Warning: this version has been completed with Google Translate , it certainly contains errors or inaccuracies.

THE Refractometer (gemological)

<table>
<tr>
<td>Name and Appearance</td>
<td>(Italian - rifrattometro)
(English - (gem) refractometer)
(French - (gems) réfractomètre)
(Spanish - (refractómetro (para gemas))
(Portuguese - (gemológico) refratômetro)
(Thai - (อัญมณี) เครื่อง วัด การ หักเห ของ แสง (X ạy̱ m ṇ ī) kher ụ̄` xng w ạ d kār h̄ ạ kh̄ e k̄hxng s̄ æ ng)
(German - (Edelstein) Refraktometer)
(Arabic - جوهرة) الانكسار مقياس
((jawharat) miqyas aliankisar)
(Russian - (драгоценный камень) рефрактометр (dragotsennyy kamen ') refraktometr)
(Mandarin -宝石） 折射 计 (Bǎ osh í) zh é sh e jì)
(Swahili - (gemological) refractometer)
(Hindi - (मणि) रेफ्रेक्टोमीटर
(hands) rephrektomeetar)</td>
<td>Photo
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<td>History</td>
<td colspan="2">Year of discovery / invention: 1869
Thomas Young was allegedly the scientist who invented the term "refractive index" in the optical sciences in 1807 . He not only created the lemma but, he redefined the refraction (term before him) as a single value, replacing the previous number which provided the ratio of two quantities. In the following years, it was defined by several symbols: n, m and μ , but it was n that gradually prevailed. Later this number was related to the Cauchy transmission equation , an empirical relationship between the refractive index and the wavelength of light of transparent materials. The French mathematician Augustin-Louis Cauchy theorized this link in 1837 . The refractive index of materials varies with the wavelength (and frequency) of light. This variable is referred to as dispersion and causes prisms to divide white light into its constituent spectral colors (rainbows). In some materials, the refractive index depends on the polarization and the direction of propagation of light. When it divides, due to the properties of the material it passes through, 2 beams of light are created. Their divergence creates a birefringence or optical anisotropy . The refractive index of liquids or solids can be measured with a refractometer. Typically, this instrument measures the angle of refraction or critical angle associated with the total internal reflection. The first to build a refractometer was the German physicist, astronomer and entrepreneur Ernst Karl Abbe (1840–1905), in 1869 . This innovative device was introduced at the height of the industrial revolution, when many productive and commercial mass manufacturing activities required the constant understanding of some properties of the objects they promoted (for example the constant sugar content in a drink). By measuring the refractive index of a sugar solution, it became possible, for example, to determine its concentration and therefore to maintain its constant level throughout the production. To complete his work, Abbe relied on lenses from Carl Zeiss Optical Works of Jena (a company famous to this day, for example supplies the lenses for some mobile phone models produced by Nokia and Vivo). In 1874 , he published the pamphlet Neue Apparate zur Bestimmung des Brechungs - Zerstreuungsvermögens und fester Körper und flüssiger (New apparatus for the determination of refraction - power of dispersion and solid and liquid bodies), which described the construction and operating principle of the refractometer he designed five years earlier. A few years later, in 1881 . Zeiss began marketing the instrument. The basic construction of the original apparatus was similar to modern versions with the difference that it did not have a graduated scale. The first models were produced only on request, for special customers and did not appear in the Carl Zeiss</td>
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catalogs before 1881. In the following years, again in these sales records, we find important facts about these prototypes. For example, the models marked with the codes "N° 148 Carl Zeiss Jena" and "Germany", were delivered to JW Queen & Co., a major instrument dealer in Philadelphia (USA) on July 2, **1890** , who resold them at the University of Michigan Department of Chemical Engineering.

The subsequent evolutions of the refractometer concerned the practicality, ease of use and / or stability of the instrument and, consequently, the development of specific tools for professional operators of different industrial fields.

In **1888,** a second device was released on the market, again based on the critical angle, the one created by Carl Pulfrich (1858-1927), different from that of Abbé, especially suitable for measuring the refractive index of liquids. Initially, this new device was made by Max Wolz in Bonn, later Pulfrich also joined Carl Zeiss.

The refractometer as an instrument was slowly changing. While the general principle was (and is to this day) always the same, over time new models were developed to increase the accuracy of the measurements. Of the important changes, one of the most significant was the introduction of jacketed temperature prisms, which took place around **1893** . Technology continued to make progress.

The situation changed with the First World War, when other manufacturers, German and non-German, began to market Abbé refractometers. The reasons were different: one was the transfer of patents to new owners as part of German war reparations, the other was economic, companies that during the war period were involved in the production of optical instruments for the army, were looking for new markets and refractometers adapted to their production profile.

Refractometry was initially used in chemical analyzes to determine the concentrations of solutions and as an aid in the identification of unknown substances. Later its applications expanded and eventually **became useful also in the field of precious stones** . The British mineralogist, Henry Miers (1858-1942), in his lectures for the Royal Society, in **1896,** already stressed the importance of considering not only the history or artistic interest of precious stones, but also some of their more curious.

By examining their refractive index and specific gravity, Miers demonstrated how tools such as the protractor, refractometer, dichroscope, and polariscope helped **determine the identity of the gems** .

In **1905** , in England, another British mineralogist. Dr **George Frederick Herbert Smith** (who worked for the British Museum of Natural History) **produced one of the first** gemological refractometers, an instrument specifically designed to measure the refractive index of gemstones (this was followed in 1907 by a brass version more great). Smith improved on preexisting tools to provide the industry with a means of measuring the refractive index of a gemstone in seconds (even without removing it from the setting). This was an exciting time of innovation in the gemological world. The years following the arrival of the refractometer saw the introduction of the spectroscope in **1907** and the creation of the first institute / association of gemology, **the** Educational Committee of the National Goldsmiths Association **, in 1908,** (which became **the Gemmological Association of Great Britain** - name assumed only in 1938 - which today is also known as Gem -A),

Smith also published a groundbreaking book titled *Gemstones* in **1912** , offering the **first text on gems** with comprehensive instructions on how to use specialist equipment. Although the gem and jewelry industry was an ancient craft, this equipment allowed jewelers to look inside the stones and these years mark the first advances in practical gemology.

Following the **First World War** , the Germans were forced to pay war reparations, some of which required the transfer of patents and designs of equipment manufactured by German industry to US and British firms. The optical devices produced in the Carl Zeiss factories in Jena, including the Abbé and Pulfrich refractometers were made **available by Bausch & Lomb (US) and Adam Hilger (UK),** while many companies that during the war had dedicated themselves to the production of optical instruments for the army with the end of the conflicts they looked for new markets. Refractometers fit their production profile well, which led to the production of many new models.

	The growing importance of the identification of the refractometer in the world of gemology led to the introduction, in **1925 ,** of a new model, designed by the famous jeweler-gemologist **BJ Tully** . This version used a rotating glass hemisphere. In 1931. Robert Shipley , having received the Diploma of Gemology from the **British Gemmological Association** (1929), through a correspondence course in the United States, founded the **Gemological Institute of America (GIA).** In the mid-1930s, he was joined by his eldest son, Robert Shipley Jr, who helped develop a series of gem testing equipment that included a microscope, diamond colorimeter, new **refractometer ,** and polariscope. In **the depression years of the 1930s** in the UK, Basil Anderson and CJ Payne researched various gem testing / identification techniques. In particular, they developed an **updated experimental version of Tully's refractometer** and formulated **a new contact liquid** (a solution of sulfur and tetraiodoethylene in diiodomethane) which until time was used throughout the gemological world. Following unsuccessful attempts by the *Rayner Optical Company* , manufacturer of the Tully refractometer, to fabricate the hemispherical prism of a material more resistant than glass, they created a truncated prism version and inserted into a small instrument designed by Rayner . Switching from a hemisphere to a prism-shaped refractometer "table" allowed for a less expensive standard glass model. This design became the basis for all future **Rayner refractometers .** In **1936** , **the** Rayner model was $ 65 (in the US) while the Tully was worth twice as much, $ 125. According to the American Gem Society (AGA), the latter was larger and gave more accurate results (source: G&G magazine of the winter of 1936). The Zeiss factory in Jena produced refractometers until destruction by Allied bombing **during the Second World War** . At the end of the conflict, Germany was divided, the same happened to Carl Zeiss. The Jena factory was located in the Russian zone, the occupying Russians relocated most of the existing Zeiss factories and equipment to the Soviet Union, along with documents and plans. The western part of the company then began work on a new device: a **new refractometer** that used a single telescope for both positioning the boundary between light and dark areas, and for reading the refractive index, which made it very easier to use. Dr. **Herbert Smith** , President of Gem -A from **1942 to 1953** developed, during the same period, the new **Herbert Smith model** which improved the instrument beyond recognition and provided the industry with a means of determining the refractive index of a gemstone. in seconds (without even having to remove it from the setting). Since then, there have been no major changes in the technology of these devices. The biggest news in the industry was the market entry of Chinese models starting in the early 2000s. Some of these tools, even very small ones, can cost $ 70-100, including RI liquid. Most of them give results that are not always reliable, however some companies (such as Fable for example) have created instruments with new designs (and not based on devices already in existence), which compete with those of more renowned associations for their lower cost.
Scientific reference laws	**History of the theory:** the great astronomer and geographer **Ptolemy** (100-170 AD) was one of the first scholars to try to understand light and how its path varied in the sky. He correctly understood that passage through atmospheric masses of different densities influenced this phenomenon. The merit of the discovery of the **law of refraction** it was long attributed to **Willebrord Snellius** (1580–1626) who derived it using trigonometric methods in 1621. However, recent studies indicate that this law was discovered nearly 600 centuries earlier, during the Islamic golden age of Baghdad by a scientist named **Ibn Sahl** (Abu Sad Al Alla Ibn Sahl, 940–1000 associated with the Abbasid court). In fact, in **984 Ibn Sahl** wrote the treatise " *On mirrors and burning lenses* ". In it, the Arab scholar expounds his understanding of how curved mirrors and lenses bend and focus light. In this work Ibn Sahl is credited with having first discovered the law of refraction, usually called **Snell's law** . Another important contribution came from the Arab mathematician, astronomer and physicist Ḥ asan Ibn al - Haytham , Latinized in **Alhazen** (965-1040), defined as "the father of modern optics". He too studied the principles of visual perception and conducted studies on the potential of glass spheres to concentrate light to create fire, examining **the double refraction of the materials used** . His most influential work by him is titled Kitāb al- Manā ẓ ir (Arabic:

كتاب المناظر , "Book of Optics"), written in the period 1011-1021, which has survived in a Latin edition. The work in the Muslim world did not end with them; three centuries later, another scholar, Kamal al Din al - Farisi (1267–1320), was able to give a first correct explanation of the rainbow phenomenon. At the end of the 16th century, **Sir Francis Bacon** (Francesco Bacon, 1561-1626) had expressed the desire to develop a microscope that would allow the examination of " **gem irregularities** ". However, those who bought and sold gems still relied on their own and experience of the trade, and there is little evidence that they were much involved in science.

Another 300 years had passed since al- Farisi 's work and, in **1669,** a Danish physician, named **Bartholinus** , noticed that a plate of transparent mineral from Iceland, (called "Iceland- spar ", a form of calcuite), it possessed the extraordinary property **of giving a double image of nearby objects** when viewed through it. Subsequent investigations showed many crystals / minerals to be doubly refractive. The apparent separation of the pair of images given by a plate cut in any direction depends on its thickness.

Also in the same period, **Sir Isaac Newton** (1643-1727), in 1672, described **refraction and double refraction** . Isaac Newton argued that the geometric nature of the reflection and refraction of light could only be explained if the light was made of particles, called *corpuscles* because waves do not tend to travel in a straight line. The British scholar indicated the "proportion of the sinuses of incidence and refraction" and recorded it as a **ratio of two numbers** , as "529 to 396" (or "almost 4 to 3") for water. At the same time, another British scientist, **Hauksbee** Francis Hauksbee (or Hawksbee , 1660–1713) defined the " **refractive ratio** " and wrote it as a relation to a **fixed numerator** , while the Scottish geologist, James Hutton (1726-1797), identified it as a ratio with a fixed denominator, such as 1.3358 to 1 (water). These early conceptions of particle theory of light laid the foundation for modern understanding of the **photon** . Around the end of the 17th century, other new and important values were introduced which contributed not only to the understanding of optical phenomena in general, but also to those involved in the light effects associated with precious stones. An important numerical value in this sense is that linked to the **speed of light** in a vacuum. This value was first determined in 1676 by the Danish Olaf Romer (1644-1710), from the astronomical observations of the moons of Jupiter. It has the unimaginably high value of 299,792,458 m / s (o 1,079,252,848.8 (1.07 billion) km / h): A ray of light from the Sun takes only 8 minutes to reach Earth. The speed of light is correlated to the refractive index, the higher its quotient, the greater the density of the stone, the more significant the change in direction of light inside the gem and its reduction in speed. To calculate its slowdown through the various precious stones, it is sufficient to divide its value by the RI of a gem (these are indicative values, since they consider virtually perfect situations).

Through a **diamond** : (RI: 2.418) about 123.984 m / s

Through **quartz** : (RI: 1.544-1.553) approximately 193.041-194.167 m / s

Through **glass** : (RI: 1.440-1.900) about 157.786-208.190 m / s

Through **beryllium / emerald** : (RI: 1.565-1.602) approx. 187.137-191.561 m / s

Through **corundum / ruby / sapphire** : (RI: 1,762-1,770) approx. 169,375-170,144 m / s

The next step is due to the French physicist Augustin-Jean Fresnel (1788-1827). who studied wave theory of light. He developed what was later known as the refractive index **from the Fresnel equation,** for which the surface component of a gemstone's brilliance (i.e. its luster or reflectivity) is proportional to the light reflected from within it and it depends on the cutting style, which in turn is partly dictated by the critical angle of the gem material.

Luster, reflectivity or reflectance of a gemstone can be qualitatively described as adamantine, vitreous, resinous, etc. However, they can also be measured in absolute terms through the relationship between the intensity of the reflected ray and that of the incident ray: the degree of luster or reflectivity of a gem (assuming a "perfect" polish) is **mainly due to its index of refraction** , but is modified by other factors such as its molecular structure and transparency.

Important concepts

	Refraction : change in direction of a wave as it passes from one medium to another caused by its change in speed. For example, waves travel faster in deep water than in those close to the surface. **Refractive index** of a material is a dimensionless number that describes the **speed at which light travels through it** . It is defined as $$n = c \backslash v$$ where ***c*** is the speed of light in vacuum and ***v*** is the speed of light through medium. For example, the refractive index of water is **1.333** , which means that light travels 1.333 times (33%) slower in water than in vacuum. **Increasing the refractive index corresponds to decreasing the speed of light in the material.** The refractive index determines how much the light path is bent or refracted when it enters a material. This is described by Snell's law of refraction, $n1 \sin\theta1 = n2 \sin\theta2$, where $\theta1$ and $\theta2$ are the angles of incidence and refraction, respectively, of a ray crossing the interface between two media with refractive indices n1 and n2. The refractive indices also determine the amount of light that is reflected when it reaches the interface, as well as the critical angle for total internal reflection, their intensity (Fresnel equations) and Brewster's angle. Brewster's angle (also known as polarization angle) refers to an optical phenomenon named after the Scottish physicist Sir David Brewster (1781–1868). Brewster's angle is a particular angle such that if a wave hits a surface according to this angle , the reflected wave is found to be polarized perpendicular to the plane of propagation. When light passes from a prime to another material that has a different refractive index, usually part of the wave is reflected by the interface between the media. At a specific angle of incidence, however, light with a particular polarization cannot be reflected. This specific angle of attack is called the "Brewster angle". **Critical angle:** the critical angle (also known as the limit angle) is that angle of incidence beyond which **a total internal reflection is obtained** (the light remains inside a gem, for example). The angle of incidence is measured relative to the normal (the line perpendicular to the surface) at the interface between two media. The importance of a gemstone's critical angle has an aspect that is not always appreciated by the owner of gemstone jewelry. If the pavilion facets of a gemstone are veiled with grease or soap, the result will be a **reduction in the overall brilliance of the stone.** This is because the RI of grease or soap is greater than that of air and this will increase the critical angle of the gem. The effect is particularly evident in the case of a brilliant cut diamond, **83% of whose brilliance derives from total internal reflection** , and is a significant reason for keeping the stone clean. **Total internal reflection:** When light travels from an optically denser material (with a higher refractive index) to an optically less dense material (with a lower refractive index), all light that reaches the boundary of the two materials is reflected back to the interior of the denser material or refracted in the less dense material, depending on the angle of incidence of light. Refraction does not occur when a light beam is 90 degrees (perpendicular) to the entry area of the beam. The **standard gemological refractometer** can exploit this phenomenon because the reflected light rays will appear as a bright area on the scale, while the refracted rays are not visible (and therefore appear dark). The light / dark boundary shown on the refractometer scale is **a visible representation of the critical angle** . The refractometer then measures the critical angle between the glass half cylinder and the gem and displays it on a graduated scale. **Kerez Effect:** Some **green tourmalines** can show up to **8 shadow edges** (tourmaline is uniaxial and should only show two shadow edges in one reading). This according to current knowledge due to heat and / or thermal shock during polishing of the table's facets. Little documentation on this subject is at hand. This phenomenon is named after CJ Kerez. **Optical character** The optical character is the value related to the way in which the rays of light travel inside the precious stones.

In double refractive materials, **incoming light is polarized in two (uniaxial) or three (biaxial) vibrational directions** .
This means that the light separates, inside the stones, and travels at different speeds and at different angles (bends) depending on the direction. This is due to the molecular density within the stone. This quality can be important in the identification of some species and allows to divide the precious stones into three categories, indicated as **optical characters** :

1. **isotropic**
2. **uniaxial**
3. **biaxial**

1. When on the refractometer, after rotating the stone in various directions, a constant reading is noticed, this indicates that they are **isotropic** or **single refraction stones** . In them, light travels in all directions at the same speed. They are formed in the cubic crystalline system (**garnet, diamond, spinel**) or the amorphous one (which does not have a regular and repeated shape), such as glass.
2. In the case of **double refraction stones** , sometimes values are measured, one of which shows a constant reading and the other a variable. These are gems with **a uniaxial optical character.** Within them, light travels differently **in two directions** .

One ray of light (the so-called ordinary ray (ω)) vibrates on the horizontal plane, while the other (extraordinary ray (ε)). vibrates on the vertical one, along the c axis. This extraordinary ray is also the optical axis along which light behaves as if it were isotropic. Precious stones belonging to the **tetragonal (zircon), hexagonal (beryllium) and trigonal (corundum) crystal systems** have a uniaxial optical character.

3. **Stones double refraction** characterized by two values both with variable readings on the refractometer. are the two-axis gems. In them, the incoming light divides, within their crystals, into two extraordinary rays, labeled as α, γ and β rays.

Stones with a biaxial optical character have **two optical axes** and are typical of the **orthorhombic, monoclinic and triclinic crystal systems** . These gems are trichroic (they show 3 colors when viewed along the 3 crystalline axes).

Alternatives to the refractometer - the Hodgkinson Method

Hodgkinson Method is an interesting system for determining the refractive indices of precious stones. It does not rely on any equipment, but requires some experience, a lot of practice, a dark room and a small incandescent light source. Simply by looking through a faceted stone, illuminated by a tenuous source of light, its RI can be estimated by moving the image that is seen inside it: the birefringence can be determined by separation of the image and the dispersion for ghostly colored fringes on the same. This system is useful for those who travel a lot or work without standard gemological equipment.
After carefully cleaning the gem, hold it very close, but without touching it, to the eye so that you can look through its board (the main upper facet). To see, through the stone, a source of light placed in the distance, such as a lamp or a light bulb. You will notice a series of reflections from the background light as they bounce inside the stone.
Roll the stone around its axis and tilt it slightly while observing its reflections. Due to its refractive properties, each reflection will appear as a small rainbow of some size. Depending on the material of the gem in question, this **iridescence** will have different properties. If the gem is isotropic, i.e. single refraction, no doubling will be seen. If, on the other hand, the gem is **doubly refractive** , it is likely that doubled or ghosted (rainbow) images will be seen. The distance between the edges of the doublings or the iridescent ones can indicate the birefringence of the gem. Since the gem can be cut in any orientation with respect to the crystalline structure (which is responsible for these phenomena), it may be necessary to examine the stone from a variety of angles to be sure it is doubly refractive.

Usage	A gemological refractometer is one of the main tools in identifying gemstones. It measures **the critical angle, the refractive index of faceted stones, from transparent** to opaque (some models), the **birefringence** and, in many cases, also the **optical**	**Limitations** Many gems have **similar RI** , so this method is almost never sufficient in distinguishing the various species (however, the results must always be verified through other tests). In stones with **curved surfaces** the values are

	character . These factors are often decisive but not sufficient to ensure effective identification.	approximate. It also cannot be used in the **separation of natural gems from synthetic ones** .

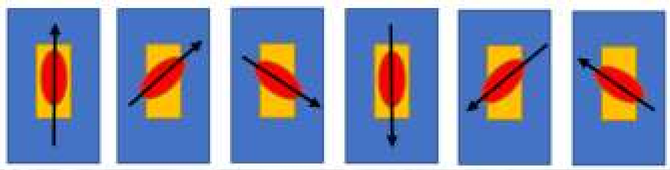
How to use

To use the refractometer:

Flat surfaces (faceted gems)

- Clean the gem with a cloth and make sure the instrument slide is clear and free from stains.
- Make sure that the instrument is in a comfortable position for use, stable and level.
- Open the lid,
- Place a small amount of liquid IR (Refractive Index or RI, more common) in the center of the top glass slide of the refractometer using the dropper built into the bottle. The drop should be about 0.5 / 1mm in diameter. This fluid is needed to create "optical contact" between the glass and the gemstone.
- Then place a polished facet of the stone on the graduated glass (using your hands and not tweezers, so as not to scratch the slide), placing it first on the metal part and gently letting it slide (without applying any pressure) towards the center of the slide, above the drop of RI. Close the refractometer lid to shield out extraneous light.
- Turn on the built-in, or pre-positioned, light on the back of the instrument
- Remove the polarizing filter (it will be used in a later step).
- Position your head and eyes about 20-25 cm from the eyepiece, adjust posture and optical piece for optimal vision.
- Look through the eyepiece and read the scale at the dividing point between the illuminated part and the shadowed part created by the critical angle of the particular gem. You can change the focus of the image by turning the eyepiece.

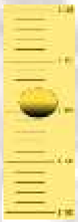
- If the gem is **individually refractive** , you will only see a line that does not move when the stone is rotated (this feature can be confirmed by polariscope examination).
- Record the value up to the third decimal place (the instruments show only 2, estimate the third by eye where possible).
- Check by turning the gem on the same facet in 2 other positions. The arms should be placed with the elbows well placed, comfortable to give stability to movements and reduce fatigue (especially if you have to examine many stones).

- If the gem is **doubly refractive** , it is best to see it by going up and down with the head.
- Rotate the stone, on the same face, with 6 different angles (as shown in the image). The higher value always has a less pronounced tone on the scale.
- 
- If the 2 values are close, you can use the polarizing filter as an aid, rotating it back and forth with your fingers, several times, while viewing the scale, to visualize the imperceptible differences in shadow).
- **optical character** of each stone can be determined through this test . If only one line moves (the other is static), the gem is uniaxial, if both move, it is biaxial. If it moves. with a wider margin. the lower line (the more marked one) the sign is negative, if it is the lighter line that changes its position the most, it is positive. To find the optimal result, rotate the stone 360 degrees, identifying the positions where the values are extreme (the most and the least wide).
- Write down the pairs of values recorded on a sheet, choosing at the end of the process the highest and the lowest (with 3 decimal numbers).
- The maximum difference corresponds to the **birefringence** of the gem.

- Make sure not only to measure the IR / RI of the board (the top face), but also of the pavilion (to make sure, for example, that it is not a composite stone).
- Stones with RI higher than 1.80 will not show any lines, in this case they will be recorded as OT (Over the Top, over the high limit). In this case you will notice a shadow up to the limit of the reading scale of the liquid RI (1,785 / 1,800) or often an amber with irregular colored spots).

Curved surfaces

- For gems with **curved surfaces** , only some types of refractometers can identify their values, through a test called "Spot RI" (Spot RI in English). This is a more complex test and does not work equally for every gem.
- It is important to identify the smoothest and most uniform surface of the gem, remembering that some stones (especially those cut in cabochons) can be **composed of different materials** (with relative distinct RIs), which alternate on their surfaces.
- Clean the stone (the procedure is the same as above) and place it over the drop of RI liquid (slightly more abundant) holding it in place with a finger, but making sure not to exert pressure so as not to scratch the slide.
- Create a point of about 1 mm (if the point is too small or too large, the values will be non-adjustable or offset).
- Notice the difference in the light and dark side of the point, place the dividing line in the center of the point.
- The point may be visible as **A.** a clear distinction (50-50), **B.** 2 distinct shadow lines or **C.** a figure that gradually goes from a light to a dark tone. In any case, try to center the middle part between the 2 shades and estimate the value, considering a margin of error depending on the clarity of the same (50-50 will give a value closer to the real one and will require a smaller rounding)



- Evaluate the result based on the clarity of the measurements (if too vague, other tests will be preferred).

The carbonates

(" birefringence / carbonate blink " or "birefringence / carbonate blink / wink")

Some gems such as (rhodochrosite, calcite, marble etc.) contain high amounts of carbonate and show **a wide birefringence** . This feature can help you identify them faster. In order to do this, once it is assumed that the material in question belongs to one of the types of stones that present this characteristic, a slightly different system must be used than that used to measure the RI of a common gem. Using a **larger fluid spot** and turning the polarizing filter with one hand (so proper coordination is required) can induce a "carbonate blink" if the birefringence is very large and a rough estimate of birefringence is sometimes possible . Looking through the refractometer eyepiece from a **distance between 25 and 40 cm** . move your head up and down a bit as if you were nodding and, at the same time, **turning the polarizing filter** back and forth with the other hand, look at the liquid point RI on the refractometer slide, identify the position in which the color changes from dark to light and vice versa. Moving with precision you can observe, in ideal conditions (with stones with well-smoothed and clean surfaces), **you will notice a transition of color** (from red to green or from dark to light, depending on the model of refractometer used). **in 2 distant areas of the refraction.** Often even estimated values can contribute to effective identification, in combination with visual analysis and verification through other tests.

Accessories

RI Liquid (or IR) : The contact **liquid (RI liquid)** is used to create optical contact between the half cylinder and the gemstone, preventing air from being trapped between the stone surface and the tool.
The liquid has its own refractive index, which **interacts with other materials** , so the amount used must be minimal, just enough to create a "thin film". With a thin film, the impact of the liquid remains very marginal with minimal effect on the reading values.
The two resulting readings are those 1. of the Total Internal Reflection, and 2. of the liquid-stone boundary (which should be minimal, as if no liquid were used). This is why you also see

	a faint reading near the highest index of the scale on the refractometer, this is the liquid reading. The refractive index of the liquid **establishes the limit** (especially that for high values) within which stones can be tested on the refractometer. Typically this value is around **1.79** , but many have a refractive index of **1.81** . Many of the commercial gems fall within this limit (with the exception, for example, of diamonds in some garnets and many synthetic stones) **It is not possible to measure the RI of stones that have a value greater than that of the liquid used** . Stones with a higher RI than liquid give you a "negative or non-indicative reading". (often this is indicated with the acronym OT - Over the Top, above the maximum). Particular salts are commonly added to increase RI, Their ability to increase RI is usually limited by their solubility in the solvent, so the RI of a given solution can be changed from that of pure liquid (e.g. water with RI of 1.333) up to the maximum obtainable from a saturated salt solution. However, this solubility can be altered by further additives, such as corona ethers **Liquids with higher RI** are available , but they are toxic and therefore not suitable for non-trained and cautious personnel. They are reserved for specially equipped laboratories and also need a special half cylinder that has a higher RI than the liquid. Liquids must be protected from exposure to strong light (especially for type 1.81) and must be **used relatively quickly** as they crystallize within a few minutes. If they are left on the refractometer slide for too long, they can dry out and their removal can damage the instrument. The chemical compositions of the liquids are: 1.79 - Saturated solution of sulfur and diidiomethane 1.81 - Saturated solution of sulfur, diidiomethane and tetraidioethylene ***It is important to wash your hands after having physical contact with these liquids, not just for the smell.*** **Types of light:** Proper illumination is one of the key features when using the refractometer. **White light can be used for individually refracting** gemstones or to make a first impression. However, in the case of **double refractive** gems , to obtain accurate values, one should then switch to a **sodium light source** . The reading of the RI values related to gems with double refraction can easily overlap when struck by white light making correct reading difficult. For this reason, the lighting standard for all gems (with an accuracy of 0.001) decimal is **light monochromatic yellow with a wavelength of approximately 589.3 nm** . This light source is historically linked to the beginnings of the practice when, at a very low cost, this color could easily be produced by burning table salt over a candle.
Precautions	Avoid scratching the glass. Avoid inhaling or swallowing RI liquid. Be sure to conduct the analyzes in suitably ventilated areas (especially if you have to conduct numerous tests). Avoid letting the RI liquid dry on the slide (wipe carefully with a soft cloth within a minute or 2 of the fluid being applied). If the RI liquid crystallizes on the glass surface, do not remove it directly, but add more fluid to dissolve the one present. For some instruments, it may be necessary to periodically replace the slide if it becomes permanently yellow or scratched. Move the gems on the slide vertically along the elongated section of the slide. If the same were to accidentally scratch, the vertical signs have less impact on the analysis of the RI than the horizontal ones (parallel to the measurements of the values). Discard the cloths used to clean gems and tool in suitable containers. Check the instrument periodically.
Set off	**Apparatus** (refractometer) equipped with eyepiece and half-cylinder with support glass (where the stone is placed) and a lid to protect the display part when the instrument is not in use . **Polarizing filter** (normally attached to the eyepiece) **Light source** (if not already included in the instrument). **RI liquid** (required for model

<table>
<tr><td>Unit of measure</td><td colspan="2">The gemological refractometer measures the refractive index of faceted and non-faceted stones (some models), from transparent to opaque, both loose and mounted (where there is the practical possibility of doing so), generally between the values of 1.30 / 1.35 and 1.79 / 1.81 .</td></tr>
<tr><td>Types (for applications in gemology)</td><td colspan="2">Gemstones are often (but not always) transparent minerals and can therefore be examined by optical methods. The refractive index is a material constant, dependent on the chemical composition of a substance. The refractometer is used to identify gem materials by measuring their refractive index, one of the main properties used to determine the type of gemstone. Due to the dependence of the refractive index on the wavelength of the light used (i.e. scattering), the measurement is normally performed at the sodium D-line (NaD) wavelength of ~ 589 nm . This is filtered by daylight or generated with a monochromatic light emitting diode (LED). Some stones such as rubies, sapphires, tourmalines and topaz are optically anisotropic. They demonstrate birefringence based on the plane of polarization of light. The two different refractive indices are classified using a polarization filter. Gemstone refractometers are available both as classic optical instruments and as electronic measuring devices with a digital display.</td></tr>
<tr><td>Famous models</td><td>The Duplex / Duplex II refractometer (GIA) - USA
Made in the USA, this refractometer has an extra large viewing window. Simplify the search for shadows.
No built-in light source, an external one should be used. (price 2022 - from 1000 + €)
The GemPro refractometer - India
Rival of the duplex II of the GIA. with removable achromatic lens + eyepiece that allow the measurement of the RI of gems with curved surfaces and scratch, chemical and anti-fog resistant half-cylinder (made of special glass) with monochromatic filter, RI liquid and external illumination (Maglight). (price 2022 - 600 + €)
The Eickhorst refractometer - Germany
This instrument offers a slightly more accurate calibrated scale than most instruments on the market (0.005 versus 0.01).
Eickhorst offers the GemLED model (price 2022 - 1.000 + €) which can be combined with the Docking Station 7 (light support, price 2022 - 500 + €)
The Kruess refractometer - Germany
The company offers both portable and standard models, with or without built-in lighting. (price 2022 - from 500 + € to 1.100 + €)
The Fable Refractometer - China
Equipped with a CZ (high hardness, with very low dispersion) support glass, light weight and possibility to test gems with curved surfaces. Low consumption battery with unique design and interior light. It is not a copy of other models (price 2022 - 300 + €).
Gem refractometer -A - United Kingdom
The model proposed by the Gemological Institute of Great Britain. (price 2022 - from 500 + €, included in RI liquid)
Digital refractometers
These devices are simple and straightforward, however they are not always reliable and must be used with knowledge of the limits associated with the individual models and with the necessary caution.
The Presidium Refractive Index Meter II (PRIM II) - Singapore
Unique electronic refractometer, which offers the possibility to measure the RI of stones with high refractive index such as diamonds, moissanites etc., being able to measure a wide range of RI, from 1.00 to 3.00 . The values are displayed instantly on a digital LED screen and does not require RI liquid. (price 2022 - 300 + €).
GEM-N-EYE digital refractometer - USA
The Gem -n-Eye III is a digital refractometer equipped with an easy-to-read OLED display and has been internally upgraded with advanced</td><td>Costs
Models for amateurs can be bought on various e-commerce platforms for around 100 USD . Generally small in size and not always reliable, these tools are from China. I am unable to test gems with curved surfaces.</td></tr>
</table>

	processing capabilities for greater accuracy in measurements. It does not require RI liquid and provides a digital reading in the form of a refractive index to 3 decimal places, along with the names of the gemstones that share that value. (price 2022 - 370 + €). Unlike a traditional critical angle refractometer, the Gem -n-Eye requires no toxic fluids and provides a digital reading in the form of a refractive index to 3 decimal places, along with the names of the gemstones that share that RI value! **Rayner refractometer Dialdex - UK - discontinued** This refractometer offered a way of reading RI values that was different from most standard refractometers because it did not have an internal graduated scale. The measurement was carried out, instead, through a window with a bright area (from external lighting) that had to be aligned with a vertical black band that appeared by turning a wheel on the side of the instrument. The reading was carried out on the calibrated wheel (used - 400 + €). **Topcon refractometer - Japan - discontinued** Robust and reliable, but has no internal light source. It was one of the most expensive refractometers around. **Additional note** There are many other lesser-known companies that make these tools. The list shown here is intended only to be indicative of some models commonly sold to those who deal with gemology (experts and non-experts).	
Innovation	**Future models expected** In recent decades, the science of refractometers has lost the innovative drive that led to its development over a century ago. gemologists still rely on models created at the end of the last century. Despite China's entry into the market, there are still no significant innovative models (2022).	**To improve** Gemological analyzes using this tool are often rather brigand. The electronic versions are still unreliable.
Curious facts	Modern refractometers are of **4 main types** : Traditional manual ones, digital handheld ones, laboratory ones and process ones online. These tools are not only used to distinguish precious stones, but in many other areas, mainly in the field of wine production and in breweries, but they are also used in various fields such as roasting. For instance: **In marine aquarium farming** , a refractometer is used to measure the salinity and specific gravity of the water. In **the automotive industry** , a refractometer is used to measure the concentration of the coolant. In the **mechanical industry** , a refractometer is used to measure the amount of concentrated coolant that has been added to the water-based coolant for the manufacturing process. In *homebrewing* , **a** type of **refractometer** is used to measure specific gravity to determine the amount of fermentable sugars, prior to fermentation, which are eventually converted into alcohol. **Some refractometers** are used by hobbyists to make **preserves** , jams and honey. In beekeeping, a model of this apparatus is used to measure the amount of water in honey. To measure the concentration of **soy milk** , which is used for making energy drinks, a special soy milk refractometer can be used. The refractometer for **brines.** equipped with a scale from 0 to 35%. it is suitable for the preparation of brines in baked goods, for grilled meats and salty cheeses (e.g. Jadel , Mozzarella, Greek Feta cheese, Balkan cheese, Bulgarian cheese, Bjalo	

	sirene, white cheese, salad cheese, cheese sheep) The same type of tool can be used for **winter road maintenance** (salt solutions to melt ice). Other models include measuring water for **washing seafood** , for preparing inhalation solutions, for making coffee blends, for drug diagnosis, in veterinary medicine, in aquarium maintenance and in agriculture.