

JUST THE FACTS

Gold and Its Alloys

Gold's quality is usually defined by karat, with each karat representing $\frac{1}{24}$ of the amount of pure gold in an alloy (as measured by weight). Thus, the higher the karat, the greater the proportion of pure gold there is. The remaining content of an alloy consists of assorted elements that combine to strengthen, provide color, or, in a few cases, act as correctives for the unwanted properties of other alloying elements.

Pure gold in its natural state is a rich, almost buttery yellow, but when alloyed, it can be produced in a range of other colors. Yellow, white, green, and rose/red golds are available as bulk metals, which are uniform in color throughout an alloy. Some blue and purple golds are also bulk metals; they are very brittle and not commonly used as jewelry alloys.

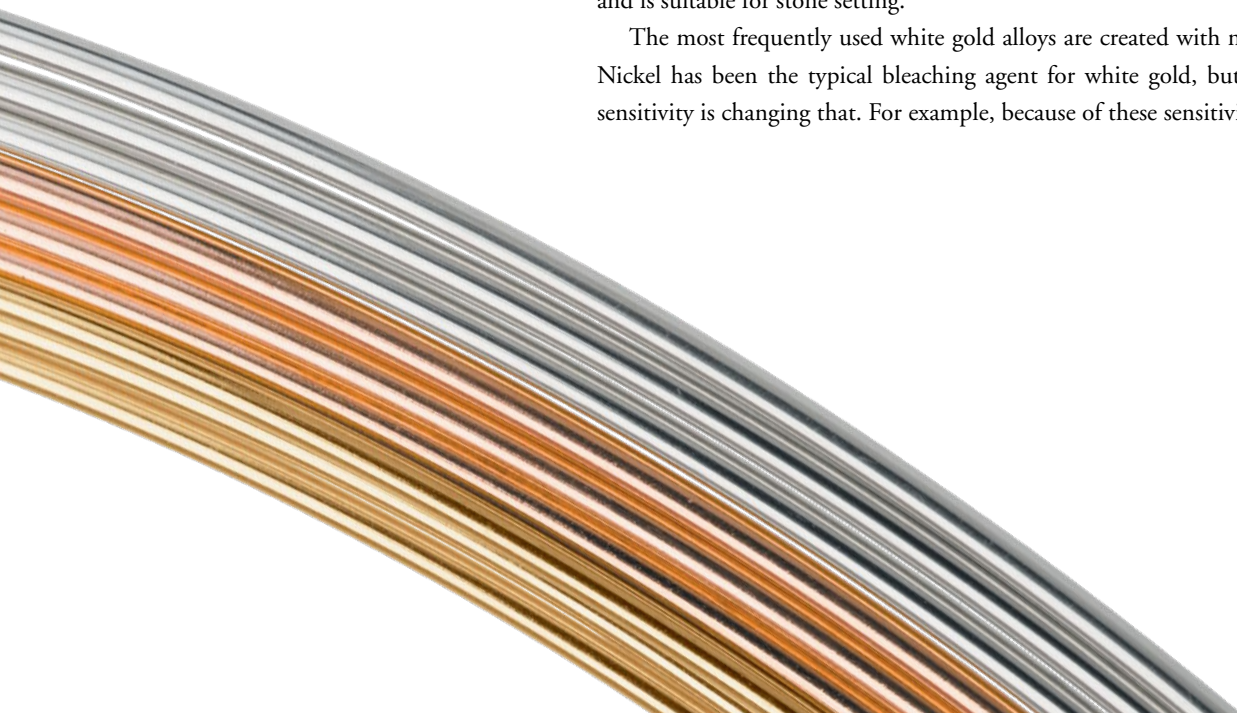
Note: Black, chocolate, and some other colors of gold are often products of surface treatments and coloring. For more on this topic, see "Plating and Coating" on page 15. There are also blue and black golds that are the products of oxidation reactions rather than coating. These alloys contain, for example, cobalt or iron, which greatly reduces ductility but also colors the gold during heat treatment.

The colored golds represented in the Ternary Alloy Color Chart (opposite) are bulk metal golds based on a ternary (three-metal) alloy of gold, silver, and copper, although other additions may be present. As shown in this image, the combination of these three primary alloys can, in varying proportions, create yellow, red, and green golds. Lower karat golds allow more color options than higher karat ones simply because the lower the karat, the greater the percentage of other metals that can be added to the mixture.

Although white appears as a color in this chart, the high percentage of silver makes these white golds less than 10k, which is not recognized as gold in the United States. Note: In the United Kingdom, a 9k alloy containing 37.5 percent gold and 62.5 percent silver is recognized (and a small amount of the silver may be replaced with, say, 3 to 5 percent copper for added strength). This alloy can be used for items of jewelry and is suitable for stone setting.

The most frequently used white gold alloys are created with nickel or palladium. Nickel has been the typical bleaching agent for white gold, but widespread nickel sensitivity is changing that. For example, because of these sensitivities, nickel content

*Yellow, white,
green, and
rose/red golds are
available as bulk
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an alloy.*

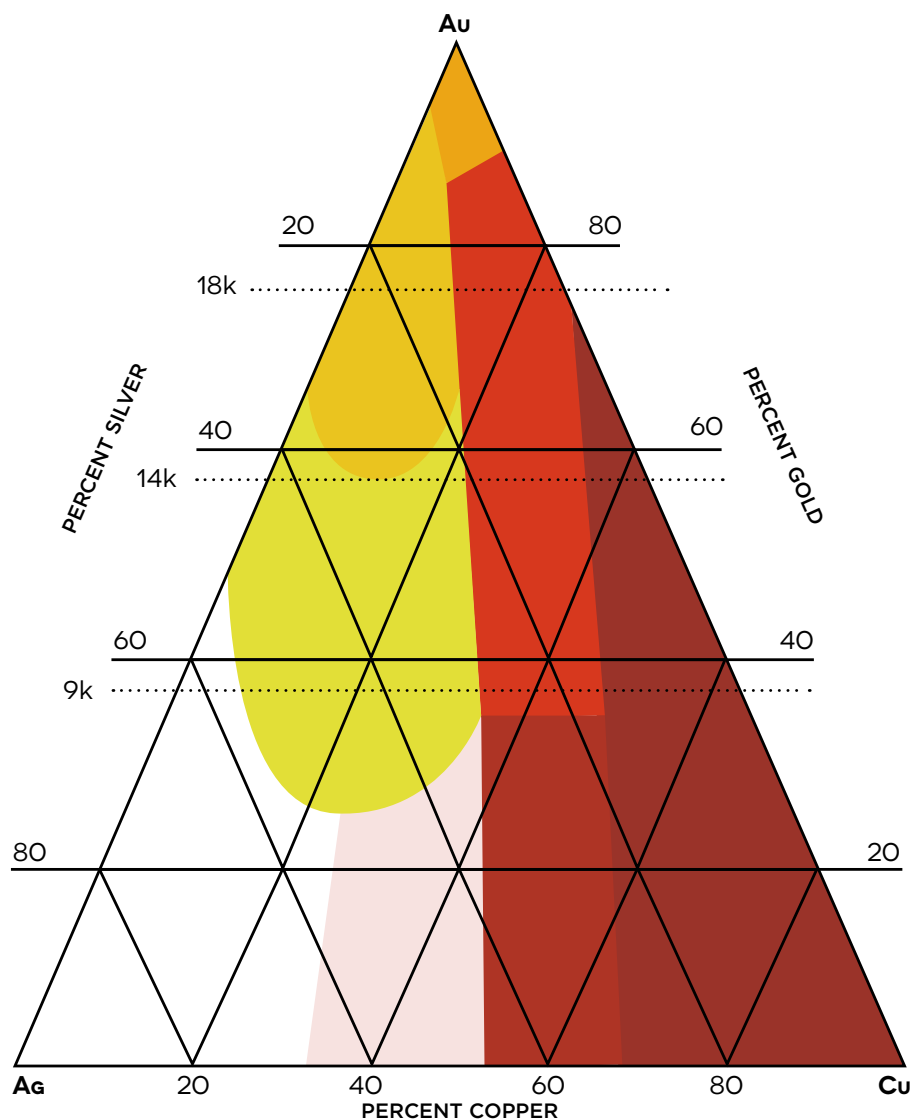


is closely regulated in the European Union. (For more about nickel standards, see chapter 8, Standards and Guidelines.) The wider effect is that nickel content of gold alloys has been reduced. However, the less nickel there is in an alloy, the more yellow-gray the alloy will be, and so rhodium plating (and, about every six months, replating) is used to make the alloy appear white.

Degrees of whiteness—or, more accurately, paleness—for white gold have not been standardized. Guidelines for the disclosure of rhodium plating to consumers have also not been formalized.

Alternatives to nickel-white gold alloys have been and are being developed. For example, palladium-white golds can be completely free of nickel; these white golds are also likely to be more expensive than the nickel whites.

TERNARY ALLOY COLOR CHART



KARAT	MINIMUM % GOLD BY WEIGHT	COMMON ALLOYING ELEMENTS ^a
24k	99.95 ^{b,c}	not applicable
22k	91.67	copper, silver, titanium ^d
18k	75.00	copper, silver, nickel, palladium, platinum, zinc
14k	58.33 ^e	copper, silver, nickel, palladium, zinc, silicon
10k	41.67	copper, silver, nickel, zinc, silicon
9k	37.50 ^f	copper, silver, nickel, zinc, silicon

This table lists the most common types of gold alloys as well as some typical alloying elements (described in greater detail in “Alloying Elements: What They Do” on page 5). Additional alloying materials include cobalt, iridium, and ruthenium, which could be added to any of the alloys above. These are also used for grain refining (see “Alloying Elements: What They Do”).

^a This table presents common additives, any of which can be included in a particular karated alloy. However, not all alloying elements in a row can or should be used together.

^b In theory, “pure” gold is 100 percent gold. In practice, “pure” or “fine” 24k gold is typically 99.95 percent gold.

^c In the United States, microalloys—created to make 24k gold harder and more durable—can be legally stamped as 24k gold if they have a 99.7 percent proportion of gold by weight. Additions of minute quantities of elements such as calcium and other light rare earth elements (e.g., cerium, gadolinium, lanthanum) have proved successful at strengthening high karat golds. US 24k microalloys are recognized as 24k in Europe and as 990 fineness in the United Kingdom.

^d There is a 23.75k gold-titanium alloy, but US standards require that it be sold as 22k gold.

^e Tolerances aside, in the United States, 14k gold is defined as being 58.33 percent gold. In some European countries and elsewhere around the world, 14k is defined as 58.5 percent gold. Some US jewelers prefer to adopt 58.5 as the standard—a key consideration if a business plans to export to countries where that is the standard.

^f Anything below 10k gold cannot be stamped or sold as gold in the United States, whereas 9k gold is common in the United Kingdom.

For more on these topics, see chapter 8, Standards and Guidelines.

Alloying Elements: What They Do

ELEMENT	GENERAL CHARACTERISTICS WHEN USED IN A GOLD ALLOY
Cobalt (Co is most commonly used in 14k–22k gold alloys.)	• Has little or no effect on color (with the exception of the specialized use described on page 2). • Increases strength, but would not be added to an alloy just to strengthen it. • Reduces grain size, improving workability of alloys. • Reduces grain growth during annealing. • Improves finishing qualities. By decreasing large grain size, reduces likelihood of an orange-peel surface, which is revealed when a fabricated workpiece is bent or deformed. (This is not the same as “orange peel” on a cast surface, which may be caused by casting too hot, too quickly, or by investment quality problems at the surface of the piece.) Note: If too much cobalt is added, polishing can be negatively affected. • Typically comprises 0.15 to 0.5 percent of an alloy. The more silver an alloy contains, the less cobalt can be used. • May lead to issues with allergic contact dermatitis if too much is added. Note: “Too much” is a variable quantity, dependent on gold, silver, and copper proportions. Typically, the addition of small quantities of cobalt is a matter for major manufacturers.
Copper (Cu is used in 9k–22k gold alloys.)	• Makes color warmer and more pink/rose/red as copper proportion increases. • Strengthens and increases hardness of an alloy. • Can increase ductility when added to white golds. • Can increase gas porosity problems. • Used in higher proportions, can make alloys brittle if they are heated and then allowed to cool slowly. In an 18k red, in particular, slow cooling can make the metal so brittle that, if dropped, it can fracture. High-copper alloys need to be quenched when hot to avoid this problem. (This can happen with 14k and 10k alloys too, but to a lesser extent than with 18k.) Note: With careful heat treatment, this property can be used to advantage to increase the hardness of a finished piece. • Promotes these characteristics in an alloy when higher proportions are used: ◦ greater susceptibility to firescale when heated, leading to extra cleanup ◦ greater susceptibility to tarnishing

ELEMENT	GENERAL CHARACTERISTICS WHEN USED IN A GOLD ALLOY
Iridium, Ruthenium (Ir and Ru are most commonly used in 14k–18k gold alloys.)	• Have little or no effect on color. • Increase strength and hardness. • Impart finer/smaller grain size to an alloy, thereby improving finishing/polishing qualities. • Should be used in very small quantities (0.01 percent or less). If too much is added to an alloy, these elements (particularly iridium) can become contaminants. • Often added to alloys containing silicon. But note: Combined with silicon, these grain refiners can contribute to the creation of silicides, which become hard spots in the gold. This is not typically evident in the first generation of use, but the more times the alloy is recycled and refined, the more silicides are created and the worse the problem becomes. Note that (1) too much silicon in the mix can exacerbate this problem, (2) the hard inclusions are very difficult to remove, even by refining, and (3) annealing the alloy after casting with recycled materials has no effect on these hard spots—the material remains hard.
Nickel (Ni is most commonly used in 9k–18k gold alloys.)	• Whitens, but a large proportion is needed to achieve a very white alloy. • Increases strength and hardness considerably. • Presents challenges with stone setting because nickel alloys are springy. • Increases time it takes to achieve a high finish, since nickel alloys are hard (typically 170 HV to 220 HV in an annealed state). • In large amounts, makes alloy susceptible to fire or quench cracking (i.e., spontaneous cracking during torch work or quenching) as well as stress corrosion cracking. • Used less and less as a whitener because of the potential for allergic contact dermatitis. The European nickel directive—updated as of March 1, 2013—places stringent restrictions on nickel release. For more on this topic, see chapter 8, Standards and Guidelines.
Palladium (Pd is most commonly used in 14k–18k gold alloys.)	• Significantly whitens but also tends to push color toward gray (which nickel does not do). Note: In the Middle East, 21k golds are recognized, and some of them may include palladium as a whitener. At 22k, it is not possible to get a white color with palladium because the gold content is too high. • Increases strength, hardness, and ductility. Increases melting point. • Makes the alloy more workable than nickel-white golds. • Produces a softer alloy that is more ductile and malleable, making a palladium-white gold more workable than a nickel white. This characteristic also makes it a good alloy for stone setting. • Improves finishing qualities over nickel alloys, which take longer to polish well due to their high hardness. • Costs significantly more than nickel-white gold. • Does not pose issues with allergic contact dermatitis.



ELEMENT	GENERAL CHARACTERISTICS WHEN USED IN A GOLD ALLOY
Platinum (Pt is not commonly used in any specific karated gold.)	• Acts as a whitener but is not as strong a bleaching agent as palladium. Note: Platinum is rarely used because it is significantly more expensive than palladium and it makes gold alloys more dense, whereas palladium makes them less so. • Impact on finishing qualities is unknown, but it's not likely to have much of an effect if any.
Silicon (Si is most commonly used in 9k–14k gold alloys.)	• Brightens the cast surface. • Increases fluidity, which improves form filling but can negatively affect ductility and malleability. • Deoxidizes. • Significantly increases grain size, which can contribute to weakness and cracking along grain boundaries. To address increased grain size, a grain refiner like iridium or ruthenium is often added to alloys containing silicon. However, combined with silicon, these grain refiners can contribute to the creation of silicides, which become hard spots in the gold. This is not typically evident in the first generation of use, but the more times the alloy is recycled and refined, the more silicides are created and the worse the problem becomes. Note that (1) too much silicon in the mix can exacerbate this problem, (2) the hard inclusions are very difficult to remove, even by refining, and (3) annealing the alloy after casting with recycled materials has no effect on these hard spots—the material remains hard. • Reduces surface roughness by creating a thin smooth silicon oxide layer on the surface (in place of a thick black copper oxide that might otherwise have formed there). • Can have very detrimental embrittling effects if excess silicon is used, even in tiny amounts, so making very careful calculations is necessary: ◦ Gold and silicon can combine to create a brittle alloy (together they form areas of very low melting temperature in the grain boundaries, which increases the likelihood of complete embrittlement of the alloy). ◦ The presence of copper helps mitigate this tendency, but additions of silicon must still be very small (0.03–0.35 percent) and proportionate to the quantity of copper in an alloy: The less copper there is in an alloy, the less silicon it can hold. ◦ Since higher karat golds often contain less copper, only the smallest amount of silicon can be added, thus the benefits of using silicon are limited. Particularly toward the lower end of the range of allowable silicon, there is no leeway for error and the risk of embrittlement is high. In addition, for these reasons, use of silicon in 18k alloys is controversial and is not recommended for higher karat alloys.

ELEMENT	GENERAL CHARACTERISTICS WHEN USED IN A GOLD ALLOY
Silver (Ag is most commonly used in 9k–22k gold alloys.)	• Makes color cooler and lighter; if added in sufficient quantities, pushes color toward green and white. • As an element in a binary alloy, can moderately harden gold. Is more likely to be used to prevent gold and copper alloys from becoming brittle when hardened with heat treatment. For more about this topic, see “Ordering” on page 17. • Can increase gas porosity. • Promotes these characteristics in an alloy if used in higher proportions: ◦ increased softness (e.g., green gold is very soft) ◦ more difficulty in finishing because of its softness ◦ greater susceptibility to tarnishing • Is a major addition to 9k white golds in the United Kingdom for stone setting and other items.
Titanium (Ti is used in some 22k gold alloys.)	• Has little or no effect on color. • Increases strength and hardness. Annealing cannot reverse hardening process. • Harder surface makes it possible to achieve a high polish. • Gold-titanium alloys do not contain other elements. • Amount of pure gold in an alloy typically ranges from 98.5 to 99 percent, so the alloy can be quality marked 22k in the United States. In the United Kingdom, the same alloy would be marked as 990 provided it passes the assay. • Is more expensive to work with than an equivalent amount of pure gold due to manufacturing and recycling costs. • Requires appropriate manufacturing facilities for a complex alloy production process; the same is needed for procedures such as vacuum melting and casting because titanium oxidizes very rapidly if melted in air and floats to the top of the melt, which negates titanium’s strengthening characteristic. For the same reason, scrap can’t be recycled in the studio—it must be refined and realloyed. • Not widely used except in the watch industry.
Zinc (Zn is most commonly used in 9k–18k gold alloys.)	• Brightens cast surfaces. • Increases strength and hardness. • Increases fluidity, which improves form filling but can negatively affect ductility and malleability. • Increases workability of 9k–18k gold but is mostly used in 14k alloys. • Deoxidizes. Note that the by-products of deoxidizing (zinc oxides) can form a film or create inclusions, both of which can contribute to surface defects. • Reduces surface roughness. • Typically used in concentrations of 3 percent or less for 18k alloys; can be up to 7 percent in 9k–14k.

Note: Elements’ characteristics were derived from multiple sources. See Credits, Notes, and Resources on page 142.

JUST THE FACTS

Silver and Its Alloys

Typically used for jewelry, sculpture, and hollowware that doesn't require the strength or durability of sterling silver, **fine/pure silver** is very soft (of the precious metals, only gold is softer). It is also well suited for jewelry components, such as bezels, that require malleability and ductility and are somewhat protected from wear and tear. Fine silver is characteristically highly reflective and a brilliant white. Contrary to popular belief, it does tarnish, though not as quickly as some of its alloys. It has a melting temperature of 961°C (1,762°F).

Traditional sterling silver is composed primarily of fine silver and copper, and has a liquidus melting point of 890°C (1,634°F). The addition of copper provides needed hardness and strength. While it may affect the malleability or ductility of the alloy, it doesn't compromise those qualities, which helps make sterling a “do anything” metal. Sterling also has a desirable white color, but it is very prone to tarnish, firescale, and firestain. Adding other alloying elements can address these issues, but they may have a cost in reduced hardness, ductility, castability, and color. Often, there can also be a literal cost: increased price.

Nontraditional sterling silver (referred to in this book as *proprietary sterling silver*) is composed of silver, typically some copper, and additional elements. Many of the extra elements are added with the goal of reducing the amount of firescale, firestain, and tarnish. There are many proprietary sterling silvers available, and likely more in development. Referring to them generally, as is done here, should not imply that they are or will always be alike: Proprietary sterling silvers may have very different characteristics from one another, and those should be discussed with the alloy's manufacturer.

Because proprietary sterling silver contains less copper than traditional sterling, it's possible to see subtle color differences between samples of each: For example, some proprietary alloys are whiter than traditional sterling.

Traditional sterling silver is considered a “do anything” alloy with a desirable white color, but it is prone to tarnish, firescale, and firestain.



	MINIMUM % SILVER BY WEIGHT	COMMON ALLOYING ELEMENTS ^a
fine/pure silver	99.9^b	not applicable
traditional/standard sterling silver	92.5	copper, phosphorus
proprietary sterling silver^c	92.5	copper, germanium, palladium, phosphorus, platinum, silicon, zinc, among others

This table lists the most common types of silver alloys as well as some typical alloying elements (described in greater detail in “Alloying Elements: What They Do” on page 22). Alloying materials not mentioned in this table include indium and tin. They are typically reserved for use in solders, where they help lower the melting point considerably.

- ^a This table presents common additives, any of which could be included in a particular silver alloy. However, not all alloying elements in a row can or should be used together.
- ^b “Pure” silver may contain very small amounts of impurities such as copper, lead, and/or iron. It may also contain traces of selenium and tellurium, which can lead to embrittlement if a proprietary mix of elements is added.
- ^c Proprietary sterling silver is also known as low-tarnish silver (or *deox* if deoxidizers are included). There are many proprietary silvers, far more than can be equitably covered in detail here. For this reason, mentions of proprietary sterling silver alloys are left intentionally general in this chapter. For specifics, consult your manufacturers and suppliers.

A number of silver alloys are not described in the chart above:

- *Britannia standard silver*: Minimum of 95.8 percent fine/pure silver. It is a recognized hallmarking standard in the United Kingdom, but is not recognized in the United States.
- *Proprietary sterling alloys that contain platinum or palladium (without copper)*: Minimum of 92.5 percent fine silver.
- *Coin (or reticulation) silver*: Minimum of 90 percent fine silver. Rarely used for jewelry.
- *800 silver*: Minimum of 80 percent fine silver. Used primarily in France, Belgium, and Germany.
- *Nickel silver (sometimes called German silver)*: Does not contain silver at all, but varying amounts of nickel, copper, and zinc.
- Specialty color “silvers” that contain less than 90 percent silver by weight are not considered silver alloys in the United States and cannot be legally sold as silver.

Alloying Elements: What They Do

ELEMENTS	GENERAL CHARACTERISTICS WHEN USED IN A SILVER ALLOY
Copper (Cu is present in almost all common silver alloys.)	• Affects color slightly, most noticeably in a comparison of traditional and proprietary silvers (where the latter contain less copper than the former). • Strengthens and increases hardness and durability. • Promotes the following characteristics, depending on the proportion used: ◦ Alloy more easily tarnishes. ◦ Alloy is more susceptible to firestain and firescale when heated, leading to extra cleanup during repair and fabrication processes. ◦ Alloy has a harder surface, making it possible to achieve a high polish.
Germanium (Ge is used in some proprietary sterling alloys.)	• Bonds to oxygen to form a passivating layer (an oxide layer on the surface of the metal that effectively seals it). This layer blocks sulfur-bearing compounds (which create tarnish) from reaching the surface of the alloy. In this way, it combats firestain, firescale, and tarnish.
Palladium (Pd is used in some proprietary sterling alloys.)	• Has no direct impact on color. Although palladium content replaces a bit of copper content, perhaps making an alloy a little whiter, it would not be added to a silver alloy for this purpose. • Increases strength. • Raises melting temperature of the silver alloy. • Is very compatible with silver in solution.
Phosphorus (P is used in sterling alloys.)	• Deoxidizes very effectively, pulling oxygen off the bond with the silver. • Must be used in very precise quantities, determined by the amount of oxygen in an alloy. • Embrittles the alloy if phosphorus is overused and it leaves a residue: ◦ When heated, the metal becomes fragile and may crumble. ◦ May cause silver to fracture when it's quenched.

ELEMENTS	GENERAL CHARACTERISTICS WHEN USED IN A SILVER ALLOY
Platinum (Pt is used in some proprietary sterling alloys, but not widely.)	• May make the silver alloy a little bit harder than palladium would. • Raises the melting point of the alloy, as palladium does. • Has cachet, perhaps more than palladium. • As compared to other alloy elements, difficult to get in solution with silver and then to get a homogenous mix.
Silicon (Si is used in some proprietary sterling alloys.)	• Brightens the surface. • Increases fluidity, which improves form filling (although silver is very fluid already). • Provides some deoxidization. • Helps reduce firestain and porosity. • Increases grain size. • Is used in very small quantities. The less copper present, the less silicon an alloy can hold. • In some proprietary alloys, is used to form a silicon dioxide film on the surface that works as a barrier to sulfide formation. However, the film can also keep solder from flowing smoothly.
Zinc (Zn is used in some proprietary sterling alloys.)	• Brightens the surface. • Increases strength and hardness, so it makes for a less ductile alloy. • Increases fluidity. • Provides some deoxidization. • As zinc oxide, can form a film or create inclusions. • Helps reduce firestain and porosity. However, too much zinc increases gas porosity. • Increases grain size. • Lowers melting point but isn't used for that purpose (silver alloys don't need improvement in that area). • Normally used in very small concentrations; exact quantities not available because that information is proprietary.

Note: Elements' characteristics were derived from multiple sources. See Credits, Notes, and Resources on page 142.



JUST THE FACTS

Platinum and Its Alloys

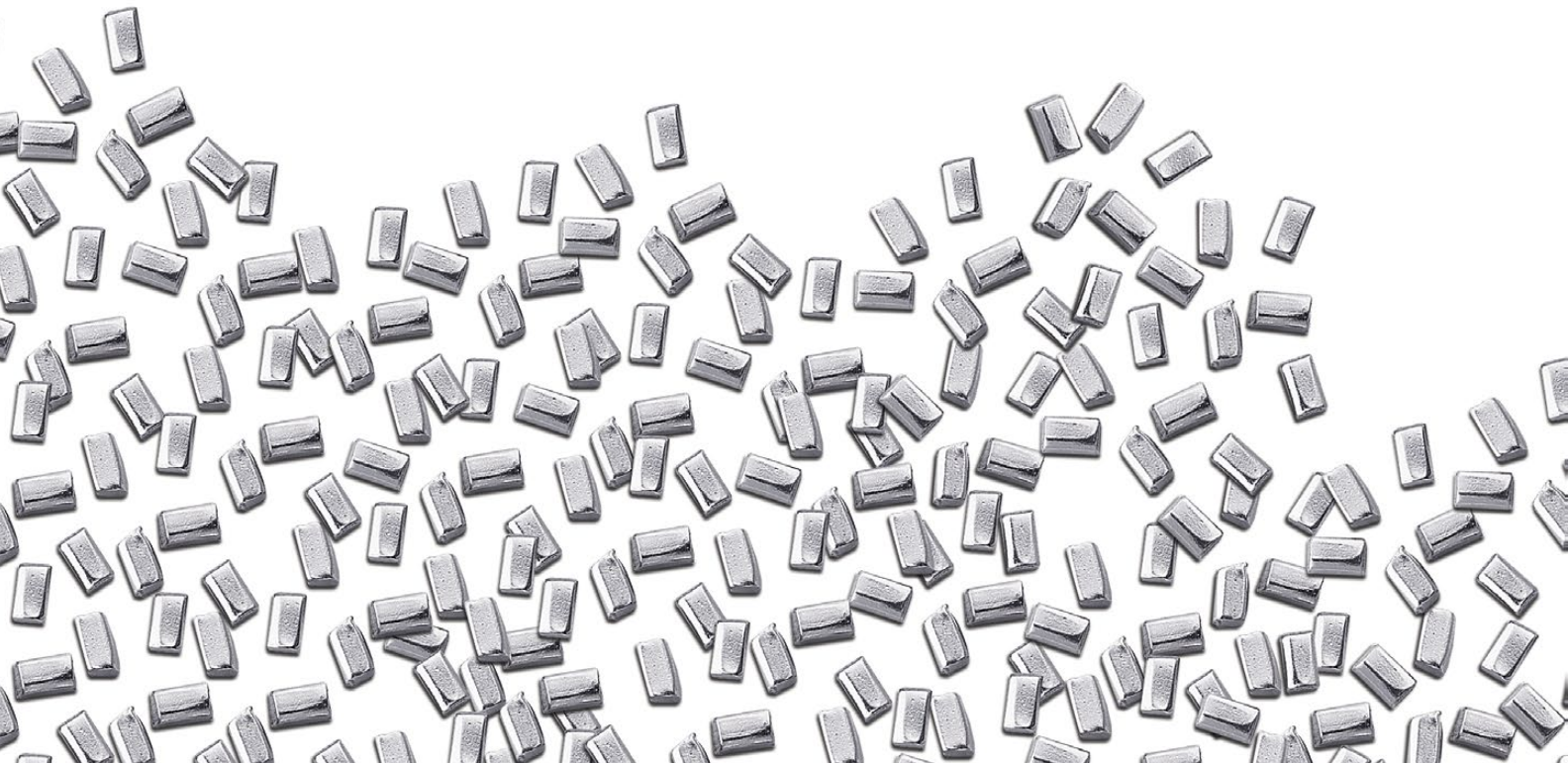
Platinum has a strong cachet for consumers, in part because of its rarity. It can also be a pleasure to work with, albeit a highly specialized art. Pure platinum is too soft to be used for jewelry making, but platinum alloys can be machined, fabricated, and cast (some yielding very fine detail). Platinum alloys are resistant to tarnish and are ideal for stone setting because the metal stays where it's put—it has little memory, so it doesn't spring back.

Platinum is one of six platinum group metals (PGMs), along with iridium, osmium, palladium, rhodium, and ruthenium. The most common platinum alloys are binary (i.e., composed of two metals). Pure platinum is often combined with one of the other PGMs to increase its hardness, and a few add non-PGMs, such as cobalt and copper, to further enhance certain characteristics. The PGM-based alloys don't typically oxidize, but the additional elements can oxidize and discolor the metal when it's heated, as during soldering and welding.

Elements are also added to platinum to create harder or more easily heat-treatable alloys (HTAs). As with other precious metal proprietary alloys, the exact mixtures used for proprietary platinum metals are not published, but typical hardening elements used are gallium, indium, and gold. Suppliers and manufacturers can provide the most accurate information about how best to work with any proprietary platinum alloy.

Although platinum alloys are white metals, they have a lower luminosity than silver, which gives them a grayer appearance. In addition, some alloying elements can subtly change the color of an alloy. In some countries, such as Japan, platinum alloys are plated with rhodium for greater whiteness.

Platinum alloys are resistant to tarnish and are ideal for stone setting because the metal stays where it's put—it doesn't spring back.



	MINIMUM % PLATINUM BY WEIGHT	COMMON ALLOYING ELEMENTS
fine/pure platinum	99.8 to 99.9 ^a	not applicable
platinum 950	95	cobalt, copper
platinum 950	95	iridium
platinum 950 ^b	95	palladium
platinum 950	95	ruthenium
platinum 900	90	iridium

This table lists the most common types of platinum alloys as well as some typical alloying elements (described in greater detail in “Alloying Elements: What They Do” on page 38). Alloying materials not mentioned in this table include tungsten (primarily used in German alloys), gallium, indium, and gold, which are generally used as hardeners.

^a Alloy quality is typically defined in parts per thousand: Platinum 950 alloys are recognized as platinum in the United States, whereas platinum 900 alloys—while in very wide use in the United States and elsewhere—cannot be called simply “platinum,” per US standards. For more information, see chapter 8, Standards and Guidelines.

^b The 900 platinum/palladium alloy is not listed here but shares very similar characteristics to its 950 counterpart.



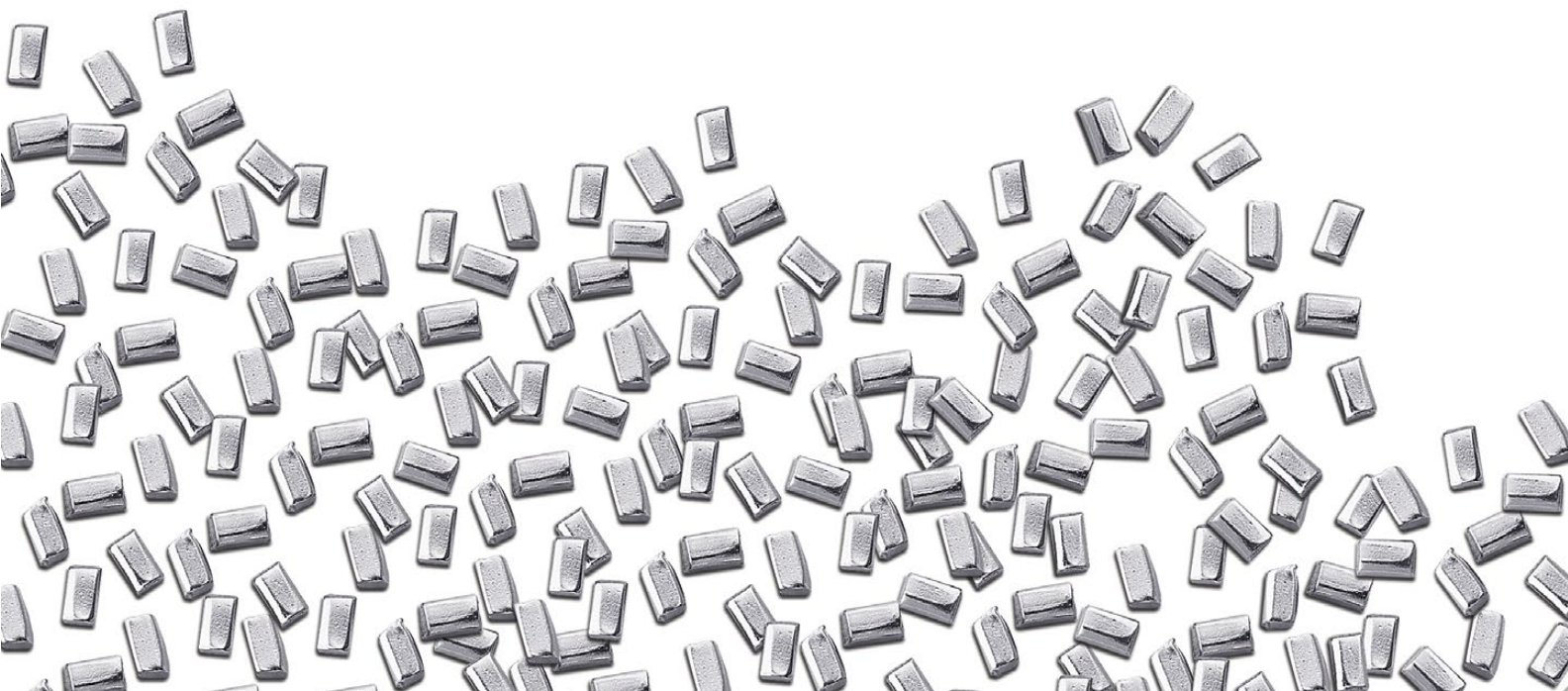
Alloying Elements: What They Do

ELEMENTS	GENERAL CHARACTERISTICS WHEN USED IN A PLATINUM ALLOY
Cobalt (Co is used in 950 alloys.)	• Creates blue tints. • Improves hardness and strength. • Reduces melting temperature. • Promotes fluidity and has excellent fill properties. • Deoxidizes. • Is itself brittle and hard, but does not embrittle the alloy. • Increases the potential for gas porosity in castings. • Tends to exhibit centerline shrinkage porosity in cast work. • Refines grain. • Improves finishing/polishing qualities by making the alloy harder. • Has some health and safety implications, but because the amount used is so small, it is not likely to cause contact dermatitis issues (although refining the alloy might). • Can make the alloy somewhat magnetic as well as susceptible to oxidation.
Copper (Cu is used in 950 alloys.)	• Has no effect on color. • Increases hardness. • Does not promote fluidity. • Reduces melting temperature. • Increases the potential for gas porosity in castings. • Refines grain.
Gold (Au is used in 950 alloys.)	• Has no effect on color. • Increases hardness. • Is heat treatable. • Refines grain. • Has high corrosion resistance.
Iridium (Ir is used in 950 and 900 alloys.)	• Has no effect on color. • Increases strength when used in small amounts and promotes rapid work hardening. • Decreases ductility when used in larger amounts. • Doesn't combine well with platinum in the 900 alloy, leading to greater hardness. • Increases melting temperature. • Refines grain. • Improves finishing/polishing qualities in the 900 alloy.



ELEMENTS	GENERAL CHARACTERISTICS WHEN USED IN A PLATINUM ALLOY
Palladium (Pd is used in 950 alloys.)	- Increases gray and somewhat dull appearance. - Hardens alloy very slightly, though the alloy remains very malleable and ductile. - Increases chance of gas porosity in castings. - Makes it harder to achieve a good finish because of its softness.
Ruthenium (Ru is used in 950 alloys.)	- Has no effect on color. - Increases strength and hardness. - Increases melting temperature. - Increases gas porosity in cast work. Tends to exhibit small, scattered microporosity. - Refines grain. - Improves finishing/polishing qualities because of the finer/smaller grain size and greater hardness that it imparts to the alloy. (See “Finishing Platinum Alloys” on page 44 for general guidelines and tips.) - Forms toxic ruthenium-oxide fumes when heated, therefore a respirator must be worn when it is melted.

Note: Elements' characteristics were derived from multiple sources. See Credits, Notes, and Resources on page 142.



JUST THE FACTS

Palladium and Its Alloys

One of the six platinum group metals, palladium came into its own as a jewelry metal in the mid-2000s, with interest driven in part by a desire for an affordable white metal. While pure palladium is too soft for jewelry making, various alloys have been developed that are suitable for either casting or fabrication.

Color differences between the palladium alloys are not typically visible to the eye unless the alloys are heated: 950 alloys develop a blue oxide when heated, and 500 alloys develop a black oxide. (Both oxides are easily removed, as described later in this chapter.) All palladium alloys are tarnish resistant at room temperature.

As with other metal alloys, some palladium alloys have proprietary formulas. Suppliers and manufacturers can provide the most accurate information about the capabilities of these alloys and how best to work with them.

*When heated,
950 alloys develop
a blue oxide and
500 alloys blacken.*



	MINIMUM % PALLADIUM BY WEIGHT	COMMON ALLOYING ELEMENTS ^a
fine/pure palladium	100 ^b	not applicable
950 traditional/ standard	95	copper, ruthenium, gallium
950 proprietary	95	copper, ruthenium, gallium, among others
500	50	silver, copper

The alloying elements in the chart above are described in more detail in “Alloying Elements: What They Do” on page 50.

^a This table presents common additives, any of which could be included in a particular palladium alloy. However, not all alloying elements in a row can or should be used together.

^b Alloy quality is defined in parts per thousand. In the United Kingdom, three hallmarks are recognized: 999, 950, and 500. In the United States, a minimum of 950 palladium has been commonly accepted by the industry for designating an alloy as “palladium.” As of late 2014, the Federal Trade Commission was considering adding standards for palladium to its *Guides for the Jewelry, Precious Metals, and Pewter Industries*; for updates, visit ftc.gov or contact MJSA (MJSA.org) or the Jewelers Vigilance Committee (jvclegal.org).



Alloying Elements: What They Do

ELEMENTS	GENERAL CHARACTERISTICS WHEN USED IN A PALLADIUM ALLOY
Copper (Cu is used in 950 and 500 alloys.)	• Has no effect on color in the 950 alloys, but it may make a 500 alloy grayer and darker. • Makes alloy harder. • May make castings brittle if they are not quenched promptly. (In the standard mix of 95 percent palladium and 5 percent copper, brittleness should not be an issue, but it could become one with the 50 percent palladium alloys.) For more on this topic, see “Quenching” on page 52. • Improves polishing qualities: The higher the proportion of copper, the harder the surface of the alloy and the easier the polishing.
Gallium (Ga is used in 950 and 500 alloys.)	• Has no effect on color. • Makes alloy harder. It also allows alloy to be age hardened. • Typically lowers the melting point of the alloy by a few degrees, which could help the fluidity of the metal during casting. • Improves finishing/polishing qualities.
Ruthenium (Ru is used in 950 and 500 alloys.)	• Has no effect on color. • Increases strength and hardness; work hardens quickly. • Typically increases the melting point of the alloy, which could affect ease of casting. • Refines grain structure. • Improves finishing/polishing qualities. • When heated, can form toxic ruthenium-oxide fumes; when melting the metal in any way, always wear a respirator.
Silver (Ag is used in 950 and 500 alloys.)	• Keeps palladium white by counteracting any color effect additional copper might have in the alloy. • Forms a complete solid solution with palladium. However, this does not seem to contribute to much if any hardening of the alloy.



Note: Elements’ characteristics were derived from multiple sources. See Credits, Notes, and Resources on page 142.