Artículo breve/Short note

ICELAND SPAR AND MODERN SCIENCE

El espato de Islandia y la ciencia moderna

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RESUMEN

El descubrimiento de los cristales transparentes de calcita en Islandia en el siglo XVII fue el comienzo del desarrollo de numerosos sectores científicos y de sus aplicaciones prácticas

PALABRAS CLAVE: Calcita, doble refracción, teoría ondulatoria de la luz, microscopio de luz polarizada, polarización, polarimetría, actividad óptica.

ABSTRACT

The discovery of the remote source of transparent calcite crystals in Iceland in the 17th century was the cause for the development of numerous sectors of science and their practical application.

KEY WORDS: Calcite, double refraction, wave theory of light, polarizing microscope, polarization, polarimetry, optical activity.

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INTRODUCTION

The study of the mineral Iceland spar opened the doors for many fields of science, for example, the nature of light, the polarizing microscope, polarimetry, crystallography, optical activity, etc. Crystals of Iceland spar were brought to Copenhagen in 1668 from Helgustadir quarry in Iceland (Fig. 1) which was part of the Danish Kingdom at that time. They were a transparent and colorless variety of very pure calcite, CaCO3, that occur in large crystals, easily divisible (Fig. 2). Quarrying was on a small scale in 1882 and 1885 by the Government which was the sole owner after 1879. In 1895–1910 the quarry was leased to a private citizen then to French Company until 1914. Operations then ceased, after supplies began arriving in Europe from South Africa. Later, optical-quality spar was also found in Mexico and other countries. Hundreds of tons were exported from Helgustadir mostly between 1850 and 1925.

Figure 1. Location of Iceland spar quarry in Iceland.
Figura 1. Ubicación de la cantera de espato de Islandia en Islandia

Figure 2. Iceland spar, a transparent calcite.
Figura 2. Muestras de espato de Islandia, una calcita transparente.

DOUBLE REFRACTION

(1625-1698) (Fig. 3) Professor at the was the first to examine these crystals and he found that when one views an object through it one sees two images of the object (Figure 4). If one passes a narrow beam of light through them, the refracted beam is split into two parts which travel through the crystal and emerge as two separate beams (Fig. 5). He wrote in 1669 a 60-page pamphlet entitled *Experimenta crystalli Islandici disdiaclastici quibus mira & insolita refractio detegitur* summarising his observations which he could not explain (Fig. 6).

Figure 3. Erasmus Bartholin (1625-1698).

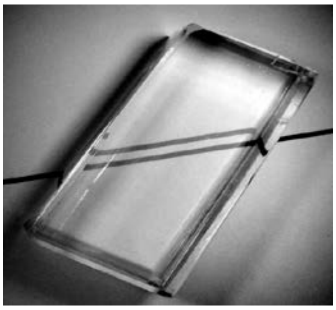


Figure 4. Double refraction in Iceland spar crystal.
Figura 4. Doble refracción en un cristal de espato de Islandia.

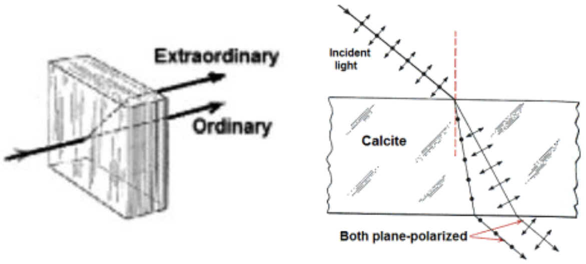


Figure 5. Illustration of double refraction in Iceland spar crystal.
Figura 5. Doble refracción en un cristal de espato de Islandia.

ERASMI BARTHOLINI
EXPERIMENTA
CRYSTALLI ISLANDICI
DISDIACLASTICI
Quibus mira & insolita
REFRACTIO
detegitur.

DEO ET REGE

ANNO 1669.

D. P.

HAFNIÆ,
Sumptibus DANIELIS PAULLI Reg. Bibl.

Figure 6. Front page of Bartolin's booklet.
Figura 6. Portada de la obra de Bartholin.

NATURE OF LIGHT

Wave theory

The Dutch scientist Christiaan Huygens (1629 –1695) (Fig. 7) spent over a year experimenting with Iceland spar after Bartholin sent him some samples. He discovered in 1678 that by rotating a second piece over the first, he could make one of the two images disappear. Taking into consideration his researches on interference and diffraction of light he proposed the wave theory: light istransverse wave propagating in two planes perpendicular to each other (Fig. 8).

Figure 7. Christiaan Huygens (1629 –1695).

Figure 8. Huygens' wave theory of light.
Figura 8. Teoría ondulatoria de la luz de Huygens

Polarization

The French physicist (1788-1827) (Fig. 9) in 1818 described double refraction in terms of polarization (Figure 10). The incident light beam waves are vibrating in all directions. Only the incident light that is vibrating in the same plane is absorbed through the first polarizing crystal while light vibrating at right angles to the crystal plane is passed through. The wave passing through is subsequently blocked by the second polarizer because this polarizer is oriented horizontally with respect to the light wave.

Figure 9 - Augustin-Jean Fresnel (1788 - 1827).

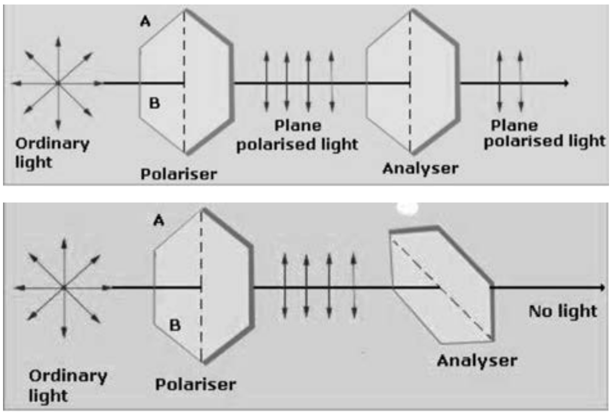


Figure 10. Explaining the phenomenon of double refraction in tourmaline.
Figura 10. Explicación del fenómeno de la doble refracción en la turmalina.

Polarizing microscope

In 1828 by William Nicol (1766–1851) (Figs 11, 12) of Edinburgh invented an optical device used to produce a beam of polarized light (Figure 13). It consists of a crystal of Iceland spar that has been cut at an angle of 68° with respect to the crystal axis, cut again diagonally, and then rejoined by a glue layer of transparent Canada balsam.

Figure 11. William Nicol (1766–1851).

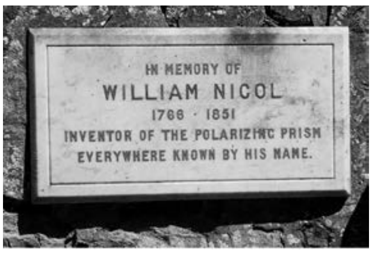
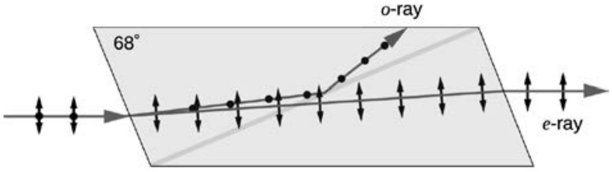


Figure 12. A memorial plaque for William Nicol.
Figura 12. Placa conmemorativa de William Nicol.



A polarizing microscope was invented to use polarized light for investigating the optical properties of rocks and minerals. The sugar industry applied this knowledge to the measurements of sugar concentration to what became known as polarimetry.

Electromagnetic theory of light

It was (1791-1867) (Fig. 14) in 1845 who discovered that a magnetic field influenced polarized light. He found that the plane of vibration of a beam of linearly polarized light incident on a piece of glass rotated when a magnetic field was applied in the direction of propagation of the beam (Fig. 15). He noted later that light is affected by an electric field thus lying the foundation for an electromagnetic theory of light.

Figure 14. Michael Faraday (1791-1867) holding the piece of glass used to demonstrate the effect of magnetism on polarized light.
Figura 14. Michael Faraday (1791-1867) con el cristal que utilizó para demostrar el efecto del magnetismo sobre la luz polarizada.

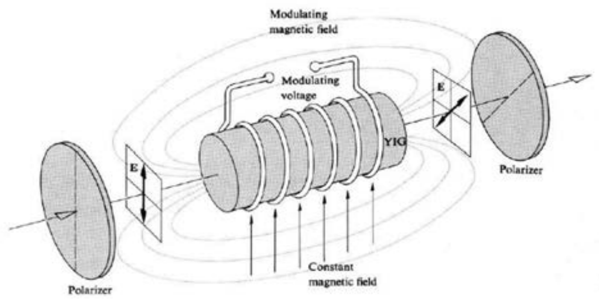


Figure 15. Polarization rotation of light in glass in a magnetic field, due to Faraday in 1845.
Figura 15. Rotación de la polarización de la luz en cristal en un campo magnético, debido a Faraday en 1845.

Figure 16. James Clerk Maxwell (1831-1879).

Figure 17. Heinrich Hertz (1857-1894).

James Clerk Maxwell (1831-1879) (Fig. 16) in his published in 1865 described his electromagnetic theory of light. This theory was experimentally proved by (1857-1894) (Fig. 17) who demonstrated the existence of electromagnetic waves ().

OPTICAL ACTIVITY

Discovery

(1786–1853) (Fig. 18) in 1811 found that some quartz crystals rotate the plane of polarized light to the right and others to the left. He also discovered that light from the moon is polarized. Subsequent experiments in 1812 by Jean-Baptiste Biot (1774-1862) (Fig. 19) extended these studies to liquids.

Figure 18. François Arago (1786–1853).

Figure 19. Jean-Baptiste Biot (1774-1862).

In 1822, the English astronomer (1792-1871) (Fig. 20) discovered that different quartz crystals, whose crystalline structures are mirror images of each other (Fig. 21), rotate linear polarization by equal amounts but in opposite directions. This phenomenon was called optical activity, i.e., the ability of rotating the plane of vibration of polarized light.

Figure 20. John Herschel (1792-1871).

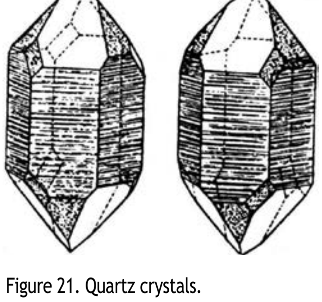


Figure 21. Quartz crystals.
Figura 21. Cristales de cuarzo.

Figure 22. Louis Pasteur (1822 –1895).

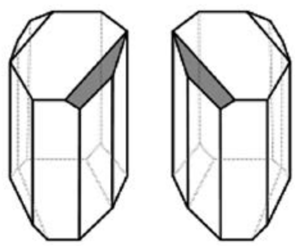


Figure 23. Two types of potassium tartrates.
Figura 23. Dos tipos de tartrato de potasio

It was Louis Pasteur (1822–1895) (Fig. 22) in 1848 who resolved a problem concerning optical activity. He found that when a solution of sodium ammonium tartrate was evaporated, crystals were formed, some of which were mirror image of the others (Fig. 23). He separated the two by handpicking and found that a solution of one type rotated polarized light to the right, and the other, an equal amount to the left.

Figure 24. Jacobus Henricus van't Hoff (1852-1911).

Figure 25. Joseph Achille Le Bel (1847-1930).

In 1874, (1852-1911) (Fig. 24) and (1847-1930) (Fig. 25) independently proposed that the phenomenon of optical activity in carbon compounds could be explained by assuming that if the four neighbours are all different, then there are two possible orderings of the neighbours around the tetrahedron, which will be mirror images of each other.

This gave rise to what became known as symmetric and asymmetric carbon atoms. An asymmetric carbon atom is an atom in a molecule of an organic compound with four mirror image atoms or groups attached to it. Such grouping permits of two different arrangements in space, leading to the existence of optical isomers. For example, in a molecule of lactic acid:

there is one asymmetric carbon atom, and two optical isomers may be formed. The two molecules have mirror-image relationship. If a molecule has more than one asymmetric carbon atom, additional isomers are possible. The isomer that rotates light to the right (clockwise) is called the *dextro-rotatory* form; the one that rotates it to the left (counter clockwise) is called the *levo-rotatory* form. The symbols (+) and (–

) are used to indicate rotations to the right and left, respectively. A mixture of the two optical isomers in equal proportions shows no rotation, and is called racemic.

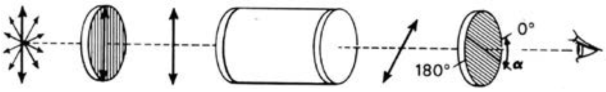


Figure 26. Measuring the concentration of a solution of sugar in the tube by means of rotation of polarized light.
Figura 26. Medición de la concentración de una solución de azúcar en el tubo por medio de rotación de la luz polarizada

Application

The polarimeter was invented in 1841 by Arago and it is used in the sugar industry for determining quality of both juice from sugar cane and the refined sucrose based on rotation of a beam of polarized light (Fig. 26).

Fluorescence

Iceland spar produced in Nuevo Leon, Mexico show fluorescence apparently due to traces of manganese

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