# Analyzing Precious Metals For Content & Purity



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# Disclaimers

The information contained in this book should be considered as a general guide and should not serve as a guarantee of performance of the test methods described. The final results will be dependent upon the developed proficiencies of the user.

While the health risks associated with these test methods are low, the chemicals involved in the tests described are highly corrosive and many are toxic in nature. It is solely the user's responsibility to assess the potential dangers involved and use the appropriate ventilation, work environment, and safety equipment.

User assumes all risks associated with the use of these test methods and solutions, including any risk to user's property or health. User must observe all proper safety precautions when working with these solutions as they contain corrosive acids. The publisher of this book shall not in any event be liable for any direct, indirect, punitive, special, incidental, or consequential damages, including, without limitation, lost revenues, or lost profits, arising out of or in any way connected with the use of the referenced testing solutions.

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# Section 1—Analyzing Precious Metal Alloys

# **Introduction:**

The methods described in this work are based on basic chemical principles, many of which have been in use for centuries. Interestingly, these methods are just as effective and useful today as when they were originally developed.



Though based on the original work by C.M. Hoke, the methods described in this book have been updated and revised to be consistent with current applicable knowledge, hardware, and chemistries. Additionally, a significant amount of new information has been added to aid your understanding of how and why these methods work.

Additionally, with the popularity of the Platinum Group Metals (PGMs) and their currently elevated prices, and therefore increased interest, we have provided significant detail regarding their analysis.

Touchstone testing compares how precious metal alloys of known and unknown fineness react to acid. For gold, the test is based on the fact that 24K gold resists all but the strongest acids. The purer the gold (the higher the karatage), the stronger the acid required to change its character or to dissolve it.

The principal of touchstone testing goes back to 600 BC. It's from these ancient practices that we get the term "acid test." To subject something to the acid test means to verify its value or quality.

When the bench jeweler in a store tests an item that comes in for repair, he begins by checking the quality stamp and noting the item's heft, color, and luster. Based on these observations, he estimates the fineness of the metal. The touchstone test verifies or disproves the estimate.

First, the jeweler rubs a tiny part of the jewelry on the touchstone. This leaves a streak of metal on the stone. He has to be careful not to damage the customer's jewelry. For example, if he's testing a ring, he should never rub the prongs. A better choice would be to test the side of the shank, which can be buffed smooth when the test is complete—or some other area that doesn't show. It's also important not to take rubbing from soldered joints because solders will contain different elements.

The bench jeweler then takes two test needles, one of the estimated karatage and one of lower or higher quality than the piece being tested. He creates streaks with these needles on either side of the original streak.

He then applies an appropriate acid solution to each streak. The tester now compares the reaction of the known streaks to the unknown. He looks for color changes and the speed with which the streaks disappear. The two streaks that react the same way are therefore inferred to be of approximately the same karatage.

The results of the touchstone test are approximate in that they rely on the jeweler's observations and experience. While the touchstone test is, in fact, fairly accurate in the 10K to 18K range, very pure samples, such as 22K and 23K gold, cannot be tested precisely because they react similarly.

Platinum and tungsten carbide rings are tested using a more complex process. Most platinum and tungsten rings can usually be evaluated by a combination of visual (color) and specific gravity tests.

# **General Precautions:**

While these test methods are well established and in common use, they do involve the use of highly corrosive and toxic chemicals. To prevent injury or adverse health effects, certain precautions must be observed.

- 1. Read, understand, and follow the recommendations made in the respective "Material Safety Data Sheets" (the MSDSs) available for each chemical used.
- 2. Use appropriate personal protective equipment ("PPE") including goggles, safety glasses or safety shield, neoprene or nitrile gloves, and a chemical apron.
- 3. Use adequate ventilation. Many of the acids and acid mixtures devolve toxic fumes. Additionally, the fumes are highly corrosive to surrounding objects. Testing should be done under a fume hood or outside.
- 4. Keep these chemicals away from children and pets.
- 5. Do not pour untreated waste chemicals down the drain. Follow the neutralization instructions in the Appendix for proper disposal.

# A note about mixing your own chemicals:

Most of the mixing you will be doing will involve creating various dilutions of concentrated acids. One of the first things every chemistry student learns is to always add acid to water and never the reverse. When concentrated acid is added to water, it is immediately diluted—a little acid in a lot of water. If the reverse is attempted—a little water added to a lot of acid, violent eruptions, boiling, or spitting can occur.

Nitric acid is subject to thermal or light decomposition. The nitrogen oxides produced dissolve partly or completely in the acid coloring it yellow. This decomposition decreases the effectiveness of your acid. Always keep your nitric acid bottles out of direct sunlight and keep your mixtures in amber colored acid bottles.

Remember that nitric acid is a strong oxidizer. Never allow concentrated nitric acid to come into contact with organic solvents (alcohols, petroleum distillates) as possible fire or explosion can occur.

# A Note About Commercially Available Testing Kits:

It seems that everybody is selling gold testing kits these days. Prices for these kits range from as little as \$12 to over \$100. What is never mentioned is that these chemical solutions have a shelf life. To assure the most accurate and, indeed, consistent results, the prudent analyst will learn to make up and use his own solutions. This ability adds to one's knowledge base and also deepens the understanding of the processes at work here.

# Section 2—The Acid/Touchstone Method for Gold and Silver (aka, "The Scratch Test")

Those involved in the buying and selling of precious metal items will often wish to know the approximate value of an article without taking time to make an assay, and without causing physical damage to the article itself. The touchstone method can quickly and effectively provide this information.

The essential tools for testing ordinary gold are shown in Figure 1. There is the flat, smooth black stone, usually of slate or fine-grained basalt; there are the so-called test standard needles—pointed bits of gold of the various finenesses available from 4 karat to 24 karat; and the acid dropping bottles.



Figure 1: Dropping bottle, touchstone, standard test needles & test plate (star)

# **Basic Procedure:**

The basic scratch test is made by rubbing the item in question on the stone to make a mark or "streak." This is then followed by making similar streaks beside it with one or two of the standard needles, and finally by observing the action of acid on these streaks.



For instance, suppose you have a gold coin or metal to test; you suspect that it is 16-karat or less. You rub it on the stone, leaving a streak of metal particles. Adjacent to the first streak you make two other streaks; one with the 18-karat needle, the other with the 14-karat needle.

# Nitric Acid Solutions:

A drop of acid is now applied across the streaks and the reaction is observed. The traditional acid that is applied is simply nitric acid. As nitric acid comes from most supply houses, it is at its full azeotropic concentration—69%. At this concentration the reactions occur very fast—almost too fast to observe effectively. To slow down the reactions, various dilutions of nitric acid are used depending upon the expected karat value. Most modern acid test kits contain four different nitric acid solutions for gold testing.

# **Bottle #1—10-Karat Solution:**

First, there is the 10-k solution that is about a 40% nitric concentration. This can be easily made by diluting full strength nitric acid with distilled or deionized water. **Remember to always add acid to water and not the reverse.** 

#### Given:

Nitric Acid with concentration B = 69.5% (this is how it usually comes from a supply house) Desired final concentration C = 40%

Desired volume of final solution = L = 50ml (typical volume of acid dropping bottles)

## Find:

y = volume of water for dilution

x = volume of acid required

$$y = L/\{1 + [C/(B - C)]\}$$

 $y = 50/\{1 + [.40/(.695-.40)]\} = 50/\{1 + [.40/.295] = 21 \text{ ml water}$ 

x = L - y

x = 50 - 21 = 29 ml acid

#### Mixing:

Simply add water to a graduated cylinder up to the 21 ml mark. Then add concentrated nitric acid to bring the level up to the sum of the two amounts—21ml + 29 ml = 50ml.

Pour it into an appropriately labeled acid dropping bottle and store on your workstation.

# **Bottle #2—14-Karat Solution:**

Second, there is the 14-k solution that is about a 60% nitric concentration—close to concentrated nitric but slightly diluted to reduce the reaction rate and minimize the outgassing typical of concentrated nitric.

Using the same dilution calculation method as above:

 $y = 50/{1 + [.60/(.695-.60)]} = 50/{1 + [.60/.095]} = 6.8 \text{ ml water}$ 

x = 50 - 6.8 = 43 ml acid

## Mixing:

As before, simply add water to a graduated cylinder up to the 7 ml mark. Then add concentrated nitric acid to bring the level up to the sum of the two amounts—7 ml + 43 ml = 50 ml.

Pour it into an appropriately labeled acid dropping bottle and store on your workstation.

# **Bottle #3—18-Karat Solution:**

The third bottle we call "Activated Nitric Solution." As the karat value of the gold piece in question increases, the effects of nitric acid are drastically reduced. In order to obtain a reaction in these higher karat materials a bit of chloride ion is added in the form of hydrochloric acid.

# **Composition:**

The 18-k solution is comprised of 25 ml 69% concentrated nitric acid, added to 6 ml water, to which is added 1 ml of the 38% hydrochloric acid.

# Mixing:

As before, simply add water to a graduated cylinder up to the 6 ml mark. Then add concentrated nitric acid to bring the level up to the sum of the two amounts—7 ml + 25 ml = 32 ml. Then finish by adding 1 ml of 38% hydrochloric acid.

Pour it into an appropriately labeled acid dropping bottle and store on your workstation.

# **Bottle #4—22-Karat Solution:**

And finally, there is the 22-k solution which is essentially a diluted aqua regia mixture. We will discuss aqua regia in more detail in a moment.

#### How Aqua Regia Works To Dissolve Gold:

Aqua Regia is a mixture of two acids—Hydrochloric Acid and Nitric Acid. Neither of these two acids acting alone will dissolve gold.

When gold is exposed to hydrochloric acid alone, nothing happens. The gold atoms are tightly bonded providing nothing for the chloride ions to attach to.

When gold is exposed to nitric acid alone, nothing appears to happen. However, at an atomic level, the nitric acid component is imperceptibly attacking the surface atoms of the gold. These gold atoms come off the surface and go into solution. An equilibrium is established whereby gold atoms coming off the surface are balanced by gold atoms re-attaching themselves to the gold surface. Thus, if left alone, the balance is maintained and the gold does not dissolve.

However, if hydrochloric acid is now added to the solution, the chloride ions attack the liberated gold atoms in solution to create Chloroauric acid thus preventing their re-attachment to the gold surface and the metallic gold is aggressively dissolved.

#### Formulation:

The traditional aqua regia mixture consists of 3 parts concentrated hydrochloric acid (38% strength) to 1 part concentrated nitric acid (69% strength).

When aqua regia is first made up, it devolves chlorine gas. Chlorine is highly toxic and corrosive. It attacks metals and so should not be left where it can reach machinery, instruments or tools. Do not stopper the bottle tightly, or it might rupture—use a vented cap on the bottle to permit the chlorine to escape.

This outgassing of chlorine is aqua regia's natural decomposition process—it has about a 3-week shelf life. Because of this, and because so little of it is required for testing, many people make up their aqua regia mixture on the spot, when ready to use it.

It is possible to mix the two acids right on the stone, after making the streak; that is, draw a little nitric acid across the metal streak, then add the hydrochloric acid.

Some workers dilute their aqua regia with one or several volumes of water; distilled water if possible. The reactions proceed more slowly with dilute acids, and therefore are easier to watch and compare. For consistency of results, the same proportions should be used every time.

# The Basic Nitric/Base Metal Reaction:

Now that we have the various nitric acid solutions created, let's see how we can apply these to give us answers to our questions.

Let's return to the touchstone where we had applied some streaks to it of different karat values. Once the acid solution is applied to the streaks, watch the way in which the streaks of metal respond. By "respond" we are referring to two things: First, the speed of the reaction by which the streaks dissolve, and second, the completeness by which the streaks are attacked.

The base metals are typically copper, silver, and zinc in most forms of jewelry. All of these metals are highly reactive in nitric acid while the gold is not.

Therefore, when nitric acid is applied to low-karat gold alloys, the gold itself is not really dissolving. Rather, the base metals are being oxidized and the gold is being liberated as either a fine dust that floats to the top of the acid puddle, or it appears as a brown cloud within the droplet. So, the lower the karat value, the higher the base metal value and the more reactive it is in nitric acid.

In the case of copper, it is nonreactive in most acids (sulfuric, hydrochloric, phosphoric) but nitric acid is an oxidizer that drives an oxidation reaction. A dilute solution of nitric acid will oxidize the copper to copper nitrate coloring the solution blue.

If the base metal is silver, the reaction with nitric acid creates silver nitrate—appearing as a white milky color in solution.

The zinc portion of the base metal will dissolve in the nitric acid to form zinc nitrate—also appearing as a white milky color in solution.

As soon as you find a standard streak whose response is the same as that of your "unknown," then you have found the approximate fineness of your unknown.

High-karat gold streaks are not affected by ordinary nitric acid. It is for use on the lower karats only, as you will soon find. Suppose, therefore, that your "unknown" is not affected by the ordinary nitric acid solutions; you will then turn to the use of the aqua regia mixtures.

## **Testing High-Karat Gold Streaks With Aqua Regia:**

As the purity of a given sample increases above the 18-karat level, the testing approach becomes a little different. Recall that 24-karat gold (pure gold) has no base metals alloyed with it. Additionally, we know that anything between 18-karat and 23-karat does possess limited base metals content.

Now, if we had a way to detect these low levels of base metals, we could easily deduce what the purity level was. This is where we can combine the abilities of our aqua regia solution to dissolve both base metals and pure gold, with an indicator solution to tell us what, besides gold, is in the solution via a color change.

# **Bottle #5—Schwerter's Solution**

Potassium Dichromate, when dissolved in a nitric acid solution is called Schwerter's solution. This useful mixture is used to detect the presence of silver and base metals (copper, brass, nickel, lead & tin).



Depending upon which metals are present, a different coloration will occur when a drop of this solution is placed on the metal in question. Though, in many commercially available test kits, it is referred to as "Silver Test Solution" or "Silver Spot Test Solution," it can detect the presence of many different base metals.

For example, pure silver will turn the solution bright red, sterling silver will turn it dark red, low grade coin silver (0.800 fine) will turn brown (largely due to the presence of copper which turns the solution brown) and even green for 0.500 silver.

#### Formula & Mixing:

For a typical 2-ounce (50 ml) size bottle of testing solution:

- Dilute 22 mls of concentrated (69%) Nitric Acid in 7 mls of distilled water.
- Dissolve 10 grams Potassium Dichromate into the solution.
- Pour into amber glass acid dropping bottle

#### **Testing with Schwerter's Solution:**

File a deep notch in the test piece and apply a drop of Schwerter's Solution in the notch. The color reaction of the solution will differ on various metals as follows:

Bright Red

Dark Red

Brown

- Gold— No color change
- Platinum— No color change
- Palladium— No color change
- Copper— Brown
- Zinc— Brown
- Brass— Dark Brown
- Nickel— Blue
- Lead— Yellow
- Tin— Yellow
- Silver, Pure—Silver, Sterling, .925—
- Silver, Coin Quality, .800—
- Silver, .500— Green

# Logical Gold Testing Per The 50/50 Elimination Principle

To simplify the thought process of gold testing we have created a simple procedure. (Note: The following test sequence is for yellow gold only, not white gold, platinum, or silver)

## Step 1—Is it high Karat gold or low?

Apply concentrated nitric acid to a test streak of the sample. If there is no effect at all, it is probably 18-Karat gold or above—go to step 2.

If there is any effect such as part of the streak dissolving or floating as a gold cloud, it is 14-Karat or below—go to step 3.

# Step 2—Is it pure Gold (24-Karat) or one of the 18 or 22-Karat alloys?

Create a test streak on a white touchstone or in a porcelain spot plate. Apply Aqua Regia solution and dissolve the test streak. Now add a drop of Schwerter's solution to the puddle to determine the type of base metal(s) present. Watch for a color change.

- No color change = pure gold
- Brown = copper
- Blue = nickel
- Bright Red = Pure Silver
- Dark Red = Sterling Silver
- Green = coin Silver
- Yellow = Lead or Tin

## Step 3—Can we confirm it is 14-Karat or below, or 18-Karat and above?

Apply 14-Karat test solution (60% dilute nitric acid) to a test streak of the sample on a black touchstone. If the effect is rapid (the base metals dissolve quickly and disappear leaving gold flecks or a cloud floating in the puddle), it is 14-Karat or below.—go to step 4

If the reaction is slow and a streak of gold remains after lightly rinsing the test stone with cold water, it is probably 18-Karat and above.—**return to step 1 and confirm.** 

## Step 4—Is it 9, 10, 12, or 14-Karat?

Apply 10-Karat test solution (45% dilute nitric acid) to a test streak of the sample on a black touchstone. If it is below 14-Karat, the base metals will be completely dissolved quickly leaving a few flecks of gold floating on the surface of the puddle.—go to step 5.

If it is 14-Karat gold, the base metals will be dissolved quickly but a gold stain will remain on the black touchstone when rinsed with cold water.

## Step 5—Is it 9, 10, or 12-Karat?

Apply 10-Karat test solution (40% dilute nitric acid) to a test streak of the sample. Detecting the difference between these low Karat value alloys is more subjective. The lower the gold content, the faster the test streak will dissolve in the test solution. Here it is useful to straddle the test streak with known steaks from test needles of known Karat-value. Then apply the 10-Karat test solution and watch for relative effects.

# **Filled and Plated Goods**

Some of the less expensive jewelry alloys on the market today consist of a very thin layer of gold alloy, on a body of base metal—the so-called rolled-gold jewelry. Another type of goods—electro-plated products—bear an even thinner film of precious metal on their surface. Additionally, many high grade gold articles are frequently finished with a light electro-deposit of fine gold, and may be further protected by lacquer.

A base metal such as brass (an alloy of copper and zinc) can be electroplated with pure gold. This process is also known as gold flash, gold finish, gold tone or gold dipped.

Base metals can also be "gold filled," which describes the process of bonding a thin layer of gold to a base metal. By definition, a gold filled piece must have 1/20th of the total weight or more of 10K gold or better. This is done because it wears better than gold plated items because there is much more gold.

Be sure to penetrate these outer layers before making your touchstone text. The use of a small file on the inside of the article, to cut this coating, may indeed prove immediately that the bulk of the article is base metal. Lacquer is readily removed by dipping in MEK or acetone (nail polish remover). Most electrodeposits or dips are so thin that they can be removed by a file, or even by rubbing the article back and forth several times on the touchstone.

If the article is one whose appearance is not cherished, you are advised to use the file at once, cutting deeply into the various parts, and dropping nitric acid into the cuts. For example, brass or German silver will instantly cause the acid to boil up and turn deep green.

# **Green Gold**

Green gold, especially if it is 18-k or thereabouts, requires special attention. It is generally comprised of 75% gold, 20% silver and 5% copper. It responds more slowly to aqua regia than yellow or red gold of the same karat, and may lead you to think that it is more valuable than it is. If possible, compare your unknown with a needle of green gold of whose fineness you are sure.



Figure 3—Example of Green & Rose Gold Man's Wedding Band

# White Gold

White golds also respond differently from that of yellow gold. We have devoted a complete section to their analysis. White gold, of course, is ordinary gold that has been whitened by the addition of some white metal. There are two whiteners in ordinary use—nickel and palladium. Most inexpensive white golds consist principally of gold and nickel, to which copper and zinc may be added, or perhaps some silver. The usual combination is gold, nickel, copper, and zinc.



Figure 4—Example of White Gold Wedding Band

Highest grade white golds, including high grade dental alloys, consist of gold, palladium, and base metals, such as copper and perhaps zinc. The dental alloys often contain some platinum as well.

Now it is evident that there is considerable difference in the value of the gold/nickel alloys and the gold/palladium alloys, even assuming that the proportion of gold might be the same.

Accordingly your first concern—after deciding that a given article is white gold—is to decide what kind of white gold—nickel/gold or palladium/gold, your sample is comprised of. These combinations are covered in more detail a bit later in Section 5.

# Learning Curve

Acquire practice in this method before trusting yourself to appraise unknowns. Ask a friend to hand you a dozen objects, of whose fineness he is sure. Or, ask him to make streaks on the touchstone with metal of whose fineness he is sure, for instance, the standard needles. Then test them yourself, and let him check up on your decisions.

After you feel that you are sure of yellow gold articles, try a few red gold and green gold pieces, noticing the slight differences.

If the article consists of several pieces, for example an old-fashioned watch-case with front, back, bezel, and bow, test each piece separately, as those less exposed to wear are often of lower value.

# **Converting from Spot Price of Gold in ounces to Grams:**

You must first find the spot price of gold (per troy ounce) in your country then convert to grams.

Thus, if the spot price of gold is \$1,500 per troy ounce and there are about 31.10 grams in a troy ounce, then the math is follows:

\$1,500 x 1 ounce/31.10 grams = \$48.23/gram

To find the value of jewelry: You need to know the karats (weight) of actual gold in the jewelry.

24kt gold is the highest gold karat available and this is basically pure gold. 14kt and 18kt are common in the US, while 22kt gold is sold overseas. If you buy an 18kt piece of jewelry, this means that this jewelry is actually only 75% gold. The remaining 25% is other metals.

So if you have 1 gram of 18kt gold jewelry, you must multiply the price per gram x percentage of gold to find the actual price in grams.  $$48.23 \times .75 = $36.17/\text{gram}.$ 

# The Acid/Touchstone Method For Silver:

Suppose you suspect that an article is made of silver. First, using MEK (Methyl Ethyl Ketone) or acetone (nail polish remover) assure removal of any lacquer coating. File off any electro-plate or other coating.



## Method #1:

Make a streak on the touchstone. Place a drop of Schwerter's Solution (Bottle #6) on the streak and note the color effect. Note that a white touchstone for this test will help you see the strong color development. Silver will show a very strong, definite red color through the formation of silver chromate.

#### Method #2:

Make a streak on the black touchstone and dissolve it in a drop of nitric acid. (Since silver is generally alloyed with copper, the drop will probably show a green color.) Now, with the point of a knife pick up one small grain of table salt drop it into the drop of solution. If silver is present a white substance will appear—silver chloride—of a cheesy consistency. This is characteristic of silver. Instead of the grain of salt you could use a tiny drop of hydrochloric acid equally well, but most people find the grain of salt more convenient to use.

# Titanium, Tungsten Carbide, and Stainless Steel

Accessories made of these three industrial metals fascinate men and women alike. The popularity of these metals in watches and other forms of jewelry is generally due to their "technical" qualities. They are tough and can take a lot of wear and tear.

Although not as commonly used in fine jewelry as Sterling Silver, White Gold or Platinum, Titanium, Stainless Steel, and Tungsten Carbide are gaining in popularity. Often used for their durability in active accessories, the metals are well suited to active consumers who will wear the jewelry on a daily basis.

# **Testing For Stainless Steel:**

This handsome but inexpensive alloy is popular for sports jewelry, men's belt buckles, wrist watches, etc. In appearance it resembles White Gold or even Platinum itself. Oddly enough it is not readily attacked by nitric acid nor by aqua regia, and for that reason it has occasionally deceived inexperienced appraisers.



It is considerably lighter in weight than either White Gold or Platinum, and can be demonstrated quickly using the Specific Gravity test.

But if you are in doubt about any article of white color and noticeable hardness, which resists the action of nitric acid and of aqua regia, try testing it with plain, concentrated (38%) **hydrochloric acid**. If possible, heat either the article or the acid somewhat. Hydrochloric acid attacks Stainless Steels promptly, making a definite spot or dissolving a test streak in a short time. Sulfuric acid also attacks Stainless Steel; so does a solution of ferric chloride. None of these chemistries will affect White Gold or Platinum.

# **Tungsten Carbide:**

Similar to the look of Platinum is Tungsten Carbide. Tungsten Carbide rings are sometimes simply called Tungsten rings. A Tungsten Carbide ring costs much less than Platinum, but is still a very highly valued quality ring for men's jewelry. Tungsten Carbide wedding bands have become just as popular as Silver and Platinum rings.



Tungsten Carbide (WC) is an inorganic chemical compound (specifically, a carbide) containing equal parts of Tungsten and Carbon atoms. Colloquially among workers in various industries (such as machining and cabinetmaking), Tungsten Carbide is often simply called "Carbide" (without precise distinction from other

Carbides). Among the lay public, the growing popularity of Tungsten Carbide rings has led to some consumers calling the material just "Tungsten," despite the inaccuracy of the usage.

In its most basic form, Tungsten Carbide is a fine gray powder, but it can be pressed and formed into shapes for use in industrial machinery, cutting tools, abrasives, other tools and instruments, and jewelry.

Tungsten Carbide is approximately three times stiffer than Steel, with a Young's modulus of approximately 550 GPa (over 90 Mpsi to steel's 30 Mpsi), and is much more dense than Steel or Titanium. It is comparable in hardness to Corundum ( $\alpha$ -Al<sub>2</sub>O<sub>3</sub>) or Sapphire and can only be polished and finished with abrasives of superior hardness such as cubic boron nitride and diamond among others, in the form of powder, wheels, and compounds.

Tungsten Carbide, also called cemented carbide, has become a popular material in the bridal jewelry industry due to its extreme hardness and high resistance to scratching. Unfortunately, this extreme hardness also means that it is prone to shattering. Tungsten is extremely hard and dense. Combined with carbon and other elements, it becomes Tungsten Carbide, which registers between 8.9 - 9.1 on the Mohs hardness scale. It's roughly 10 times harder than 18K-Gold and four times harder than Titanium and is equal to a natural Sapphire's hardness. In addition to its design and high polish, it is this technical nature that is part of its attraction to consumers.

Tungsten Carbide is a non-metallic material in powder form (in and of itself highly inert chemically), bound together by sintering with a carrier. The available carriers are Nickel or Cobalt. While the Cobalt binder is more resistant to chemical attack, a quality tungsten ring should show no cobalt on the test report. High value tungsten wedding bands use nickel as the binding element.

<u>Hydrochloric acid</u> attacks samples most severely. The most aggressive chemical attack was by the <u>Ferric</u> <u>Chloride (FeCl<sub>3</sub>) solution</u>.

Tungsten Carbide products are often made from Tungsten Carbide powder cemented with another metal. This metal is often Cobalt or Nickel, both of which are magnetic. Cobalt cemented Tungsten Carbide is magnetic enough to be picked up with a strong magnet. Tungsten Carbide by itself would have very low to no ferromagnetic properties.

## **Titanium Alloys:**

Titanium is a natural element which has a silver-greyish-white color. Titanium is the hardest natural metal in the world. It is very strong—three times the strength of Steel and much stronger than Gold, Silver and Platinum and yet is very light in weight. Pure Titanium is also 100% hypoallergenic which means that it is safe for anyone to wear as it will not react to your skin.



Titanium provides several unique factors that make it the ideal metal for jewelry rings. It is very strong, more dent, bend and scratch resistant than Gold, Silver and Platinum, is lightweight and importantly offers an exotic array of colors which other metals simply do not. Titanium can be colored blue, purple, and black rainbow colors.

Jewelry is often 99.9% pure commercial grade Titanium—the same as that used in surgical implants. Pure Titanium will not produce skin irritation or discoloration. It does not react to sunlight, salt water or anything that the body emits.

Titanium is non-magnetic making it ideal where electromagnetic interference is a problem.

Titanium is considered a white metal but is actually more gray in color. Unlike Gold it is used in jewelry in its pure form (approximately 99% pure). Titanium is extremely long wearing.

Titanium is very lightweight, so a Titanium ring will feel much lighter than an 18kt Gold ring and much lighter than a Platinum ring.

Unlike other metals (such as Gold, Platinum and Silver) Titanium is a difficult metal to work with from a jewelry perspective. Titanium is a very hard metal which wears down tools very quickly.

Soldering is used in the manufacture of the majority of traditional jewelry items. Because titanium cannot be soldered, the method of making some jewelry items is restricted when using Titanium.

For example Titanium cannot be used to make a prong setting for an engagement ring. That is why you will see that many Titanium rings have parallel bands rather than tapering bands and why you will not see Titanium rings with prong settings.



While the raw material—Titanium metal, is generally less expensive than 9kt White Gold, because Titanium is difficult to make into jewelry, the labor costs associated with its processing can drive up the price of Titanium jewelry. White Gold will still normally command a higher price than Titanium.

# Section 3—Non-Chemical Tests

# Flame Testing:

If you can turn the flame of a propane or an oxy/propane torch on a piece of suspected metal, you can, within a few seconds, obtain an excellent idea of its nature. Nickel, chromium, brass, and most other base metals promptly turn black. Most base metals will melt, forming oxides of characteristic color and form. White gold alloys will melt promptly in the oxy/propane flame; more slowly in propane only. Or, if the flame is removed before actual melting occurs, a definite darkening is visible.



Stainless steel soon shows a darkening; if heated further it will ignite and burn with a hissing and sparkling flame; the final result will be a shapeless lump of black oxides.

Tungsten and molybdenum change color at low temperatures, and soon begin to burn in the oxy/propane flame, though they probably will not become actually molten.

The response of Platinum and its high grade alloys to a flame is highly characteristic. (By high grade alloys we mean Iridio-Platinum, or other alloys in which only Platinum-group metals are present.) Suppose you bring the metal to a brilliant red heat, and then remove the flame; there will be no darkening whatever. Heat it still further using an oxy/gas flame, and melt it; it melts smoothly and cleanly, without forming any oxide or crust. When the button cools, it will be white and smooth. Base metals, treated in that way, become a mass of clinkered oxide.

An experienced Platinum melter learns a lot about a piece of Platinum merely by melting it. Iridio-Platinum alloys are slower to melt than soft Platinum; the more Iridium, the higher the melting point. If much Palladium is present, the melting point will be noticeably lower, and there will be a tendency to spit. Pure Palladium has the interesting quality of adsorbing large volumes of gas when hot; the metal swells and puffs up; when cooled, this gas is expelled, with accompanying spitting. Palladium forms colored oxides; and films of color will play across the surface of the metal. If heated rapidly, the oxide will disappear, so that by quenching the button at the right moment, a clean white surface is obtained.

Low grade Platinum alloys, when heated rapidly, will darken in proportion to the base metal present.

Fine gold, heated to redness, will cool without changing color. But if even small amounts of silver or copper are present, the surface after cooling will show a film of oxide.

# Specific Gravity—Weight vs. Density:

The ratio between the weight of a given piece of metal and its volume is known as its density (typical units of grams/ml). And the ratio of this density to the density of water is known as its specific gravity. These basic facts can be of help in the process of identifying alloys. For a given volume of material, Platinum, for example, is noticeably heavier than Silver, Nickel, or Gold. Both Iridio-Platinum and Palladio-Platinum have very high specific gravities but Palladio-Platinum is lower.



Alloys will of course be different; thus ordinary gold is much lighter than fine gold; different kinds of brass have different specific gravities; green Golds are a little heavier than red Golds, and so on. White Golds and other Gold alloys are lighter than Platinum, while Stainless Steel, Silver, Nickel, and Palladium are so much lighter that the differences are immediately obvious. Bullion dealers, and others handling metal in quantities, find this method useful even in the delicate task of learning whether a piece of Platinum is a high grade or low grade alloy.

## The History:

This method enlists Archimedes' Principle of Buoyancy—"a body immersed in a fluid is buoyed up by a force equal to the weight of the fluid it displaces." So if you know what the buoyancy force is, and you know the density of the fluid (water) you can conclude what its displaced volume is. And with that, you can deduce its density which is specific to each of the various materials.

Archimedes is probably best remembered by the anecdotal story of his discovery of a method for determining the volume of an object with an irregular shape. King Hieron of Syracuse had asked Archimedes to find out if the royal goldsmith had cheated him by putting silver in his new gold crown, but Archimedes clearly could not melt it down in order to measure it and establish its density, so he was forced to search for an alternative solution.

While taking a bath, he noticed that the level of the water in the tub rose as he got in, and he had the sudden inspiration that he could use this effect to determine the volume (and therefore the density) of the crown. In his excitement, he apparently rushed out of the bath and ran naked through the streets shouting, "Eureka! Eureka!" ("I found it! I found it!").

## The Physics:

Specific gravity is simply the ratio of the density (weight for a given volume) of an object relative to the density of water. And density is the measure of the weight of something relative to its volume—as in grams/milliliter. The other simplifying factor, thanks to the metric system, is that the density of water is, by definition, equal to 1 gram/milliliter. And, further, by definition, the specific gravity of water is 1.0.

Knowing an object's weight and its volume, one can calculate its density in grams/milliliter. And, since we have defined its specific gravity as the ratio of this density to that of water (1.0 grams/milliliter), we see that an object's specific gravity is the same as its density (any number divided by 1 is just the number).

Most importantly, note that in the equation where two densities are divided, the units of volume cancel out. In other words, dividing one value of grams/milliliter by another value of grams/milliliter is the same as dividing one value in grams by another value in grams—or ounces divided by ounces, or pounds divided by pounds, etc. Therefore, we don't even need to deal with densities—only weights. So, to determine an object's specific gravity using water, one simply has to divide its weight in air by the buoyancy force (its weight in air minus its weight in water).

#### **Equipment Required:**

A balance and weights or a digital scale, a piece of thread, and a beaker or cup of water.



## Method #1 (Classical) Using a Balance:

- 1. Weigh the article using the balance tray and record this weight in grams.
- 2. Next, hang the object from the balance and immerse it in a beaker of water and record this weight.
- 3. Subtract the second weight from the first to calculate the buoyancy force which is the weight of the water thus displaced.
- 4. The specific gravity will be the first weight divided by this difference.

## Method #2 Using a Digital Scale:

- 1. Weigh the article using the scale and record this weight in grams.
- 2. Next, place a beaker of water on the scale and tare it out (zero the scale).
- 3. Hang the item from a piece of thread and immerse it into the beaker of water—without touching the sides or bottom of the beaker.
- 4. Record this weight. The scale is reading out the actual buoyancy force (the force of the water pushing up) or weight of the fluid displaced.
- 5. The specific gravity of the object will then be the first weight divided by the second weight.

## Method #3 (Streamlined Version) Using a Digital Scale:

- 1. Place a beaker of water on the scale and tare it out (zero the scale).
- 2. Hang the item from a piece of thread and immerse it into the beaker of water—without touching the sides or bottom of the beaker. Record this weight. This is the actual buoyancy force or weight of the fluid displaced.
- 3. Next, release the thread and let the object settle at the bottom of the beaker. Record this weight which is the actual weight of the item.
- 4. The specific gravity of the object will then be the actual weight divided by the suspended weight.

#### Example #1 (using classical method #1):

A piece of metal weighed in air = 6 grams. When the object was suspended in the cup of water, it weighed only 5.5 grams. The buoyancy force is therefore 6 - 5.5 = 0.5.

Specific gravity is the weight in air divided by the buoyancy weight, or, in this case, 6 divided by 0.5 = 12.

A glance at the table below shows that the specific gravity of 10-karat yellow gold is 11.7. You therefore suspect that your article may be made of low-karat yellow gold. Further tests with acid should be made to confirm this suspicion.

Be sure to get rid of bubbles of air that may attach themselves to your article; they will upset the reading. These are especially to be looked for with carved or filigree work.

#### Example #2 (using streamlined method #3):

A beaker of water is placed on a digital scale and zeroed. A man's gold wedding band is suspended from a piece of thread and immersed into the water. The scale now reads 3 grams which is the buoyancy force (the weight of the water displaced). The thread is slackened to allow the ring to sink to the bottom of the beaker. The scale now reads the full weight of the ring—40 grams.

The specific gravity is then calculated by dividing 40 grams by 3 grams which equals 13.3

A glance at the table below shows that the specific gravity of 14-karat yellow gold is 13.26. You therefore suspect that your article may be made of 14-karat yellow gold. Further tests with acid should be made to confirm this suspicion.

Platinum, pure	21.37
Gold, pure	19.32
18-K Green Gold	15.8 (more or less, depending upon proportions of alloying metals)
18-K Yellow Gold	15.1
14-K Yellow Gold	13.26
Palladium	12.16
10-K Yellow Gold	11.7
Sterling silver	10.4
Copper	8.93

#### Here are the specific gravities of a few metals:

# **Example of Commercial Laboratory Density Meter**

The Electronic Densimeter provides a highly accurate calculation of specific gravity of almost any object of any shape. The revolutionary compact design makes specific gravity measurement simple and accurate.



#### **Features:**

- For measuring solid and liquid specific gravity
- Density resolution: 0.0001g/cm<sup>3</sup>
- Capable of measuring solid specific gravity and volume, and its variations down to the fourth decimal place.
- Densimeter with super-accuracy of density resolution of 0.0001g/cm3
- Very simple measuring procedure allows anyone to use easily
- Solid volume and specific gravity of solid and liquid can be measured with one unit.

# Visual Methods—The Karat or Quality Mark:

A US-made gold article is usually only marked with the karatage and the manufacturer's trademark. The way US manufacturers mark platinum jewelry depends on how many parts per thousand of pure platinum it contains. Silver articles of US origin are stamped "sterling" if they are at least 92.5 percent pure silver.



In the US, most manufacturers use a karat stamp on gold jewelry, even though FTC regulations don't require it. The FTC does require, however, that if they use the karat stamp, they must also trademark the item. Failure to do this is a violation of the 1961 amendment to the National Stamping Act of 1906. The Act requires trademarks on items of silver, platinum, and the platinum group metals. All trademarks must be registered with the US patent office.

Tungsten carbide rings all have companies' trademarks on the inside of each tungsten ring. Tungsten rings that do not have trademarks of the jeweler are usually cheap imitations.

While quality marks should not be relied upon for complete accuracy, they provide a place to start your further analysis. Also, in many cases, as in the case of dental alloys, there is no stamp.



Figure 4: A jeweler's loupe

Government, consumers, competitors, and industry organizations can sue manufacturers and retailers that violate federal laws. The best way for a jeweler to protect against "underkarating" fraud is to buy only registered trademarked and quality stamped gold jewelry.

This won't completely protect a jeweler from legal action, but articles marked with registered trademarks can be easily traced, so they're less likely to lead to charges of underkarating.

There are several precautions to be observed. While the laws regarding the stamping of platinum alloys exist, a great deal of platinum jewelry now in use was made before these laws were drafted. Accordingly some of the marks on platinum jewelry can be misleading.

For years palladium was more expensive than platinum; therefore it was accepted practice to use palladium in platinum, without mentioning the fact. Later on, the price of palladium fell below that of platinum, and a metal that had once enhanced the value of an article became a diluent. This is why an analyst should test platinum goods with extra care.

Here are a few other reasons for caution regarding the karat stamp:

- An old article may have been repaired with the addition of much solder and even a new low-karat segment.
- Rolled gold requires special care. It consists largely of a base metal, such as brass, with a thin layer of gold on the outside. Usually this outer layer is 12-karat or 10-karat.
- You may find a karat stamp reading "1/10 12-k," or perhaps "1/20 10-k." That means in the first instance that the article is 9/10 brass, and the other tenth consists of 12-karat gold. In other words, the article when new was only one-tenth 12-karat gold, or one twentieth fine gold. Now, after years of usage, this outer layer is worn and thin.

Conversely, very old gold jewelry can often be worth more than ordinarily expected. Years ago, when platinum was substantially cheaper than gold, it was sometimes used as the base metal in an otherwise gold alloy. It thus acted as an extender and provided hardness to the gold, and, unlike with the addition of silver, without increasing its tendency to tarnish. With Platinum prices where they are today, depending upon the amount of Platinum used, it may be enough to noticeably increase the value of the article.

Articles such as candlesticks are often made of a hollow metal shell which is filled or loaded, sometimes with a metal like lead which has been melted and poured in. Sometimes the base alone is loaded. This same scheme has been used with heavy link bracelets, etc., and has occasionally deceived the inexperienced observer.



# **Other Marks:**

#### "Plumb Gold":

Before 1976, an item marked 14K in the USA is allowed to be as much as  $\frac{1}{2}$  karat short of 14/24 gold (58.33%). The same is true of 10k through 24K. To differentiate a particular piece of jewelry from what may be allowed, some jewelers add a stamp in a ring such as 14KP, which means the item is "plumb", or has the full 14 parts gold and 10 parts alloy. Contrary to popular misnomer, the P does not stand for plated.

#### **Platinum Marks:**

Jewelry can contain different percentages of pure platinum. The US Federal Trade Commission (FTC) publishes guidelines for acceptable marking standards for platinum jewelry sold in the US.

Platinum content is usually expressed as the amount of pure platinum the jewelry contains in parts per thousand. Compare this measurement method to percentage (%) which is parts per hundred.

Jewelry that contains at least 950 parts per thousand (equivalent to 95 parts per hundred, or 95%) of pure Platinum may be marked or described as "Platinum."

Jewelry that contains 850, 900 or 950 parts per thousand of pure platinum may be marked "Plat" or "Pt" if a number is used in front of the term to disclose the amount of pure platinum in the alloy. For example:

850 Plat or 850 Pt 950 Plat or 950 Pt

Jewelry that contains at least 950 parts per thousand of platinum group metals, with at least 500 parts per thousand of the total pure platinum, may be marked as platinum as long as the numbers of each metal are disclosed. For example:

600 Pt. 350 Ir., 600 Plat. 350 Irid. = 600 parts pure Platinum and 350 parts Iridium 550Pt. 350Pd. 50Ir., or 550Plat. 350Pall. 50Irid. = 550 parts pure Platinum, 350 parts Palladium and 50 parts Iridium

European gold jewelry is marked with numbers that indicate their percentage of gold. For example, 18K gold is marked 750 to indicate 75% gold. 14K gold is marked 585 for 58.5%.

# **Ferromagnetism—The Magnet:**

Ferromagnetism is the basic mechanism by which certain materials (most commonly, iron, nickel and cobalt) form permanent magnets, or are attracted to magnets.



Gold buyers often employ a magnet, especially for locating small steel springs in bracelets, or the like. If a piece of metal is strongly attracted by the magnet, it is plainly made of a steel alloy or perhaps a martensitic stainless steel (the 400-series; 410, 416, 440C, etc.). However, some other alloys, including monel and some kinds of white gold, can also be responsive to a magnet due to the presence of nickel. Thus, as with all the test methods discussed so far, the magnet is used to provide one additional clue or eliminate a possibility and should not be relied upon too implicitly.



#### Using a Magnet:

Rare earth and other powerful magnets can be helpful in checking for base metal (non-precious metals containing nickel or iron) items. By checking every lot/item before you start testing, the magnet can save you time.

Most items attracted by a magnet will not only contain little or no precious metal but most refiners will not accept them when you want to sell your gold. Conversely, you will find that most gold plated and gold filled jewelry and most costume jewelry will not be attracted to the magnet so to confirm the precious metal content, you will still have to use one of the previously-discussed testing methods.

NOTE: Jewelry clasps on neck chains (trade names: "lobster claws" and "spring rings") contain a metal leaf spring inside to function properly so you do not have to worry if they are attracted to the magnet you can look for a quality stamp or just go on to further testing.

Items that are slightly attracted to your magnet will require more inspection and testing. Jewelry that has a heavy Rhodium plating (bright silver color) like on bracelets or charms will show some magnetism to a strong magnet. For heavy Rhodium plated items to be properly checked for precious metal content, you must get through the surface and do a destructive test (cut deep into the metal).

Metal Aluminum	Magnetic Effect Non-magnetic
Cobalt	Magnetic
Gold	Non-magnetic
Platinum	Non-magnetic
Palladium	Non-magnetic
Rhodium	Non-magnetic (Note 3)
Steel	Strongly magnetic
Silver	Non-magnetic
Nickel	Slightly magnetic (Note 4)
Copper	Non-magnetic
Zinc	Non-magnetic
Brass (copper/zinc alloy)	Non-magnetic
Bronze (copper/tin alloy)	Non-magnetic
Stainless Steel, Austenitic (300-series, 303, 304, 316, 347)	Non-magnetic (Note 1)
Stainless Steel, Martensitic (400-series, 410, 416, 440C)	Noticeably magnetic
Tungsten Carbide	Magnetic (due to cobalt or nickel binders)
Titanium	Non-magnetic

#### Notes:

- 1. This alloy typically used for watches and other jewelry.
- 2. This alloy typically used for cutlery.
- 3. Since most Rhodium is used as a plating over a base metal, a layer of Nickel us often used as a barrier layer to protect the base metals from the sulfuric acid used in the Rhodium plating bath. This Nickel layer can give provide the slightly magnetic pull.
- 4. Nickel is one of the three common elements that are ferromagnetic around room temperature. Alnico permanent magnets based partly on nickel are of intermediate strength between iron-based permanent magnets and the rare-earth magnets.

# Section 4—Platinum and Its Alloys

# **Extension of the Acid/Streak Method:**

Thus far, you have learned the touchstone method as it applies to yellow gold, wherein you took ordinary gold articles such as coins or rings, rubbed them on a black stone called a touchstone, and tested the streaks of metal with either nitric acid or aqua regia. And by comparing these streaks with streaks made with standard bits of gold (from test needles or test stars), you established the fineness of the test piece. With the now-high prices of Platinum, and its popularity in jewelry, it becomes a natural step to extend this process to cover the Platinum group metals.



This analysis first requires that the presence of Platinum is established and confirmed. Maybe it is not platinum at all—maybe it is stainless steel, or tungsten carbide, or silver, or white gold, or perhaps a good piece of base metal alloy like brass with plating of chromium or rhodium.

Assuming it reveals itself to be a Platinum alloy, what is it comprised of? Iridio-Platinum? Palladio-Platinum? Or platinum that is alloyed with gold, nickel, copper, or silver?

# **Detecting The Presence Of Platinum:**

The process you will use here is one of elimination at first. Using the various test tools you now have at hand, the concept is to see if you can get some positive test result that is either consistent or inconsistent with Platinum.

## **Specific Gravity Test:**

The first clue is the weight of the object relative to its size. Platinum is extremely dense—more dense than gold by almost 15%. Similar-appearing alloys of primarily nickel and silver are much lighter than Platinum. White gold is slightly lighter. So a specific gravity test could easily be conducted.

## **Ferromagnetism Test:**

While Platinum is non-magnetic, Nickel is attracted slightly by the magnet. But Nickel is not likely to be found in a piece of Platinum jewelry. So obviously, if you are getting a slightly magnetic positive result in a white piece of jewelry, it is likely that Nickel is present, and it is most likely a sample of White Gold instead of a Platinum alloy.

# **Acid Testing:**

Both Nickel and Silver are acted upon promptly by nitric acid. But Platinum is not. Chromium plating, though it resists nitric acid, is dissolved easily by hot hydrochloric acid or hot sulphuric acid, neither of which will even touch Platinum.

Aqua Regia at room temperature will not touch Platinum but you now know it will quickly dissolve pure gold, white gold and all of the associated base metals.

Aqua Regia, when warmed, will however dissolve Platinum.

# **Rhodium Plating:**

Rhodium plate is especially deceptive and therefore the prudent precious metals trader must be aware of its existence and its behavior.

Rhodium is a metal closely related to Platinum—costing more per ounce at this time than Platinum itself. It can be deposited electrolytically in a very thin layer on base-metal articles, to give them a handsome appearance, free from tarnish, and at small expense. Additionally, it is commonly applied over White Golds to afford this inherent protection.

Rhodium is not attacked by nitric acid, aqua regia, nor any other single acid. It is fairly hard to file almost as hard as chromium plate. But the deposit used is always so thin that a few strokes of the file are enough to penetrate it and expose the base-metal below.

# What Platinum Alloy Is It?

Once it has been established that a piece is, in fact, Platinum, the next step is to determine the composition of the alloy. By the process of elimination you are now sure it is not white gold, chromium-plate or silver. So now one must determine if it is a high grade Iridio-Platinum, Platinum containing more Palladium, or possibly one of those alloys to which considerable Gold, Palladium, Nickel, or possibly other metals have been added.

Shortly after Platinum and its alloys came into prominence, Platinum "needles" appeared on the market, similar in principle to the gold standard needles, but consisting of Platinum, Iridio-Platinum, and Platinum alloyed with more or less Palladium.

At once it was noted that while a Gold streak dissolves promptly in aqua regia, a Platinum streak is very slow to dissolve. This slow solubility is one of the distinguishing marks of pure Platinum and Iridio-Platinum—the latter being even slower to dissolve than pure Platinum. The lower grade Platinum alloys—those containing Palladium, and especially those containing Gold and base metals as well—dissolve more rapidly.

As in the case of Gold, the test is a comparison of the behavior of metal streaks on the touchstone. A streak is made with the unknown, then with two or more of the standard needles, aqua regia is applied, and the effect of the acid is watched.

To hasten matters, heat the stone until it is uncomfortably hot to the hand. At that temperature, even the refractory Iridio-Platinum will dissolve in aqua regia.

At some point, someone noticed that it is easier to see the Platinum reactions on a white stone than on a black one. And further, for our purposes, probably the handiest device is a porcelain plate bearing small cavities or depressions. This is called a "spot plate" and can be procured from any chemical supply house.

We spoke before of the lower-grade Platinum alloys—those containing Gold and base metals such as Nickel or Copper, as well as Palladium. Compared with Iridio-Platinum, these dissolve readily in aqua regia. Unfortunately, they may be confused with certain of the White Golds and some kinds of dental alloys—that is, if the only test you apply is simply this one involving the speed of reaction with aqua regia. In other words, the basic touchstone method does not tell us enough. The actual composition of the unknown test piece is desired.

# Does It Contain Gold, Palladium, etc.?

We shall now consider in detail the modern developments of the method, whereby it is easy to detect the presence of Palladium or Gold (or both) in a Platinum alloy. These methods also allow the detection of Platinum, Palladium or Nickel in White Gold or dental alloys or in solutions.

These tests, while essentially chemical, are well within the abilities of any intelligent layman. The equipment required is inexpensive and readily obtainable.

## The Basic Strategy:

As before, we make a streak with our unknown and dissolve it in aqua regia. Then we add certain chemicals to the solution, and by noting the color changes that occur we can deduce the composition of our unknown.

# **Glass Acid Dropping Bottles:**

Notice first the use of the so-called "dropping bottles." These have grooves in the stoppers, and with them you can easily get one drop, or as many drops as you wish without waste. If these are unobtainable you can manage with ordinary bottles and a handful of medicine droppers or small glass rods. We prefer the amber glass dropping bottles. They protect the chemistries from the effects of ambient light. They are all glass, including the cap and thus there are no neoprene or rubber dropper bulbs to disintegrate from the acid effects. And finally, nitric acid has detrimental effects on plastic bottles when used to store for long periods of time.

**Porcelain Spot Plate:** Instead of a black touchstone, we shall rub our unknown and our standard needles in the cavities of the spot plate. Then we shall dissolve each streak in aqua regia. Then we shall test these resulting mixtures with one or more of the solutions in the dropping bottles.



Figure 3: Dropping Bottle & Spot Plates

The spot plate itself needs a little preparation—the glaze must be removed. Rub a little emery (sometimes referred to as buffing compound, or valve lapping compound) into each cavity, just enough to give a dull surface. The surface thus becomes slightly abrasive so streaks can be created.

Next, mix up some fresh aqua regia per the standard recipe of one part nitric acid to three parts hydrochloric acid. Mix it under a fume hood or where otherwise the ventilation is excellent. Remember, the fumes are toxic and highly corrosive. And remember, do not stopper the bottle tightly because of the gas evolved.

Next, you will need to mix up your next solution; Stannous Chloride Solution—originally referred to by C.M. Hoke as "Testing Solution A." This solution is without a doubt one of the most useful solutions yet devised for anyone handling precious metals, or solutions containing them. When properly used, it will quickly tell whether you have Gold, Silver, Platinum, or Palladium, and it will give you clues as to the proportions of each. It is easy to make up, and very easy to use:

# Bottle #6—Stannous Chloride Solution (aka, "Platinum Solution", "Testing Solution A"):

Purchase the following from a convenient chemical supply house:

- Stannous chloride, reagent grade, crystalline, 50 grams
- Tin metal, reagent grade, granulated, mossy tin, or tin foil, 50 grams
- Hydrochloric acid, 500 ml

### Mixing:

Measure out 1.5 grams of the stannous chloride crystals and place in a 50 ml size dropping bottle. Add 1.5 grams of the tin metal, and fill the bottle two-thirds full of water. Ordinary tap water will do. Now add 30 ml of hydrochloric acid to make the bottle almost full. This gives a milky liquid which is ready to use. The tin metal will dissolve very slowly, keeping the solution saturated with tin. Label the bottle "Stannous Chloride Solution" (or "Testing Solution A").

Important Note: "Testing Solution A" must be made up freshly from time to time. It loses its effectiveness completely in a few weeks. Therefore, begin the day's work by checking its behavior against a drop of standard gold solution; if it fails to respond, throw it away at once.

#### **Applications:**

Stannous Chloride Solution, when properly used, shows the presence of several different precious metals in solution. In order to get acquainted with the color changes involved, you should first make up some solutions containing these precious metals. You should have a solution containing Gold, one containing Platinum, and another containing Palladium. This method is so useful that most analysts wind up with a whole series of standard solutions, so perhaps you might as well get a half dozen additional dropping bottles in the first place.
# **The Standard Solutions:**

To make up a standard solution, simply dissolve a small piece of metal in a little aqua regia, then add water.

# **Platinum Standard Solution:**

For instance, dissolve exactly a grain of pure platinum wire in a little aqua regia, using a small porcelain dish and heat it gently until all the metal dissolves. Use as little aqua regia as will do the work. Wash the solution with water into a two-ounce bottle, and fill the bottle with water. Label this bottle "One Grain Platinum Standard in 2 Fluid Ounces of Solution."

# **Palladium Standard Solution:**

Dissolve exactly a grain of pure Palladium wire in a little aqua regia, using a small porcelain dish until all the metal dissolves. Use as little aqua regia as will do the work. Wash the solution with water into a twoounce bottle, and fill the bottle with water. Label this bottle "One Grain Palladium Standard in 2 Fluid Ounces of Solution."

# **Gold Standard Solution:**

Dissolve exactly a grain of pure gold in a little aqua regia, using a small porcelain dish until the metal dissolves. As before, use as little aqua regia as will do the work. Wash the solution with water into a twoounce bottle, and fill the bottle with water. Label this bottle "One Grain Gold Standard in 2 Fluid Ounces of Solution."

**Note:** While at the early stages of your development when you are trying to become acquainted with the various solutions, it is not necessary to use exact measurements. But later on, when trying to approximate the amount of precious metal in a solution, it will be extremely helpful to have standard solutions made up with a definite weight of precious metal in a definite volume of liquid.

Thus, it saves time to make up your solutions in the beginning according to specific concentrations. Some analysts may use 100 milligrams to 100 ml of solution. It makes no difference which units are used but get in the habit of using the same units every time.

# **Using Stannous Chloride Solution:**

Place a drop of this Stannous Chloride Test Solution into a cavity of the spot plate. Add one drop of Platinum Standard Solution to the same cavity. Notice the pale yellow color. Add a drop or more of Testing Solution. If properly prepared, the two will react instantly to give a deep yellow or brown color. If too concentrated, the color will be almost black; in that case, dilute the Platinum solution with an equal volume of water. This deep yellow color with Solution A is a characteristic of Platinum and Iridium.

# **Gold Detection Sensitivity:**

In another cavity, place one drop of your Standard Gold solution, and add a drop of Stannous Chloride Test Solution. After several moments add several more drops of Stannous Chloride Solution. Note the first intense dark color—deep purple or black. This is characteristic of gold. After it stands a few minutes, notice the purple stain on the white porcelain.

Now, in another cavity, take just one drop of your Standard Gold solution, and dilute it with five drops of plain water. Take one drop of this dilute gold, in another cavity, and add a drop of Stannous Chloride solution. Note that the color is still definite. Dilute with five more drops of plain water, and try again. See how dilute this Gold solution must be before it becomes so weak that you cannot detect a change with the Stannous Chloride Solution. You will find that Stannous Chloride Solution is very sensitive, and will reveal the presence of a very small percentage of gold—on the order of parts per thousand.

# **Palladium:**

In the same way, learn the color-changes shown when mixing Palladium Standard solution with Stannous Chloride Solution. This color-change is even more interesting than the others. When the two drops are first combined, you see a deep yellow, not unlike the effect produced by Platinum. After a few minutes the yellow turns blue-green. This blue-green color is characteristic of Palladium.

# Silver Chloride Precipitate:

Silver solutions, such as silver nitrate, do not give any color-reaction with Stannous Chloride Solution. What you will see when the two are mixed is a white cheesy precipitate of silver chloride, similar to that obtained when table salt is added to a silver nitrate solution.

# **Platinum:**

Next, take some platinum metal and rub it hard, several times, in a cavity of your spot plate. Heat the spot plate until it is too warm to be held comfortably in the hand.

One way to do this is to slip it into a pan of water and heat the water to a boil; lift out the plate by tongs and wipe it dry. Another way is to set the spot plate on steam pipes or on an electric hot plate. Holding it over a flame is alright if you move it around and keep it from getting too hot on one side and cracking.

Next, dissolve the Platinum streak in a few drops of aqua regia. (If your plate is too hot, the acid will boil away; if too cool the reaction will be very slow.)

Finally, add a drop or so of Stannous Chloride Solution to this cavity and note the color change.

Repeat this process, using a piece of fine Gold, and again using a piece of Palladium. With these metals the plate need not be heated so strongly. Note also that Palladium dissolves readily in plain nitric acid.

By this time you are reasonably acquainted with the color-changes produced by Platinum, Palladium, and Gold, in solution, when mixed with Stannous Chloride Solution.

# Detecting Gold, Platinum, and Palladium in the Presence of Each Other:

The next step is to use the principles just learned to detect Palladium in metal that is mostly Platinum. This is especially valuable when testing dental alloys or buying metal that may be contaminated or of low grade.

If you have a standard needle of a Platinum-Palladium alloy, rub it on your spot plate, warm the plate, dissolve the streak in aqua regia, and test the solution with Stannous Chloride Solution.

Can your eye detect the difference between that effect and the effect produced by pure Platinum?

Next, rub pure Platinum in a cavity, and make a few rubs in the same cavity using a bit of fine Gold. Suppose you make fifteen rubs with Platinum, and three rubs with Gold. Again warm the plate, dissolve the streaks in aqua regia, and test with Stannous Chloride Solution.

Can your eye detect the presence of that small amount of gold?

Also, can your eye detect the presence of all three metals—Gold, Platinum, and Palladium—at the same time, in a single drop of solution?

Your eye may not be able to do this the first time. But after a little experience, you will know which metals are present and roughly the proportion of each.

Do not let the liquids dry on your spot plate. Wash them off at the end of the day. If stains remain, dissolve them in a little aqua regia, let it act, then wash well.

# Notes For Using Stannous Chloride Solution:

Stannous Chloride Solution has just been shown to be useful in identifying Platinum, Palladium, and Gold. Its color-changes, when added to a drop of solution containing any one of these metals, are pronounced and characteristic. Even when two or three of these metals are together in solution, their identifying colors can be picked out.

Of course the inexperienced user sometimes gets confusing results. Sometimes the colors refuse to appear. This may be due to the fact that one solution or another has lost its strength; or, more likely, contains too much acid.

Remember that both aqua regia and Stannous Chloride Solution have short shelf lives and must be mixed freshly on a regular basis.

Conversely, the Standard Solutions do not expire. If properly kept in glass-stoppered bottles they will keep for years. But when you make them up, do not use an excessive amount of acid to dissolve your bits of metal. If too much aqua regia is used, the tests will be weakened or even destroyed. The excess acid can be driven off by evaporating the solutions gently until almost dry, then adding a little water.

In the process of dissolving the streaks of metal made on the spot plate, you sometimes use more aqua regia than is needed. There again you can remove the excess by warming the spot plate gently; if the drop should go entirely dry, add one or two drops of plain water to bring your substances back again into solution.

Another situation that may confuse the beginner is to find an alloy containing much Platinum and very little Palladium; or much Gold and very little Palladium. He finds that the Palladium color is obscured by the intense reactions of the Platinum or the Gold.

As the user's eye becomes more skilled the analyst can detect smaller and smaller proportions; however, he will be glad to know that there is another solution that is especially valuable in detecting small amounts of Palladium—"DMG Solution"...

# Section 5—The White Golds: Detecting Palladium and Nickel



# **Bottle #7—DMG Solution:**

This solution has the ability to indicate the presence of Nickel, even in small amounts. It will indicate the presence of Nickel in a Platinum alloy; in a White Gold alloy; in a dental alloy; or in a solution. And, as we will see in a moment, it will also indicate the presence of Palladium and Nickel when both are present in small amounts in an alloy that is largely Platinum or Gold.

### Formulating DMG Solution:

Measure out one gram of dimethyl glyoxime. One gram will be enough for several hundred spot plate tests. It is a white or pale yellow powder. The chemical name is pronounced "dye-methyl glyoxeem" but most chemists just call it "DMG."

Dissolve this gram of DMG by bringing it to a boil in about 100 ml of water—about 4 fluid ounces. The powder dissolves rather slowly. Let it cool and if possible let it stand overnight; then filter. It is important that the solution be clear and free from sediment or crystals. It is now ready to place in a dropping bottle, which should be labeled DMG. It keeps quite well for years, except that you may have to filter it again.

### **DMG Behavior:**

Place a very small drop of the Palladium Standard solution in a cavity of the spot plate. Dilute it with several drops of water to obtain a pale yellow solution; then place one drop of the pale solution in a clean cavity.

Now do the same thing with a drop of your Platinum Standard solution, and with your Gold Standard solution; a drop to a cavity. All three will exhibit a pale yellow color.

Add a drop or two of DMG Solution to each cavity. Note the precipitate that forms, and its color. Note that the pale yellow colors do not change, but that in the cavity containing Palladium you will see a precipitate, or sediment forming at once. Note carefully that while Stannous Chloride Solution gives prompt changes in color, DMG distinguishes between Palladium and the other metals by forming a precipitate.

You can see this more clearly by obtaining a few small test tubes. In tube number 1, place a few drops of Platinum Standard solution; in tube number 2, a little of your Palladium Standard solution; in tube number

3, some Gold Standard solution. Be sure that all the solutions are clear and free from sediment. Now add a few drops of DMG to each test tube, and note the change in the Palladium tube.

In a fourth test tube add several drops of water and a very small amount of Palladium solution; add DMG and see how small a quantity of Palladium is the smallest that you can detect. With practice in looking at precipitates, your eye will detect smaller and smaller percentages.

Be sure that all your solutions are clean and free from precipitates or flocculence; otherwise you will be deceived.

# **DMG and Nickel:**

Now this is where DMG gets interesting. Scratch on the spot plate with a five-cent piece (a nickel). Dissolve the streak with a drop of nitric acid or aqua regia. Add a drop or two of DMG. Note that nothing special happens.

Repeat this step but after dissolving the nickel streak in acid, add a big drop of ammonium hydroxide (ammonia). This addition neutralizes the acids. Now add the DMG. If you used enough ammonia to kill the acid, you will see a very beautiful and characteristic color change to bright red.

Note this particularly: While the test for Palladium appears only in an acid solution; the test for Nickel must be made in a basic (alkaline) solution.

This ability of DMG to selectively detect the presence of these two metals separately is very handy.

Suppose you have a piece of so-called Platinum as an unknown, and you suspect that it may contain both Nickel and Palladium. First make the streak on the spot plate and get it into solution with aqua regia. Then add DMG. If Palladium is present you will see the copious precipitate, canary yellow in color. Now add enough ammonia to make the mixture smell faintly. If Nickel is there, you will at once see the beautiful bright red—all in one cavity of your spot plate.

Continue to test various scraps of metal, such as cheap White Gold, (which is almost sure to contain Nickel) and high-grade dental alloys, (which are almost sure to contain Palladium).

# Effective Use Of The Spot Plate To Identify An Unknown:

We are now ready to test unknown metals. Suppose you have a piece of jewelry, and you suspect it of being low-grade Palladio-Platinum, possibly containing Gold and Nickel. Get a spot plate with 12 cavities—a matrix of 3 x 4.



Layout the cavities as follows:

# Left Column of 3 Cavities:

Make scratches with your unknown (call it "alloy x") in the three cavities to the left. Make from 10 to 25 scratches in each cavity; with soft metals a few scratches are enough; with hard ones use more. Count the scratches, so as to use the same number every time in a given test.

# Second Column of 3 Cavities:

In the second column of cavities, make scratches with a metal of known composition, whose nature you believe to be similar to your unknown. Let us call this "Alloy A."

Suppose you suspect your unknown of being 200/800 Palladio-Platinum. In that case, the second scratches should be made with a test needle of that composition.

# Third Column of 3 Cavities:

In the third row of cavities, make scratches with some other combination of metals, which you suspect may resemble your unknown x. For example, you might make fifteen scratches with pure Platinum and five scratches with fine Gold. Call this "Alloy B."

### Fourth Column of 3 Cavities:

In the fourth row it might be useful to make scratches of some further combination which may or may not resemble x. For example, make fifteen scratches with pure Platinum and five scratches with a piece of pure Nickel. Call this "Alloy C."

# **Dissolution:**

The next step is to dissolve every one of these streaks in aqua regia. Remember that with platinum alloys you must heat the plate (a small hot plate is recommended for this to assure temperature uniformity). With Gold alloys this heating is not necessary. Into each cavity drop exactly the same amount of aqua regia using the dropping bottle. One or two drops will probably be enough. Give the streaks time to dissolve; indeed, you can gather considerable information regarding your unknown by noticing the promptness with which it dissolves in aqua regia. In some cases the color may prove helpful; you will recall that both Copper and Nickel give green solutions; unfortunately for this case, Gold, Platinum, Palladium and Iridium all give the same color—yellow.

After the streaks have all dissolved, begin your tests.

# **Top Row—Stannous Chloride Solution:**

Starting with the four cavities across the top of the matrix, place about three drops, more or less, of Stannous Chloride Solution into each cavity. Use the same number of drops in each case; you may need as much as five drops.

# Middle Row—DMG Solution:

Now to the middle row of cavities, add two or three drops of DMG.

# Bottom Row-Neutralize with ammonia, then DMG:

In the bottom row of cavities, add first a big drop of ammonia, then one or two drops of DMG.

# Analysis:

Compare the way in which your unknown responds to these tests with the reactions caused by alloys or mixtures whose nature you are sure of. Sometimes it helps to let the spot plate stand a while—half an hour, or overnight. New colors may appear.

If your unknown is strikingly different in its reactions from your knowns, then start all over again, using another set of knowns.

As you can see, this is a lot like detective work. The success of this method lies in practice, attention to detail, documenting the contents of each spot, and good lighting. Additionally, it should go without saying, that a prime requirement for good results is good housekeeping—keeping your spot plate and work area clean.

# Section 6—Understanding the Common Precious Metal Alloys



While there are several academic reasons for learning how to analyze the content and purity of precious metals, the most common purpose is related to the buying, selling, and recovery of precious metals.

Sometimes, in order to understand what one is looking at it helps to know what it is used for, where it is found, and what common base metals are generally alloyed with the precious metals to achieve particular purposes in specific applications.

The following sections will focus on each of the precious metal alloys, their history, composition, unique characteristics, and the applicable testing/analysis methods.

There are many different metals and alloys used in modern jewelry making. The two precious metals most often used are alloys of silver and gold.

The type of jewelry you can wear is not just determined by your wallet - but also by the way your body reacts to and tolerates exposure to metals.

Sterling silver tarnishes, especially in hot, humid weather. It contains 7.5% copper by weight, which reacts with common air pollutants, darkening the surface of the metal. This can prompt skin irritation if your skin is sensitive to nickel or copper.

If you have noticed that you have an itch that persists with drying and reddening of your skin where your jewelry touches it, you are probably sensitive to the alloy in the metal.

Gold and silver are known to be non – reactive metals; but that does not mean that everyone can wear any type of gold or silver jewelry without any problem. Higher karat gold alloys tend to be better tolerated than lower karat qualities because there is less of the reactive metal in the alloy. Many people wear 18K or 22K gold jewelry for this reason.

Sterling silver is .925 pure, or 92.5% silver by weight, a very high percentage. Most people don't have any problems wearing sterling silver jewelry. Modern silver alloys don't contain nickel, the usual irritant in jewelry metals. Lower percentage silver alloys like vintage "European" silver can irritate your skin more easily than sterling silver jewelry if you have copper sensitive skin, because old European silver is .800 fine, or 80% silver / 20% copper.

# **Gold Alloys:**

Pure 24K gold is hypoallergenic. It doesn't cause irritation to the body. However, the metals mixed with gold to make it harder or enhance the color of gold can cause adverse skin reactions.

Gold alloys are available in many colors. The color of the alloy is determined by the percentage and type(s) of metal "mixed" with the pure gold.

Rose gold contains more copper; until recently white gold was traditionally made with nickel. Now it is also made with palladium, a platinum family metal; green gold is made with an alloy of fine silver.

There are many other combinations. The percentage of gold used is directly related to the karat content of the alloy. It does not matter what type of metal is "mixed" with the gold, just how much.

For instance, 10 karat yellow gold is 41.67% pure gold and 58.33% "other metals", mostly copper, maybe some silver and most likely some nickel or zinc to add hardness.

In the United States gold must be at least 9K to be sold as karat gold. Lower karat gold alloys have a higher percentage of the other metals added to them. They tend to react to the pollutants and other impurities in the air faster than higher karat gold alloys. This means that the high percentage of copper or other metal in the lower karat alloy will tarnish (or oxidize), just like sterling silver items do. This can occur especially in hot weather when the metals react to salt in perspiration.

If you have a problem with sterling silver, medium to low karat gold will probably give you difficulties as well. Medium to low karat gold has a higher percentage of copper in it than sterling silver.

Nickel allergies are the most common. Many people have problems wearing white gold - the problem isn't the gold. It's actually nickel that causes skin reactions.

The new palladium white gold alloys are a bit more expensive, but are hypoallergenic.

#### Silver Alloys:

Sterling silver is generally used for jewelry, and that is what most people think of when they see silver. Silver also comes in various quality grades, measured by 1/1000 parts per gram. There are impurities that naturally occur in silver at the molecular level. These impurities consist of other metals—usually copper, but traces of other metals can also be found. These trace impurities are insignificant, and would be too costly to remove—so .999 silver is considered pure.

As with gold, silver in its fine state is a non-reactive metal—allergies are possible but very rare. People who have problems wearing silver jewelry are usually allergic to the copper in the alloyed metal, not the silver.

During the European Industrial Revolution, people found that their .800 silver was tarnishing much faster than before—a reaction to the new pollutants in the air—from burning coal in the factories!

Fine, or pure, silver with no copper content does not tarnish easily-it can get dirty, of course.

There is a new alloy called Argentium® Silver. It is sterling, but contains germanium in place of copper. Argentium® doesn't develop firescale as easily during soldering and doesn't tarnish the way traditional sterling silver does.

### **Plated and Filled:**

There are different grades and methods of bonding precious metals to a less expensive base metal, as indicated in the chart at the right. Many jewelry items are made of either plated or filled metals. This is done to keep the cost of these items as low as possible.

The whole piece, as with a chain, or in many cases, the clasp and metal parts of an otherwise top quality gemstone bead necklace or bracelet. If it is taken care of and worn properly, such as over a sweater, a necklace with plated parts can last for a very reasonable length of time, even years - but eventually the plated metal parts will oxidize or the plating will wear through to the base metal.

Filled metals are much higher quality. They have one or more layers of precious metal bonded to a base with heat and pressure. Filled materials are at least 1/20 precious metal by weight. They are much longer lasting than ordinary plated objects. Filled metal objects are marked with a quality stamp, such as 12k GF or 14k GF.

Platinum is a precious metal that costs more than gold. It usually is mixed with other similar metals, known as the platinum group metals: iridium, palladium, ruthenium, rhodium and osmium. Platinum is extremely dense, and is much heavier than gold or silver. Platinum has a remarkably high level of durability so it does not wear or tarnish like other metals. White gold is rhodium plated to give it the same white look as platinum, but eventually the rhodium wears off and the white gold takes on a yellow cast. White gold jewelry should be rhodium plated every few years to maintain its whiteness. Platinum does not yellow or tarnish and maintains its white appearance with little maintenance and can develop a hazy patina over time.

Platinum is not susceptible to problems like stress cracking or corrosion as can be the case with white gold. Though platinum can scratch, it is more durable than white gold and does not wear down or abrade like gold. Scratches can easily be removed by buffing, and all that is required to maintain platinum is to soak it in a mild solution of soap and warm water followed by a gently rubbing with a soft bristled brush.

Platinum is considered to be the "most precious" of the precious metals. Platinum is your metal of choice, when only the best will do. Rarer than gold, stronger and more enduring, platinum is also the choice of jewelry designers for fine heirloom quality jewelry.

Palladium is one of six metals in the platinum family. It has similar characteristics of platinum, such as high melting temperature, cool gray color, durability and rarity, however, it is much less dense (lower specific gravity). Palladium is a soft silver-white metal that resembles platinum. It is the least dense and has the lowest melting point of the platinum group metals. Palladium is the metal of choice to mix with pure gold to create the finest white gold. Like platinum, it will develop a hazy patina over time.

# Section 7—The Gold Alloys

# **Summary of Section Contents**

8-Karat Gold—A low-end alloy which cannot legally be called gold in the U.S.

10-Karat Gold—An alloy typically for low-end jewelry

12-Karat Gold—An overlay alloy

14-Karat Gold—Most popular alloy for mid-price-point jewelry

16-Karat Gold—Most commonly used as a dental alloy

18-Karat Gold—A higher grade that serves as the foundation of White Golds

20-Karat Gold—Old European alloy for high-end jewelry, still in use

21-Karat Gold—Commonly used for jewelry in the Middle East

22-Karat Gold—High end jewelry and bullion coins, "Indian Gold"

23-Karat Gold—Used for gold leaf and gilding

24-Karat Gold—Pure gold, fine gold



### **Composition:**

This low-grade Gold alloy cannot legally be called "Gold" in the United States. It is typically alloyed with some combination of copper and zinc. By definition, it is 33.3% gold by weight—8 parts gold, 16 parts base metals.



# **Applications:**

A low grade Gold alloy that is not considered Gold in the U.S. It's hard, but it can tarnish. It's light in color and considered a low-end alloy.

# **Testing with Nitric Acid Solution:**

A diluted form of nitric acid (40% concentration) readily attacks any base metals present and dissolves them completely. The diluted acid is used because this reaction occurs too fast to observe effectively with concentrated nitric acid. Streaks created on a test plate of a Gold sample that contains 8-Karat Gold will disappear quickly.

# The Chemistry:

The base metals are typically Copper and Zinc. These metals are highly reactive in nitric acid while the Gold is not.

Therefore, when nitric acid is applied to low-karat Gold alloys, the Gold itself is not really dissolving. Rather, the base metals are being oxidized and the Gold is being liberated as a fine dust that floats to the top of the acid puddle and is rinsed away. So, the lower the karat value, the higher the base metal value and the more reactive it is in nitric acid.

# **Composition:**

10-Karat Gold is typically alloyed with some combination of copper, silver, zinc, and nickel. By definition, it is 41.6% gold by weight—10 parts gold, 14 parts base metals.

In practice, Gold designated 10K contains 37.5 percent pure gold by volume and 62.5 percent other metals. Metal of less than 10K gold content cannot be sold as "gold" in the U.S. A typical 10K gold alloy contains 37.5 percent gold, 52 percent silver, 4.9 percent copper, 4.2 percent zinc and 1.4 percent nickel. "Rose" 10K gold contains a higher percentage of copper and slightly more gold, lending it a reddish cast.



# **Applications:**

The lowest common gold alloy is not considered gold in some places, as the content is less than 50% gold. It's hard, but it can tarnish a bit. It's lighter in color and considered a low-end alloy,

### **Testing with Nitric Acid Solution:**

A diluted form of nitric acid (40% concentration) readily attacks any base metals present and dissolves them completely. The diluted acid is used because this reaction occurs too fast to observe effectively with concentrated nitric acid. Streaks created on a test plate of a gold sample that contains 10-Karat gold will disappear.

### The Chemistry:

The base metals are typically copper and silver in most low-end jewelry. These metals are highly reactive in nitric acid while the gold is not.

Therefore, when nitric acid is applied to low-karat gold alloys, the gold itself is not really dissolving. Rather, the base metals are being oxidized and the gold is being liberated as a fine dust that floats to the top of the acid puddle and is rinsed away. So, the lower the karat value, the higher the base metal value and the more reactive it is in nitric acid.

In the case of copper, it is nonreactive in most acids (sulfuric, hydrochloric, phosphoric) but nitric acid is an oxidizer that drives an oxidation reaction. A dilute solution of nitric acid will oxidize the copper to copper nitrate coloring the solution blue.

If the base metal is silver, the reaction with nitric acid creates silver nitrate—a white milky color in solution.

# **Composition:**

12-Karat Gold is typically alloyed with some combination of silver and copper. To this basic alloy, zinc and silicon are often added to improve manufacturability through grain refinement, form filling of casting molds, and improving as-cast surface finishes. 12-Karat Gold is exactly 50% gold—12 parts gold, 12 parts base metals.



# **Applications:**

The strongest of the common gold alloys—half gold and equal parts silver and copper is very hard. It is not commonly used except as an overlay on gold filled jewelry.

# **Testing with Nitric Acid Solution:**

A diluted form of nitric acid (40% concentration) rapidly attacks any base metals present and dissolves them completely. Streaks created on a test plate of a gold sample that contains 12-Karat gold will disappear.

### The Chemistry:

The base metals are typically copper and silver in most low-end jewelry. These metals are highly reactive in nitric acid while the gold is not.

Therefore, when nitric acid is applied to low-karat gold alloys, the gold itself is not really dissolving. Rather, the base metals are being oxidized and the gold is being liberated as a fine dust that floats to the top of the acid puddle and is rinsed away. So, the lower the karat value, the higher the base metal value and the more reactive it is in nitric acid.

In the case of copper, it is nonreactive in most acids (sulfuric, hydrochloric, phos) but nitric acid is an oxidizer that drives an oxidation reaction. A dilute solution of nitric acid will oxidize the copper to copper nitrate coloring the solution blue.

If the base metal is silver, the reaction with nitric acid creates silver nitrate—a white milky color in solution.

### **Composition:**

14-Karat Gold is typically alloyed with some combination of silver and copper. To this basic alloy, zinc and silicon are often added to improve manufacturability through grain refinement, form filling of casting molds, and improving as-cast surface finishes. 14-Karat Gold is 58.3% gold by weight—14 parts gold, 10 parts base metals.



# **Applications:**

A popular alloy for most medium price point jewelry. It is hard enough to stand up to daily wear and minimize scratching while holding its shape.

# **Testing with Nitric Acid Solution:**

A diluted form of nitric acid (40% concentration) rapidly attacks any base metals present and dissolves them completely. Streaks created on a test plate of a gold sample that contains 14-Karat gold will disappear.

### The Chemistry:

The base metals are typically copper or brass (alloy of copper and zinc) in most jewelry, although silver has been used also. All of these metals are highly reactive in nitric acid while the gold is not.

Therefore, when nitric acid is applied to low-karat gold alloys, the gold itself is not really dissolving. Rather, the base metals are being oxidized and the gold is being liberated as a fine dust that floats to the top of the acid puddle and is rinsed away. So, the lower the karat value, the higher the base metal value and the more reactive it is in nitric acid.

In the case of copper, it is nonreactive in most acids (sulfuric, hydrochloric, phos) but nitric acid is an oxidizer that drives an oxidation reaction. A dilute solution of nitric acid will oxidize the copper to copper nitrate coloring the solution blue.

If the base metal is silver, the reaction with nitric acid creates silver nitrate—a white milky color in solution.

The zinc portion of the base metal will dissolve in the nitric acid to form zinc nitrate—a white milky color in solution.

# Alloy:

16-Karat Gold is typically alloyed with some combination of silver and copper. To this basic alloy, zinc and silicon are often added to improve manufacturability through grain refinement, form filling of casting molds, and improving as-cast surface finishes. 16-Karat Gold is 67.8% gold by weight—16 parts gold, 8 parts base metals.



# **Applications:**

Gold crowns, fillings and bridgework are usually made of 16-karat gold, an alloy that contains other metals such as silver, zinc and copper. This combination makes gold dental work soft enough to shape but hard enough to form a biting surface.

# **Testing with Nitric Acid Solution:**

A diluted form of nitric acid (40% concentration) rapidly attacks any base metals present and dissolves them completely. Streaks created on a test plate of a gold sample that contains 16-Karat gold will dissolve more slowly than in the case of the 14-Karat alloy, and they will not completely disappear.

# The Chemistry:

The base metals are typically copper and silver. Both of these metals are highly reactive in nitric acid while the gold is not.

If the base metal is silver, the reaction with nitric acid creates silver nitrate—a white milky color in solution.

# **Composition:**

This is the workhorse alloy for high-end jewelry and serves as the foundation for the White Gold alloys. 18-Karat Gold is typically alloyed with a combination of silver, and copper for the yellow Golds and either Platinum or Palladium for the White Golds. To this basic alloy, zinc and silicon are often added to improve manufacturability through grain refinement, form filling of casting molds, and improving as-cast surface finishes. 18-Karat Gold is 75% gold by weight—18 parts gold, 6 parts base metals.



### Variations:

18-Karat Gold can be alloyed in different ways resulting in different colors.

•	Red Gold:	75% Gold, 25% Copper
•	Rose Gold:	75% Gold, 22.25% Copper, 2.25% Silver
•	Pink Gold:	75%, 20% Copper, 5% Silver
•	White Gold:	75% Gold, 25% Platinum
•	White Gold:	75% Gold, 25% Palladium
•	White Gold:	75% Gold, 10% Palladium, 10% Nickel, 5% Zinc
•	Soft Green Gold:	75% Gold, 25% Silver
•	Light Green Gold:	75% Gold, 23% Copper, 2% Cadmium
•	Green Gold:	75% Gold, 20% Silver, 5% Copper
•	Deep Green Gold:	75% Gold, 15% Silver, 6% Copper, 4% Cadmium

# **Applications:**

18-Karat gold has been found to be the perfect balance between gold purity and strength for use in jewelry.

# **Testing with Acid Solutions:**

A gold alloy of 14 K or lower will dissolve when nitric acid is added. But when the karat moves to 18 or higher the nitric acid causes no visible reaction. Only a dilute form of Aqua Regia solution can dissolve the higher karats of gold.

# **Composition:**

20-Karat Gold is typically alloyed with a combination of silver, and copper. To this basic alloy, zinc and silicon are often added to improve manufacturability through grain refinement, form filling of casting molds, and improving as-cast surface finishes. 20-Karat Gold is 83.3% gold by weight—20 parts gold, 4 parts base metals. Silver typically comprises 10% of the alloy and copper at 7%.

The 20-Karat gold alloy is nearly pure gold. It is commonly available in Europe.



### **Applications:**

An old European alloy—not commonly used anymore but still appears in custom or limited-production high-end jewelry.

### **Testing with Acid Solutions:**

Nitric acid by itself will have no visible effect on 20-Karat Gold. Streaks created on a test plate of a gold sample that contains 20-Karat gold will not be affected by the application of concentrated nitric acid.

Conversely, 20-Karat Gold can effectively be dissolved using Aqua Regia solution.

### The Chemistry:

The application of Aqua Regia will completely dissolve a test streak. The gold, thus dissolved resides in solution in the test puddle. If this puddle is then transferred to a white spot test plate and Schwerter's solution is applied, a color change is expected indicating the specific base metal present.

# 21-Karat Gold Alloy ("Saudi Gold")

# **Composition:**

21-Karat Gold is typically alloyed with a combination of silver, and copper. To this basic alloy, zinc and silicon are often added to improve manufacturability through grain refinement, form filling of casting molds, and improving as-cast surface finishes. 21-Karat Gold is 87.5% gold by weight—21 parts gold, 3 parts base metals. Silver typically comprises 9% of the alloy and copper at 2-3%.

The 21-Karat gold alloy is nearly pure gold. It is commonly available in the Middle East. The value is usually the same as the market price.



# **Applications:**

Commonly used for jewelry in the Middle East-hence the nickname, "Saudi Gold."

#### **Testing with Acid Solutions:**

Nitric acid by itself will have no visible effect on 21-Karat Gold. Streaks created on a test plate of a gold sample that contains 21-Karat gold will not be affected by the application of concentrated nitric acid.

Conversely, 21-Karat Gold can effectively be dissolved using Aqua Regia solution.

#### The Chemistry:

The application of Aqua Regia will completely dissolve a test streak. The gold, thus dissolved resides in solution in the test puddle. If this puddle is then transferred to a white test plate and Schwerter's solution is applied, a color change is expected indicating the specific base metal present.

# **Composition:**

22-Karat Gold is typically alloyed with a combination of silver, and copper. To this basic alloy, zinc and silicon are often added to improve manufacturability through grain refinement, form filling of casting molds, and improving ascast surface finishes. 22-Karat Gold is 91.6% gold (by weight)—22 parts gold, 2 parts base metals. Silver typically comprises 5% of the alloy and copper at 3%.



#### **Applications:**

High end jewelry and bullion coins (e.g., American Gold Eagles and South African Krugerrands). Also referred to as "Indian" jewelry due to its popularity in India, Bangladesh.

### **Testing with Acid Solutions:**

Nitric acid by itself will have little effect on 22-Karat Gold. Streaks created on a test plate of a gold sample that contains 22-Karat gold will show very little apparent reaction.

# The Chemistry:

The application of Aqua Regia will completely dissolve a test streak. The gold, thus dissolved resides in solution in the test puddle. If this puddle is then transferred to a white test plate and Schwerter's solution is applied, there should be only a minor color change. The color change should indicate a predominance of silver.

# 23-Karat Gold

# **Composition:**

23-Karat Gold is as pure as gold gets for practical applications. 23-Karat Gold is typically alloyed with a predominance of silver with a little copper for hardness. 23-Karat Gold is 95.8% Gold by weight—23 parts Gold, 1 part base metals. Silver typically comprises 3% of the alloy and copper at 1%.



### **Applications:**

Rarely used for jewelry due to its lack of hardness. Mostly used for gold leaf and gilding applications.

#### **Testing with Acid Solutions:**

Nitric acid by itself will have no visible effect on 23-Karat Gold. Streaks created on a test plate of a gold sample that contains 23-Karat gold will not be affected by the application of concentrated nitric acid.

Conversely, 23-Karat Gold can effectively be dissolved using Aqua Regia solution.

### The Chemistry:

The application of Aqua Regia will completely dissolve a test streak. The gold, thus dissolved resides in solution in the test puddle. If this puddle is then transferred to a white test plate and Schwerter's solution is applied, there should be only a minor color change. The color change should indicate a predominance of silver.

# 24-Karat Gold

#### **Composition:**

24-Karat Gold is pure Gold. 24K gold is also called fine gold and it is greater than 99.7% pure gold. Proof gold is even finer, with over 99.95% purity, but it is only used for standardization purposes and is not used for practical jewelry. 24-Karat Gold is pure—there is no alloying with base metals.



#### **Applications:**

Rarely used for jewelry due to its lack of hardness. Mostly used for bullion coins (specifically Canadian Maple Leafs and Gold American Buffalo coins) or for plating over harder base metals to provide the ultimate in corrosion resistance or conductivity.

#### **Testing with Acid Solutions:**

Nitric acid by itself will have no visible effect on 24-Karat Gold. Streaks created on a test plate of a gold sample that contains 24-Karat gold will not be affected by the application of concentrated nitric acid.

Conversely, 24-Karat Gold can effectively be dissolved using Aqua Regia solution.

# The Chemistry:

The application of Aqua Regia will completely dissolve a test streak. The gold, thus dissolved resides in solution in the test puddle. If this puddle is then transferred to a white test plate or spot plate and Schwerter's solution is applied, there should be no color change. Any presence of base metals, thus indicating a lower Karat value, will result in a color change.

# Section 8—The Silver Alloys

# **Introduction:**

Fine Silver is 99.9% pure and is generally too soft for producing functional objects; therefore, the Silver is usually alloyed with Copper to give it strength while preserving the ductility and beauty of the precious metal. Other metals can replace the Copper, usually with the intent to improve various properties of the basic Sterling alloy such as reducing casting porosity, eliminating firescale, and increasing resistance to tarnish.



These replacement metals include Germanium, Zinc and Platinum, as well as a variety of other additives, including Silicon and Boron.



A number of alloys, such as Argentium Sterling Silver, have appeared in recent years, formulated to lessen firescale or to inhibit tarnish, and this has sparked heavy competition among the various manufacturers, who are rushing to make claims of having the best formulation. However, no one alloy has emerged to replace Copper as the industry standard, and alloy development is a very active area.

# Historical Development of Silver Jewelry Alloys:

Fine Silver alone is a very soft metal that can be easily bent. To strengthen fine Silver, metallurgists alloyed it with Copper. The alloy of 925 parts fine Silver with 75 parts Copper known as "Sterling Silver" was standardized throughout Europe in the early Renaissance. Its naturally white color and reasonable cost make Sterling the most popular metal on the market.

But Sterling Silver has its drawbacks. While Sterling has been known and used for centuries, tarnish and firescale (a blotchy purple-gray discoloration) have been the bane of jewelers and silversmiths for just as long. And, while Sterling Silver retains much of the softness of fine Silver, making it easy to work (malleable), the softness reduces its durability. Faceted gemstones, with their hard, sharp edges, are known to cut through Sterling Silver mountings. Metalsmiths developed tarnish removers and special polishing procedures to temporarily remove the discolorations in Sterling Silver, but a different white metal alloy was needed to address the durability question.

To resolve these problems, White Gold was developed in the mid-1800s as a response to the need for a more durable white jewelry metal. White Gold is an alloy of naturally-yellow Gold and other white metals, such as Zinc, Nickel, and Silver. White Gold has the benefits of durability and resistance to tarnish and firescale, but it is brittle and requires a plating of Platinum or Rhodium to look truly white. Once the plating wears off, allergic reactions may occur and a light, naturally yellow tint shows through. White Gold, in various reformulations, is marketed as an affordable alternative to Platinum. But, with its cost as high as that of yellow gold and its significantly reduced malleability, White Gold isn't the metal of choice for most artisans.



# Example of typical Sterling Silver wedding band

Platinum has been a known element since the time of the Egyptian pharaohs, but the technology needed to refine and work with it wasn't available until the Industrial Revolution.



Example of typical Platinum wedding band

A strong, naturally white, hypoallergenic metal that doesn't tarnish or firescale, Platinum has a dense molecular structure that offers high malleability—attributes that make Platinum a durable and versatile jewelry metal. The fine lacework Platinum filigree of the Edwardian period is a testament to Platinum's excellent malleability. However, Platinum's high melting temperature makes normal jewelry techniques such as casting and soldering difficult, while its rarity and weight make it cost-prohibitive to consumers and artisans alike.

Then Platinum/Sterling was developed. The Platinum is used to replace at least some of the copper present in a typical Sterling Silver alloy, which provides a greater light reflectivity (by refining the grain structure) and resistance to tarnish (thought to be caused by oxidation of copper) than standard Sterling Silver.



# Example of typical Platinum-Sterling wedding band

Platinum Sterling is a cheaper alternative to White Gold. It is also hard wearing and very white and so does not require Rhodium plating like white gold.

Tests performed by the American Assay and Gemological Office showed that the whiteness of Platinum-Sterling alloys exceeds that of both Sterling Silver and White Gold, and the new 3.5 percent Platinum Sterling displays six times more resistance to tarnishing than the standard Sterling alloy.

The composition of Platinum Sterling is now well-established with three alloys commercially available all containing standard 92.5% sterling silver and 1%, 3.5% or 5% platinum. A small amount of Gallium can also be added to the alloy to ease manufacturing.

# **Fine Silver**

# **Composition:**

Fine silver has a millesimal fineness of 999. Also called pure silver, or three nines fine, fine silver contains 99.9% silver, with the balance being trace amounts of impurities.



### **Applications:**

This grade of Silver is used to make bullion bars for international commodities trading and investment in Silver. In the modern world, fine Silver is understood to be too soft for general use.

### **Testing with Schwerter's Solution:**

The strategy here is simply to see if the metal, that is supposed to be pure, is contaminated with one or more of the possible base metals.

File a deep notch in the test piece and apply a drop of Schwerter's Solution in the notch. The color reaction of the solution will differ on various metals as follows:

- Silver, Pure— Bright Red
- Silver, Sterling, .925— Dark Red
- Silver, Coin Quality, .800— Brown
- Silver, .500— Green
- Platinum— No color change
- Palladium— No color change
- Copper— Brown
- Zinc— Brown
- Brass— Dark Brown
- Nickel— Blue
- Lead— Yellow
- Tin— Yellow

# **Sterling Silver**

# **Composition:**

Sterling Silver is an alloy of Silver containing 92.5% by weight of Silver and 7.5% by weight of other metals, usually Copper. The Sterling Silver standard has a minimum millesimal fineness of 925.



### The Chemistry:

Chemically, Silver is not very reactive—it does not react with oxygen or water at ordinary temperatures, so does not easily form a silver oxide. However, it is attacked by common components of atmospheric pollution: Silver Sulfide slowly appears as a black tarnish during exposure to airborne compounds of Sulfur (byproducts of the burning of petroleum fuels and some industrial processes), and low level ozone reacts to form Silver Oxide. As the purity of the Silver decreases, the problem of corrosion or tarnishing increases because other metals in the alloy, usually Copper, may react with oxygen in the air.

### **Testing with Schwerter's Solution:**

The strategy here is to confirm which of the possible base metals are present. If it is, in fact, Sterling Silver, it should contain a small percentage of copper. Alternatively, if it is one of the newer alloys such as Platinum Sterling, it will show no copper reaction.

File a deep notch in the test piece and apply a drop of Schwerter's Solution in the notch. The color reaction of the solution will differ on various metals as follows:

- Silver, Pure— Bright Red
- Silver, Sterling, .925— Dark Red
- Silver, Coin Quality, .800— Brown
- Silver, .500— Green
- Platinum— No color change
- Palladium— No color change
- Copper— Brown
- Zinc— Brown
- Brass— Dark Brown
- Nickel— Blue
- Lead— Yellow
- Tin— Yellow

# **Argentium Sterling Silver:**

Argentium Sterling Silver is a modern Sterling Silver alloy which modifies the traditional alloy (92.5% silver + 7.5% copper) by replacing some of the copper with the metalloid Germanium. As it retains the 92.5% silver content of the traditional alloy, it is still referred to as Sterling Silver. Argentium Silver is patented and trademarked by Argentium Silver Company, UK.





Argentium Silver is the result of research by Peter Johns at the Art and Design Research Institute (ADRI), School of Art & Design, Middlesex University. The project began in 1990 with research on the effects of Germanium additions to Silver alloys. Germanium was discovered to impart the following properties to Sterling Silver:

- Firescale elimination
- High tarnish resistance
- Precipitation hardening and simple heat-hardening properties
- Increased ductility
- Increased thermal and electrical resistance (making alloys suitable for welding and laser forming)
- Environmental advantages (associated with not having to remove or plate over firescale)

Many of these properties significantly affect the traditional methods of working Silver. For instance the absence of firescale eliminates tedious and time-consuming steps required by the Silver worker using traditional Sterling Silver. It also eliminates the need for plating the final product which is often done on manufactured items because of the problems introduced by firescale. Tarnish resistance is of significant importance to both Silver workers and the wearer of Silver jewelry.

# **Testing with Schwerter's Solution:**

Being nearly of the same composition as Sterling Silver, it should contain a small percentage of copper. Alternatively, if it is one of the newer alloys such as Platinum Sterling, it will show no copper reaction.

# **Britannia Silver:**

Britannia Silver is an alloy of Silver containing 95.84% Silver, with the balance usually Copper.

This standard was introduced in England by Act of Parliament in 1697 to replace Sterling Silver (92.5% Silver) as the obligatory standard for items of "wrought plate."



Britannia standard Silver was introduced by the English government as part of the great re-coinage scheme of William III from 1696, when attempts were made to limit the clipping and melting of Sterling Silver coinage. It was thought that by maintaining a higher standard for plate, there would be less incentive to put the newly issued Sterling coins in the melting pot.

Sterling Silver was approved again for use by silversmiths from 1 June 1720, and thereafter Britannia Silver has remained an optional standard for Silver assay in the United Kingdom and Ireland. Since the hallmarking changes of January 1, 1999, Britannia Silver has been denoted by the millesimal fineness hallmark 958, with the symbol of Britannia being applied optionally. The Silver bullion coins of the Royal Mint issued since 1998, known as "Britannias" for their reverse image, are minted in Britannia standard Silver.

Britannia Silver should not be confused with "Britannia metal", a pewter-like alloy containing no Silver.

# **Testing with Schwerter's Solution:**

As with Sterling Silver, the strategy here is to confirm which of the possible base metals are present. A small percentage of copper content is the expectation. Alternatively, if it is one of the newer alloys such as Platinum Sterling, it will show no copper reaction.

File a deep notch in the test piece and apply a drop of Schwerter's Solution in the notch. The color reaction of the solution will differ on various metals as follows:

•	Silver, Pure— Silver, Sterling, .925—	Bright Red Dark Red
•	Silver, Coin Quality, .800— Silver, .500—	Brown Green

- Platinum— No color change
- Palladium— No color change
- Copper— Brown
- Zinc— Brown
- Brass— Dark Brown
- Nickel— Blue
- Lead— Yellow
- Tin— Yellow

# Shibuichi:

Shibuichi is an alloy which can be patinated into a range of subtle muted shades of blue or green, through the use of Rokushō treatments. Its name means "one-fourth" in Japanese and indicates the standard formulation of one part silver to three parts copper, though this may be varied according to the desired effect. A 5% silver / 95% copper alloy is also marketed as "Shibuichi".



A wide range of colors can be achieved using the whole range of alloy compositions, even above 50% silver. 90% Copper and 10% Silver for a dark grey and down to 70% Copper and 30% Silver for lighter grays.

It is a common misconception that both Copper and Silver oxides form, but in fact a detailed study has shown that only Copper oxides are formed on the Copper rich regions of the material's microstructure, while the Silver rich regions are left largely untouched.

For most of its history, Shibuichi was mostly used to ornament various fittings for Katana until the Meiji reforms, when most sword makers began to make purely decorative objects instead. The material is often used in Mokumegane combinations. Similar alloys have been used elsewhere but the use of Shibuichi to achieve different colored patinas appears to have remained nearly unknown outside Japan, until recent interest from artisans in the West.

# German Silver:

German Silver (not to be confused with Nickel Silver, which is also referred to by this same term) has a millesimal fineness of 800. It is one of several Silver standards used in Germany, and has been in use since 1884. The alloy is 80% pure Silver and 20% Copper or other metals.



**Egyptian Silver:** Egyptian silver is identical to German silver, described above.

# **Platinum Sterling Silver:**

One of the most promising new metals is a Platinum-Sterling alloy that resists tarnish and firescale, is remarkably white, is very malleable, and is as durable as karated Gold.



Platinum Sterling is a registered trademark name of ABI Precious Metals, Inc. The trademark covers a range of alloys whose primary constituents are Platinum and Silver, primarily used in jewelry. The range of Platinum Sterling alloys was developed in 2003 by Marc Robinson, and its solder was created by Chuck Bennett.

American Bullion Inc. (ABI) Precious Metals, of Carson, California, created this new alloy and has developed three grades of Platinum Sterling. The grade depends on the percentage of Platinum in the alloy. Initial tests by the American Assay and Gemological Office state that the level of white color in the Platinum-Sterling alloys outshines that of both traditional Sterling and White Gold.

In metallurgical laboratory tests, the new 3.5 percent Platinum-Sterling ranked six times more resistant to tarnish than the traditional Sterling Silver alloy.

### Metalsmithing techniques:

Platinum-Sterling has been tested with many mainstream metalsmithing processes and has performed with results similar to those of 14k yellow Gold. While test versions of Platinum-Sterling solders are available, American Bullion Inc. (ABI) suggests using 10k white gold solders to match the color and tarnish resistance of platinum sterling. When used in casting and in fabrication, the Platinum-Sterling showed no discernible firescale. Techniques such as milling, engraving, stone setting, laser welding, and electroplating all produced excellent results.

While Platinum-Sterling's rigidity would normally indicate a loss of malleability, this is not the case with this alloy. Ingots 6.5mm (1/4-in.) thick of the 3.5 percent Platinum Sterling have been milled to 28 gauge (0.32mm) without annealing and have shown no cracking or splitting at the edges. Platinum-Sterling will work-harden when pushed to deform or reduce in high percentages. For hydraulic-press, matrix-die, or roll-printing applications, annealing of Platinum-Sterling is recommended in an oven set to 700C (1292F) for 20 minutes, followed by immediate cold-water quenching to gain the greatest malleability. Torch-annealing smaller pieces of platinum sterling to a pale rose-colored glow, then quenching them in cold water and briefly soaking them in pickle, resulted in adequately annealed metal for fabrication, with a clean surface exhibiting no firescale or oxidation.

Platinum's greater specific gravity, pieces made of Platinum-Sterling alloys weigh slightly more than those made of traditional Sterling in the same size and gauge. Platinum-Sterling also has increased rigidity; in the same gauge, Platinum-Sterling is less deformable than regular Sterling and actually shares more malleability factors with 14k Yellow Gold than with Silver. Increased rigidity is also responsible for the metal's greater durability when used in detailed work and gemstone setting.

Cost is another point of difference; Platinum Sterling hits the middle ground, at a cost of approximately ten times that of traditional Sterling, yet still at roughly a quarter of the price per troy ounce of 14k Gold.

Hallmark stamping of finished Platinum-Sterling pieces may be the most difficult part of working with this new alloy. According to current Federal Trade Commission (FTC) guidelines, only objects that contain 950 parts per thousand of pure Platinum alloyed with other Platinum group metals (PGMs) may be stamped Platinum (Pt, Plat.). There are currently no guidelines for legally identifying Platinum-Sterling as such, and this issue remains under debate in the manufacturing jewelry industry. At the time of publication, the Platinum Guild International (PGI), the public relations company formed by Platinum mining concerns and manufacturers, is lobbying for Platinum in jewelry to remain pure, regardless of the benefits that other alloys may bring to the marketplace.

Fortunately, while there are regulations requiring a minimum of disclosure, there are no regulations restricting disclosure of an alloy's content. Therefore, many metalsmiths now working with Platinum-Sterling are stamping their work with the traditional "925" or "Sterling" stamps and then adding the "3.5%" or "5% Pt" stamp to indicate the Platinum content.

# **Mexican Silver:**

Mexican Silver has a millesimal fineness of 950. The Mexican Silver alloy is 95% pure Silver and 5 per cent Copper or other metals. From 1930 to 1945, Mexican Silver had a millesimal fineness of 980.



# **Testing with Schwerter's Solution:**

As with Sterling Silver, the strategy here is to confirm which of the possible base metals are present. A small percentage of copper content is the expectation. Alternatively, if it is one of the newer alloys such as Platinum Sterling, it will show no copper reaction.

File a deep notch in the test piece and apply a drop of Schwerter's Solution in the notch. The color reaction of the solution will differ on various metals as follows:

•	Silver, Pure—	Bright Red
•	Silver, Sterling, .925-	Dark Red
•	Silver, Coin Quality, .800-	Brown
•	Silver, .500—	Green
•	Platinum— No color change	:

- Palladium-No color change ٠
- Copper-Brown •
- Zinc-Brown •
- Dark Brown Brass-.
- Nickel-Blue •
- Yellow • Lead-
- Tin— Yellow •
# **Coin Silver:**

Coin Silver has a millesimal fineness of 900. The term "Coin Silver" was derived from the fact that much of it was made from melting down Silver coins.

It is important here to note that there are differences between the coin Silver standard and the coin Silver alloy, as actually used in making Silver objects. The coin Silver standard in the United States was 90% Silver and 10% Copper, as dictated by US FTC guidelines.

However, in silversmithing, coins could come from other nations besides the United States, and thus coin Silver objects could vary from 750 millesimal fineness (75% Silver) to 900 (90% Silver).

Coins were used as a source of Silver in the US until 1868, shortly after the discovery of the Comstock silver lodes in Nevada, which provided a significant source of Silver. Around this time the Sterling standard was adopted by the American Silver industry.



## **Testing with Schwerter's Solution:**

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As with Sterling Silver, the strategy here is to confirm which of the possible base metals are present. A small percentage of copper content is the expectation. Alternatively, if it is one of the newer alloys such as Platinum Sterling, it will show no copper reaction.

File a deep notch in the test piece and apply a drop of Schwerter's Solution in the notch. The color reaction of the solution will differ on various metals as follows:

- Silver, Pure-Bright Red •
- Silver, Sterling, .925-•
  - Dark Red Silver, Coin Quality, .800-
  - Brown Silver, .500-Green
- Platinum— No color change •
- No color change Palladium-•
- Copper-Brown •
- Zinc-Brown
- Brass-Dark Brown
- Nickel-Blue •
- Lead— Yellow •
- Tin— Yellow

# **Scandinavian Silver:**

Scandinavian silver has a millesimal fineness of 830. The Scandinavian silver alloy contains 83% pure silver and 17% copper or other metals.



# **Testing with Schwerter's Solution:**

As with Sterling Silver, the strategy here is to confirm which of the possible base metals are present. A small percentage of copper content is the expectation. Alternatively, if it is one of the newer alloys such as Platinum Sterling, it will show no copper reaction.

File a deep notch in the test piece and apply a drop of Schwerter's Solution in the notch. The color reaction of the solution will differ on various metals as follows:

_	Cileren Deres	Duinht	D . 1
•	Silver, Pure—	Bright	Rea

- Silver, Sterling, .925— Dark Red
- Silver, Coin Quality, .800— Brown
- Silver, .500— Green
- Platinum— No color change
- Palladium— No color change
- Copper— Brown
- Zinc— Brown
- Brass— Dark Brown
- Nickel— Blue
- Lead— Yellow
- Tin— Yellow

# **Section 9—The Platinum Group Metals**

Palladium, Platinum, Rhodium, Ruthenium, Iridium and Osmium form a group of elements referred to as the Platinum group metals (PGMs). These have similar chemical properties, but Palladium has the lowest melting point and is the least dense of them.

The unique properties of Palladium and other Platinum group metals (PGMs) account for their widespread use—a quarter of all goods manufactured today either contain PGMs or have a significant part in their manufacturing process played by PGMs.

The significance of the PGMs to you as a metals buyer or seller is that the current outlook for these metals over the next 10 years seems most likely to be one of historically high prices. This outlook is supported by expectations of increased fabrication demand, constrained supplies, and rising investment demand as a result of these positive supply and demand fundamentals.



South Africa is the largest producer of Platinum and Rhodium and the second largest producer of Palladium. Given the high degree of production concentration from South Africa, supply of these metals is very sensitive to issues related to mining in this country. Shortfalls of resources such as electricity, skilled labor, and water, are expected to negatively affect supply from South Africa. Importantly, many of these issues are largely unresponsive to the metal price levels. None of these problems are expected to be resolved soon and are expected to add to production costs, which should be supportive of the current price trends.

The PGMs are largely produced as by-products in Russia and North America, with the exception of North American Palladium and Stillwater Mining, and therefore supply from these regions is largely influenced by the production of the primary metals, typically Nickel and Copper.

A growing global auto population, tightening emissions standards, and the lack of commercially viable substitutes for PGMs in auto catalysts are expected to bode well for the fabrication demand of these metals going forward. Auto catalysts are the largest source of demand for the PGMs, which has resulted in growing concerns over the effects of new technologies such as electric vehicles and nanotechnology. Demand from the electronics sector and other industrial sectors is expected to grow at a healthy pace for the foreseeable future.

China is the largest consumer of Platinum jewelry. Populations in newly industrialized countries such as China are becoming more affluent and thus driving the demand upwards.

While investment demand has always played an important role in influencing the prices of PGMs, the compelling fundamentals resulting from constrained supplies and rising fabrication demand are expected to increase investor interest in these metals, adding to the upward trend in prices. In addition to hedge funds and wealthy individuals who have traditionally invested in these strategic metals, the launch of physically backed Platinum and Palladium ETFs (exchange traded funds) in 2007 has accentuated the role of this particular portion of the PGM market.

There are no futures markets for these metals, so that the only way to make money directly from exotic PGMs is to buy them and wait for the price to rise. But this is not a bad strategy given the current economic world outlook, and given that PGMs are authentically rare, and present in only tiny amounts in the earth's crust. Even Platinum ore contains only a few parts per million (at most) of Platinum, and much smaller concentrations of the exotic PGMs.

The exotic PGMs are not mined for themselves, but are produced entirely as a byproduct of Platinum and Nickel mining. This means that supplies of these metals do not respond to changes in demand. If a particular metal is in short supply, its price will rise dramatically, and fall just as dramatically if demand slackens. For example, Rhodium currently is trading at about \$1200/Troy oz.—about three times what it was trading for a few years ago. The price of Ruthenium also has increased more than three fold over the past few years, and over five fold since its historic low.



# Section 10—The Platinum Jewelry Alloys

# The Platinum Alloys for Jewelry:

In its pure state, Platinum is quite soft, so it is necessary to alloy it, taking just 50 parts per thousand (5%) of an alloy metal to give Platinum the hardness, the fluidity or the work characteristic to do just about any task.



Combining alloying elements creates "purpose alloys" which can further enhance particular properties or functions; e.g. a combination of 3% Cobalt and either 2 or 7% Palladium may be used to combine good casting properties with a particular polishing ability and color.

In the United States of America, to be described as "Platinum", an item must be comprised of a fineness of no less than 95% Platinum and 5% PGM's. Above 95%, the item can be stamped "PLATINUM" or "PLAT." For alloys with 75-95% Platinum, the other PGM's that are present must also be stamped; e.g. IRIDPLAT for 10% Iridium alloy.



Only the USA allows "Karat Platinum" alloys. The most common alloys in America are 95% Platinum with 5% Ruthenium or 5% Cobalt and 90% Platinum with 10% Iridium.

Platinum is among the finest, purest and rarest precious metals on earth, and has an understated elegance that appeals to both men and women. One of the strongest and most enduring metals in the world, it is also one of the heaviest, weighing 60% more than Karat Gold. It is ideal for jewelry worn every day because it exhibits little material loss, even after prolonged wear.

In the U.S., Platinum jewelry generally contains 90% or 95% pure Platinum. By comparison, 18-Karat Gold is 75% pure Gold and 14-Karat Gold is 58% pure Gold. Platinum is hypoallergenic and resists tarnish.

One of the rarest precious metals on earth, platinum is found in only a few locations in the world. To produce a single ounce of Platinum, a total of 10 tons of ore must be mined. In comparison, only three tons of ore are required to produce one ounce of Gold. Rarity lends Platinum its cachet.

Platinum's rich, white luster perfectly complements diamonds and other precious gems. Its neutral color enhances a stone's brilliance and depth.

Platinum jewelry appeals to many people today because of its subtle beauty and elegant understatement. Many Platinum jewelry designs are accented with 18-Karat gold, creating a sophisticated, versatile and fashionable look.

Platinum has a rich and noble history. It was first used by the ancient Egyptians about three thousand years ago. Eight hundred years later, the South American Incas worked with platinum. The first platinum jewelry in Europe appeared around the year 1780, at the court of Louis XVI of France.

It may surprise you that, although Platinum has been around for centuries, it has only been used to fashion jewelry for less than two centuries. It is both an ancient and a young metal.

Platinum is hypoallergenic, resists tarnish, is one of the strongest precious metals in the world and is extremely durable.

Signs of wear, including scratches, will inevitably appear in all precious metals, even with Platinum. Due to platinum's amazing durability and strength, however, there is little or no material loss when it is scratched.

#### **Catalysis:**

The most common use of Platinum is as a catalyst in chemical reactions, many times as Platinum black. It has been employed in this application since the early 19th century, when Platinum powder was used to catalyze the ignition of hydrogen. Its most important application is in automobiles as a catalytic converter, which allows the complete combustion of low concentrations of unburned hydrocarbons from the exhaust into carbon dioxide and water vapor. Platinum is also used in the petroleum industry as a catalyst in a number of separate processes, but especially in catalytic reforming of straight run naphthas into higher-octane gasoline which becomes rich in aromatic compounds.

Platinum metal also strongly catalyzes the decomposition of hydrogen peroxide into water (in the form of flashing into steam) and oxygen gas—a phenomenon useful for rocket motors.

# **Fine Platinum**

## **Composition:**

Fine platinum is typically 99.997% pure platinum with minor trace contaminants.



#### **Applications:**

Pure Platinum, as with pure Gold, is too soft for practical jewelry applications. It is typically used in bullion coins, ingots or bars and also for use in catalysts for its unique ability to advance chemical reactions.

#### **Testing For the Purity of Platinum:**

Given that it has already been determined that a given sample is, in fact, comprised of Platinum, the process is then to confirm there is no presence of any base metals. Thus, the process is to see if you can get some positive test result that is inconsistent with pure Platinum.

## Acid Testing:

Both Nickel and Silver are acted upon promptly by nitric acid. But Platinum is not. Aqua Regia at room temperature will not touch Platinum but you now know it will quickly dissolve pure gold, white gold and all of the associated base metals. Aqua Regia, when warmed, will however dissolve Platinum and anything else it may contain.

If you suspect that your sample may contain both Nickel and Palladium, and is therefore not pure Platinum, proceed to the DMG test.

First make the streak on the spot plate and get it into solution with aqua regia. Then add DMG Solution. If Palladium is present you will see the copious precipitate, canary yellow in color. Now add enough ammonia to make the mixture smell faintly. If Nickel is there, you will at once see the beautiful bright red—all in one cavity of your spot plate.

Obviously, if the sample is, in fact, pure Platinum, there will be no color reaction or precipitates.

# 950 Platinum—50 Ruthenium

#### **Composition:**

950 platinum with 50 parts per thousand of Ruthenium. This Pt/Ru alloy has a Vickers hardness of 130. When it is cold hammered, or die struck, the hardness increases to 210. It melts at  $1795^{\circ}C - 1780^{\circ}C$  and is widely used in the US, Europe, & Hong Kong.



#### **Applications:**

This is the preferred jewelry alloy according to the Platinum Guild. The mix creates a good alloy for the making of tubing, which is then sliced off and machined or die struck.

#### **Chemistry:**

Although the first Platinum processing techniques date back to Ancient Egypt (700 BC), it wasn't widely used until the 18th century. From 1901-1940, Platinum was the metal of choice until World War II. Due to governmental needs, Platinum was restricted from use in jewelry, and White Gold became the new white metal of choice. By the late 80's, after its removal from the restricted metals list, Platinum began to regain popularity in fine jewelry.

The highest level of purity available in Platinum bands is 95% Platinum and 5% Ruthenium. This particular combination is generally referred to as PLAT or PT950. This indicates the level of purity as required by the FTC ("Plat." or "Pt." for Platinum & "950" for the parts per thousand). The addition of Ruthenium also makes it more durable than rings made with Iridium or Cobalt.

## Acid Testing:

The process here is to assure there is no presence of any of the common base metals just as was done with pure Platinum. As before, we can enlist the use of the DMG solution to assure there is no presence of Nickel or Palladium.

First make the streak on the spot plate and get it into solution with aqua regia. Then add DMG Solution. If Palladium is present you will see the copious precipitate, canary yellow in color. Now add enough ammonia to make the mixture smell faintly. If Nickel is there, you will at once see the beautiful bright red—all in one cavity of your spot plate.

Obviously, if the sample is, in fact, either pure Platinum, or one in which it is alloyed with Ruthenium, there will be no color reaction or precipitates.

# 950 Platinum—50 Cobalt

#### **Composition:**

Pt/Co has a Vickers hardness of 135, and can be hardened through cold hammering up to 270. It is slightly ferromagnetic and has a melting range of  $1770^{\circ}C - 1680^{\circ}C$ .



#### **Applications:**

Creates a good flowing alloy best suited for casting. This alloy is still used in the US, Europe, & Hong Kong.

Platinum cobalt alloy has been found by some jewelers to be the strongest alloy to hold your diamond securely and does not tarnish or lose its shine with time.

#### Analysis:

Once again, by the process of elimination, this alloy can be identified by differentiating it from the others. As with the pure Platinum or Platinum/Palladium/Nickel testing, the presence or lack of these elements can be confirmed. Then an inspection using a rare earth magnet can establish the presence of Cobalt.

# 950 Platinum—50 Iridium

### **Composition:**

This system has a Vickers hardness of 80 and that can lead to castings that are quite soft. As a fabrication alloy, however 950/50 Pt/Ir can be made reasonably hard through cold-working. It is still used in Germany and Japan for safety catches and pins.



Platinum–Iridium alloy is used for jewelry and surgical pins. A readily worked alloy, Platinum–Iridium is much harder, stiffer, and more resistant to chemicals than pure Platinum, which is relatively soft. Platinum–Iridium is also very resistant to high-temperature electric sparks and is widely used for electrical contacts and electrodes.

#### Analysis:

Once again, by the process of elimination, this alloy can be identified by differentiating it from the others. As with the pure Platinum or Platinum/Palladium/Nickel testing, the presence or lack of these elements can be confirmed. Then an inspection using a rare earth magnet can establish the presence or lack of Cobalt.

# 900 Platinum—100 Iridium

#### **Composition:**

This alloy has a melting range of  $1800^{\circ}$ C –  $1780^{\circ}$ C with a Vickers hardness of 110.



#### **Applications:**

An American favorite for the hand fabrication of jewelry due to its increased hardness along with malleability. The former international standard for the meter of length and the ones still in use for the kilogram of mass were constructed from the alloy containing 90 percent Platinum and 10 percent Iridium.

#### Analysis:

Once again, by the process of elimination, this alloy can be identified by differentiating it from the others. As with the pure Platinum or Platinum/Palladium/Nickel testing, the presence or lack of these elements can be confirmed. Then an inspection using a rare earth magnet can establish the presence or lack of Cobalt.

# Section 11—Palladium



# **Introduction:**

Palladium is a chemical element with the chemical symbol **Pd** and an atomic number of 46. It is a rare and lustrous silvery-white metal discovered in 1803 by William Hyde Wollaston. He named it after the asteroid Pallas, which was itself named after the epithet of the Greek goddess Athena, acquired by her when she slew Pallas.

Over half of the supply of Palladium, along with its Platinum cousin, goes into catalytic converters, which convert up to 90% of harmful gases from auto exhaust (hydrocarbons, carbon monoxide, and nitrogen dioxide) into less-harmful substances (nitrogen, carbon dioxide and water vapor).

Palladium is also used in electronics, dentistry, medicine, hydrogen purification, chemical applications, and groundwater treatment. Palladium plays a key role in the technology used for fuel cells, which combine hydrogen and oxygen to produce electricity, heat, and water.

Palladium is a soft silver-white metal that resembles Platinum. It is the least dense and has the lowest melting point of the Platinum group metals. It is soft and ductile when annealed and greatly increases its strength and hardness when it is cold-worked.



Ore deposits of Palladium and other PGMs are rare, and the most extensive deposits have been found in the Norite belt of the Bushveld Igneous Complex covering the Transvaal Basin in South Africa, the Stillwater Complex in Montana, United States, the Thunder Bay District of Ontario, Canada, and the Norilsk Complex in Russia. Recycling is also a source of palladium, mostly from scrapped catalytic converters. The numerous applications and limited supply sources of palladium result in the metal attracting considerable investment interest.

#### **Chemistry:**

Palladium dissolves slowly in sulfuric, nitric and hydrochloric acids. It does, however dissolve quickly and effectively in room-temperature aqua regia. This metal also does not react with oxygen at normal temperatures (and thus does not tarnish in air). Palladium heated to 800°C will produce a layer of Palladium (II) oxide (PdO). It lightly tarnishes in a moist atmosphere containing sulfur.

The largest use of Palladium today is in catalytic converters. Palladium is also used in jewelry, in dentistry, watch making, in blood sugar test strips, in aircraft spark plugs and in the production of surgical instruments and electrical contacts. Palladium is also used to make professional transverse flutes. As a commodity, palladium bullion has ISO currency codes of XPD and 964. Palladium is one of only four metals to have such codes, the others being Gold, Silver and Platinum.

#### Catalysis

When it is finely divided, such as in Palladium on carbon, Palladium forms a versatile catalyst and speeds up hydrogenation and dehydrogenation reactions, as well as in petroleum cracking. A large number of carbon-carbon bond forming reactions in organic chemistry (such as the Heck and Suzuki coupling) are facilitated by catalysis with Palladium compounds. (see Palladium Compounds and palladium-catalyzed coupling reactions). In addition, Palladium, when dispersed on conductive materials, proves to be an excellent electrocatalyst for oxidation of primary alcohols in alkaline media.

#### Electronics

The second-biggest application of Palladium in electronics is in the manufacture of multilayer ceramic capacitors, in which Palladium (and Palladium-Silver alloys) are used as electrodes. Palladium (sometimes alloyed with nickel) is used in connector platings in consumer electronics.

It is also used in plating of electronic components and in soldering materials. The electronic sector consumed 1.07 million troy ounces (33.2 tonnes) of palladium in 2006, according to a Johnson Matthey report.

#### Technology

Hydrogen easily diffuses through heated Palladium; thus, it provides a means of purifying the gas. Membrane reactors with Pd membranes are therefore used for the production of high purity hydrogen. Palladium is a part of the Palladium-hydrogen electrode in electrochemical studies. Palladium(II) chloride can oxidize large amounts of carbon monoxide gas, and is used in carbon monoxide detectors.

#### Hydrogen storage

Palladium readily absorbs hydrogen at room temperatures forming Palladium hydride. While this property is common to many transition metals, Palladium is unique by the high absorption capacity and by that it does not lose its ductility until high x values. This property has been investigated for designing an efficient, yet inexpensive hydrogen storage material (Palladium itself is prohibitively expensive for this purpose).

## Jewelry

Palladium itself has been used as a precious metal in jewelry since 1939, as an alternative to Platinum for making White Gold. This use resulted from the naturally white color of palladium, which required no rhodium plating. Palladium is proportionally much lighter than Platinum. Similar to Gold, Palladium can be beaten into a thin leaf form as thin as 100 nm (1/250,000 in). Unlike Platinum, Palladium may discolor upon heating to above 400 °C (752 °F); it is relatively brittle and reacts with strong acids such as nitric acid.

Palladium is one of the three most popular metals used to make White Gold alloys (Nickel and Silver are the most common). Palladium-Gold is a more expensive alloy than Nickel-Gold, but seldom causes allergic reactions.

When Platinum was declared a strategic government resource during World War II, many jewelry bands were made out of Palladium. As recently as September 2001, Palladium was more expensive than Platinum and rarely used in jewelry also due to the technical obstacle of casting. However, the casting problem has been resolved and its use in jewelry has increased because of a large spike in the price of Platinum and a drop in the price of Palladium.

Prior to 2004, the principal use of Palladium in jewelry was the manufacture of white gold. In early 2004, when gold and Platinum prices rose steeply, China began fabricating significant volumes of Palladium jewelry and used 37 tons of Palladium for this purpose in 2005. Changes of the relative price between Palladium and Platinum after 2008 lowered demand for Palladium again.

In January 2010, hallmarks for Palladium were introduced by assay offices in the United Kingdom, and it became a legal requirement to hallmark all articles of jewelry described as being wholly or partly made of Palladium. Articles can be marked as containing a minimum of either 500, 950 or 999 parts per thousand of Palladium.

Palladium is the "newest" white metal to make a splash among jewelry makers. A Platinum group metal that's not actually new, Palladium shares many of Platinum's rich benefits at more affordable prices. Its qualities make it a favorite metal for many different styles of jewelry.



Palladium, like Platinum, is a very pure metal. Look for 950 Palladium, which means that the metal used is 95% pure, and is usually mixed with 5% Ruthenium. Sometimes jewelers use a 90% Palladium/10% Iridium combination. Both Ruthenium and Iridium, like Palladium, are among the group of metals related to Platinum.

#### The Look:

Palladium has garnered much attention from jewelers since it offers many of the benefits of Platinum bright white color, purity, and strength—at a more affordable price. Jewelry designers are taking advantage of Palladium's strong, light characteristics and creating new white-metal jewelry that is solid and bold but affordable.

#### Advantages and Disadvantages:

Palladium does not require plating to maintain its lustrous white color, and it is hypoallergenic. It will not tarnish. However, Palladium is neither as rare nor as heavy as Platinum.

#### **Precautions:**

As a Platinum-group metal, the bulk material is quite inert. But finely divided Palladium metal can be pyrophoric (i.e. it can self-ignite in the presence of oxygen). Although contact dermatitis has been reported, the amount of data on the effects of exposure to Palladium is limited. It has been shown that people with an allergic reaction to Palladium also react to Nickel.

#### Analysis:

Recall the ability of DMG to selectively detect the presence of both Palladium and Nickel in the same sample on your spot plate.

Suppose you have a sample (scrap jewelry or industrial waste) that you suspect may contain Palladium. As before, make the streak on the spot plate and get it into solution with aqua regia. Then add DMG. If Palladium is present you will see the copious precipitate, canary yellow in color.

Now add enough ammonia to raise the pH into the alkaline range—making the mixture smell faintly. If Nickel is there, you will at once see the beautiful bright red—all in one cavity of your spot plate.

# Section 12—Rhodium

Rhodium is a chemical element that is a rare, silvery-white, hard, and chemically inert transition metal and a member of the Platinum group. Naturally occurring Rhodium is usually found as the free metal, alloyed with similar metals. It is one of the rarest precious metals.



Rhodium is a so-called noble metal, resistant to corrosion, found in Platinum or Nickel ores together with the other members of the Platinum group metals. It was discovered in 1803 by William Hyde Wollaston in one such ore, and named for the rose color of one of its chlorine compounds, produced after it reacted with the powerful acid mixture aqua regia.



The element's major use (more that 80% of world Rhodium production) is as one of the catalysts in the three-way catalytic converters in automobiles. Because Rhodium metal is inert against corrosion and most aggressive chemicals, and because of its rarity, Rhodium is usually alloyed with Platinum or Palladium and applied in high-temperature and corrosion-resistive coatings. White gold is often plated with a thin Rhodium layer to improve its optical impression while Sterling Silver is often Rhodium plated for tarnish resistance.

Rhodium is a hard, silvery, durable metal that has a high reflectance. Rhodium metal does not normally form an oxide, even when heated. Oxygen is absorbed from the atmosphere only at the melting point of Rhodium, but is released on solidification. Rhodium has both a higher melting point and lower density

than Platinum. It is not attacked by most acids—it is completely insoluble in nitric acid and dissolves only slightly in room temperature aqua regia.

Rhodium is used as an alloying agent for hardening and improving the corrosion resistance of Platinum and Palladium. These alloys are used in furnace windings, bushings for glass fiber production, thermocouple elements, electrodes for aircraft spark plugs, and laboratory crucibles.

Rhodium is a highly reflective white metal. It is commonly known as the most expensive metal on earth. This extremely hard, durable, and beautiful metal is often used to plate optical instruments, but now the benefits of this unique metal are being used in the jewelry industry.

Rhodium is the finish of choice for top end fine jewelry. Most high end White Gold and Platinum jewelry seen in boutiques are plated with Rhodium. This is because Platinum and White Gold by themselves, while beautiful, over time the finish can be easily scratched and become very dull.

This is particularly true for White Gold because high karat Gold is often times very soft. Rhodium is an extremely hard metal which is rated a full 6.0 on the Mohs hardness scale. When Platinum and White Gold are finished with a Rhodium plate, an invisible shield is created. The metal bonds very well and doesn't quickly rub off like one would expect from most other plating materials. This invisible shield gives years of scratch resistant enjoyment.

In addition to adding a protective layer, the Rhodium finish beautifies the piece of jewelry as well. Rhodium is highly reflective and it has a gorgeous deep luster that is a bit darker than White Gold, which is just a plain bright white finish. The deep dark luster combined with the high reflection produces a truly unique finish that differentiates the high end products from what can be easily mistaken as stainless steel or silver.

Sterling Silver products are also coated with Rhodium, just like the top end White Gold and Platinum jewelry. This is done to give the same benefits of great looks and protection. Without the Rhodium coating, Sterling Silver jewelry tarnishes rather quickly due to the Copper content. Sterling Silver jewelry is known to scratch, lose its luster and tarnish. All of these problems are solved when the Rhodium coat is applied and the finish is instantly transformed to the exact same finish found in jewelry costing one hundred times more. Rhodium coated products all look the same, regardless of what metal is underneath. Therefore, Rhodium coated Brass or Sterling Silver products will look exactly like Rhodium coated White Gold or Platinum products.

#### **Acid Detection:**

Rhodium is the only one of the Platinum Group Metals that is not attacked by any of the acids, including hot aqua regia.

The detection of palladium, platinum and rhodium with *p*-nitrosodiphenylamine

# Section 13—Osmium

Osmium is a chemical element with the symbol Os and atomic number 76. It is a hard, brittle, blue-gray or blue-black transition metal in the Platinum family and is the densest naturally occurring element, with a density of 22.59 g/cm3 (slightly greater than that of Iridium and twice that of Lead). It is found in nature as an alloy, mostly in Platinum ores; its alloys with Platinum, Iridium, and other Platinum group metals are employed in fountain pen tips, electrical contacts, and other applications where extreme durability and hardness are needed.



Because of the volatility and extreme toxicity of its oxide, osmium is rarely used in its pure state, and is instead often alloyed with other metals. Those alloys are utilized in high-wear applications. Osmium alloys such as Osmiridium are very hard and, along with other Platinum group metals, are used in the tips of fountain pens, instrument pivots, and electrical contacts, as they can resist wear from frequent operation.

An alloy of 90% Platinum and 10% Osmium is used in surgical implants such as pacemakers and replacement of pulmonary valves.

The metal is used in a few alloys and in industry as a catalyst. At one time it would be encountered in the nibs of high-quality fountain pens, compass needles, and clock bearings—applications that harness its extreme hardness and corrosion resistance.

Like Palladium, powdered Osmium effectively absorbs hydrogen atoms. This could make Osmium a potential candidate for a metal hydride battery electrode. However, Osmium is expensive and would react with potassium hydroxide, the most common battery electrolyte.

Osmium has high reflectivity in the ultraviolet range of the electromagnetic spectrum; for example, at 600 angstroms Osmium has a reflectivity twice that of Gold. This high reflectivity is desirable in space-based UV spectrometers which have reduced mirror sizes due to space limitations. Osmium-coated mirrors were flown in several space missions aboard the Space Shuttle, but it soon became clear that the oxygen radicals in the low earth orbit are abundant enough to significantly deteriorate the Osmium layer.

#### Uses of Osmium:

Osmium is principally used alloyed with other metals in the Platinum group to produce very hard alloys. An alloy of 90% Platinum and 10% Osmium is used in surgical implants such as pacemakers and replacement heart valves.

#### **Mechanical Properties:**

Osmium is paramagnetic—that is, it will be attracted to a strong magnet but will not retain its own magnetism.

# Section 14—Ruthenium

Ruthenium is a chemical element with symbol Ru and atomic number 44. It is a rare transition metal belonging to the Platinum group of the periodic table. Like the other metals of the Platinum group, Ruthenium is inert to most chemicals.



The Baltic German scientist Karl Ernst Claus discovered the element in 1844 and named it after Ruthenia, the Latin word for Rus' (ancient Russia). Ruthenium usually occurs as a minor component of Platinum ores and its annual production is only about 20 tons.

Most Ruthenium is used for wear-resistant electrical contacts and the production of thick-film resistors. A minor application of Ruthenium is its use in some Platinum jewelry alloys.

Fission products of Uranium-235 contain significant amounts of Ruthenium and the lighter Platinum group metals and therefore used nuclear fuel might be a possible source of Ruthenium. The complicated extraction is expensive and the radioactive isotopes of Ruthenium that are present would make storage for several half-lives of the decaying isotopes necessary. This makes this source of Ruthenium unattractive and no large-scale extraction has been started.

Because of its ability to harden Platinum and Palladium, Ruthenium is used in Platinum and Palladium alloys to make wear-resistant electrical contacts. In this application, only thin plated films are used to achieve the necessary wear-resistance. Because of its lower cost and similar properties compared to Rhodium, the use as a plating material for electric contacts is one of the major applications. The thin coatings are either applied by electroplating or sputtering.

#### **Mechanical Properties:**

Ruthenium is paramagnetic—that is, it will be attracted to a strong magnet but will not retain its own magnetism.

# Section 15—Iridium

Iridium is the chemical element with atomic number 77, and is represented by the symbol Ir. A very hard, brittle, silvery-white transition metal of the platinum family, Iridium is the second-densest element (after Osmium) and is the most corrosion-resistant metal, even at temperatures as high as 2000°C. Although only certain molten salts and halogens are corrosive to solid Iridium, finely divided iridium dust is much more reactive and can be flammable.



Iridium was discovered in 1803 among insoluble impurities in natural Platinum. Smithson Tennant, the primary discoverer, named Iridium for the goddess Iris, personification of the rainbow, because of the striking and diverse colors of its salts. Iridium is one of the rarest elements in the Earth's crust, with annual production and consumption of only three tons.

Iridium metal is employed when high corrosion resistance at high temperatures is needed, as in high-end spark plugs, crucibles for recrystallization of semiconductors at high temperatures, and electrodes for the production of chlorine in the chloralkali process.

Iridium is found in meteorites with an abundance much higher than its average abundance in the Earth's crust.

Iridium is white, resembling Platinum, but with a slight yellowish cast. Because of its hardness, brittleness, and very high melting point, solid Iridium is difficult to machine, form, or work, and thus powder metallurgy is commonly employed instead. It is the only metal to maintain good mechanical properties in air at temperatures above 1600°C. Iridium has a very high boiling point (10th among all elements) and becomes a superconductor at temperatures below 0.14 K.

Iridium's modulus of elasticity is the second-highest among the metals, only being surpassed by Osmium. This, together with a high shear modulus and a very low figure for Poisson's ratio (the relationship of longitudinal to lateral strain), indicate the high degree of stiffness and resistance to deformation that have rendered its fabrication into useful components a matter of great difficulty. Despite these limitations and Iridium's high cost, a number of applications have developed where mechanical strength is an essential factor in some of the extremely severe conditions encountered in modern technology.

The measured density of Iridium is only slightly lower (by about 0.12%) than that of Osmium, the densest element known. X-ray crystallographic data yielded densities of 22.56 g/cm3 for iridium and 22.59 g/cm3 for osmium.

Iridium is the most corrosion-resistant metal known. It is not attacked by almost any acid, aqua regia, molten metals or silicates at high temperatures. It can, however, be attacked by some molten salts, such as sodium chloride, sodium cyanide and potassium cyanide, as well as oxygen and the halogens (particularly fluorine) at higher temperatures.

#### Applications

The demand for iridium surged from 2.5 tons in 2009 to 10.4 tons in 2010, mostly because of electronicsrelated applications that saw a rise from 0.2 to 6 tons—Iridium crucibles are commonly used for growing large high-quality single crystals, demand for which has increased sharply.

The high melting point, hardness and corrosion resistance of Iridium and its alloys determine most of its applications. Iridium and especially Iridium–Platinum alloys or Osmium–Iridium alloys have a low wear and are used, for example, for multi-pored spinnerets, through which a plastic polymer melt is extruded to form fibers, such as rayon. Osmium–Iridium is used for compass bearings and for balances.

Corrosion and heat resistance makes Iridium an important alloying agent. Certain long-life aircraft engine parts are made of an Iridium alloy and an Iridium–Titanium alloy is used for deep-water pipes because of its corrosion resistance. Iridium is also used as a hardening agent in Platinum alloys. The Vickers hardness of pure Platinum is 56 HV while Platinum with 50% of Iridium can reach over 500 HV.

Devices that must withstand extremely high temperatures are often made from Iridium. For example, high-temperature crucibles made of Iridium are used in the Czochralski process to produce oxide single-crystals (such as sapphires) for use in computer memory devices and in solid state lasers. The crystals, such as Gadolinium Gallium Garnet and Yttrium Gallium Garnet, are grown by melting pre-sintered charges of mixed oxides under oxidizing conditions at temperatures up to 2100 °C. Its resistance to arc erosion makes iridium alloys ideal for electrical contacts for spark plugs.

#### Precautions

Iridium in bulk metallic form is not biologically important or hazardous to health due to its lack of reactivity with tissues. However, finely ground Iridium powder can be hazardous to handle, as it is an irritant and pyrophoric (may auto-ignite in presence of air). Very little is known about the toxicity of iridium compounds because they are used in very small amounts, but soluble salts, such as the iridium halides, could be hazardous due to elements other than iridium or due to Iridium itself. However, most Iridium compounds are insoluble, which makes absorption into the body difficult.

#### **Uses of Iridium**

The main use of Iridium is as a hardening agent for Platinum alloys. With Osmium, it forms an alloy that is used for tipping pens, and compass bearings. Iridium is used in making crucibles and other equipment that is used at high temperatures. It is also used to make heavy-duty electrical contacts.

Iridium was used in making the international standard kilogram, which is an alloy of 90% Platinum and 10% Iridium.

#### **Mechanical Properties:**

Iridium is paramagnetic—that is, it will be attracted to a strong magnet but will not retain its own magnetism.

# Section 16—Definition of Terms For Precious Metals Testing

Alloy: A mixture or combination of two or more metals, usually accomplished by melting them together.

**Avoirdupois Ounce - (oz)**: Sometimes referred to as a Commodity ounce, is equal to 437.5 grains (28.35 grams). It is 3.63 grams less than the Troy ounce (ozt). Avoirdupois ounce should never be used in pricing precious metals (beware some people don't know this and weigh their gold using a Commodity ounce scale (letter scale) and advertise it for sale.

**Azeotrope:** A mixture of two or more liquids in which its components cannot be altered by simple distillation. This happens because, when an azeotrope is boiled, the vapor it produces has proportionate constituents as the original mixture. Because their composition is unchanged by distillation, azeotropes are also called (especially in older texts) constant boiling mixtures. The word azeotrope is derived from the Greek words that mean "no change on boiling".

**Base Metals:** Usually copper, silver, or nickel, used to enhance the physical properties of otherwise too soft precious metals.

**Bullion:** Any refined precious metal, such as Gold, Silver, Platinum, and Palladium, which is in a state or condition where its value depends primarily upon its precious metal content and not its form.

**Carat:** Internationally, this term is used interchangeably with Karat in defining the fineness of gold. In the United States, the term with this spelling is used only to define the weights of gems.

**Carat (abbreviation ct):** The carat is defined as a unit of mass equal to 200 mg (0.007055 oz), and it is used for measuring the weights of gemstones and pearls. Sometimes known as the metric carat which is divisible into one hundred points of two milligrams each. Here are several ways to express 1 carat as in diamond carat: 1 ct. = 1/5 gram, 100 points, 200 milligrams or 4 grainier.

#### **Comparative table of weights:**

- 1 Troy dwt. = 1.555 metric grams
- 1 Troy oz. = 31.103 metric grams
- 1 Troy pound = 5760 grains
- 1 Avoirdupois ounce = 437.5 grains = 28.4 metric grams
- 1 Avoirdupois pound = 7000 grains
- A Troy ounce is heavier than an avoirdupois ounce.
- A Troy pound is lighter than an avoirdupois pound.

Fine gold: Pure gold, unalloyed; also 24-k gold, or 100% pure gold, or gold that is 1000 fine.

**Karat:** A twenty-fourth part; used to express the proportion of gold in an alloy; thus pure gold is 24-k; 18-k gold is 18/24<sup>th</sup> or <sup>3</sup>/<sub>4</sub> gold, the remaining 6/24ths being other metals. Eighteen karat gold may also be described as 750 fine; 12-k gold as 500 fine; etc.

Penny Weight: A unit of 24 grains or 1/20 of a Troy ounce (1.555 grams). Abbreviation: dwt, pwt.

**Plated goods:** Articles made of an inexpensive metal, coated electrolytically with a thin deposit of some other metal such as gold or silver. Normally the deposit is extremely thin. Thin deposits of nickel, chromium, rhodium, and other metals are also applied electrolytically.

**Platinum Group of Metals:** Six related metals belong to the Platinum Group of Metals ("PGMs")— Platinum, Rhodium, Iridium, Palladium, Ruthenium and Osmium. Like platinum, they are rare and thus, expensive.

**Rolled gold or filled gold:** Material consisting of a core or base of some inexpensive alloy, for example brass or German silver, coated or topped by a thin layer of a gold alloy. The stamp "1/20 12-k" means that the article is rolled or filled gold, one-twentieth of the article's weight being 12-k gold.

**Sterling Silver:** A silver alloy containing 925 parts silver and 75 parts base metal (usually copper). The entire article is of the same composition throughout.

Troy Ounce: This is the only ounce used in the pricing of precious metals, Gold, Platinum, and Silver.

- 1 troy ounce (ozt) is 480 grains
- A grain is exactly 64.79891 mg
- 1 troy ounce is exactly 31.1034768 g, rounded to 31.1g.
- The gram is the weight now most used in trading precious metals.

Troy Pennyweight: Units that were previously used in weighing precious metals:

24 grains = 1 Troy pennyweight (dwt.)

20 dwt. = 1 Troy ounce (oz.) = 480 grains

12 Troy oz. = 1 Troy pound (rarely used)

Vermeil: A trade term for Gold plating over a silver base metal.

# Section 17—Equipment Used in Testing Precious Metals

The following tools and chemical supplies are readily available from <u>www.chemical-supermarket.com</u>:

#### **Chemicals:**

- Nitric Acid, concentrated, 69%
- Hydrochloric Acid, concentrated, 38%
- Potassium dichromate
- Stannous Chloride
- Dimethyl Glyoxime
- Ferrous Sulphate
- Aqua regia kit with vented cap

## **Tools/Equipment:**

- Touchstone, black basalt
- Touchstone, white basalt
- Spot Test Plate, Porcelain, 12-Pocket
- Testing Star, Yellow Gold
- Testing Star, Platinum Alloys
- Testing Star, White Gold Alloys
- Acid Dropping Bottles (amber glass, ground glass caps, professionally labeled for each of the testing solutions.
- Magnet, rare earth (e.g. Neodymium)
- Scale, gram, digital

# Section 18—The Acid Dropping Bottle

These laboratory quality amber flint glass dropping bottles have precision ground glass neck and stopper. They can be used for a variety of liquids, but specifically ideal for acids.

The stopper has two channels in the side, and the bottle neck has two grooves—when the stopper is turned so that the channels align with the grooves, liquid can be poured drop by drop. The bottles stand about 100mm tall (about 4") and they hold 50ml.



## **Important Features:**

These are ideal for the highly corrosive acids used in precious metals testing because there are no plastics or elastomers to deteriorate. Nitric acid oxidizes everything except glass. Even high quality high density propylene Nalgene bottles will show the effects of nitric over time.

When not in use, the stoppers are simply turned so the channels and grooves are out of alignment and the precision ground cap seals securely in the neck. When ready for use, simply turn the cap to align the channels and grooves for easy drop by drop dispensing.

Additionally, for Aqua Regia, the cap can remain with channels and grooves aligned to assure proper venting of the bottle to prevent pressure build-up.

#### **Precautions:**

When pouring chemical from these bottles always place your index finger over the top of the cap to assure it does not come out. The fit of the ground glass cap to the neck is high precision but the only thing holding them in is gravity and a little friction.

# Section 19—Nitric Acid Facts & Information

## Introduction:

Based on the importance of this chemical in precious metals testing and on the number of questions we get on almost a daily basis, we felt it important and would be of great convenience to the user to provide this information summary.

# **Overview:**

Nitric acid ( $HNO_3$ ), also known as aqua fortis and spirit of niter, is a highly corrosive, strong mineral acid. The pure compound is colorless, but aging samples that have had sunlight exposure tend to acquire a yellow or brown cast due to the accumulation of oxides of nitrogen.



# **Concentration vs. Purity & Chemical Grades:**

These two terms are commonly confused. Purity is a measurement in % of how few contaminants are in the final product. Thus, a product labeled as "Technical Grade" will be of a purity level between 96 and 98%. Alternatively, a product labeled as "Reagent Grade" can have much higher purity levels—as high as 99.998%.

Concentration, on the other hand, is a measurement of how much dinitrogen tetroxide  $(N_2O_4)$  is dissolved in water thus becoming nitric acid. Nitric acid of commercial interest usually consists of the maximum boiling azeotrope of nitric acid and water, which is approximately 68% HNO<sub>3</sub>, (approx. 15 molar). This is considered concentrated or technical grade, while reagent grades are specified at 69%, 69.5%, or even 70% HNO3. An older density scale is occasionally seen, with concentrated nitric acid specified as 42° Baumé.

When the solution contains more than 86% HNO<sub>3</sub>, it is referred to as fuming nitric acid. Fuming nitric acid is further characterized as white fuming nitric acid ("WFNA") or red fuming nitric acid ("RFNA"), at concentrations above 95%.

## **Measurement Units of Concentration:**

An even greater area of confusion comes in specifying concentration values. Most common is %, followed by Molarity and Normality, and finally Baume'.

## Percentage (%):

When we say a sample of nitric acid has a 70% concentration it means that 70% of the weight of the sample is comprised specifically of (HNO<sub>3</sub>). Using 70% concentrated Nitric Acid as an example: 70% Nitric Acid means that 100 grams of this acid contains 70 grams of HNO3. The concentration is expressed at 70% wt./wt. or 70 wt. % HNO3.

#### Molarity:

Some chemists and analysts prefer to work in acid concentration units of Molarity (moles/liter). To calculate the Molarity of a 70% Nitric Acid sample, the number of moles of HNO<sub>3</sub> present in 1 liter of acid needs to be calculated.

The molarity (M) and percentage (%) relationship depends on the density of solution (d) along with the molecular weight (mw) of the dissolved substance. Two equations depicting the inter-relationship are as follows:

 $M = \% \times d / (100\% \times mw)$ 

 $\% = M \times 100\% \times mw \ / \ d$ 

Knowing that the density of concentrated nitric acid solution to be 1.390 g/mL, we can extrapolate that the weight of 1 L of 70% HNO<sub>3</sub> to be 1,390 grams. Knowing that the solution is 70 wt % would then allow the number of grams of HNO<sub>3</sub> to be calculated: (0.700) x (1,390g) = 973 grams HNO<sub>3</sub> per liter. Dividing the grams of HNO<sub>3</sub> by the molecular weight of HNO<sub>3</sub> (63 g/mole) gives the number of moles of HNO<sub>3</sub>/L or Molarity, which is 15.4 M.

## Normality:

There is a relationship between normality and molarity. Normality can only be calculated when we deal with reactions, because Normality is a function of equivalents. Normality refers to compounds that have multiple chemical functionalities, such as sulfuric acid,  $H_2SO_4$ . A 1 Molar solution of  $H_2SO_4$  will contain only one mole of  $H_2SO_4$  in 1 liter of solution, but if the solution is titrated with a base, it will be shown to contain the equivalent of two moles of acid. This is because a single molecule of  $H_2SO_4$  contains two acidic protons (H+ Ions). Thus, a 1 M solution of  $H_2SO_4$  will be 2 N. The "Normality" of a solution is the "Molarity" multiplied by the number of equivalents per mole.

Now, in the case of nitric acid (HNO<sub>3</sub>), a mole only contains a single acidic proton (H+ ion), and thus the Normality and the Molarity of nitric are equal. And therefore, for the example, 70% nitric acid which we showed to be 15.7 Molarity is also 15.7 Normality (or 15.7 Normal).

Wt/wt %	Density (g/ml)	Molarity	Normality
70	1.39	15.4	15.4
68	1.38	14.9	14.9
50	1.28	10.2	10.2
49.2	1.28	10	10
40	1.23	7.8	7.8
30	1.18	5.6	5.6
25	1.15	4.6	4.6
20	1.12	3.6	3.6
15	1.10	2.6	2.6
10	1.07	1.7	1.7
6.1	1.05	1	1
5	1.04	0.815	0.815
1	1.05	0.162	0.162

# Nitric Acid Concentration Conversions:

#### **Reactions with metals:**

Nitric acid reacts with most metals but the details depend on the concentration of the acid and the nature of the metal. Dilute nitric acid behaves as a typical acid in its reaction with most metals. Magnesium, manganese and zinc liberate hydrogen gas. Others devolve the nitrogen oxide gases.

Nitric acid can oxidize non-active metals such as copper and silver for which the reaction rate depends on temperature and the acid concentration. For example, copper reacts with dilute nitric acids at ambient temperatures.

Upon reaction with nitric acid, most metals give the corresponding nitrates—copper nitrate, silver nitrate. Alternatively, reactions with other metals give the oxides—Tin Dioxide, Titanium Dioxide.

Some precious metals, such as pure gold and platinum group metals do not react with nitric acid, though pure gold does react with aqua regia, a mixture of concentrated nitric acid and hydrochloric acid. However, some less noble metals (Silver, Copper) present in some gold alloys can be easily oxidized and dissolved by nitric acid, leading to color changes of the gold-alloy surface. Nitric acid is used as an inexpensive and effective means in jewelry stores and pawn shops to quickly spot low-gold alloys (< 14 karats) and to rapidly assess the gold purity.

Although chromium (Cr), iron (Fe) and aluminum (Al) readily dissolve in dilute nitric acid, the concentrated acid forms a metal oxide layer that protects the bulk of the metal from further oxidation. The formation of this protective layer is called passivation. Typical passivation concentrations range from 20–50% by volume (See ASTM A967-05). Metals which are passivated by concentrated nitric acid are Iron, Cobalt, Chromium, Nickel, and Aluminum.

#### **Reactions with non-metals:**

Being a powerful oxidizing acid, nitric acid reacts violently with many organic materials and the reactions may be explosive.

Reaction with non-metallic elements, with the exceptions of nitrogen, oxygen, noble gases, silicon and halogens, usually oxidizes them to their highest oxidation states as acids with the formation of nitrogen dioxide for concentrated acid and nitric oxide for dilute acid.

## **Production:**

The manufacture of nitric acid is a three-stage process. The first stage is the oxidation of ammonia using a Platinum/Rhodium catalyst to produce Nitric Oxide (NO) and water. Next, this Nitric Oxide is reacted with more oxygen to produce Nitrogen Dioxide (NO<sub>2</sub>). This is further reacted to produce Dinitrogen Tetroxide (N<sub>2</sub>O<sub>4</sub>) which is absorbed into water to produce the nitric acid.

The aqueous  $HNO_3$  obtained can be concentrated by distillation up to about 68% by mass. Further concentration to 98% can be achieved by dehydration with concentrated sulfuric acid.

## **Safety Considerations:**

Nitric acid is a strong acid and a powerful oxidizing agent. The major hazard posed by it is chemical burn as it carries out acid hydrolysis with proteins (amides) and fats (esters) and decomposes living tissues (e.g. skin and flesh) readily. Concentrated nitric acid stains human skin yellow due to its reaction with the keratin. These yellow stains turn orange when neutralized. Systemic effects are unlikely, however, and the substance is not considered a carcinogen or mutagen.

The standard first aid treatment for acid spills on the skin is, as for other corrosive agents, irrigation with large quantities of water. Washing is continued for at least ten to fifteen minutes to cool the tissue surrounding the acid burn and to prevent secondary damage. Contaminated clothing is removed immediately and the underlying skin washed thoroughly.

Being a strong oxidizing agent, reactions of nitric acid with compounds such as cyanides, carbides, metallic powders can be explosive and those with many organic compounds, such as turpentine, are violent and hypergolic (i.e. self-igniting). Hence, it should be stored away from bases and organics.

### Decomposition of Nitric Acid By Light Exposure:

When exposed to intense light sources (such as direct sunlight) nitric acid will decompose into the Nitrogen Oxide gases such as Nitrogen Dioxide and Nitrogen Oxide. These NOx gases can dissolve in the aqueous acid solution and impart a yellow to light brown color to the otherwise clear acid.



To prevent this decomposition, always keep your nitric acid out of direct sunlight, and when not in use, keep it locked away in a cool and dark area such as a corrosive liquids cabinet.

#### **Baumé Scale:**

Though not in common use today, nevertheless, occasionally these units arise. The Baumé ( $^{\circ}Bé$ ) Scale was named after the French pharmacist, Antoine Baumé. It was originally devised to correlate to the percentage concentration (% w/w) of a brine solution (salt in water). Two scales evolved, both with zero for the density of pure water, however, with one of the scales for solutions less than the density of water, and the other for solutions greater than the density of water.

To convert from °Bé to specific gravity and density, and back again, at 60 degrees Fahrenheit:

Specific Gravity (SG) of a fluid that is heavier than water =  $145/(145 - {^{\circ}Be})$ 

Or:

 $^{\circ}\text{B}\acute{e} = 145 - (145/\text{SG})$ 

#### **Example:**

Given a sample of 10 Molar nitric acid (which is the same as 49.2% concentration), from the table its density is read as 1.28, and we know that its specific gravity is also 1.28.

 $^{\circ}\text{Be} = 145 - (145/\text{SG}) = 145 - (145/1.28) = 145 - 113.3 = 31.7$ 

# Section 20—Hydrochloric Acid Facts & Information

## Introduction:

Equally important to nitric acid in precious metals testing is hydrochloric acid. And, once again, based on the number of questions we get we felt it important to provide this information summary.



#### **Overview:**

Hydrochloric acid is a clear, colorless solution of hydrogen chloride (HCl) in water. It is a highly corrosive, strong mineral acid with many industrial uses. Hydrochloric acid is found naturally in gastric acid.

Historically called muriatic acid, and spirits of salt, hydrochloric acid was originally produced from vitriol (sulfuric acid) and common salt. It first appeared during the Renaissance.

Hydrogen chloride (HCl) is a monoprotic acid, which means it can dissociate (i.e., ionize) only once to give up one H+ ion (a single proton). In aqueous hydrochloric acid, the H+ joins a water molecule to form a hydronium ion,  $H_3O^+$ 

The other ion formed is  $Cl^{-}$ , the chloride ion. Hydrochloric acid can therefore be used to prepare salts called chlorides, such as sodium chloride, potassium chloride, calcium chloride, etc. Hydrochloric acid is a strong acid, since it is essentially completely dissociated in water.

Of the six common strong mineral acids in chemistry, hydrochloric acid is the monoprotic acid least likely to undergo an interfering oxidation-reduction reaction. It is one of the least hazardous strong acids to handle; despite its acidity, it consists of the non-reactive and non-toxic chloride ion. Intermediate-strength hydrochloric acid solutions are quite stable upon storage, maintaining their concentrations over time. These attributes, plus the fact that it is available as a pure reagent, make hydrochloric acid an excellent acidifying reagent.

Hydrochloric acid is produced in solutions up to 38% HCl (concentrated grade). Higher concentrations up to just over 40% are chemically possible, but the evaporation rate is then so high that storage and handling need extra precautions, such as pressure and low temperature. Bulk industrial-grade is therefore 30% to 34%, optimized for effective transport and limited product loss by HCl vapors. Solutions for household purposes in the US, mostly cleaning, are typically 10% to 12%, with strong recommendations to dilute before use.

## **Precautions:**

Concentrated hydrochloric acid (fuming hydrochloric acid) forms acidic mists. Both the mist and the solution have a corrosive effect on human tissue, with the potential to damage respiratory organs, eyes, skin, and intestines. Avoid mixing hydrochloric acid with common oxidizing chemicals, such as sodium hypochlorite (bleach, NaClO) or potassium permanganate (KMnO4), as the toxic gas chlorine is produced.

Personal protective equipment such as rubber or PVC gloves, protective eye goggles, and chemical-resistant clothing and shoes are used to minimize risks when handling hydrochloric acid. Additionally, always use with adequate ventilation or under a chemical fume hood.

### **Concentration vs. Purity & Chemical Grades:**

These two terms are commonly confused. Purity is a measurement in % that indicates how few contaminants are in the final product. Thus, a product labeled as "Technical Grade" will be of a purity level between 96 and 98%. Alternatively, a product labeled as "Reagent Grade" can have much higher purity levels—as high as 99.998%.

Concentration, on the other hand, is a measurement of how much hydrogen chloride (HCl) is dissolved in water thus becoming hydrochloric acid. Hydrochloric acid of commercial interest usually consists of the maximum practical saturation of hydrogen chloride and water, which is approximately 38%. This is considered concentrated or technical grade.

#### **Measurement Units of Concentration:**

An even greater area of confusion comes in specifying concentration values. Most common is %, followed by Molarity and Normality, and finally the archaic Baume'.

#### Percentage (%):

When we say a sample of hydrochloric acid has a 38% concentration it means that 38% of the weight of the sample is comprised specifically of Hydrogen Chloride (HCl). Using 38% concentrated Hydrochloric Acid as an example: 38% Hydrochloric Acid means that 100 grams of this acid contains 38 grams of HCl. The concentration is expressed as 38 weight percent, 38% wt./wt. or 38 wt. % HCl.

#### Molarity:

Some chemists and analysts prefer to work in acid concentration units of Molarity (moles/liter). To calculate the Molarity of a 38% Hydrochloric Acid sample, the number of moles of HCl present in 1 liter of acid needs to be calculated.

The molarity (M) and percentage (%) relationship depends on the density of solution (d) along with the molecular weight (mw) of the dissolved substance. Two equations depicting the inter-relationship are as follows:

 $\mathbf{M} = \% \times \mathbf{d} / (100\% \times \mathbf{mw})$  $\% = \mathbf{M} \times 100\% \times \mathbf{mw} / \mathbf{d}$ 

Knowing that the density of concentrated Hydrochloric acid solution to be 1.19 g/mL, we can extrapolate that the weight of 1 L of 38% HCl to be 1,190 grams. Knowing that the solution is 38 wt % would then allow the number of grams of HCl to be calculated:  $(0.38) \times (1,190g) = 452$  grams HCl per liter. Dividing the grams of HCl by the molecular weight of HCl (36.5 g/mole) gives the number of moles of HCl/L or Molarity, which is 12.4 M.

#### Normality:

There is a relationship between normality and molarity. Normality is a function of equivalents. Normality refers to compounds that have multiple chemical functionalities, such as sulfuric acid,  $H_2SO_4$ . A 1 Molar solution of  $H_2SO_4$  will contain only one mole of  $H_2SO_4$  in 1 liter of solution, but if the solution is titrated with a base, it will be shown to contain the equivalent of two moles of acid. This is because a single molecule of  $H_2SO_4$  contains two acidic protons (H<sup>+</sup> Ions). Thus, a 1 M solution of  $H_2SO_4$  will be 2 N. The "Normality" of a solution is the "Molarity" multiplied by the number of equivalents per mole.

Now, in the case of Hydrochloric acid (HCl), a mole only contains a single acidic proton ( $H^+$  ion), and thus the Normality and the Molarity of Hydrochloric acid are equal. And therefore, for the example, 38% HCl which we showed to be 12.4 Molarity is also 12.4 Normality (or 12.4 Normal).

Hydrochloric Acid Concentration Conversions:					
Wt/wt %	Density (g/ml)	Molarity	Normality		
38	1.19	12.4	12.4		
35	1.17	11.2	11.2		
31.5	1.16	10	10		
25	1.12	7.7	7.7		
20	1.10	6.0	6.0		
15	1.07	4.4	4.4		
10	1.05	2.9	2.9		
5	1.02	1.4	1.4		
3.7	1.02	1	1		
1	1.00	0.274	0.274		

### **Baumé Scale:**

As we did with the nitric acid...

To convert from °Bé to specific gravity and density, and back again, at 60 degrees Fahrenheit:

Specific Gravity (SG) of a fluid that is heavier than water =  $145/(145 - {^{\circ}Be})$ 

Or:

 $^{\circ}\text{Be} = 145 - (145/\text{SG})$ 

#### **Example:**

Given a sample of 6 Molar hydrochloric acid (which is the same as 30% concentration), from the table its density is read as 1.16, and we know that its specific gravity is also 1.16.

 $^{\circ}\text{Be} = 145 - (145/\text{SG}) = 145 - (145/1.16) = 145 - 125 = 20$ 

# Section 21—Aqua Regia Facts & Information

# Introduction:

Aqua Regia ("Royal Water"), or nitro-hydrochloric acid is a highly corrosive mixture of acids—a fuming orange solution. The mixture is formed by freshly mixing concentrated nitric acid and hydrochloric acid, usually in a volume ratio of 1:3. Its name reflects its ability to dissolve the so-called royal or noble metals, gold and platinum. However, titanium, iridium, ruthenium, tantalum, osmium, rhodium and a few other metals are capable of withstanding its corrosive properties.

# **Applications:**

Aqua regia is primarily used to produce chloroauric acid used for refining highest quality (99.999%) gold. It is also used in etching and in specific analytic procedures. It is sometimes used in laboratories to clean glassware of organic compounds and metal particles.

Due to the reaction between its components resulting in its decomposition, aqua regia quickly loses its effectiveness (yet remains a strong acid), so its components are usually only mixed immediately before use.

Aqua regia dissolves 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  $(Au^{3+})$ .

The hydrochloric acid provides a ready supply of chloride ions (Cl<sup>-</sup>), which react with the gold ions to produce chloroaurate anions, also in solution. The reaction with hydrochloric acid is an equilibrium reaction which favors formation of chloroaurate anions (AuCl<sup>4–</sup>). 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. In addition, gold may be dissolved by the free chlorine present in aqua regia.

## **Dissolving Platinum:**

The reaction of platinum with aqua regia is considerably more complex. The initial reactions produce a mixture of chloroplatinous acid ( $H_2PtCl_4$ ) and nitrosoplatinic chloride (( $NO)_2PtCl_4$ ). 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.

The chloroplatinous acid can be oxidized to chloroplatinic acid by saturating the solution with chlorine while heating.

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(III) chloride. Platinum in the filtrate, as hexachloroplatinate(VI), is converted to ammonium hexachloroplatinate by the addition of ammonium chloride. This ammonium salt is extremely insoluble, and it can be filtered off. Strong heating converts it to platinum metal.

Unprecipitated hexachloroplatinate (IV) is reduced with elemental zinc, and a similar method is suitable for small scale recovery of platinum from laboratory residues.

## Decomposition of aqua regia:

Upon mixing of concentrated hydrochloric acid and concentrated nitric acid, chemical reactions begin to occur. These reactions result in the volatile products nitrosyl chloride and chlorine as evidenced by the fuming nature and characteristic orange color of aqua regia. As the volatile products escape from solution, the aqua regia loses its potency. Nitrosyl chloride can further decompose into nitric oxide and chlorine. This dissociation is equilibrium-limited. Therefore, in addition to nitrosyl chloride and chlorine, the fumes over aqua regia contain nitric oxide. Because nitric oxide reacts readily with atmospheric oxygen, the gases produced also contain nitrogen dioxide,  $NO_2$ .

## **Disposal:**

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.

# **Precautions:**

Make and use this preparation only under a fume hood or where there is significant ventilation. The fumes devolved when the two acids are initially mixed are highly toxic.

Never tightly cap the bottle in which the acids are mixed. The fumes that are released in the mixing reaction can build up significant pressure. We provide an aqua regia kit which contains a glass mixing bottle that has a vented cap to allow or the release of this gas pressure.

# Section 22—Table of Metals and Their Responses to Acid and Flame

This table shows the reactions of the more common metals and their alloys to cold, full-strength nitric acid, to cold full-strength hydrochloric acid, and to the oxygen-gas flame. It is assumed that the sample will be in the form of small articles—neither as a finely-divided powder nor a large mass. Specific gravities are given in the usual units—water = 1.0—and melting points are expressed in degrees Centigrade.

## The small raised numerals refer to the following notes:

- 1. Iron, steel and chromium under concentrated nitric acid often remain "passive" or insoluble for some time. But if scratched, or touched with a wire of some dissimilar metal, they will suddenly begin to react.
- 2. Lead is readily soluble in warm nitric acid, especially if the latter is diluted. It dissolves slowly in hot hydrochloric acid, but on cooling the white insoluble lead chloride precipitates out.
- 3. Silver when treated with hot hydrochloric acid, or hot aqua regia, is slowly converted into the white insoluble silver chloride.
- 4. Tin is converted by nitric acid into a white gelatinous solid called meta-stannic acid. It dissolves promptly in hot hydrochloric acid; slowly in cold.

Metal	Sp. Grav.	Flame Effects	Nitric	Hydrochloric	M.P.°C
Aluminum	2.70	Ignites; White oxide	Slowly soluble	Quickly soluble	658
Chromium	6.92	Ignites; Dark oxide	Insoluble	Soluble in hot	1,505
Copper	8.93	Melts; Dark oxides	Green Sol.	Insoluble	1,083
Fine Gold	19.32	Melts cleanly	Insoluble	Insoluble	1,065
Iron (Steel)	7.85	Ignites, sparkles Dark oxides	Insoluble <sup>1</sup>	Soluble, brown	1,505
Lead	11.34	Melts then ignites	Colorless sol <sup>2</sup>	Insoluble	327
Mercury	13.6	Boils; evaporates	Colorless sol	Insoluble	-38
Nickel	8.6	Blackens	Green sol	Slowly sol	1,452
Palladium	12.16	Melts; swells	Brown sol	Insoluble	1,542
Platinum	21.37	Melts cleanly	Insoluble	Insoluble	1,750
Silver	10.50	Melts; spits	Colorless sol	Insoluble <sup>3</sup>	961
Tin	7.31	Burns to dark oxides	Insoluble <sup>4</sup>	Slowly sol	232
Zinc	7.1	Ignites to white oxide	Colorless sol	Colorless sol	419

# Section 23—Gas Torch Selection for Flame Testing

# MAPP Gas (3,670°F in air, 5,300°F in oxygen)

MAPP gas is a trademarked name belonging to Linde Group, previously to Dow, for a fuel gas based on a stabilized mixture of methylacetylene (propyne) and propadiene. The name comes from the original chemical composition: methylacetylene-propadiene propane. MAPP gas is also widely used as a generic name for UN 1060 stabilized methylacetylene-propadiene (unstabilized methylacetylene-propadiene is known as MAPD).



MAPP gas is widely regarded as a safer and easier-to-use substitute for acetylene.

MAPP gas can be used in combination with oxygen for heating, soldering, brazing and even welding due to its high flame temperature of 2925 °C (5300 °F) in oxygen. Although acetylene has a higher flame temperature (3160 °C, 5720 °F), MAPP has the advantage that it requires neither dilution nor special container fillers during transport, allowing a greater volume of fuel gas to be transported at the same given weight, and it is much safer in use.

The MAPP/oxygen flame is not entirely appropriate for welding steel, due to the high concentration of hydrogen in the flame - higher than acetylene, but lower than any of the other petroleum fuel gases. The hydrogen infuses into the molten steel and renders the welds brittle. For small-scale welding with MAPP this is not too serious a problem as the hydrogen escapes readily, and MAPP/oxygen can in practice be used for welding small steel parts.

MAPP/oxygen was advantageously used in underwater cutting, which requires high gas pressures (under such pressures acetylene polymerizes explosively, making it dangerous to use). However, underwater oxy/fuel gas cutting of any kind has been replaced by exothermic cutting due to the much faster cut rate and greater safety.

MAPP gas is also used in combustion with air for brazing and soldering, where it has considerable advantages over competing propane fuel due to its high combustion temperature of 2,020 °C (3,670 °F) in Air.

The biggest disadvantage of MAPP gas is cost; it is typically one-and-a-half times as expensive as propane at the refinery, and up to four times as expensive to the consumer. It is no longer used much in any large-scale industry - for larger scale users acetylene/oxygen is more economic than MAPP/oxygen when high flame temperatures are needed, and propane/air is more economic when big overall heats are needed.

However, for the small-scale user the MAPP/oxygen flame is still highly desirable, having higher flame temperatures and energy densities than any flame other than acetylene/oxygen, but without the dangers and inconveniences of acetylene/oxygen. Jewelers, glass bead makers, and many others find it very useful. Plumbers, refrigeration and HVAC engineers and other tradesmen also value the high heat capacity of the MAPP/air flame; MAPP was until recently widely used, supplied in small to medium size containers.
**Note:** In the spring of 2008, true MAPP gas production ended in North America when production was discontinued at the only remaining plant making it. Current products labeled ""MAPP" are in fact MAPP substitutes. These versions are stabilized liquefied petroleum gas (LPG) with high levels of propylene.

## Propane Gas (3,623°F in air, 5,110°F in oxygen)

A propane torch is a tool for burning the flammable gas propane ( $C_3H_8$ ). The maximum adiabatic flame temperature a propane torch can achieve with air is 2,268° Kelvin (1,995 °C/3,623 °F). Some propane torches are also used with a tank of pure oxygen to achieve a flame temperature nearing 3,095° Kelvin (2,820 °C/5,110 °F).



Propane torches are frequently employed to solder copper water pipes. It can also be used for some low temperature welding applications, as well as for brazing dissimilar metals together.

In addition to above, a large factor in the temperature of the flame is the percent of oxygen mixing with the propane. With air/fuel torches, since air contains about 21% oxygen, to obtain the maximum flame temperature with air, you must use a very large ratio of air/fuel. Even these glass bead making torches, which are essentially Bunsen burners with an added air pump can only achieve temperatures of 2,012 °F (1,100 °C).

# Section 24—Waste Chemical Disposal

Fortunately, the volume of chemicals required for the effective testing of precious metals is extremely small. But, nevertheless, given that many of the solutions created for this purpose have shelf lives, they will therefore need to be disposed of periodically. Following are a series of methods and considerations for the disposal of waste chemicals.

As you have learned from the formulation of the test solutions, most of the chemicals involved are acids and are easily disposed of once diluted and neutralized. When neutralizing an acid, the pH can be tested quickly by the following method. Make a saturated solution of sodium bicarbonate in water. A small amount of sodium bicarbonate solution poured into the acid will make a "fizz", which is a release of carbon dioxide. Since carbon dioxide evolves from these procedures, insure adequate ventilation is available. This "fizz" will indicate that the solution is still acidic, and needs more base to be added. Always stir the mixture and do a final check of the pH before pouring the neutralized acid down the drain.

### 1. Nitric Acid Solutions:

Spent nitric acid solutions can simply be diluted with water down to about a 5% concentration and then neutralized with a commonly available, harmless base such as sodium bicarbonate (baking soda). The resulting compounds will include sodium nitrate (a non-toxic salt sometimes added to meats as a preservative), carbon dioxide and water.

Check the pH with a test strip to assure it is at a neutral level (between 6 and 8) and then simply dispose of it down the drain.

### 2. Hydrochloric Acid:

Spent hydrochloric acid can simply be diluted with water and then neutralized with a harmless base such as sodium bicarbonate (baking soda). The resulting compounds will include sodium chloride (common table salt), carbon dioxide and water.

Check the pH with a test strip to assure it is at a neutral level (between 6 and 8) and then simply dispose of it down the drain.

### 3. Aqua Regia:

Comprised of nitric acid and hydrochloric acid, spent aqua regia can simply be diluted with water and then neutralized with a harmless base such as sodium bicarbonate (baking soda).

As with nitric acid and hydrochloric acid, the resulting compounds will include sodium chloride (common table salt), sodium nitrate, carbon dioxide, and water.

Check the pH with a test strip to assure it is at a neutral level (between 6 and 8) and then simply dispose of it down the drain.

### 4. Schwerter's Solution:

Comprised of nitric acid and potassium dichromate. Mix with a reducing agent (e.g. ferrous sulfate) to reduce it to trivalent chromium. Precipitate trivalent chromium out of solution in the form of chromium hydroxide. This is done by raising the pH to 8.5 by adding sodium carbonate. The chromium hydroxide will fall right out of solution. Filter and dry precipitated chromium hydroxide. Dispose of in accordance with local, state and federal regulations.

### 5. DMG Solution:

Comprised of dimethyl glyoxime in water. First, the shelf life of this solution is on the order of years. Second, in the event that a small amount of the solution needs to be disposed of, recall that 4 ounces of the solution contained only 1 gram of this compound. Disposal of this small amount is well within the practicality of small volume exemption. Additionally, this compound is of extremely low toxicity as evidenced by the fact that it is not regulated for transport.

# Section 25—Hardness Testing

#### Vickers Hardness Testing:

This is a common method for measuring the hardness of metals, particularly those with extremely hard surfaces. The surface is subjected to a standard pressure for a standard length of time by means of a pyramid-shaped diamond. The diagonal of the resulting indention is measured under a microscope and the Vickers Hardness value read from a conversion table.

The hardness of a material is calculated from the size of an impression produced under load by a pyramidshaped diamond indenter. Devised in the 1920s by engineers at Vickers, Ltd., in the United Kingdom, the diamond pyramid hardness test, as it also became known, permitted the establishment of a continuous scale of comparable numbers that accurately reflected the wide range of hardnesses found in steels.

The indenter employed in the Vickers test is a square-based pyramid whose opposite sides meet at the apex at an angle of 136°. The diamond is pressed into the surface of the material at loads ranging up to approximately 120 kilograms-force, and the size of the impression (usually no more than 0.5 mm) is measured with the aid of a calibrated microscope.

The correct Vickers designation is the number followed "HV" (Hardness Vickers). The advantages of the Vickers hardness test are that extremely accurate readings can be taken, and just one type of indenter is used for all types of metals and surface treatments. Although thoroughly adaptable and very precise for testing the softest and hardest of materials, under varying loads, the Vickers machine is a floor standing unit that is more expensive than the Brinell or Rockwell machines.

#### **Mohs Hardness Scale:**

Mohs hardness is defined by how well a substance will resist scratching by another substance. It is a rough measure of the resistance of a smooth surface to scratching or abrasion, expressed in terms of a scale devised (1812) by the German mineralogist Friedrich Mohs. The Mohs hardness of a mineral is determined by observing whether its surface is scratched by a substance of known or defined hardness.

To give numerical values to this physical property, minerals are ranked along the Mohs scale, which is composed of 10 minerals that have been given arbitrary hardness values. The minerals contained in the scale are shown in the Table. Also shown are other materials that approximate the hardness of some of the minerals. As is indicated by the ranking in the scale, if a mineral is scratched by orthoclase but not by apatite, its Mohs hardness is between 5 and 6.

In the determination procedure it is necessary to be certain that a scratch is actually made and not just a "chalk" mark that will rub off. If the species being tested is fine-grained, friable, or pulverulent, the test may only loosen grains without testing individual mineral surfaces; thus certain textures or aggregate forms may hinder or prevent a true hardness determination. For this reason the Mohs test, while greatly facilitating the identification of minerals in the field, is not suitable for accurately gauging the hardness of industrial materials such as metals or ceramics. For these materials a more precise measure is to be found in the Vickers hardness or Knoop hardness.

Another disadvantage of the Mohs scale is that it is not linear; that is, each increment of one in the scale does not indicate a proportional increase in hardness. For instance, the progression from calcite to fluorite (from 3 to 4 on the Mohs scale) reflects an increase in hardness of approximately 25 percent, while the progression from corundum to diamond, on the other hand (9 to 10 on the Mohs scale), reflects a hardness increase of more than 300 percent.

Rockwell C Scale	Brinell Hardness	Vickers Hardness	Tensile Strength (approx.)		Rockwell C Scale	Brinell Hardness	Vickers Hardness	Tensile Strength (approx.)	
Brale Penetrator	10mm Tungsten Carbide Ball	Pyramidic Diamond			Brale Penetrator	10mm Tungsten Carbide Ball	Pyramidic Diamond		
I \$0kgf	3.000kgf	l 0kgf	ksi	kg/mm'	1 S0kgf	3.000kgf	10kgf	ksi	kg/mm
67		900	-	-	43	400	423	201	141
66	1 - N - N - Z	865	-	-	42	390	412	196	138
65	739	832	-	-	41	381	402	191	134
64	722	800	-	-	40	371	392	186	131
63	705	772	-	-	39	362	382	181	127
62	688	746		-	38	353	372	176	124
61	670	720	-	-	37	344	363	172	121
60	654	697	-	-	36	336	354	167	118
59	634	674	329	232	35	327	345	163	114
58	615	653	319	224	34	319	336	159	112
57	595	633	307	216	33	311	327	154	109
56	577	613	297	209	32	301	318	149	105
55	560	595	288	202	31	294	310	146	102
54	543	577	279	196	30	286	302	142	99
53	525	560	269	189	29	279	294	138	97
52	512	544	262	184	28	271	286	134	94
51	496	528	253	178	27	264	279	130	92
50	481	513	245	172	26	258	272	127	89
49	469	498	238	167	25	253	266	125	88
48	455	484	231	162	24	247	260	122	85
47	443	471	224	158	23	243	254	120	84
46	432	458	218	153	22	237	248	116	82
45	421	446	212	149	21	231	243	113	80
44	409	434	206	145	20	226	238	.111	78

# Section 26—Refiners of Precious Metal Waste

### **Reclamation/Refining/Smelting:**

By any of several names, reclamation is the process by which the precious metals are extracted from waste, scrap, or old jewelry. Having been involved with high tech industry and reclamation of precious metal wastes for many years, we have established a network of service suppliers for this purpose.

The service suppliers listed below handle many types of scrap and charge a very reasonable fee for the reclamation.

### WIT Refining

Contact: Mark, Fred or Rex 538 Phelan Avenue San Jose, California 95112 (408) 295-6414 www.witrefining.com

#### **G&E Refurbishing**

Contact: Javier Luna 2551 West Winton Avenue, #6C Hayward, California 94545 (510) 264-9124