

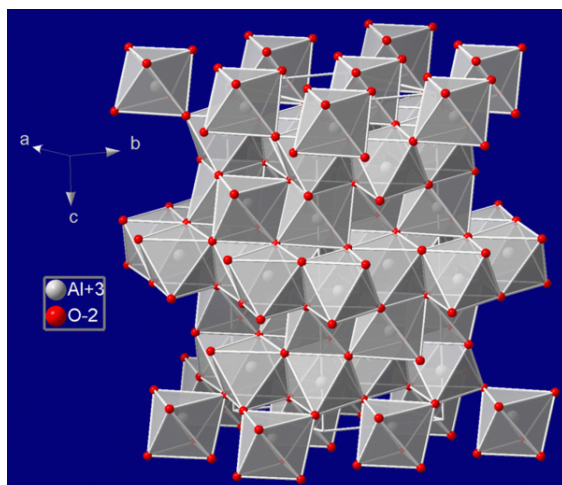
# Ruby

This article is about the mineral or gem. For other uses, see **Ruby** (disambiguation).

A **ruby** is a pink to blood-red colored **gemstone**, a variety of the mineral **corundum** (aluminium oxide). Other varieties of gem-quality corundum are called **sapphires**. Ruby is one of the traditional **cardinal gems**, together with **amethyst**, **sapphire**, **emerald**, and **diamond**.<sup>[3]</sup> The word *ruby* comes from *ruber*, Latin for red. The color of a ruby is due to the element **chromium**.

The quality of a ruby is determined by its color, cut, and clarity, which, along with **carat** weight, affect its value. The brightest and most valuable “red” called blood-red or “pigeon blood”, commands a large premium over other rubies of similar quality. After color follows clarity: similar to diamonds, a clear stone will command a premium, but a ruby without any needle-like **rutile inclusions** may indicate that the stone has been treated. Ruby is the traditional **birthstone** for July and is usually more pink than garnet, although some rhodolite garnets have a similar pinkish hue to most rubies. The world’s most expensive ruby is the **Sunrise Ruby**.

## 1 Physical properties

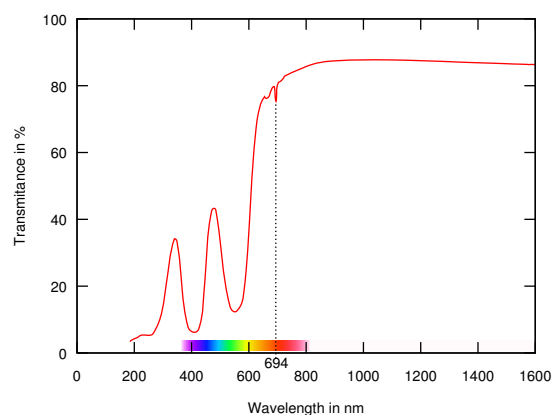


Crystal structure of rubies

Rubies have a **hardness** of 9.0 on the **Mohs scale** of mineral hardness. Among the natural gems only **moissanite** and **diamond** are harder, with diamond having a Mohs hardness of 10.0 and moissanite falling somewhere in be-

tween corundum (ruby) and diamond in hardness. Sapphire, ruby, and pure corundum are  $\alpha$ -alumina, the most stable form of  $\text{Al}_2\text{O}_3$ , in which 3 electrons leave each aluminum ion to join the regular octahedral group of six nearby  $\text{O}^{2-}$  ions; in pure corundum this leaves all of the aluminum ions with a very stable configuration of no unpaired electrons or unfilled energy levels, and the crystal is perfectly colorless.

When a chromium atom replaces an occasional aluminum atom, it too loses 3 electrons to become a chromium<sup>3+</sup> ion to maintain the charge balance of the  $\text{Al}_2\text{O}_3$  crystal. However, the  $\text{Cr}^{3+}$  ions are larger and have **electron orbitals** in different directions than aluminum. The octahedral arrangement of the  $\text{O}^{2-}$  ions is distorted, and the energy levels of the different orbitals of those  $\text{Cr}^{3+}$  ions are slightly altered because of the directions to the  $\text{O}^{2-}$  ions.<sup>[4]</sup> Those energy differences correspond to absorption in the ultraviolet, violet, and yellow-green regions of the spectrum.



Transmittance of ruby in optical and near-IR spectra. Note the two broad violet and yellow-green absorption bands and one narrow absorption band at the wavelength of 694 nm, which is the wavelength of the ruby laser.

If one percent of the aluminum ions are replaced by chromium in ruby, the yellow-green absorption results in a red color for the gem.<sup>[4]</sup> Additionally, absorption at any of the above wavelengths stimulates **fluorescent** emission of 694-nanometer-wavelength red light, which adds to its red color and perceived **luster**.

After absorbing short-wavelength light, there is short interval of time when the crystal lattice of ruby is in an excited state before fluorescence occurs. If 694-nanometer photons pass through the crystal during that time, they

can stimulate more fluorescent photons to be emitted in-phase with them, thus strengthening the intensity of that red light. By arranging mirrors or other means to pass emitted light repeatedly through the crystal, a ruby laser in this way produces a very high intensity of coherent red light.

All natural rubies have imperfections in them, including color impurities and inclusions of **rutile** needles known as “silk”. Gemologists use these needle inclusions found in natural rubies to distinguish them from synthetics, simulants, or substitutes. Usually, the rough stone is heated before cutting. These days, almost all rubies are treated in some form, with heat treatment being the most common practice. Untreated rubies of high quality command a large premium.

Some rubies show a three-point or six-point **asterism** or “star”. These rubies are cut into **cabochons** to display the effect properly. Asterisms are best visible with a single-light source and move across the stone as the light moves or the stone is rotated. Such effects occur when light is reflected off the “silk” (the structurally oriented **rutile** needle inclusions) in a certain way. This is one example where inclusions increase the value of a gemstone. Furthermore, rubies can show color changes—though this occurs very rarely—as well as **chatoyancy** or the “cat’s eye” effect.

### 1.1 Ruby vs. pink sapphire

Generally, gemstone-quality corundum in all shades of red, including pink, are called rubies.<sup>[5][6]</sup> However, in the United States, a minimum color saturation must be met to be called a ruby; otherwise, the stone will be called a **pink sapphire**.<sup>[5]</sup> Drawing a distinction between rubies and pink sapphires is relatively new, having arisen sometime in the 20th century. Often, the distinction between ruby and pink sapphire is not clear and can be debated.<sup>[7]</sup> As a result of the difficulty and subjectiveness of such distinctions, trade organizations such as the **International Colored Gemstone Association** (ICGA) have adopted the broader definition for ruby which encompasses its lighter shades, including pink.<sup>[8][9]</sup>

## 2 Natural occurrence

The **Mogok Valley** in Upper **Myanmar** (Burma) was for centuries the world’s main source for rubies. That region has produced some very fine rubies, but in recent years few good rubies have been found there. In central Myanmar, the area of Mong Hsu began producing rubies during the 1990s and rapidly became the world’s main ruby mining area. The most recently found ruby deposit in Myanmar is in **Namya** (Namyazeik) located in the northern state of **Kachin**.

Historically, rubies have also been mined in **Thailand**,

in the **Pailin** and **Samlout District** of **Cambodia**, as well as in **Afghanistan**, **Australia**, **Brazil**, **Colombia**, **India**, **Namibia**, **Japan**, and **Scotland**; after the **Second World War** ruby deposits were found in **Madagascar**, **Nepal**, **Pakistan**, **Tajikistan**, **Tanzania**, and **Vietnam**.<sup>[10]</sup> In **Sri Lanka**, lighter shades of rubies (often “pink sapphires”) are more commonly found. **Republic of Macedonia** is the only country in mainland Europe to have naturally occurring rubies. They can mainly be found around the city of **Prilep**. Macedonian ruby has a unique raspberry color. The ruby is also included on the Macedonian Coat of Arms. A few rubies have been found in the **U.S. states** of **Montana**, **North Carolina**, **South Carolina** and **Wyoming**.

**Spinel**, another red gemstone, is sometimes found along with rubies in the same gem gravel or marble. Red spinel may be mistaken for ruby by those lacking experience with gems. However, the finest red spinels can have a value approaching that of the average ruby.<sup>[11]</sup>

## 3 Factors affecting value

Rubies, as with other gemstones, are graded using criteria known as the four Cs, namely color, cut, clarity and carat weight. Rubies are also evaluated on the basis of their geographic origin.

**Color:** In the evaluation of colored gemstones, color is the most important factor. Color divides into three components: *hue*, *saturation* and *tone*. Hue refers to “color” as we normally use the term. Transparent gemstones occur in the *pure spectral hues* of red, orange, yellow, green, blue, violet.<sup>[12]</sup> In nature, there are rarely pure hues, so when speaking of the hue of a gemstone, we speak of primary and secondary and sometimes tertiary hues. Ruby is defined to be red. All other hues of the gem species corundum are called sapphire. Ruby may exhibit a range of secondary hues, including orange, purple, violet, and pink.



• A naturally occurring ruby crystal



- Natural ruby with inclusions



- Rubies set in jewelry



- A cut pink ruby

The finest ruby is described as being a vivid medium-dark toned red. Secondary hues add an additional complication. Pink, orange, and purple are the normal secondary hues in ruby. Of the three, purple is preferred because it reinforces the red, making it appear richer.<sup>[12]</sup> Purple also occupies a position on the color wheel halfway between red and blue. When a purplish-red ruby is set in yellow, the yellow neutralizes its complement blue, leaving the stone appearing to be pure red in the setting.

## 4 Treatments and enhancements

Improving the quality of gemstones by treating them is common practice. Some treatments are used in almost all cases and are therefore considered acceptable. During the late 1990s, a large supply of low-cost materials caused a sudden surge in supply of heat-treated rubies, leading to a downward pressure on ruby prices.

Improvements used include color alteration, improving transparency by dissolving rutile inclusions, healing of fractures (cracks) or even completely filling them.

The most common treatment is the application of heat. Most rubies at the lower end of the market are heat treated to improve color, remove *purple tinge*, blue patches, and

silk. These heat treatments typically occur around temperatures of 1800 °C (3300 °F).<sup>[13]</sup> Some rubies undergo a process of low tube heat, when the stone is heated over charcoal of a temperature of about 1300 °C (2400 °F) for 20 to 30 minutes. The silk is partially broken, and the color is improved.

Another treatment, which has become more frequent in recent years, is lead glass filling. Filling the fractures inside the ruby with **lead glass** (or a similar material) dramatically improves the transparency of the stone, making previously unsuitable rubies fit for applications in jewelry.<sup>[14]</sup> The process is done in four steps:

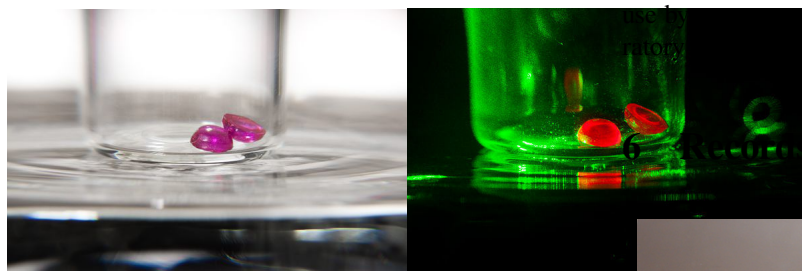
1. The rough stones are pre-polished to eradicate all surface impurities that may affect the process
2. The rough is cleaned with **hydrogen fluoride**
3. The first heating process during which no fillers are added. The heating process eradicates impurities inside the fractures. Although this can be done at temperatures up to 1400 °C (2500 °F) it most likely occurs at a temperature of around 900 °C (1600 °F) since the rutile silk is still intact.
4. The second heating process in an electrical oven with different chemical additives. Different solutions and mixes have shown to be successful, however mostly lead-containing glass-powder is used at present. The ruby is dipped into oils, then covered with powder, embedded on a tile and placed in the oven where it is heated at around 900 °C (1600 °F) for one hour in an oxidizing atmosphere. The orange colored powder transforms upon heating into a transparent to yellow-colored paste, which fills all fractures. After cooling the color of the paste is fully transparent and dramatically improves the overall transparency of the ruby.<sup>[15]</sup>

If a color needs to be added, the glass powder can be “enhanced” with copper or other metal oxides as well as elements such as sodium, calcium, potassium etc.

The second heating process can be repeated three to four times, even applying different mixtures.<sup>[16]</sup> When jewelry containing rubies is heated (for repairs) it should not be coated with boracic acid or any other substance, as this can etch the surface; it does not have to be “protected” like a diamond.

The treatment can be identified by noting bubbles in cavities and fractures using a 10x loupe.<sup>[17]</sup>

## 5 Synthetic and imitation rubies



ruby under a normal light (top) and under a green laser light (bottom). Red light is emitted

In 1837, Gaudin made the first synthetic rubies by fusing potash alum at a high temperature with a little chromium as a pigment. In 1847, Ebelmen made white sapphire by fusing alumina in boric acid. In 1877, Frenic and Freil made crystal corundum from which small stones could be cut. Frimy and Auguste Verneuil manufactured artificial ruby by fusing  $\text{BaF}_2$  and  $\text{Al}_2\text{O}_3$  with a little chromium at red heat. In 1903, Verneuil announced he could produce synthetic rubies on a commercial scale using this flame fusion process.<sup>[18]</sup> By 1910, Verneuil's laboratory had expanded into a 30 furnace production facility, with annual gemstone production having reached 1,000 kilograms (2,000 lb) in 1907.

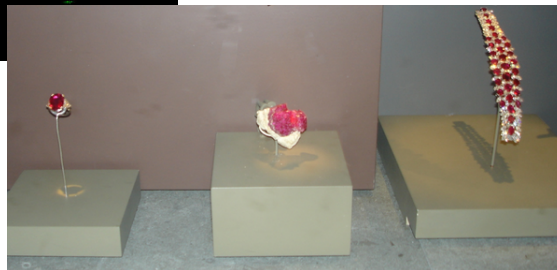
Other processes in which synthetic rubies can be produced are through Czochralski's pulling process, flux process, and the hydrothermal process. Most synthetic rubies originate from flame fusion, due to the low costs involved. Synthetic rubies may have no imperfections visible to the naked eye but magnification may reveal curves, striae and gas bubbles. The fewer the number and the less obvious the imperfections, the more valuable the ruby is; unless there are no imperfections (i.e., a "perfect" ruby), in which case it will be suspected of being artificial. Dopants are added to some manufactured rubies so they can be identified as synthetic, but most need gemological testing to determine their origin.

Synthetic rubies have technological uses as well as gemological ones. Rods of synthetic ruby are used to make ruby lasers and masers. The first working laser was made by Theodore H. Maiman in 1960.<sup>[19]</sup> Maiman used a solid-state light-pumped synthetic ruby to produce red laser light at a wavelength of 694 nanometers (nm). Ruby lasers are still in use. Rubies are also used in applications where high hardness is required such as at wear exposed locations in modern mechanical clockworks, or as scanning probe tips in a coordinate measuring machine.

Imitation rubies are also marketed. Red spinels, red garnets, and colored glass have been falsely claimed to be rubies. Imitations go back to Roman times and already in the 17th century techniques were developed to color foil red—by burning scarlet wool in the bottom part of the furnace—which was then placed under the imitation

stone.<sup>[20]</sup> Trade terms such as **balas ruby** for red spinel and **rubellite** for red tourmaline can mislead unsuspecting buyers. Such terms are therefore discouraged from gemological associations such as the Laboratory Gemmological Association (LMHC).

## 6 Records and famous rubies



Rubies at the National Museum of Natural History, Washington, D.C., USA

- The Smithsonian's National Museum of Natural History in Washington, D.C. has some of the world's largest and finest ruby gemstones. The 23.1 carats (4.62 g) Burmese ruby, set in a platinum ring with diamonds, was donated by businessman and philanthropist Peter Buck in memory of his late wife Carmen Lúcia. This gemstone displays a richly saturated red color combined with an exceptional transparency. The finely proportioned cut provides vivid red reflections. The stone was mined from the Mogok region of Burma (now Myanmar) in the 1930s.<sup>[21]</sup>
- In 2007 the London jeweler Garrard & Co featured on their website a heart-shaped 40.63-carat ruby.<sup>[22]</sup>
- On December 13/14, 2011 Elizabeth Taylor's complete jewellery collection was auctioned by Christie's. Several ruby-set pieces were included in the sale, notably a ring set with an 8.24 ct gem that broke the 'price-per-carat' record for rubies (\$512,925 per carat, i.e. over \$4.2 million in total),<sup>[23]</sup> and a necklace<sup>[24]</sup> that sold for over \$3.7 million.
- The Liberty Bell Ruby is the largest mined ruby in the world. It was stolen in a heist in 2011.<sup>[25]</sup>
- The Sunrise Ruby is the world's most expensive ruby, most expensive coloured gemstone, and most expensive gemstone other than a diamond. In May 2015, it sold at auction in Switzerland to an anonymous buyer for US\$30 million.<sup>[26]</sup>
- A synthetic ruby crystal became the gain medium in the world's first optical laser, conceived, designed and constructed by Theodore H. "Ted" Maiman,



on the 16th of May, 1961 at Hughes Research Laboratories.<sup>[19][27]</sup> The concept of electromagnetic radiation amplification through the mechanism of Stimulated Emission had already been successfully demonstrated in the laboratory by way of the Maser, using other materials such as ammonia and indeed, later, ruby, but the Ruby Laser was the first device to work at optical (694.3 nm) wavelengths. Maiman's prototype laser is still in working order.

## 7 Historical and cultural references

- In Job 28:18 and Proverbs 3:15, wisdom is more valuable than rubies. In Proverbs 31:10, a wife of noble character is worth more than rubies.
- An early recorded transport and trading of rubies arises in the literature on the North Silk Road of China, wherein about 200 BC rubies were carried along this ancient trackway moving westward from China.<sup>[28]</sup>
- Rubies have always been held in high esteem in Asian countries. They were used to ornament armor, scabbards, and harnesses of noblemen in India and China. Rubies were laid beneath the foundation of buildings to secure good fortune to the structure.<sup>[29]</sup>

## 8 See also

- Anyolite
- Gemology
- List of gemstones
- List of minerals
- Verneuil process

## 9 References

- [1] Corundum data on Webmineral
- [2] Ruby on Gemdat.org
- [3] *Precious Stones*, Max Bauer, p. 2
- [4] "Ruby: causes of color". Retrieved 28 Mar 2016.
- [5] Matlins, Antoinette Leonard (2010). *Colored Gemstones*. Gemstone Press. p. 203. ISBN 0-943763-72-X.
- [6] Reed, Peter (1991). *Gemmology*. Butterworth-Heinemann. p. 337. ISBN 0-7506-6449-5.
- [7] Wise, Richard G. "Gemstone Connoisseurship; The Finer Points, Part II".
- [8] Hughes, Richard W. "Walking the line in ruby & sapphire". ruby-sapphire.com.
- [9] Federman, David. "Pink Sapphire". Modern Jeweler.
- [10] <http://www.gemsociety.org/article/ruby-sapphire-identifying-origin-understanding-value-rarity-gem-corundum>
- [11] Wenk, Hans-Rudolf; Bulakh, A. G. (2004). *Minerals: their constitution and origin*. Cambridge, U.K.: Cambridge University Press. pp. 539–541. ISBN 0-521-52958-1.
- [12] Wise, Richard W. (2006). *Secrets Of The Gem Trade, The Connoisseur's Guide To Precious Gemstones*. Brunswick House Press. pp. 18–22. ISBN 0-9728223-8-0.
- [13] *The Heat Treatment of Ruby and Sapphire*. Bangkok, Thailand: Gemlab Inc. 1992. ISBN 0940965100.
- [14] Vincent Pardieu Lead Glass Filled/Repaired Rubies. Asian Institute of Gemological Sciences Gem Testing Laboratory. February 2005
- [15] Richard W. Hughes (1997), *Ruby & Sapphire*, Boulder, CO, RWH Publishing, ISBN 978-0-9645097-6-4
- [16] Milisenda, C C (2005). "Rubine mit bleihaltigen Glasern gefüllt". *Zeitschrift der Deutschen Gemmologischen Gesellschaft* (in German). Deutschen Gemmologischen Gesellschaft. **54** (1): 35–41.
- [17] "Lead Glass-Filled Rubies". *GIA Global Dispatch*. Gemological Institute of America. 2012.
- [18] "Bahadur: a Handbook of Precious Stones". 1943. Retrieved 2007-08-19.
- [19] Maiman, T.H. (1960). "Stimulated optical radiation in ruby". *Nature*. **187** (4736): 493–494. Bibcode:1960Natur.187..493M. doi:10.1038/187493a0.
- [20] "Thomas Nicols: A Lapidary or History of Gemstones". 1652. Retrieved 2007-08-19.
- [21] "The Carmen Lúcia Ruby". *Exhibitions*. Retrieved 2008-02-28.
- [22] "Garrards – Treasures (large and important jewelry pieces)". Retrieved 2010-11-08.
- [23] The Legendary Jewels, Evening Sale & Jewelry (Sessions II and III) | Press Release | Christie's. Christies.com (2011-12-14). Retrieved on 2012-07-11.
- [24] Elizabeth Taylor's ruby and diamond necklace. News.yahoo.com (2011-09-07). Retrieved on 2012-07-11.
- [25] <http://philadelphia.cbslocal.com/2012/01/09/irreplaceable-2-million-ruby-stolen-in-wilmington-jewelry-heist/>
- [26] "World's most expensive coloured gem sells for \$30m". *BBC*. 13 May 2015. Retrieved 13 May 2015.

- [27] “Laser inventor Maiman dies; tribute to be held on anniversary of first laser”. Laser Focus World. 2007-05-09. Retrieved 2007-05-14.
- [28] C. Michael Hogan, Silk Road, North China, The Megalithic Portal. 19 November 2007
- [29] Smith, Henry G. (1896). “Chapter 2, Sapphires, Rubies”. *Gems and Precious Stones*. Charles Potter Government Printer, Australia.

## 10 External links

- International Colored Stone Association’s ruby overview page
- Webmineral crystallographic and mineral info

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### 11.1 Text

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Parrot, Digger3000, Stwalkerster, Noah Salzman, Optakeover, Jose77, Wizard191, Iridescent, Arpvarma, Wjejskenewr, RMRayner, IvanLanin, Bobamneritiopsis, Bifgis, Gil Gamesh, Coucelles, Donquixote99, Tawkerbot2, Daniel5127, ChrisCork, SlippyD, JForget, CmdrObot, Glutatizblu, Ale jrb, B4Ctom1, Picaroon, Jesse Viviano, Saleemhali, FlyingToaster, Godardesque, Ken Gallagher, Oksanasgems, Besieged, Notme676, Cyhawk, Gogo Dodo, ST47, John R G, Compuserf, JLD, Thrapper, Aldis90, Ohnjaynb, Korgone, Thijs!bot, Epbr123, Miss Dark, IsaacSapphire, N5iln, Edwardx, Bigdavesmith, Headbomb, Marek69, JustAGal, Silverdragonn, Dfrg.msc, Noclervname, Alessandriana, Mentifisto, JEBrown87544, AntiVandalBot, The Obento Musubi, Luna Santin, Akgradecki, Seaphoto, SummerPhD, Gemwise, Lugia 1985, Naveen Sankar, Mfrisk, Spencer, Kcirtap28, Myanw, DOSGuy, Mikenorton, JAnDbot, Milonica, DuncanHill, Barek, AlexFolland, Jheiv, Awien, Doctorhawkes, SiobhanHansa, Bongwarrior, VoABot II, Polytrope, Sarahj2107, Mallow's Basement, Catgut, Indon, Daarznicks, Alekjds, Loonymonkey, Mkdw, Tins128, Heliac, DerHexer, Arulraja, Gjd001, Thfinch, Bivalve, Danieliness, MartinBot, Axlq, SmokeySteve, Hugo Dufort, Mschel, Leyo, Gunkarta, Barry Arthur, J.delanoy, Rhinestone K, Gem-fanat, 12dstring, GeoWriter, J Dezman, McSly, Idunno271828, 97198, Warut, Belovedfreak, Jorfer, Wabadee, Brancron, MetsFan76, Tygrrr, LastChanceToBe, SoCalSuperEagle, Lwalt, Hammersoft, VolkovBot, Kachyna, Scorwin, Spark Arrestor, Vlmastra, Philip Trueman, Drunkenmonkey, TXiKiBoT, Mrzubrow, Vipinhari, Ragemanchoo, Jazzwick, NPrice, Rei-bot, Aymatth2, Vanished user ikijeirw34iuaeolaseriffic, INXS-Girl, Claidheamohmor, AllGloryToTheHypnotoad, LeaveSleaves, KC Panchal, Madhero88, Falcon8765, Purgatory Fubar, AlleborgoBot, JDub90, PGWG, Cleopatra427, IndulgentReader, SieBot, Sonicology, Tresiden, Seskasha, Krawi, Gerakibot, Theone93, Dawn Bard, Avivco, Caltas, Triwbe, Keilana, Ipredictariot2, Flyer22 Reborn, Radon210, Ding Do Do, David Adam 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