mayo 2001-2005	3646	13.5%
Average		**8.94%**

Many of those present in the ESCD congress, privately questioned Dr Fowler's findings on the allergenic nature and positive skin reactions due to gold, which has been used and worshipped for thousands of years without any obvious complaints of skin related issues, from those participating in mining, other ways of prospecting, or those wearing jewellery.

The major argument for such questioning was the lack of demonstrable evidence related to the release of gold ions upon its interaction with human body fluids. For metal-induced allergic contact dermatitis to occur, the above condition would have to be satisfied. Given gold's high resistance to corrosion, there will always be some doubt about whether gold can ionise sufficiently in an environment such as human body fluids, to then be able to serve as an allergen.

Several theories have been presented in the literature to justify the ionisation of gold and its interaction with a human body fluid such as sweat. One of them is that a small amount of inert gold is converted to a soluble form by amino acids present in body fluids and absorbed by the skin.

It has also been postulated that cosmetic powders that contain micro abrasives such as titanium dioxide might abrade jewellery and act as carriers to the face and eyelids. Please note that gold is considered to be a relatively common allergen that appears to induce dermatitis around the face and eyelids.

The jeweller's gold in reality also contains copper, zinc, tin and other base metals. It was suggested that increased base metal content in the gold alloy, is associated with increased gold dissolution; thus, lower-carat gold would release more gold ions than a higher-carat gold. This suggests that lower-carat gold would cause more intense skin reactions than pure gold in gold-sensitive patients.

If a body fluid does 'react' with a gold alloy, then ionisation of other elements present in the alloy material will also take place. If we view this situation as a micro-corrosion, some ion species will be subject to 'sacrificial corrosion' faster than others. That does not stop the more noble ions (i.e. gold) being released into the fluid as the 'sacrificial corrosion of other base metals occurs.

All the above theories have some credible scientific basis but are not entirely convincing due to the lack of tangible evidence. Notably, experiments in vitro, carried out at the AnchorCert laboratory of the Birmingham Assay Office, involving several gold alloy materials ranging from 999.9 parts per thousands to less than 9-carat gold alloys (dominated by base metals) with simulated sweat/salt solutions demonstrated little to no gold ion formation.

In one of the North American Contact Dermatitis Group (NACDG) analysis, an allergic reaction to gold was statistically linked to concomitant nickel allergy, while another study associated concomitant gold to palladium allergy. This means that the threshold for gold to cause an allergenic reaction would be reduced considerably if a patient was already sensitive to either nickel or palladium. These findings make some sense provided; it can be demonstrated that gold does ionise in a human bodily fluid such as sweat. In our opinion, more research is needed to further investigate the relationship between allergy due to gold and other metals.

The conclusive dermatological evidence which was based on patch testing data presented in the ESCD[3] 2016 congress indicated that complex interactions between gold and the human body are still poorly understood.

We carried out a literature search to find conclusive dermatological evidence in support of Dr Fowler's argument that **gold should be the allergen of the decade, century, and perhaps, the millennium**. A summary of the evidence, based on patch testing and cases of cutaneous contact allergy to gold provided by Jennifer K. Chen, and Heather P. Lampel is presented in tables 2, 3a[9] & 3b[9] /Appendix I. These tables truly explain the gravity of the situation our society is facing with regards to gold allergy. The literature search data indicates that there is something beneath the behaviour of gold which is yet to be fully characterised, particularly when it is in direct and prolonged contact with body fluids released by human skin, and that it warrants further investigation. The studies on this subject should pay greater attention to gold corrosion and its ionisation in specific human body fluids. This would explain the provenance of gold allergy phenomenon more scientifically and unravel the mystery of gold induced allergic contact dermatitis.

2. **METAL ALLERGY -** WHAT IS METAL INDUCED ALLERGIC CONTACT DERMATITIS (MACD) AND HOW DOES IT DEVELOP?

Dermatitis means an inflammation of the skin. The term 'contact dermatitis' is used when this skin inflammation is caused by contact of the skin with something in its immediate environment. There are two types of contact dermatitis - Allergic Contact Dermatitis (ACD) and Irritant Contact Dermatitis (ICD). When a specific substance, after repeated and prolonged contact, sensitises the immune system and triggers an allergic response, which causes local inflammation, then the reaction is termed as Allergic Contact Dermatitis (ACD), and the substance is called an allergen. If such inflammation of the skin is caused by its exposure to metal allergens, then it is termed as Metal Induced Allergic Contact Dermatitis' (MACD).

Certain substances such as detergents, soaps, cleaners, chemicals, even hard water with chlorine etc., can abrade, irritate or traumatise the skin when in direct contact. These substances can strip the skin of its natural oils and remove its surface protective layer if in contact with the skin for long enough. This can lead to skin damage which causes irritation/inflammation. It is then termed as Irritant Contact Dermatitis (ICD).

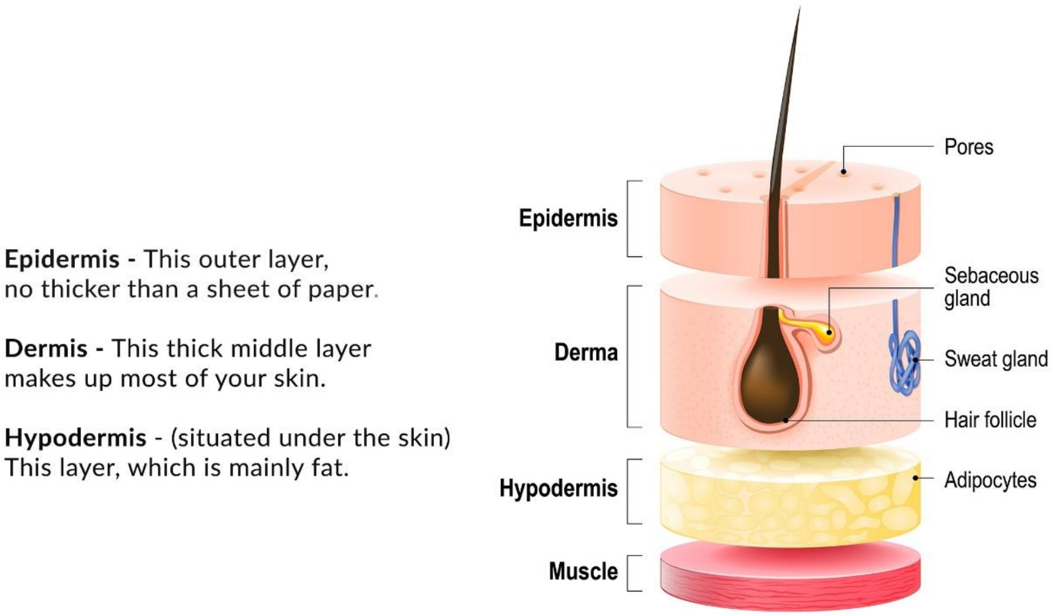
Metal-Induced Allergic Contact Dermatitis develops in two stages:

a) Induction (sensitization) phase
b) Elicitation phase

The induction phase begins when the release of a metal (allergen) is above a specific threshold limit. Metal ions enter into the dermis (middle layer of skin, figure 1) and sensitise the immune system by triggering an immune response which creates a "memory" of the said metal as an allergen to respond to during future exposure. It is largely a non-reversible effect (i.e. once allergic, likely to continue being allergic). Skin allergy due to metal is classed as a Type 4 allergic reaction, often called delayed-type hypersensitivity as the reaction takes several days to develop. In the case of gold, the allergic reaction takes a significantly longer time to develop than with other metals.

The elicitation phase is when the immune response is triggered, and the immune system recognises the previously "memorised" metal allergen(s) and causes a Metal-induced Allergic Contact Dermatitis (MACD) reaction. It is a reversible reaction (i.e. allergic reaction heals after exposure stops). The threshold level of the metal ion concentration (µg/cm2/week) required to trigger the elicitation phase is considerably lower than the level needed for the induction phase. Both phases require the **ionic** metal allergen to cross the epidermis and enter the dermis to provoke an immune reaction.

Figure 1: The Layers of The Human Skin



Picture1

3. ESSENTIAL CONDITIONS FOR MACD TO OCCUR

For metal-induced allergic contact dermatitis (MACD) to occur, primarily the following four conditions must be satisfied:

a) The metal in the material must corrode. Unless metal corrodes, metal ions will not be released.

$$M \text{ (Metal)} \rightarrow Mn^{n+} \text{ (Metal Ion)} + ne^{-} \text{ (Electrons)}$$

b) The metallic material must be in direct and prolonged contact with body fluids. Corrosion requires an extraction medium (e.g. sweat, saliva, tissue, etc.) to take place, as the electrochemical dissolution of metals occurs when metals dissolve in an electrolyte. For this to happen, the metal must be in direct contact with body fluids (sweat, saliva, tissue, etc.).

c) The resulting corrosion must generate a sufficient number of soluble metal ions (>threshold limit). Prolonged contact of the metal with skin, will generate additional and potentially sufficient allergenic metal ions to surpass the threshold limit required for MACD induction or elicitation.

d) The metallic material must be in direct and prolonged contact with the skin. The generated metal ions must penetrate the skin barrier (epidermis & dermis) to cause an allergic reaction. For this to happen, direct contact of the metal with the skin is essential.

4. ALLERGIC RESPONSES TO SKIN CONTACT WITH GOLD AND GOLD ALLOYS

Most people come into contact with metallic gold and gold alloys, either through wearing gold jewellery or coming in contact with these materials in dental restorations and prostheses. As stated in preceding paragraphs, the availability of gold ions is essential to induce and elicit allergic contact dermatitis. The electrochemical nobility of gold suggests that the pure metal is unlikely to react with sweat solutions unless they are contaminated with complexants or powerful oxidising agents. To verify if gold alloys used in jewellery could release gold ions in an artificial sweat solution, a leading supplier of gold jewellery alloy materials was approached, and various grades and colours of semi-finished gold alloy materials used in jewellery applications were procured. These semi-finished gold alloys which were not jewellery articles were subjected to the EN1811:2011 + A1:2015 procedure which involved placing the sample materials in an artificial sweat solution undisturbed for seven days, following the conditions specified in the EU standard. The sweat solution was subsequently analysed by ICP-OES technique, and metal release results expressed in $\mu g/cm^2$/week. The gold release results of alloy materials tested, and their compositions are shown in tables 4a and 4b / Appendix I. The alloy compositions shown in Table 5 / Appendix I, were analysed by XRF technique to determine which major elements were present in the alloys to a reasonable level of accuracy.

Besides above, several samples of a gold reference disc which is used as certified reference material in the nickel release test by EN1811:2011 + A1:2015 were repeatedly analysed for both gold and nickel release following the migration procedure detailed in the BS EN 16128:2015 standard applicable to spectacle frames and eyewear. The BS EN 16128:2015 migration test comprises two steps, the release of nickel into a highly-absorbing type test paper soaked with artificial sweat solution which is left in direct contact with test samples for 168 hrs ± 2 hours in a controlled condition and second, and the subsequent quantitative analytical detection of nickel released into the paper. This procedure mimics the condition of the skin (paper socked with artificial sweat) in direct and prolonged contact with the metallic surface (reference disc, Composition: Au 76%, Cu 16%, Ni 6%, Zn 2%). This procedure demonstrated the expected amount of nickel released from the reference disc but little to no gold ion formation/ release.

The in vitro release experiments as above of the various semi-finished gold alloys ranging from 999.9 fine gold to less than 9-carat gold alloys (dominated by base metals) with artificial sweat solution including the gold reference disc (tables 4a,4b & 5 / Appendix I), demonstrated little or no gold ion formation/release. The only inference that can be drawn from these experiments is that skin contact with semi-finished un-plated gold alloys is unlikely to have any potential to induce irritant or allergic contact dermatitis due to golds' inability to form a soluble ion with artificial sweat.

Please note that our above experimentation involved only semi-finished alloy materials of various caratages and not the finished jewellery. This issue is addressed in the later part of this paper.

5. GOLD ALLERGY – REAL EVIDENCE

The development rate of soluble metal ions at the metal-skin interface is a highly complex and variable process and depends on several factors including electrochemical characteristics of the metal /alloy, the supply of perspiration, its composition, the pH of perspiration (acidity/ alkalinity), the temperature conditions, the metal elements' ability to form coordinate/ covalent bond and the associated bond energy, etc. In addition to these properties, other factors such as the size and, in particular, the specific surface area of the metal tested, the exposure time, the mass or surface area and the presentation of the surfaces will all play a part in determining the level of soluble metal ions available at the metal-skin interface. Favourable conditions at the metal-skin interface, therefore, must exist for the metal to produce biologically active soluble metal ions and to elicit a skin reaction. An allergic reaction will not take place in the absence of the formation of biologically active soluble metal ions on human skin. It is difficult if not impossible to predict in advance if a favourable condition does exist for gold jewellery or gold-containing materials to cause skin allergy on direct and prolonged contact with skin.

Our experimentation detailed in section 4 above, has conclusively proven that semi-finished gold alloy materials do not have any potential for inducing irritant or allergic contact dermatitis due to golds' inability to form a soluble ion with artificial sweat. However, on the contrary, our literature search revealed that a sizable section of individuals did, experience an allergic reaction due to gold from jewellery items and that the allergic reaction healed after exposure stopped. This indicated that finished jewellery probably behaves differently to semi-finished alloy materials in artificial sweat. As our above experimentation involved only semi-finished alloy materials of various caratages and not finished jewellery, to address this situation, a plan was therefore drawn to test approximately **2000** jewellery components for gold release following the EN1811:2011 + A1:2015 procedure. These jewellery components included randomly selected precious and non-precious items, some electro-plated jewellery, watches and some non-metallic and textile products, etc. These components were from regular batches of commercial items received for routine testing and were not specifically chosen for this specific project. Only a few of the articles were known to have the presence of gold either in their alloy material or in their plating. At that stage, our sole objective was to collect conclusive evidence of gold solubility from finished items of jewellery into artificial sweat with EN1811:2011 + A1:2015 test conditions. Once it could be proven that gold present in a finished piece of jewellery (plated or un-plated) does react with artificial sweat and does form soluble metal ions, then further data about conditions and mechanism(s) under which gold release can take place could be ascertained from thorough investigation of the specific test samples that released gold.

In Appendix I, tables 6, 7a, 7b & 7c provide the samples references, XRF compositions along with batch Nos. & ICP tube references, ICP-spectra details and photographs of samples that were found to be releasing gold in artificial sweat solution. Those familiar with analysis of ICP-OES spectra can see from the ICP-OES spectra & data (pictures 4 to 20 in Appendix 1) the conclusive presence of gold released by these test samples.

6. **SUMMARY OF FINDINGS & CONCLUSION OF EXPERIMENTATION INVOLVING FINISHED JEWELLERY ITEMS:**

The following can be concluded from the detailed analysis of test results of the above experimentation, involving approximately 2000 jewellery components:

a) The finished jewellery (& watches) articles which were found to be releasing soluble gold ions were gold plated articles, so the release of soluble gold ion can be attributed to the presence of gold plating.

b) The majority of gold-plated alloy material releasing gold were steel alloys. Gold plated copper was also found to be releasing soluble gold ions.

c) Not all gold-plated alloy materials released gold ions in bodily solutions.

d) Finished jewellery behaves differently to semi-finished alloy materials in artificial sweat.

The overall conclusion that can be drawn from the above is:

- *Gold plating over the surface of an alloy material tends to react with the artificial sweat producing soluble gold ions provided conditions are favourable.*
- *The dissolution of gold plating in the artificial sweat solution is conclusively proven, but the mechanism of dissolution needs a clear scientific explanation.*

As stated in the preceding paragraphs that our literature search has revealed that a sizable section of individuals did, experience an allergic reaction due to gold from jewellery items and that the allergic reaction healed after exposure stopped. It has not been clearly documented anywhere in the literature, whether the pieces of jewellery people experienced an allergic reaction to were plated or unplated. For arguments' sake, we will assume that some of the jewellery items which triggered allergic reactions in gold sensitised individuals were indeed un-plated. If this is true, then we either need conclusive evidence or scientific explanation to prove that un-plated article can also react with artificial sweat and release soluble gold ions. This issue has been addressed, in 'the discussion' section below.

7. THE DISCUSSION

It is clear from the findings above that gold plating on the material surface of an article could interact with artificial sweat solution and produce soluble gold ions. It was also true that not all gold-plated materials produced soluble gold ions. This implies that the surface gold plating reacts with artificial sweat by some mechanism currently unknown and produces soluble metal ions only when favourable conditions exist.

All the finished jewellery items were subjected to similar test conditions, which involved placing the test sample materials into artificial sweat solution undisturbed for seven days, as described in ISO standard BS EN 1811:2011 + A1: 2015. The sweat solutions were subsequently analysed by ICP-OES technique and results expressed in mg/l & $\mu g/cm^2$/week. The only variable, in this case, was the test items themselves and the quality of the gold plating on their surfaces. Under what condition gold plating can produce soluble gold ions in an artificial sweat solution needs a scientific explanation, and also, we need to examine if a similar explanation/ argument could be extended further to answer why some gold sensitised individuals experienced an allergic reaction from un-plated finished jewellery items.

We are aware from our knowledge of electrochemistry that if the difference in electrode potential (V) of the metal being deposited and its undercoat/substrate is too high, then the metal deposit will not adhere firmly onto the substrate. This is the reason a low carat gold strike beneath the surface gold coating is preferred by gold platers as this gold interlayer reduces the electrode potential (V) difference between the top gold coat and the substrate and improve adherence of plating substantially. Further, the interlayer of a low carat gold beneath the surface of a higher carat gold plating not only improves adherence but also helps reduce any porosity in the plating, resulting in a plated surface that hardly shows any peeling phenomenon. Although this needs to be proven beyond doubt, but based on our knowledge of electrochemistry, we are of the view that gold plating tends to react with artificial sweat producing soluble gold ions when it is not in perfect uncharged equilibrium with its substrate due to the difference in electrode potential. A perfect gold surface will not expose to battery/sacrificial corrosion conditions nor release gold ions. That being said, on an atomic scale, no plating is a perfect plating. In a nutshell, poor/ substandard quality gold plating with viewable defects is most likely responsible for the majority of cases where the release of soluble gold ions was detected. Normally, due to gold's nobility, the production of significant amounts of soluble gold ions is hindered therefore, gold release may not always be above the threshold level required to cause an allergic reaction in gold sensitised individuals. This supports and explains the fact that although millions of people have worn gold jewellery over the years but seldom we see the cases where individuals suffered from allergic contact dermatitis due to gold in jewellery.

Another source of gold ions is in the grain boundaries of the cast and finished jewellery including wrought items. Soldered/ welded assemblies in such unplated jewellery items introduce macro potential difference which like plated item could also cause the release of gold ions into sweat. The quantum of gold release, whether it will be above the threshold limit, will depend on the size of potential difference which in turn depends on the size of macro defects.

The above argument i.e. the introduction of macro potential difference, explains why sometimes finished unplated gold jewellery can release gold ions when in direct and prolonged contact with bodily sweat and trigger an allergic reaction. In this case, again, it is down to the macro defects which could be present in jewellery due to improper soldering or welding etc. Currently, our above argument with respect to un-plated jewellery items is not proven by the test data, but it has scientific merit of its own. We are continuing our broader studies to explore this argument further, and the outcome may be part of our next research paper on a similar subject. Our current focus is to explore further the reasons behind the release of gold ions from materials which are gold plated.

As all the items that released gold into sweat solution were gold plated so it is easy to presume that substandard gold plating would have allowed the production of soluble gold ions due to its interaction with artificial sweat as stated above. Before continuing our discussion further, it is, therefore, necessary to define what is classed as 'a substandard gold plating result' to answer the question of how feasible the dissolution of gold is in artificial sweat.

8. WHAT CAN BE CLASSED AS SUBSTANDARD GOLD PLATING?

A layer of decorative gold plating may look bright and smooth to the casual observer, but often the deposit itself has microcracks, inclusions, and trapped metal contaminants. Many factors cause these undesirable features (cracks, breaches, etc.). Poor surface preparation before plating, the omission of steps like the pre-cleaning, pickling, rinsing or activation steps etc., contamination of the plating bath (due to lack of filtration, agitation etc.), or wrong d.c. power supply, all can contribute to some degree. In addition to this, if too much hydrogen (caused by d.c. overvoltage/ or low metal content in plating bath) is created by the electrolysis of water, the gold/metal deposit itself will become too hard and brittle due to the build-up of internal stress. This stress can also cause **macro cracking and poor adhesion** throughout the entire structure of the metal coating, especially in thick coatings. In our opinion gold plating with such viewable defects, would be classed as substandard plating.

Further, the base metals (such as steel, brass, copper etc. or under plate surface) form oxides when exposed to oxygen in the atmosphere. This occurs while plating, during the standing time or during the transfer time from one plating bath to another. These oxides make the surface passive and chemically inactive. Such chemically inactive surfaces will not bond with any other materials. A non-adherent deposit (peeling effect) will be the result of plating any metal onto a surface which has turned into its oxide during the process of plating. Such plated layers will also be termed as substandard.

Picture 2

Picture 3

The data suggest that substandard deposits occur mainly due to poor surface preparation of the metal substrate; not adhering strictly to the standard pre-cleaning cycle of the metal surface before plating and not following the plating instructions (current, concentration, time, filtration etc.) recommended by the supplier of proprietary plating salts/ solution. The key here is 'PROCESS CONTROL'.

If the surface-preparation part of the plating cycle is inadequate, then the application of any plated deposit may result in blisters, discolouration, pitting corrosion, and poor adhesion, pinholes, and other defects. Also, the metal deposit will not adhere firmly to the base metal surface if it is greasy/oily.

In our opinion, non-adhering surface plating is more vulnerable to attack in artificial sweat, but the mechanism of dissolution needs a clear scientific explanation.

THE DISCUSSION (CONTINUE…)

To ascertain if the gold plating of the finished jewellery (& watches) samples found to be releasing gold ions into artificial sweat was really of the substandard quality, we examined the surface gold plating of the articles after the release test under a high-powered microscope and by X-Ray plating technique. We noticed that plating had micro/ macro defects, a non-adherent deposit showing a peeling effect. It is probable that a small portion of such loosely-adhering / non-adhering gold deposit, dissolved into the artificial sweat by some mechanism currently unknown to us and produced soluble gold ions. These could, in turn, cause an allergic reaction to the human skin upon direct and prolonged contact with skin if conditions are favourable and gold ions release is above the threshold level. There are, however, some limitations to our observations that deserve attention. Our high power magnification observation of defective plating was conducted after these gold plated samples had already been subjected to the wear corrosion test (EN 12472:2009) and after they had been left in artificial sweat for seven days, which could cause corrosion and detachment of a portion of gold plating. In such circumstances, it is difficult to say that the plating in its original form would have been substandard in nature. But at the same time, it cannot be denied that gold did dissolve into artificial sweat and that all the samples where the gold release was detected, were gold plated and that the majority of the items had steel or a copper base.

9. CONCLUSION:

In conclusion, gold is an element that has certainly been associated with some adverse skin reactions. It should be viewed as an element that can lead to skin disorders/ allergy, but only under special conditions.

Our research has conclusively proven that the semi-finished gold alloy materials do not have any potential for inducing irritant or allergic contact dermatitis due to golds' inability to form a soluble ion with artificial sweat. These alloy materials are non-sensitising and safe from a gold allergy point of view. However, materials plated with thin gold layers with viewable defects may react with sweat when conditions are favourable and produce soluble gold ions which could be associated with skin allergy cases due to gold.

Gold plating tends to react with artificial sweat producing soluble gold ions when it is not in perfect uncharged equilibrium with its substrate due to their difference in electrode potential. Probably, for this reason, a small amount of non-adherent segregated gold plating particles produces soluble gold ions which are absorbed by the skin upon their interaction with bodily fluids. This occurs during direct and prolonged contact and can cause skin allergy when metal absorption is higher than the induction /elicitation threshold limits.

Another source of gold ions is in the grain boundaries of the cast and finished jewellery including wrought items. Soldered/ welded assemblies in such items introduce macro potential difference which like plated items could also cause the release of gold ions into sweat. The quantum of gold release, whether it will be above the threshold limit, will depend on the size of potential difference which in turn depends on the size of macro defects. This explains why some un-plated jewellery items release gold ions when in direct and prolonged contact with bodily sweat and trigger allergic reaction.

Gold, due to its nobility, hinders the production of significant amounts of soluble gold ions and due to this reason, even on direct and prolonged contact with skin, the gold ion concentration required to trigger an allergic reaction in gold sensitised individuals may not always be above the threshold level. This supports and explains the fact that although millions of people have worn gold jewellery over the years but we seldom see the cases where individuals suffered from allergic contact dermatitis due to gold in jewellery.

These findings are based on limited test data. Further and broader studies, rigorously conducted, are needed to firmly answer the questions related to the mechanism of gold dissolution, when plated/un-plated articles are in contact with body fluids.

It has however been established beyond doubt, that gold does react with sweat when conditions are favourable, and this could be associated with prevalent gold allergy cases.

10. GOLD DISSOLUTION IN BODILY FLUID – FUTURE WORK

Gold dissolution in a bodily fluid is of significant interest to a wide range of Scientists and Dermatologist. We are currently working on a theory that envisages the removal of material from the gold alloy-based surface to form ions in sweat solution leaving behind a charged surface vacancy. These vacancies create a potential difference across the Stern layer that accelerates or retards the removal of ions. In this way, the surface potential difference is caused by and influences the rate of the removal of gold ions. From this theory, probably a mathematical model of gold dissolution may be derived. The model may also describe the effect of Na^+ and Cl^- ions, as well as the effect of lactic acid and other alloying elements. Gold electrochemical nobility factor will also be taken into account while driving this model.

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APPENDIX I

Table 2. Results of patch testing with gold, in different regions. (Jennifer K. Chen and Heather P. Lampel)					
First Author	**Total No. of Patients**	**% of Positive Reactions**	**Clinical Relevance (R/Q/P/N)**	**Test Material**	**Region, Years**
Warshaw, et al.32	5106	8.7	NR	Gold sodium thiosulfate 0.5% pet	North America, 2003-4
Pratt, et al.31	4900	10.2	10.2/27.1/7.0/NR	Gold sodium thiosulfate 0.5% pet	North America, 2001-2
Marks, et al.33 1998-2000	5806	10.5	14.8/29.2/6.9/NR	Gold sodium thiosulfate 0.5% pet	North America, 1998-2000
Marks, et al.19 1996-98	4101	9.5	40.6 overall	Gold sodium thiosulfate 0.5% pet	North America, 1996-1998
Davis, et al.16	375	10.1	42.1/34.2/5.3/18.4	Gold sodium thiosulfate 0.25% pet	United States, 2000-2009
Davis, et al.16	1105	18.4	40.4/45.3/3.0/8.9	Gold sodium thiosulfate 0.5% pet	United States, 2000-2009
Davis, et al.16	90	23.3	23.8/71.4/0/4.8	Gold sodium thiosulfate 2% pet	United States, 2000-2009
Davis, et al.16	966	6.9	53.7/29.9/4.5/10.4	Gold chloride 0.5% alc	United States, 2000-2009
Davis, et al.16	1098	20.2	37.4/47.7/2.7/9.5	Potassium dicyanoaurate 0.1% aq	United States, 2000-2009
Wentworth, et al.3	1904	5.8	27/54.1/1.8/17.1	Gold sodium thiosulfate 0.25% pet	United States, 2006-2010
Wentworth, et al.3	3081	9.2	23.8/55.7/2.1/18.1	Gold sodium thiosulfate 0.5% pet	United States, 2006-2010
Wentworth, et al.3	1110	17	19.6/51.9/4.2/24.3	Gold sodium thiosulfate 2% pet	United States, 2006-2010
Fleming, et al.76	373	2.1	NR	Gold sodium thiosulfate 0.5% pet, 0.05% pet	Scotland, 1996
Sabroe, et al.36	100	13	53.8 overall	Gold sodium thiosulfate 0.5% pet	England, 1995
McKenna, et al.37	278	4.6	46 overall	Gold sodium thiosulfate 0.5% pet	Ireland, 1994
Bruze, et al.45	1056	10	NR	Gold sodium thiosulfate 0.5% pet	Sweden, 1991-1993
Bjorkner, et al.38	823	8.6	NR	Gold sodium thiosulfate 0.5% pet	Sweden, 1991-1992
Silva, et al.39	2853	0.8	NR	Gold sodium thiosulfate 0.5% pet	Portugal, 1995
Silva, et al.39	2853	0.07	NR	Potassium cyanoaurate 0.1% aq	Portugal, 1995
Trattner, et al.40	406	8.4	5.9 overall	Gold sodium thiosulfate 0.5% pet	Israel, <2000
Boonchai, et al.41	852	30.7	14.6 overall	Gold sodium thiosulfate 0.5% pet	Thailand, 2000-2009
Nonaka, et al.43	931	5.9	NR	Gold chloride 0.2% aq, gold sodium thiosulfate 0.5% pet	Japan, 1990-2009
Nakada, et al.42	377	10.3	NR	Gold chloride 0.2% aq	Japan, 1989-1995
Lee, et al.442001	255	3.1	Clinical relevance “minimal”	Gold sodium thiosulfate 0.5% pet	Korea, 1998-2000
NR = not reported, R = clinically relevant, Q = questionably relevant, P = formerly relevant, N = not relevant					

Table 3a. Case reports of cutaneous contact allergy to gold. (Jennifer K. Chen and Heather P. Lampel)				
First Author	**Source of Exposure**	**Type of Reaction**	**No. of Patients**	**Region, Year**
Forster, et al.79	14k gold orbital implants	Allergic contact dermatitis involving eyelids and periorbital region	1	United States, 1949
Chenoweth, et al.53	18k gold ring and watch	Dermatitis of the hands and forearms	1	Australia, 1957
Cowan, et al.54	11k gold ring, gold sleepers	Allergic contact dermatitis of the ring finger and earlobes	1	England,1960
Fox, et al.55	Gold rings and watch	Allergic contact dermatitis under jewelry	1	United States, 1961
Shelley, et al.64	Crystals of gold trichloride	Chronic papular eruption at site of contact on right forearm	1	United States, 1963
Comaish, et al.56	9k gold earrings, 18k gold rings, gold watch	Allergic contact dermatitis under jewelry, appeared on other ring finger when ring transferred to the other hand	1	England, 1969
Elgart, et al.57	Gold earrings, ring, and wristwatch, gold crown	Allergic contact dermatitis under jewelry, irritation of gingiva mucosa around crown	1	United States, 1971
Petros, et al.58	Gold earrings	Allergic contact dermatitis and papular dermal reaction of the earlobes	1	England, 1973
Young59	Gold earrings and ring	Nodular pruritic dermatitis under jewelry	1	Netherlands, 1974
Iwatsuki, et al.69	Gold earrings	Lymphomatoid allergic contact dermatitis of the earlobes	3	Japan, 1987
Fowler, et al.60	14k gold earrings, gold necklace and ring	Allergic contact dermatitis under jewelry	2	United States, 1988
Aoshima, et al.70	Gold earrings	Granulomatous allergic contact dermatitis	1	Japan, 1988
Goh, et al.108	Gold plating	Allergic contact dermatitis of the hands and forearms	1	Singapore, 1988
Kobayashi, et al.71	Gold earrings	Lymphocytoma cutis-like allergic contact dermatitis of the earlobes	1	Japan, 1992
Osawa, et al.61	Gold earrings	Allergic contact dermatitis of the earlobes	1	Japan, 1994
Tan, et al.66	Gold smelting	Airborne allergic contact dermatitis of the forehead and forearms	1	Australia, 1996
Armstrong, et al.72	Gold earrings	Granulomatous contact dermatitis	1	Ireland, 1997
Fleming, et al.73	Gold earrings	Lymphomatoid allergic contact dermatitis of earlobes and retro-auricular eczematous plaques	1	Scotland, 1997
Wiesner, et al.62	Gold earrings, ring, necklace, bracelet	Allergic contact dermatitis under jewelry	1	Germany,1998
Estlander, et al.67	Gold plating, metallic gold	Allergic contact dermatitis of the fingers and eyelids, conjunctivitis	1	Finland, 1998
Suzuki77	Gold earrings	Allergic contact dermatitis of earlobes	3	Japan, 1998
Sperber, et al.4	Jewelry sales, gold etching	Hand dermatitis that resolved when away from work (the authors also present a third case, of chronic diffuse papular dermatitis unclear if due to gold)	2	United States, 2003
Nagashima, et al.74	18k gold earrings	Granulomatous allergic contact dermatitis of the earlobes	1	Japan, 2004

Table 3b. Case reports of cutaneous contact allergy to gold. (Jennifer K. Chen and Heather P. Lampel)				
First Author	**Source of Exposure**	**Type of Reaction**	**No. of Patients**	**Region, Year**
O'Donoghue, et al.63	Gold on a hearing aid mould, 9k gold ring (however, also allergic to nickel and plastic)	Allergic contact dermatitis on the right concha, tragus, preauricular, ring finger	1	England, 2004
Conde-Taboada, et al.75	Gold earrings	Lymphomatoid contact dermatitis of the earlobes	1	Spain, 2007
Bjorkner, et al.89	Gold eyelid weights, + gold ring in 1 patient	Eyelid erythema and swelling, + periorbital and ring finger dermatitis in 1 patient	4	Sweden, 2008
Mehta, et al.68	22k gold nose ring, 18k gold earrings	Nodular contact dermatitis at sites of piercings	2	India, 2010
Giorgini, et al.65	Gilding, gold plating	Airborne contact dermatitis with involvement of the eyelids, +/- glabella, neck	2	Italy, 2010

Table 4a. Gold release from gold alloys.						
Description	**Component Description**	**ICP-Tube. Ref.**	**Sample Type**	**Alloy Type**	**Batch No**	**Gold ((µg / cm2 / Week))**
(46% uncertainty applied)						
999.9 Fine Gold Wire	REP 1	1	Non-earring	Gold Alloy	16	0.0000
	REP 2	2	Non-earring	Gold Alloy	16	0.0000
	REP 3	3	Non-earring	Gold Alloy	16	0.0000
CQA 050, COOKSONS	H6/8 BI1635574/12	4	Non-earring	Gold Alloy	16	0.0000
18CT WHITE GOLD SOLDER PANELS EWG500, COOKSONS	01/3 BI1635574/13	5	Non-earring	Gold Alloy	16	0.0011
18CT WHITE GOLD SOLDER PANELS MWG588, COOKSONS	03/3 BI1635574/15	6	Non-earring	Gold Alloy	16	0.0039
18CT WHITE GOLD SOLDER PANELS HWG833, COOKSONS	02/3 BI1635574/14	7	Non-earring	Gold Alloy	16	0.0000
CLA 050 18CT YELLOW HB SHEET COOKSONS	H3/8 BI1635574/7	8	Non-earring	Gold Alloy	16	0.0000
CLD 050 18CT HAB YELLOW GOLD SHEET, COOKSONS	H8/8 BI1635574/8	9	Non-earring	Gold Alloy	16	0.0000

Table 4b. Gold release from gold alloys.						
Description	**Component Description**	**ICP-Tube. Ref.**	**Sample Type**	**Alloy Type**	**Batch No**	**Gold ((µg / cm2 / Week))**
(46% uncertainty applied)						
CLE 050, 18CT MEDIUM WHITE GOLD SHEET	H4/8 BI1635574/9	10	Non-earring	Gold Alloy	16	0.0000
CLU 050, 18WNC SHEET	H7/8 BI1635574/10	11	Non-earring	Gold Alloy	16	0.0000
CLU 1001, 18CT WNC WHITE GOLD SHEET	H2/8 BI1635574/11	12	Non-earring	Gold Alloy	16	0.0000
Plate D - Imperial Smelting, Gold Plate, Plain, 18k, White, Ni	REP 1	13	Non-earring	Gold Alloy	16	0.0000
	REP 2	14	Non-earring	Gold Alloy	16	0.0000
	REP 3	15	Non-earring	Gold Alloy	16	0.0000
Plate C - Imperial Smelting, Gold Plate, Plain, 10k, White, 525	REP 1	16	Non-earring	Gold Alloy	16	0.0000
	REP 2	17	Non-earring	Gold Alloy	16	0.0000
	REP 3	18	Non-earring	Gold Alloy	16	0.0000
CGD 050 0.6G, 14CT A YELLOW SHEET	H1/8 BI1635574/6	19	Non-earring	Gold Alloy	16	0.0000
Plate A - Imperial Smelting, Gold Plate, Plain, 10k, White, 525	REP 1	20	Non-earring	Gold Alloy	16	0.0000
	REP 2	21	Non-earring	Gold Alloy	16	0.0000
	REP 3	22	Non-earring	Gold Alloy	16	0.0000
Plate B - Imperial Smelting, Gold Plate, Plain, 10k, White, 525	REP 1	23	Non-earring	Gold Alloy	16	0.0000
	REP 2	24	Non-earring	Gold Alloy	16	0.0000
	REP 3	25	Non-earring	Gold Alloy	16	0.0000
CAA 050, 9CT YELLOW DF SHEET	Z1/4 BI1635574/1	26	Non-earring	Gold Alloy	16	0.0000
CAG 100, 9PS SHEET,	Z2/4 BI1635574/2	27	Non-earring	Gold Alloy	16	0.0000
CAL 050, 9CT MEDIUM RED SHEET	Z4/4 BI1635574/5	28	Non-earring	Gold Alloy	16	0.0000
CAR 050, 9CT MEDIUM WHITE SHEET	Z3/4 BI1635574/3	29	Non-earring	Gold with high Silver Alloy	16	0.0000
CAJ 165, 9SPW SHEET	H5/8 BI1635574/4	30	Non-earring	Gold with high Silver Alloy	16	0.0000
Nickel Free Large gold Plated Backs 320 S/A3 01090666	REP 1	63	Non-earring	Copper Alloy	16	0.0000
	REP 2	64	Non-earring	Copper Alloy	16	0.0000
	REP 3	65	Non-earring	Copper Alloy	16	0.0000

Table 5. Composition of gold alloys tested.									
ICP-Tube. Ref.	**Cu**	**Zn**	**Fe**	**Ni**	**Cr**	**Au**	**Ag**	**Pt**	**Pd**
	%	%	%	%	%	%	%	%	%
4	5.2			0.13	0.54	91.11	3.02		
5	6.25	16.5		7.22		50.69	19.35		
6		18.76		8.39		72.85			
7		6.91		10.81		82.28			
8	8.98					75.05	15.96		
9	12.59					75.05	8.34	4.03	
10						76.34	11.87		11.79
11	13.2	3.57				74.62			
12	13.16	3.58		8.42		74.85			
13		3.08	12.8	8.69		75.12			
14		3.08	12.8	8.69		75.12			
15		3.08	12.8	8.69		75.12			
16	19.68	6.58		11.99		61.75			
17	19.68	6.58		11.99		61.75			
18	19.68	6.58		11.99		61.75			
19	30.57	5.62				58.33	5.47		
20	36.41	7.21		11.73		44.64			
21	36.41	7.21		11.73		44.64			
22	36.41	7.21		11.73		44.64			
23	41.49	6.57		8.8		42.98			
24	41.49	6.57		8.8		42.98			
25	41.49	6.57		8.8		42.98			
26	41.92	9.16				37.55	11.35		
27	44.69	0.52				37.24	17.56		
28	57.9					36.98	2.75		
29	0.9	5.91				37.77	55.43		
30	8.2	2.37				38.19	53.61		
63	62.00 Cu	25.60 Zn	1.66 Sn	0.15 Co		9.72 Au	Others 0.88%		
64	62.00 Cu	25.60 Zn	1.66 Sn	0.15 Co		9.72 Au	Others 0.88%		
65	62.00 Cu	25.60 Zn	1.66 Sn	0.15 Co		9.72 Au	Others 0.88%		

Table 6. Gold release from jewellery samples.						
Batch No., Method No.	**ICP-Tube. Ref.**	**Component Description**	**ICP-Tube. Ref.**	**Sample Type**	**Flask Volume (ml)**	**Gold released (mg/l)**
(46% uncertainty applied)						
880F, 20A	2	Earring Post	2	Earring	10	0.0026
880F, 20A	7	Necklace Chain	7	Non-Earring	10	0.0014
880F, 20A	9	Necklace pendant ring	9	Non-Earring	20	0.0019
881F, 20A	2	Watch crown	2	Non-Earring	10	0.0448
124, 20C	86	Watch crown	86	Non-Earring	10	0.0178
124, 20C	89	Watch crown	89	Non-Earring	10	0.0069
124, 20C	132	Watch crown	132	Non-Earring	10	0.0101
144, 20C	163	Watch long strap	163	Non-Earring	50	0.0166
144, 20C	267	Watch clasp pin	267	Non-Earring	10	0.0133
145, 20C	115	Watch buckle	115	Non-Earring	10	0.0336
145, 20C	151	Watch long strap	151	Non-Earring	50	0.0028
145, 20C	156	Watch clasp box	156	Non-Earring	10	0.0097
145, 20C	157	Watch clasp box rectangular bottom plate	157	Non-Earring	10	0.0064
146, 20C	129	Watch case	129	Non-Earring	50	0.0022
146, 20C	131	Watch buckle	131	Non-Earring	20	0.0085
147, 20C	74	Necklace chain	74	Non-Earring	10	0.0046
150, 20C	111	Watch bracelet	111	Non-Earring	50	0.0187

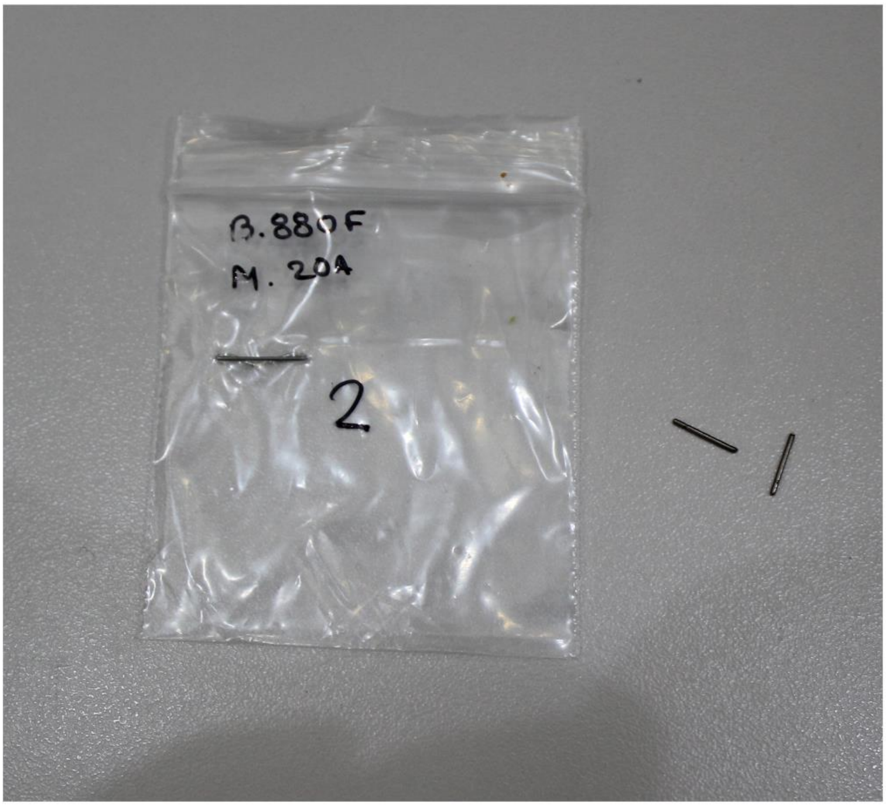
Table 7a. Composition of jewellery samples that released gold.

Batch No., Method No.	**ICP-Tube. Ref.**	**ICP Description**	**XRF Description**	**Scrapped (S) / Un-scrapped (U)**	**XRF % data**	**Comments**
880F, 20A	2	Earring Post with portion of gold-plated stud	Earring Post	U	Ti 99.83%, Te 0.17%	Stud plating attached to post released Au, not post itself.
				S	Ti 100%	
880F, 20A	7	Necklace Chain	Necklace Chain - Yellow	U	Au 3.92%, Cu 96.08%	N/A
				S	Cu 82.95%, Zn 8.78%, Ca 8.27%	
880F, 20A	9	Necklace pendant ring	Necklace pendant ring - Yellow	U	Cu 95.40%, Zn 2.59%, Au 2.01%	All tested as one sample for release.
				S	Cu 100%	
			Necklace pendant ring - White	U	Cu 99.24%, Rh 0.48%, Pd 0.28%	
				S	Cu 100%	
881F, 20A	2	Watch crown	Watch crown top - Yellow	U	Fe 69.90%, Cr 16.72%, Ni 10.46%, Mo 1.88%, Au 1.04%	All tested as one sample for release.
				S	Fe 70.81%, Cr 17.04%, Ni 10.27%, Mo 1.88%	
			Watch crown bottom - Grey	U	Fe 73.06%, Cr 18.62%, Ni 8.32%	
				S	Fe 71.72%, Cr 18.05%, Ni 9.33%, Mo 0.91%	
124, 20C	86	Watch crown	Watch crown side - Yellow	U	Fe 69.05%, Cr 16.63%, Ni 9.51%, Mo 1.93%, Mo 1.93%, Au 1.37%, Ti 1.52%	All tested as one sample for release.
			Watch crown bottom - Grey	U	Fe 74.16%, Cr 18.02%, Ni 7.82%	
			Watch crown side - Yellow	S	Fe, 71.08%, Cr 16.53%, Ni 9.96%, Co 0.38%, Mo 2.04%	
			Watch crown bottom - Grey	S	Fe 73.81%, Cr 18.82%, Ni 7.37%	
124, 20C	89	Watch crown	Watch crown side - Yellow	U	Fe 68.58%, Cr 17.69%, Ni 9.93%, Mo 1.86%, Au 1.02%, Ti 0.77%, Ba 0.14%	All tested as one sample for release.
				S	Fe 70.59%, Cr 17.68%, Ni 9.85%, Mo 1.89%	
			Watch crown bottom - Grey	U	Fe 73.88%, Cr 18.58%, Ni 7.53%	
				S	Fe 70.90%, Cr 17.99, Ni 9.48%, Co 0.22%, Mo 1.41%	

Table 7b Composition of jewellery samples that released gold.						
Batch No., Method No.	**ICP-Tube. Ref.**	**ICP Description**	**XRF Description**	**Scrapped (S) / Un-scrapped (U)**	**XRF % data**	**Comments**
124, 20C	132	Watch crown	Watch crown top - Yellow	U	Fe 65.97%, Cr 16.53%, Ni 8.82%, Co 0.40%, Ti 5.92%, Mo 1.92%, Au 0.98%	All tested as one sample for release.
				S	Fe 71.92%, Cr 16.60%, Ni 9.08%, Co 0.58%, Mo 1.81%	
			Watch crown bottom - Grey	U	Fe 73.66%, Cr 18.62%, Ni 7.50%, Co 0.21%	
				S	Fe 72.47%, Cr 18.46%, Ni 7.93%, Co 1.13%	
144, 20C	163	Watch long strap	Watch long strap - Chain part	U	Fe 71.35%, Cr 18.29%, Ni 7.63%, Ti 1.96%, Au 0.77%	All tested as one sample for release.
				S	Fe 73.45%, Cr 18.48%, Ni 7.29%, Ti 0.52%, Ba 0.25%	
			Watch long strap - Strap ends	U	Fe 71.35%, Cr 18.84%, Ni 7.45%, Co 0.19%, Ti 2.39%	
				U - Au requested	Fe 70.98%, Cr 18.78%, Ni 7.41%, Co 0.21%, Ti 2.35%, Au 0.27%	
				S	Fe 73.20%, Cr 18.94%, Co 0.31%, Ni 7.55%	
144, 20C	267	Watch clasp pin	Watch clasp pin	U (Area1)	Cu 62.93%, Fe 16.53%, Ni 16.66%, Ca 2.29%, Zn 1.58%	N/A
				U (Area 2)	Cu 64.39%, Ni 28.91%, Fe 5.62%, Ca 1.08%	
				U (Area 2) - Au Requested	Cu 64.25%, Ni 28.87%, Fe 5.63%, Ca 1.09%, Au 0.16%	
				S	Fe 79.86%, Cu 15.46%, Ni 4.09%, Mn 0.58%	
145, 20C	115	Watch buckle	Watch buckle	U	Fe 66.93%, cr 17.61%, Ti 8.00%, Co 0.60%, Ni 6.00%, Au 6.00%	N/A
				S	Fe 72.88%, Cr 18.25%, Ni 7.83%, Co 0.20%, Ti 0.64%, Ba 0.21%	
145, 20C	151	Watch long strap	Watch long strap	U	Fe 72.59%, Mn 12.17%, Cr 11.19, Au 0.69, Cu 0.99%, Ti 1.62%, Ni 0.75%	N/A
				S	Fe 74.51%, Cr 14.13%, Mn 9.35%, Cu 0.87%, Ni 1.14%	

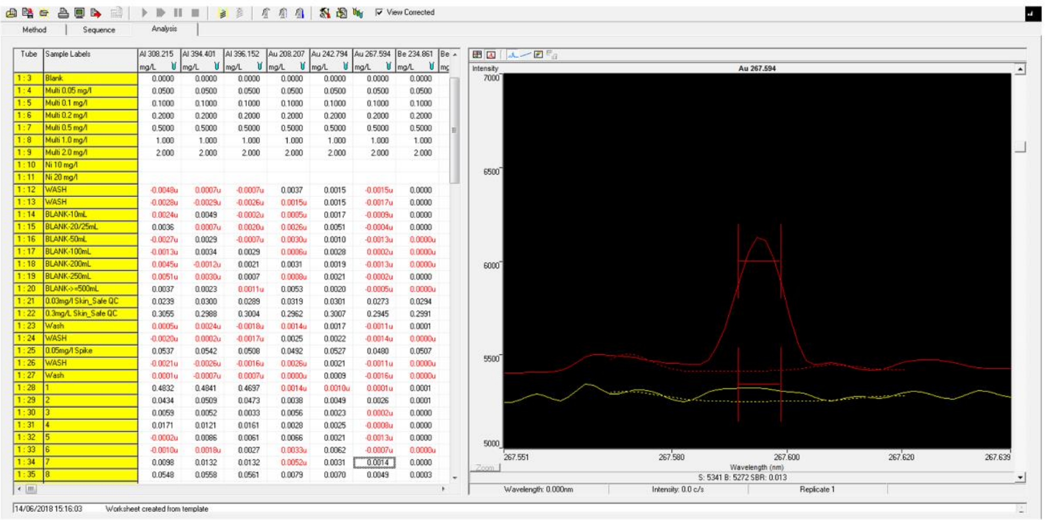
Table 7c. Composition of jewellery samples that released gold.						
Batch No., Method No.	**ICP-Tube. Ref.**	**ICP Description**	**XRF Description**	**Scrapped (S) / Un-scrapped (U)**	**XRF % data**	**Comments**
145, 20C	156	Watch clasp box	Watch clasp box	S	Fe 70.27%, Cr 14.22%, Mn 9.12%, Au 0.83%, Cu 1.65%, Ti 2.97%, Ni 0.93%	N/A
				U	Fe 73.49%, Cr 14.55%, Mn 9.33%, Cu 1.43%, Ni 1.20%	
145, 20C	157	Watch clasp box rectangular bottom plate	Watch clasp box rectangular bottom plate	U	Fe 72.11%, Cr 13.50%, Mn 10.11%, Cu 1.09%, Au 0.54%, Ni 1.00%, Ti 1.02%, Ba 0.62%	N/A
				S	Fe 74.36%, Cr 13.56, Mn 9.90%, Cu 0.88%, Ni 1.30%	
146, 20C	129	Watch case	Watch case	U	Fe 67.06%, Cr 16.70%, Ni 9.60%, Co 0.36%, Mo 1.99%, Au 1.64%, Ti 2.65%	N/A
				S	Fe 72.29%, Cr 16.40%, Ni 9.51%, Mo 1.80%	
146, 20C	131	Watch buckle	Watch buckle	U	Fe 68.71%, Cr 18.15%, Ti 5.40%, Co 0.29%, Au 1.58%, Ni 5.86%	N/A
				S	Fe 73.31%, Cr 18.56%, Ni 7.95%, Co 0.17%	
147, 20C	74	Necklace chain	Necklace chain	U	Cu 86.41%, Ni 10.35%, Zn 3.25%	N/A
				U - Au requested	Cu 85.37%, Ni 10.32%, Zn 3.05%, Au 1.26%	
				S	Cu 89.06%, Zn 10.76%, Ni 0.18%	
				S - Au requested	Cu 89.01%, Zn 10.74%, Ni 0.16%, Au 0.09%	
150, 20C	111	Watch bracelet	Watch bracelet	U	Fe 73.29, Cr 13.49%, Mn 9.99%, Au 0.81%, Cu 1.54%, Ni 0.88%	N/A
				S	Fe 74.63%, Cr 11.67%, Mn 12.06%, Cu 0.75%, Ni 0.89%	

Batch 880F, 20A, component 2



Picture 4

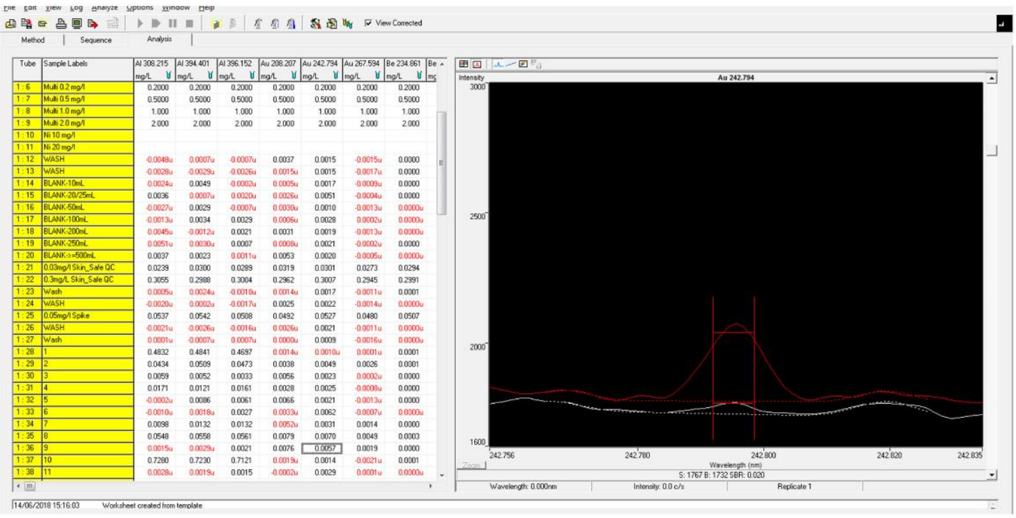
Batch 880F, 20A, component 7



Tube	Sample Labels	Al 308.215 mg/L	Al 394.401 mg/L	Al 396.152 mg/L	Au 208.207 mg/L	Au 242.794 mg/L	Au 267.594 mg/L	Be 234.861 mg/L
1 : 3	Blank	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1 : 4	Multi 0.05 mg/l	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500
1 : 5	Multi 0.1 mg/l	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000	0.1000
1 : 6	Multi 0.2 mg/l	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
1 : 7	Multi 0.5 mg/l	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
1 : 8	Multi 1.0 mg/l	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1 : 9	Multi 2.0 mg/l	2.000	2.000	2.000	2.000	2.000	2.000	2.000
1 : 10	Ni 10 mg/l							
1 : 11	Ni 20 mg/l							
1 : 12	WASH	-0.0048u	0.0007u	-0.0007u	0.0037	0.0015	-0.0015u	0.0000
1 : 13	WASH	-0.0028u	-0.0029u	-0.0026u	0.0015u	0.0015	-0.0017u	0.0000
1 : 14	BLANK-10mL	0.0024u	0.0049	-0.0002u	0.0005u	0.0017	-0.0009u	0.0000
1 : 15	BLANK-20/25mL	0.0036	0.0007u	0.0020u	0.0026u	0.0051	-0.0004u	0.0000
1 : 16	BLANK-50mL	-0.0027u	0.0029	-0.0007u	0.0030u	0.0010	-0.0013u	0.0000u
1 : 17	BLANK-100mL	-0.0013u	0.0034	0.0029	0.0006u	0.0028	0.0002u	0.0000u
1 : 18	BLANK-200mL	0.0045u	-0.0012u	0.0021	0.0031	0.0019	-0.0013u	0.0000u
1 : 19	BLANK-250mL	0.0051u	0.0030u	0.0007	0.0008u	0.0021	-0.0002u	0.0000
1 : 20	BLANK->=500mL	0.0037	0.0023	0.0011u	0.0053	0.0020	-0.0005u	0.0000u
1 : 21	0.03mg/l Skin_Safe QC	0.0239	0.0300	0.0289	0.0319	0.0301	0.0273	0.0294
1 : 22	0.3mg/L Skin_Safe QC	0.3055	0.2988	0.3004	0.2962	0.3007	0.2945	0.2991
1 : 23	Wash	0.0005u	0.0024u	-0.0018u	0.0014u	0.0017	-0.0011u	0.0001
1 : 24	WASH	-0.0020u	0.0002u	-0.0017u	0.0025	0.0022	-0.0014u	0.0000u
1 : 25	0.05mg/l Spike	0.0537	0.0542	0.0508	0.0492	0.0527	0.0480	0.0507
1 : 26	WASH	-0.0021u	-0.0026u	-0.0016u	0.0026u	0.0021	-0.0011u	0.0000u
1 : 27	Wash	0.0001u	-0.0007u	0.0007u	0.0000u	0.0009	-0.0016u	0.0000u
1 : 28	1	0.4832	0.4841	0.4697	0.0014u	0.0010u	0.0001u	0.0001
1 : 29	2	0.0434	0.0509	0.0473	0.0038	0.0049	0.0026	0.0001
1 : 30	3	0.0059	0.0052	0.0033	0.0056	0.0023	0.0002u	0.0000
1 : 31	4	0.0171	0.0121	0.0161	0.0028	0.0025	-0.0008u	0.0000
1 : 32	5	-0.0002u	0.0086	0.0061	0.0066	0.0021	-0.0013u	0.0000
1 : 33	6	-0.0010u	0.0018u	0.0027	0.0033u	0.0062	-0.0007u	0.0000u
1 : 34	7	0.0098	0.0132	0.0132	0.0052u	0.0031	0.0014	0.0000
1 : 35	8	0.0548	0.0558	0.0561	0.0079	0.0070	0.0049	0.0003

Picture 5

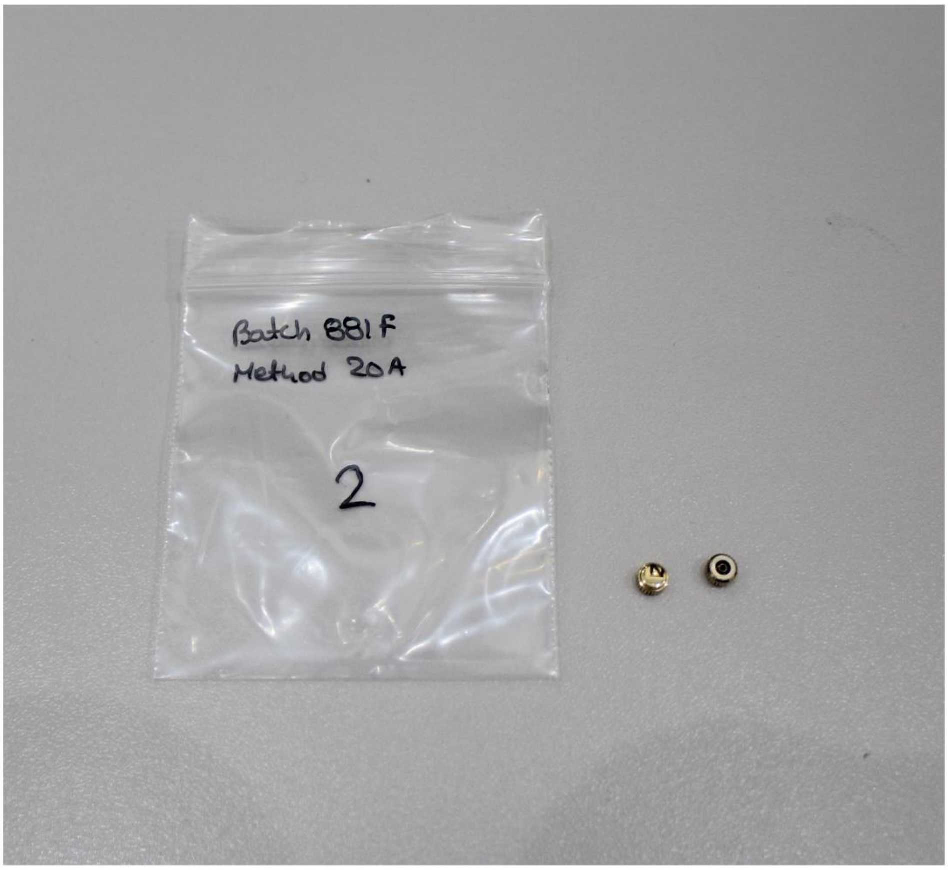
Batch 880F, 20A, component 9

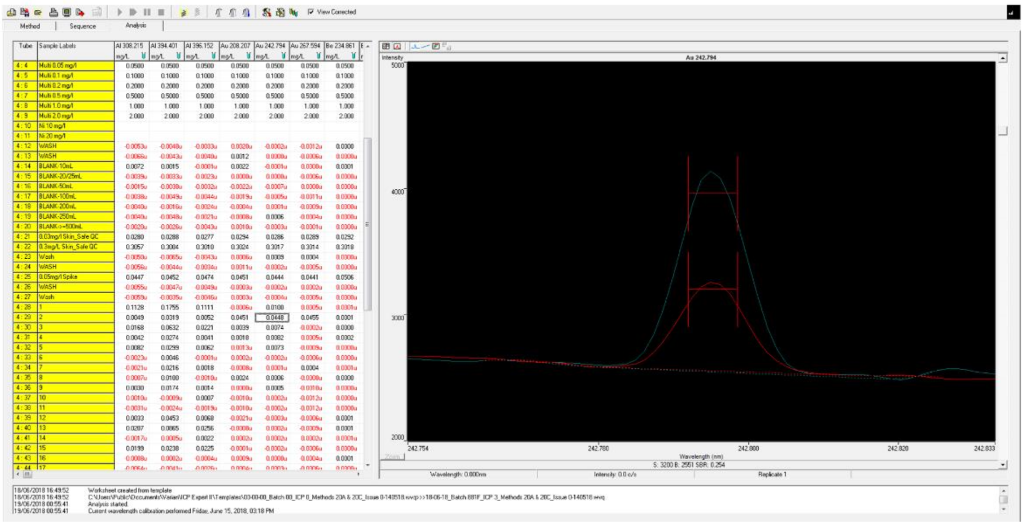


Tube	Sample Labels	Al 308.215 mg/L	Al 394.401 mg/L	Al 396.152 mg/L	Au 208.207 mg/L	Au 242.794 mg/L	Au 267.594 mg/L	Be 234.861 mg/L
1 : 6	Multi 0.2 mg/l	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
1 : 7	Multi 0.5 mg/l	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000
1 : 8	Multi 1.0 mg/l	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1 : 9	Multi 2.0 mg/l	2.000	2.000	2.000	2.000	2.000	2.000	2.000
1 : 10	Ni 10 mg/l							
1 : 11	Ni 20 mg/l							
1 : 12	WASH	-0.0048u	0.0007u	-0.0007u	0.0037	0.0015	-0.0015u	0.0000
1 : 13	WASH	-0.0028u	-0.0029u	-0.0026u	0.0015u	0.0015	-0.0017u	0.0000
1 : 14	BLANK-10mL	0.0024u	0.0049	-0.0002u	0.0005u	0.0017	-0.0009u	0.0000
1 : 15	BLANK-20/25mL	0.0036	0.0007u	0.0020u	0.0026u	0.0051	-0.0004u	0.0000
1 : 16	BLANK-50mL	-0.0027u	0.0029	-0.0007u	0.0030u	0.0010	-0.0013u	0.0000u
1 : 17	BLANK-100mL	-0.0013u	0.0034	0.0029	0.0006u	0.0028	0.0002u	0.0000u
1 : 18	BLANK-200mL	0.0045u	-0.0012u	0.0021	0.0031	0.0019	-0.0013u	0.0000u
1 : 19	BLANK-250mL	0.0051u	0.0030u	0.0007	0.0008u	0.0021	-0.0002u	0.0000
1 : 20	BLANK->=500mL	0.0037	0.0023	0.0011u	0.0053	0.0020	-0.0005u	0.0000u
1 : 21	0.03mg/l Skin_Safe QC	0.0239	0.0300	0.0289	0.0319	0.0301	0.0273	0.0294
1 : 22	0.3mg/L Skin_Safe QC	0.3055	0.2988	0.3004	0.2962	0.3007	0.2945	0.2991
1 : 23	Wash	0.0005u	0.0024u	-0.0018u	0.0014u	0.0017	-0.0011u	0.0001
1 : 24	WASH	-0.0020u	0.0002u	-0.0017u	0.0025	0.0022	-0.0014u	0.0000u
1 : 25	0.05mg/l Spike	0.0537	0.0542	0.0508	0.0492	0.0527	0.0480	0.0507
1 : 26	WASH	-0.0021u	-0.0026u	-0.0016u	0.0026u	0.0021	-0.0011u	0.0000u
1 : 27	Wash	0.0001u	-0.0007u	0.0007u	0.0000u	0.0009	-0.0016u	0.0000u
1 : 28	1	0.4832	0.4841	0.4697	0.0014u	0.0010u	0.0001u	0.0001
1 : 29	2	0.0434	0.0509	0.0473	0.0038	0.0049	0.0026	0.0001
1 : 30	3	0.0059	0.0052	0.0033	0.0056	0.0023	0.0002u	0.0000
1 : 31	4	0.0171	0.0121	0.0161	0.0028	0.0025	-0.0008u	0.0000
1 : 32	5	-0.0002u	0.0086	0.0061	0.0066	0.0021	-0.0013u	0.0000
1 : 33	6	-0.0010u	0.0018u	0.0027	0.0033u	0.0062	-0.0007u	0.0000u
1 : 34	7	0.0098	0.0132	0.0132	0.0052u	0.0031	0.0014	0.0000
1 : 35	8	0.0548	0.0558	0.0561	0.0079	0.0070	0.0049	0.0003
1 : 36	9	0.0015u	0.0029u	0.0021	0.0076	0.0057	0.0019	0.0000
1 : 37	10	0.7280	0.7230	0.7121	0.0019u	0.0014	-0.0021u	0.0001
1 : 38	11	0.0028u	0.0019u	0.0015	-0.0002u	0.0029	0.0001u	0.0000u

Picture 6

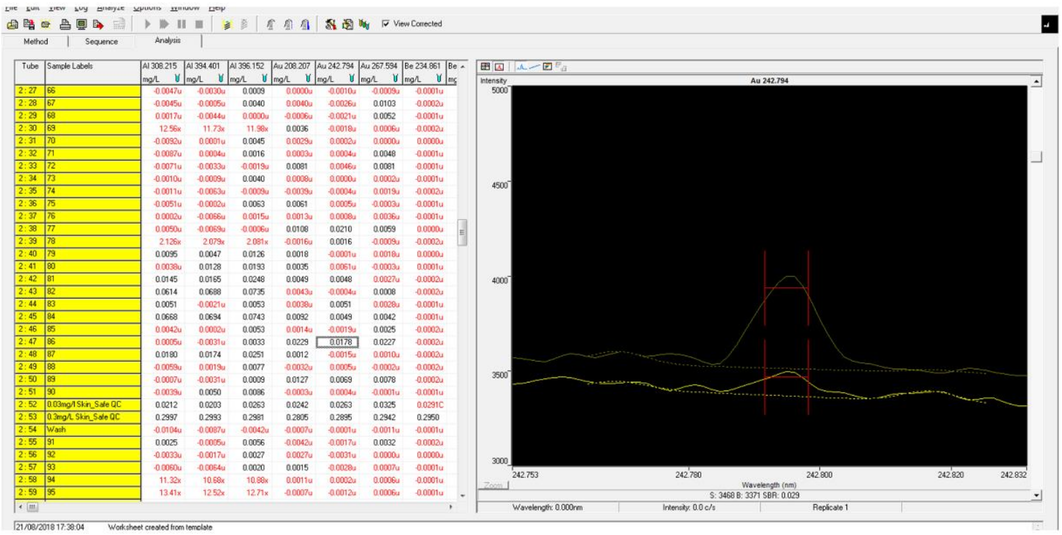
Batch 881F, 20A, component 2





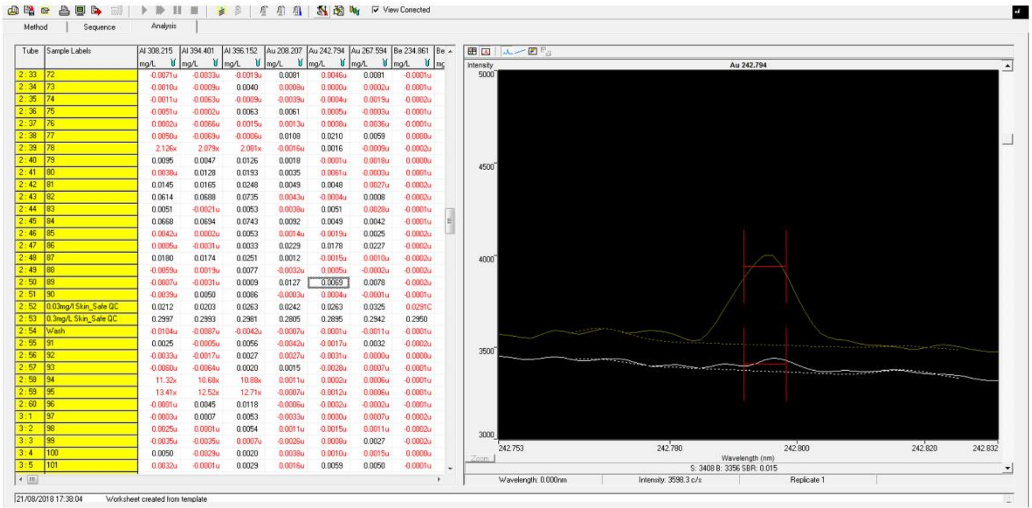
Picture 7

Batch 124, 20C, component 86



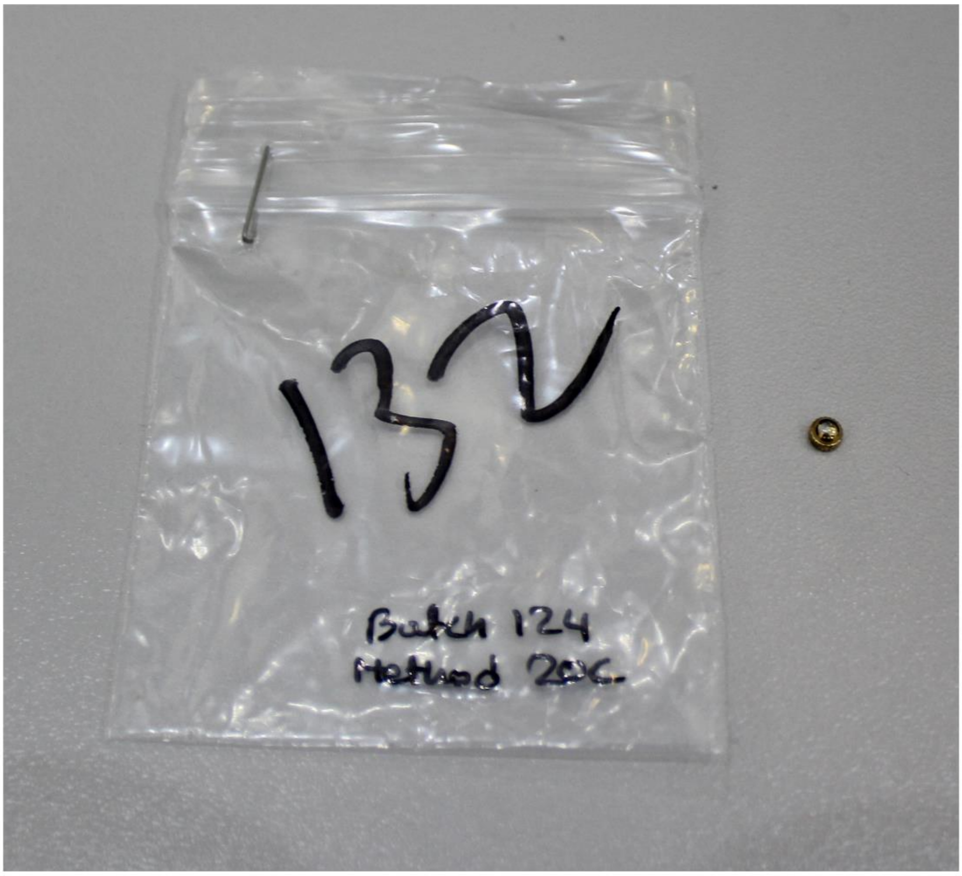
Picture 8

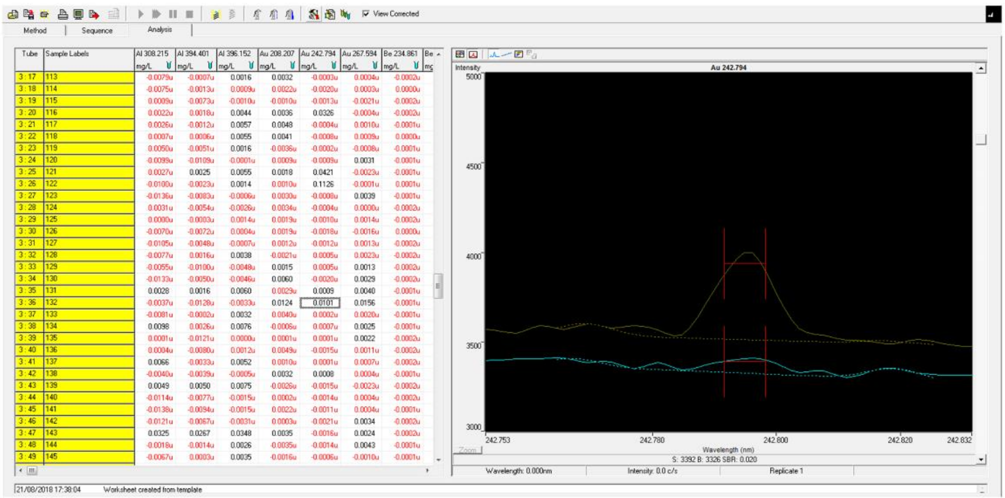
Batch 124, 20C, component 89



Picture 9

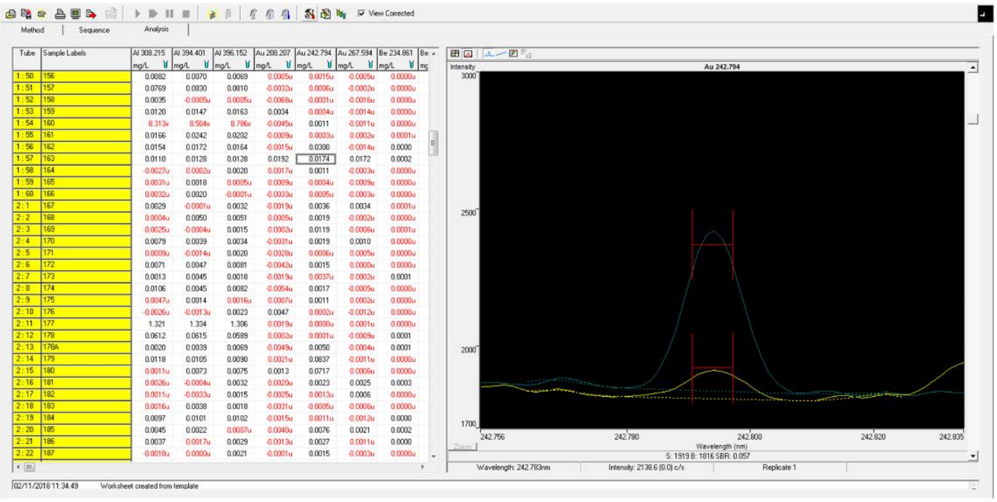
Batch 124, 20C, component 132





Picture 10

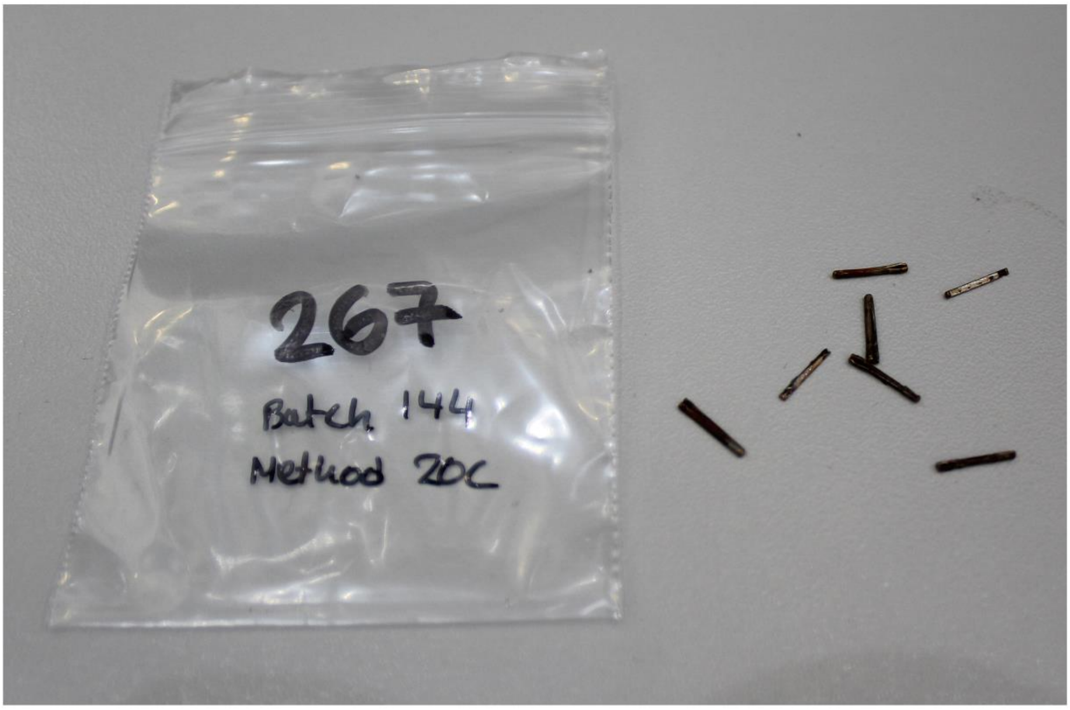
Batch 144, 20C, component 163

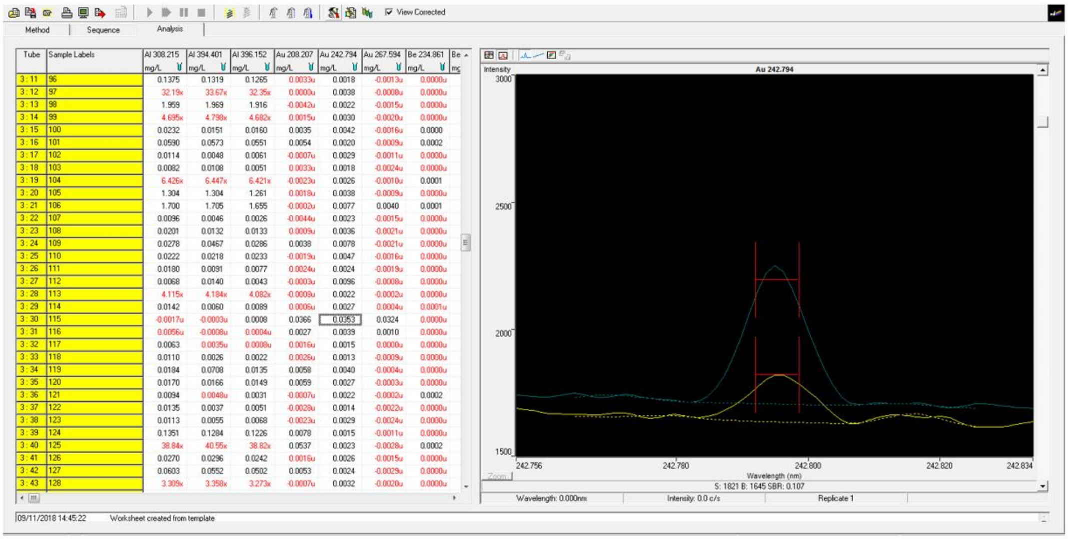


Tube	Sample Labels	Al 308.215 mg/L	Al 394.401 mg/L	Al 396.152 mg/L	Au 208.207 mg/L	Au 242.794 mg/L	Au 267.594 mg/L	Be 234.861 mg/L
1 : 50	156	0.0082	0.0070	0.0069	0.0005u	0.0015u	-0.0005u	0.0000u
1 : 51	157	0.0769	0.0830	0.0810	-0.0032u	0.0006u	-0.0002u	0.0000u
1 : 52	158	0.0035	-0.0005u	0.0005u	-0.0068u	-0.0001u	-0.0016u	0.0000u
1 : 53	159	0.0120	0.0147	0.0163	0.0034	-0.0004u	-0.0014u	0.0000u
1 : 54	160	8.313x	8.504x	8.786x	-0.0045u	0.0011	-0.0011u	0.0000u
1 : 55	161	0.0166	0.0242	0.0202	-0.0009u	0.0003u	0.0002u	0.0001u
1 : 56	162	0.0154	0.0172	0.0164	-0.0015u	0.0300	-0.0014u	0.0000
1 : 57	163	0.0110	0.0128	0.0128	0.0192	0.0174	0.0172	0.0002
1 : 58	164	-0.0027u	0.0002u	0.0020	0.0017u	0.0011	-0.0003u	0.0000u
1 : 59	165	0.0031u	0.0018	0.0005u	0.0009u	-0.0004u	-0.0009u	0.0000u
1 : 60	166	0.0032u	0.0020	-0.0001u	-0.0033u	0.0005u	-0.0003u	0.0000u
2 : 1	167	0.0029	-0.0001u	0.0032	-0.0019u	0.0036	0.0034	0.0001u
2 : 2	168	0.0004u	0.0050	0.0051	0.0005u	0.0019	-0.0002u	0.0000u
2 : 3	169	-0.0025u	-0.0004u	0.0015	0.0002u	0.0119	-0.0006u	0.0001u
2 : 4	170	0.0079	0.0039	0.0034	-0.0031u	0.0019	0.0010	0.0000u
2 : 5	171	0.0009u	-0.0014u	0.0020	-0.0028u	0.0006u	0.0005u	0.0000u
2 : 6	172	0.0071	0.0047	0.0081	-0.0042u	0.0015	0.0000u	0.0000u
2 : 7	173	0.0013	0.0045	0.0018	-0.0019u	0.0037u	0.0002u	0.0001
2 : 8	174	0.0106	0.0045	0.0082	-0.0054u	0.0017	-0.0005u	0.0000u
2 : 9	175	0.0047u	0.0014	0.0016u	0.0007u	0.0011	0.0002u	0.0000u
2 : 10	176	-0.0026u	-0.0013u	0.0023	0.0047	0.0002u	-0.0012u	0.0000u
2 : 11	177	1.321	1.334	1.306	0.0019u	0.0000u	0.0001u	0.0000u
2 : 12	178	0.0612	0.0615	0.0589	0.0002u	0.0001u	-0.0009u	0.0001
2 : 13	178A	0.0020	0.0039	0.0069	-0.0049u	0.0050	-0.0004u	0.0001
2 : 14	179	0.0118	0.0105	0.0090	0.0021u	0.0837	-0.0011u	0.0000u
2 : 15	180	0.0011u	0.0073	0.0075	0.0013	0.0717	0.0006u	0.0000u
2 : 16	181	0.0026u	-0.0004u	0.0032	0.0020u	0.0023	0.0025	0.0003
2 : 17	182	0.0011u	-0.0033u	0.0015	-0.0025u	0.0013u	0.0006	0.0000u
2 : 18	183	0.0016u	0.0038	0.0018	-0.0031u	-0.0005u	-0.0006u	0.0000u
2 : 19	184	0.0097	0.0101	0.0102	-0.0015u	0.0011u	-0.0012u	0.0000
2 : 20	185	0.0045	0.0022	0.0007u	0.0040u	0.0076	0.0021	0.0002
2 : 21	186	0.0037	0.0017u	0.0029	-0.0013u	0.0027	0.0011u	0.0000
2 : 22	187	-0.0018u	0.0000u	0.0021	-0.0001u	0.0015	-0.0003u	0.0000u

Picture 11

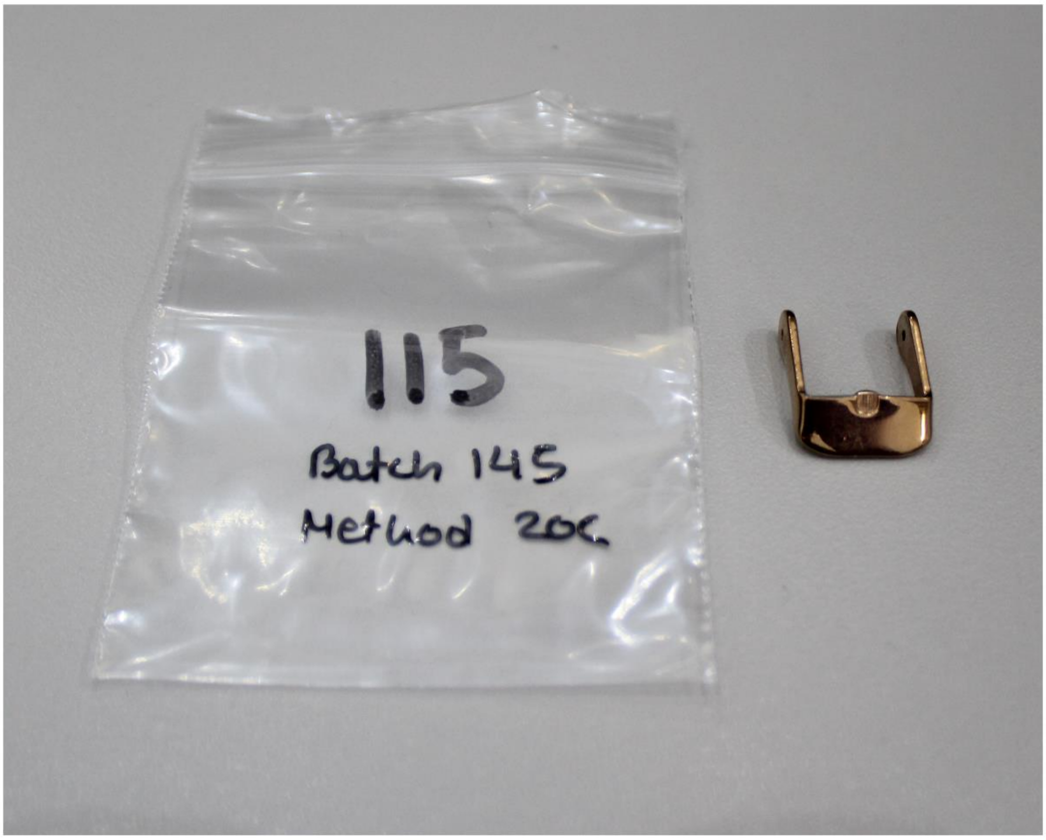
Batch 144, 20C, component 267

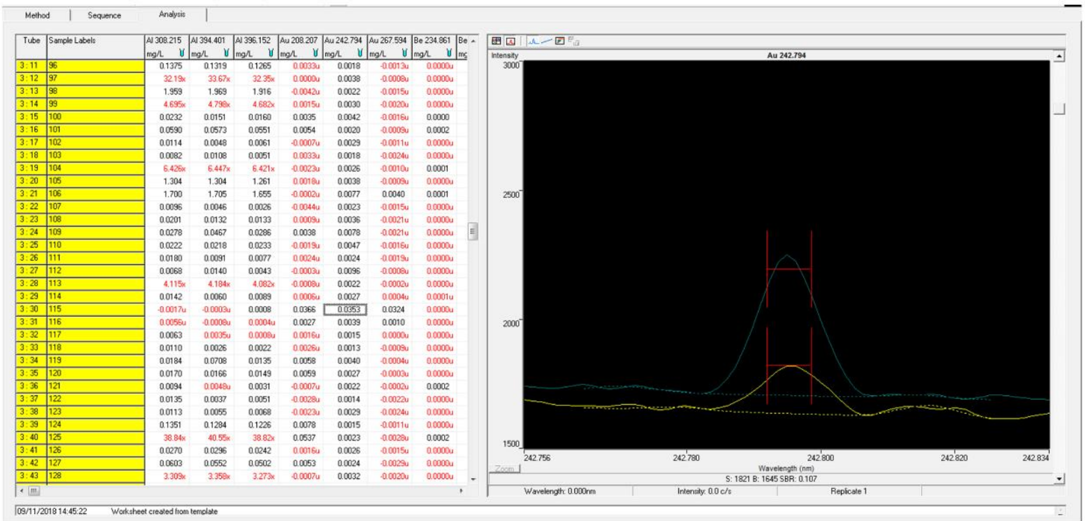




Picture 12

Batch 145, 20C, component 115

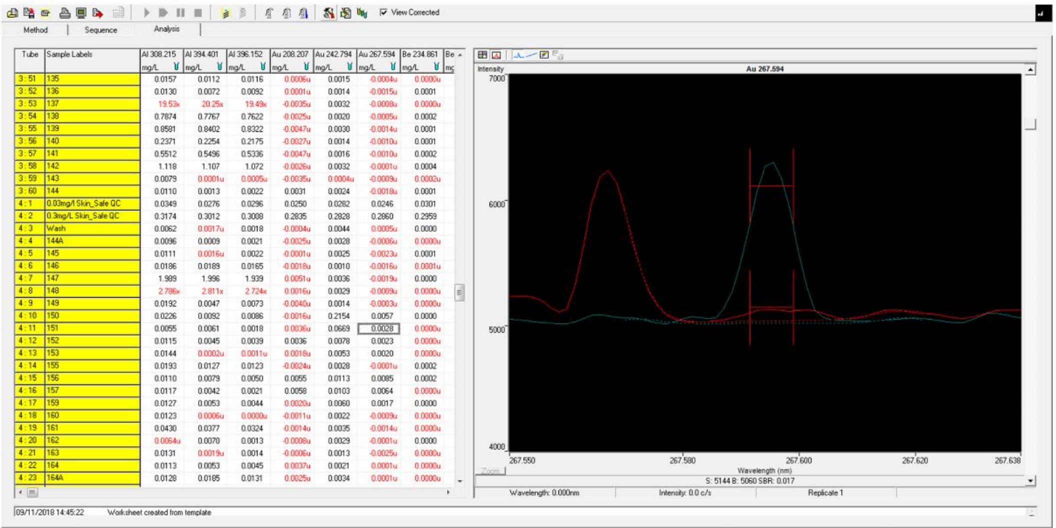




Tube	Sample Labels	Al 308.215 mg/L	Al 394.401 mg/L	Al 396.152 mg/L	Au 208.207 mg/L	Au 242.794 mg/L	Au 267.594 mg/L	Be 234.861 mg/L
3 : 11	96	0.1375	0.1319	0.1265	0.0033u	0.0018	-0.0013u	0.0000u
3 : 12	97	32.19x	33.67x	32.35x	0.0000u	0.0038	-0.0008u	0.0000u
3 : 13	98	1.959	1.969	1.916	-0.0042u	0.0022	-0.0015u	0.0000u
3 : 14	99	4.695x	4.798x	4.682x	0.0015u	0.0030	-0.0020u	0.0000u
3 : 15	100	0.0232	0.0151	0.0160	0.0035	0.0042	-0.0016u	0.0000
3 : 16	101	0.0590	0.0573	0.0551	0.0054	0.0020	-0.0009u	0.0002
3 : 17	102	0.0114	0.0048	0.0061	-0.0007u	0.0029	-0.0011u	0.0000u
3 : 18	103	0.0082	0.0108	0.0051	0.0033u	0.0018	-0.0024u	0.0000u
3 : 19	104	6.426x	6.447x	6.421x	-0.0023u	0.0026	-0.0010u	0.0001
3 : 20	105	1.304	1.304	1.261	0.0018u	0.0038	-0.0009u	0.0000u
3 : 21	106	1.700	1.705	1.655	-0.0002u	0.0077	0.0040	0.0001
3 : 22	107	0.0096	0.0046	0.0026	-0.0044u	0.0023	-0.0015u	0.0000u
3 : 23	108	0.0201	0.0132	0.0133	0.0009u	0.0036	-0.0021u	0.0000u
3 : 24	109	0.0278	0.0467	0.0286	0.0038	0.0078	-0.0021u	0.0000u
3 : 25	110	0.0222	0.0218	0.0233	-0.0019u	0.0047	-0.0016u	0.0000u
3 : 26	111	0.0180	0.0091	0.0077	0.0024u	0.0024	-0.0019u	0.0000u
3 : 27	112	0.0068	0.0140	0.0043	-0.0003u	0.0096	-0.0008u	0.0000u
3 : 28	113	4.115x	4.184x	4.082x	-0.0008u	0.0022	-0.0002u	0.0000u
3 : 29	114	0.0142	0.0060	0.0089	0.0006u	0.0027	0.0004u	0.0001u
3 : 30	115	-0.0017u	-0.0003u	0.0008	0.0366	0.0353	0.0324	0.0000u
3 : 31	116	0.0056u	-0.0008u	0.0004u	0.0027	0.0039	0.0010	0.0000u
3 : 32	117	0.0063	0.0035u	0.0008u	0.0016u	0.0015	0.0000u	0.0000u
3 : 33	118	0.0110	0.0026	0.0022	0.0026u	0.0013	-0.0009u	0.0000u
3 : 34	119	0.0184	0.0708	0.0135	0.0058	0.0040	-0.0004u	0.0000u
3 : 35	120	0.0170	0.0166	0.0149	0.0059	0.0027	-0.0003u	0.0000u
3 : 36	121	0.0094	0.0048u	0.0031	-0.0007u	0.0022	-0.0002u	0.0002
3 : 37	122	0.0135	0.0037	0.0051	-0.0028u	0.0014	-0.0022u	0.0000u
3 : 38	123	0.0113	0.0055	0.0068	-0.0023u	0.0029	-0.0024u	0.0000u
3 : 39	124	0.1351	0.1284	0.1226	0.0078	0.0015	-0.0011u	0.0000u
3 : 40	125	38.84x	40.55x	38.82x	0.0537	0.0023	-0.0028u	0.0002
3 : 41	126	0.0270	0.0296	0.0242	0.0016u	0.0026	-0.0015u	0.0000u
3 : 42	127	0.0603	0.0552	0.0502	0.0053	0.0024	-0.0029u	0.0000u
3 : 43	128	3.309x	3.358x	3.273x	-0.0007u	0.0032	-0.0020u	0.0000u

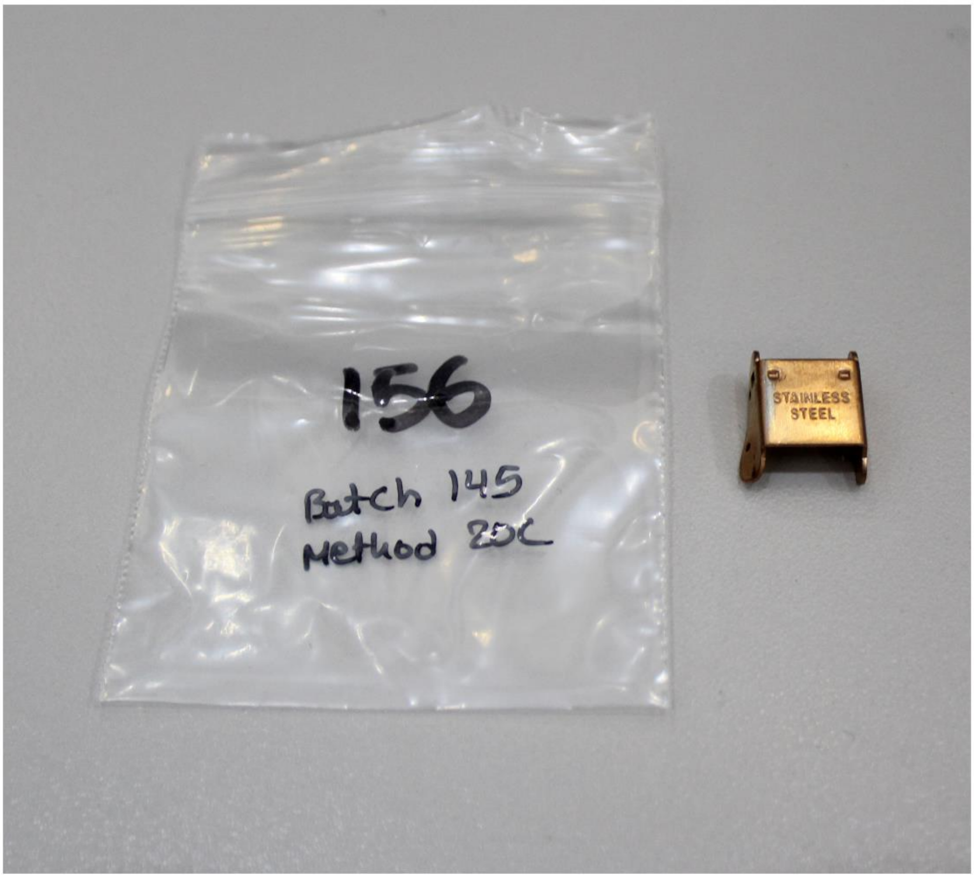
Picture 13

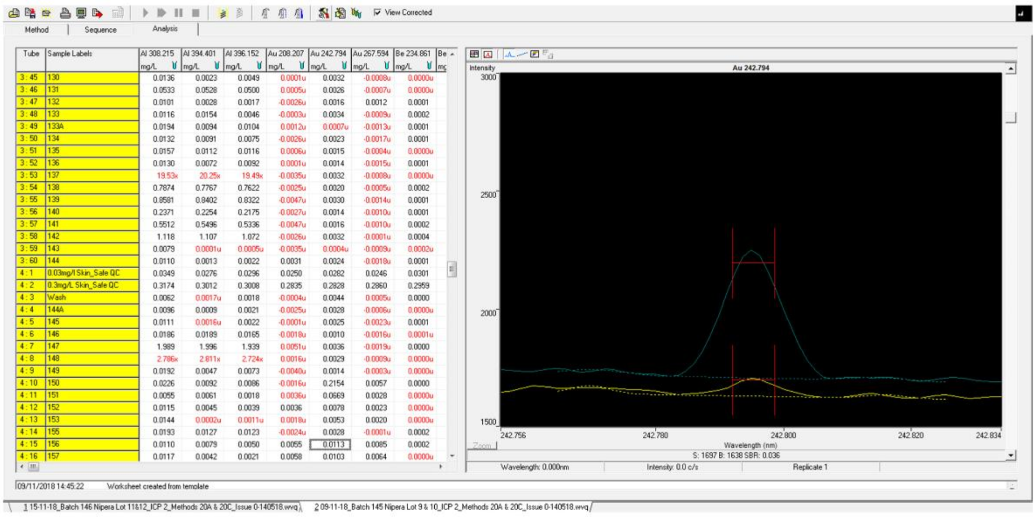
Batch 145, 20C, component 151



Picture 14

Batch 145, 20C, component 156

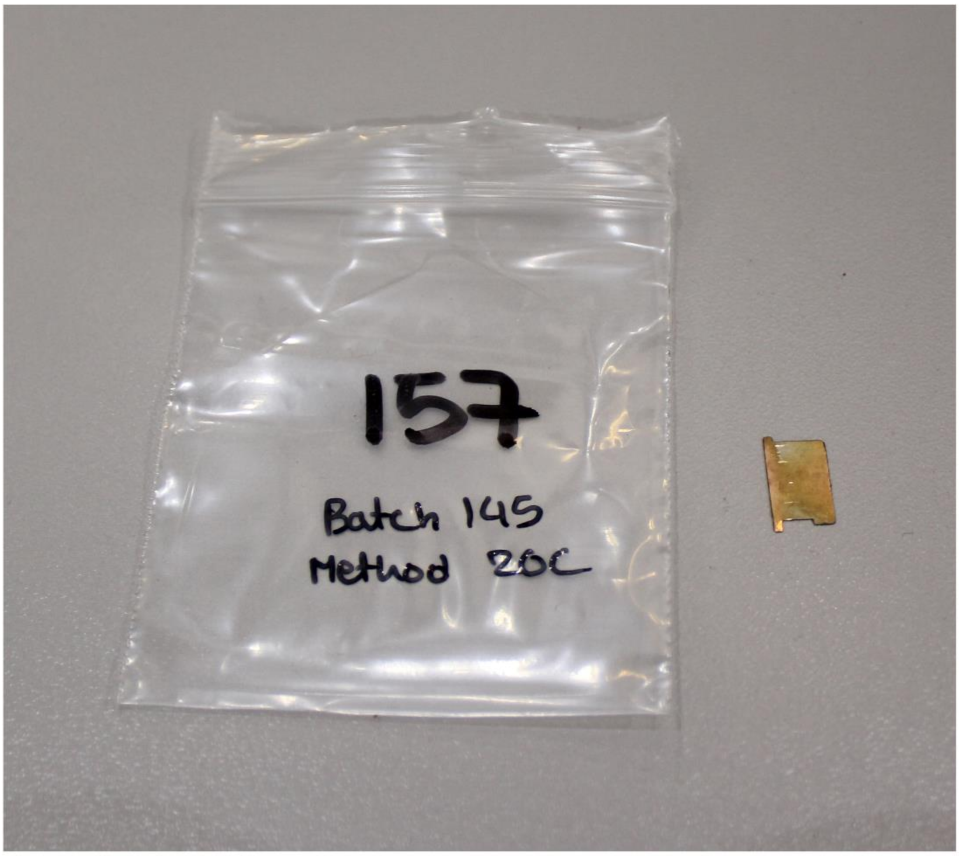


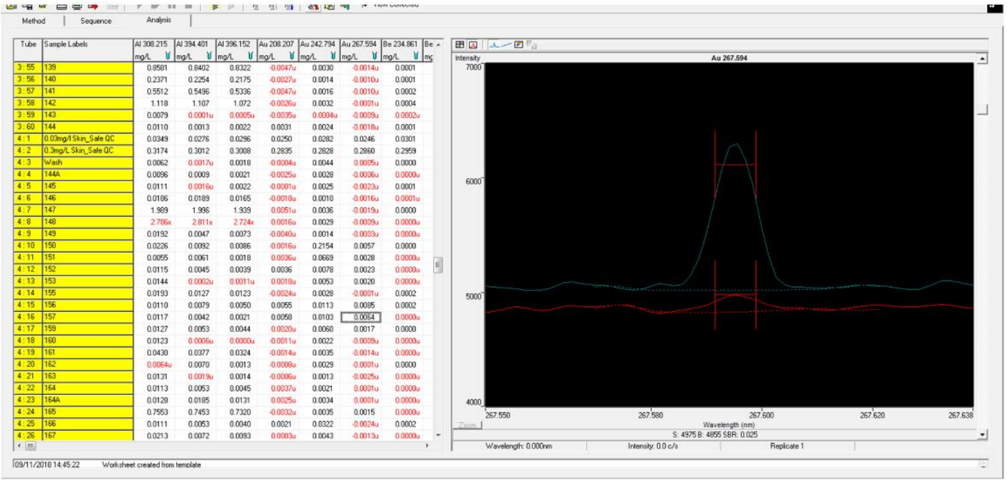


Tube	Sample Labels	Al 308.215 mg/L	Al 394.401 mg/L	Al 396.152 mg/L	Au 208.207 mg/L	Au 242.794 mg/L	Au 267.594 mg/L	Be 234.861 mg/L
3 : 45	130	0.0136	0.0023	0.0049	0.0001u	0.0032	-0.0008u	0.0000u
3 : 46	131	0.0533	0.0528	0.0500	0.0005u	0.0026	-0.0007u	0.0000u
3 : 47	132	0.0101	0.0028	0.0017	-0.0026u	0.0016	0.0012	0.0001
3 : 48	133	0.0116	0.0154	0.0046	-0.0003u	0.0034	-0.0009u	0.0002
3 : 49	133A	0.0194	0.0094	0.0104	0.0012u	0.0007u	-0.0013u	0.0001
3 : 50	134	0.0132	0.0091	0.0075	-0.0026u	0.0023	-0.0017u	0.0001
3 : 51	135	0.0157	0.0112	0.0116	0.0006u	0.0015	-0.0004u	0.0000u
3 : 52	136	0.0130	0.0072	0.0092	0.0001u	0.0014	-0.0015u	0.0001
3 : 53	137	19.53x	20.25x	19.49x	-0.0035u	0.0032	-0.0008u	0.0000u
3 : 54	138	0.7874	0.7767	0.7622	-0.0025u	0.0020	-0.0005u	0.0002
3 : 55	139	0.8581	0.8402	0.8322	-0.0047u	0.0030	-0.0014u	0.0001
3 : 56	140	0.2371	0.2254	0.2175	-0.0027u	0.0014	-0.0010u	0.0001
3 : 57	141	0.5512	0.5496	0.5336	-0.0047u	0.0016	-0.0010u	0.0002
3 : 58	142	1.118	1.107	1.072	-0.0026u	0.0032	-0.0001u	0.0004
3 : 59	143	0.0079	0.0001u	0.0005u	-0.0035u	0.0004u	-0.0009u	0.0002u
3 : 60	144	0.0110	0.0013	0.0022	0.0031	0.0024	-0.0018u	0.0001
4 : 1	0.03mg/l Skin_Safe QC	0.0349	0.0276	0.0296	0.0250	0.0282	0.0246	0.0301
4 : 2	0.3mg/L Skin_Safe QC	0.3174	0.3012	0.3008	0.2835	0.2828	0.2860	0.2959
4 : 3	Wash	0.0062	0.0017u	0.0018	-0.0004u	0.0044	0.0005u	0.0000
4 : 4	144A	0.0096	0.0009	0.0021	-0.0025u	0.0028	-0.0006u	0.0000u
4 : 5	145	0.0111	0.0016u	0.0022	-0.0001u	0.0025	-0.0023u	0.0001
4 : 6	146	0.0186	0.0189	0.0165	-0.0018u	0.0010	-0.0016u	0.0001u
4 : 7	147	1.989	1.996	1.939	0.0051u	0.0036	-0.0019u	0.0000
4 : 8	148	2.786x	2.811x	2.724x	0.0016u	0.0029	-0.0009u	0.0000u
4 : 9	149	0.0192	0.0047	0.0073	-0.0040u	0.0014	-0.0003u	0.0000u
4 : 10	150	0.0226	0.0092	0.0086	-0.0016u	0.2154	0.0057	0.0000
4 : 11	151	0.0055	0.0061	0.0018	0.0036u	0.0669	0.0028	0.0000u
4 : 12	152	0.0115	0.0045	0.0039	0.0036	0.0078	0.0023	0.0000u
4 : 13	153	0.0144	0.0002u	0.0011u	0.0018u	0.0053	0.0020	0.0000u
4 : 14	155	0.0193	0.0127	0.0123	-0.0024u	0.0028	-0.0001u	0.0002
4 : 15	156	0.0110	0.0079	0.0050	0.0055	0.0113	0.0085	0.0002
4 : 16	157	0.0117	0.0042	0.0021	0.0058	0.0103	0.0064	0.0000u

Picture 15

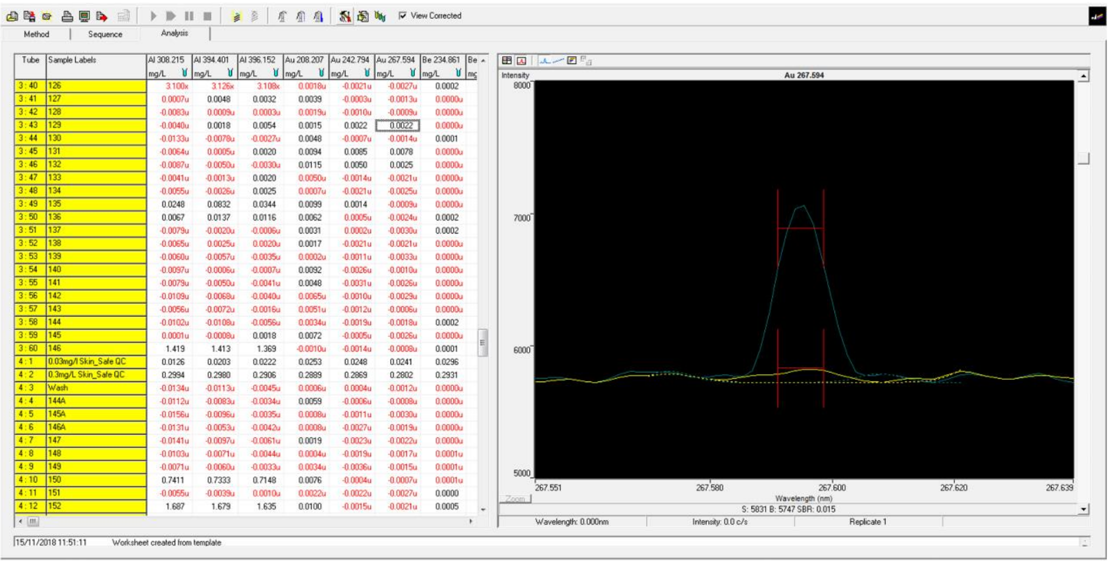
Batch 145, 20C, component 157





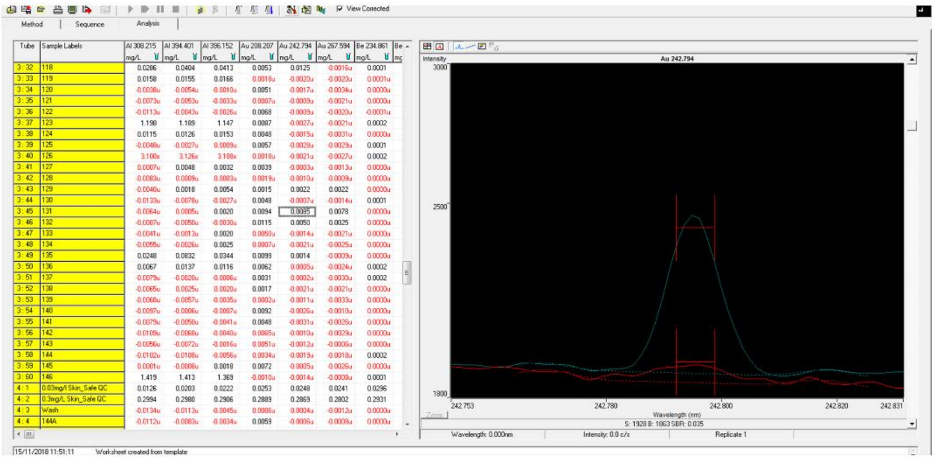
Picture 16

Batch 146, 20C, component 129



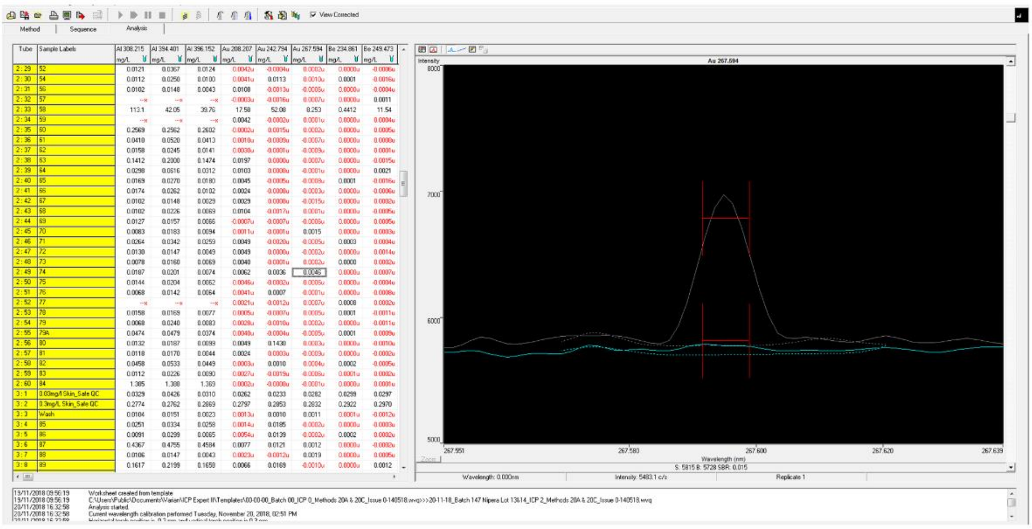
Picture 17

Batch 146, 20C, component 131



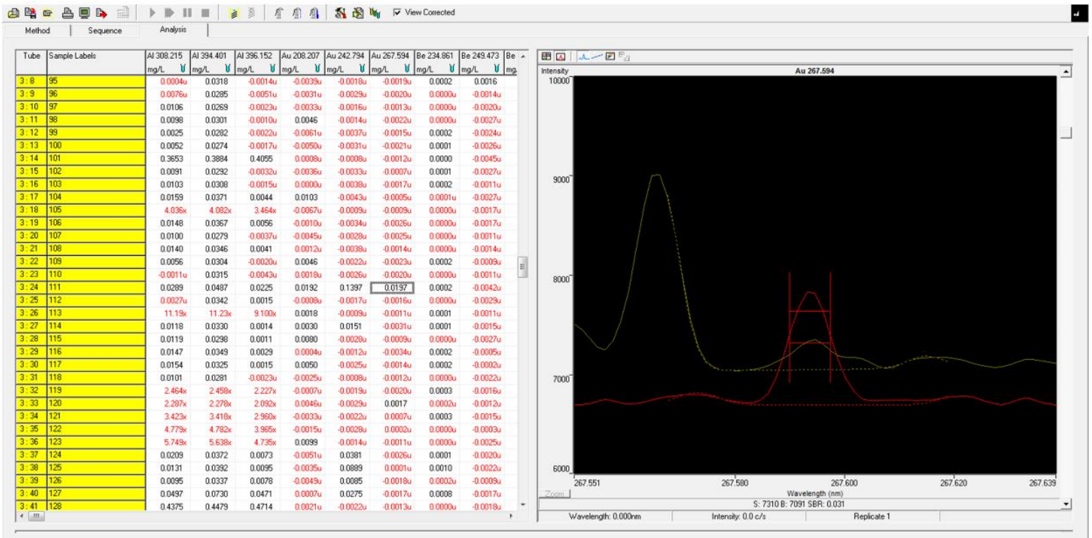
Picture 18

Batch 147, 20C, component 74



Picture 19

Batch 150, 20C, component 111



Picture 20