

VIBGYOR SPECTRUM OF RAINBOW FOLLOWS PHYSICS AND CHEMISTRY

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ABSTRACT

A rainbow is an optical phenomenon caused by refraction, internal reflection and dispersion of light in water droplets resulting in a continuous spectrum of light appearing in the sky. The rainbow takes the form of a multi-coloured circular arc. Rainbows caused by sunlight always appear in the section of sky directly opposite the sun. Rainbows can be caused by many forms of airborne water. These include not only rain, but also mist, spray, and airborne dew.

KEYWORDS: sunlight, rain water droplets, refraction, dispersion, reflection, primary rainbow, secondary rainbow.

Overview: A rainbow spectrum is a continuous band of colours—traditionally remembered as ROYGBIV (Red, Orange, Yellow, Green, Blue, Indigo, and Violet)—created when white sunlight is bent and split by water droplets.

How It Works

- Dispersion: Sunlight enters a raindrop, slows down, and bends (refraction), which splits the white light into individual wavelengths.
- Reflection: The light bounces off the inner back surface of the water droplet.
- Exiting: As the light leaves the drop, it bends again, sending a spread of coloured light toward your eyes.
- Angle: Red light bends the least (appearing on the outer edge of the arc), while violet bends the most (appearing on the inner edge).

Key Facts.

- Continuous vs. Seven Colours: While Isaac Newton named seven distinct colours to match musical notes, a real rainbow is actually a smooth, continuous physical spectrum containing an infinite gradient of shades.

- Viewer Position: You must have the sun directly behind you to see a rainbow in the moisture ahead.
- Pure vs. Blended: Unlike a mathematically pure laboratory spectrum made with a glass prism, a natural rainbow features colours that overlap and blur together because of overlapping light paths from millions of different-sized droplets.

A rainbow forms when sunlight undergoes refraction, internal reflection, and dispersion inside atmospheric water droplets.

Sunlight and Rain: It appears when the sun shines through rain, mist, or spray.

Position: It always forms in the section of the sky directly opposite the sun.

Light Bending: Water droplets bend (refract) and split white sunlight into separate colours (dispersion) before reflecting it back to your eyes.

Colours of the Rainbow: A standard rainbow displays seven distinct colour bands in order from top to bottom: Red, Orange, Yellow, Green, Blue, Indigo, and Violet.

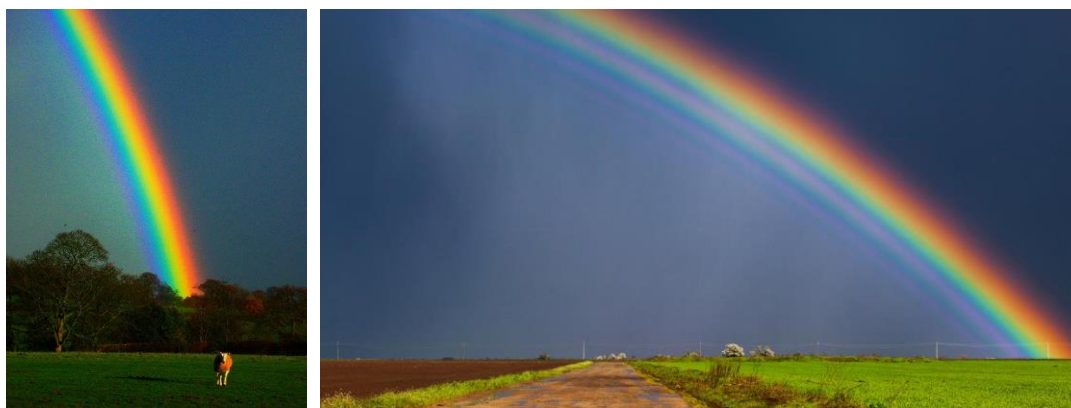


Figure-1: Rainbow.

A rainbow forms when sunlight is refraction-bent, reflected, and separated into its component colours inside water droplets in the atmosphere.

Steps of Formation

- **Refraction (Bending):** Sunlight enters a water droplet, slowing down and bending because water is denser than air.
- **Dispersion (Splitting):** White light splits into individual wavelengths (colours) because each colour bends at a slightly different angle.
- **Internal Reflection (Bouncing):** The light bounces off the inner back surface of the water droplet.
- **Second Refraction (Exiting):** As the light leaves the droplet, it bends once more, further spreading out the colours toward the viewer.

Viewing Conditions

- **Position:** The sun must be behind the observer, and the rain or water droplets must be in front.
- **Direction:** Rainbows always appear in the exact opposite direction of the sun.

- **Colours:** Red appears on the outer edge of the primary arc, and violet appears on the inner edge.

The rainbow spectrum is the band of visible colours created when white sunlight passes through water droplets in the air and separates into different wavelengths.

Colours and Order.

The visible spectrum contains a continuous range of colours, traditionally remembered by the acronym ROYGBIV.

- Red: Longest wavelength (~620–750 nm), appearing on the outer edge of a rainbow arc.
- Orange: Wavelength of ~590–620 nm.
- Yellow: Wavelength of ~570–590 nm.
- Green: Wavelength of ~495–570 nm.
- Blue: Wavelength of ~450–495 nm.
- Indigo: A deep blue shade between blue and violet.
- Violet: Shortest wavelength (~380–450 nm), appearing on the inner edge of the arc.

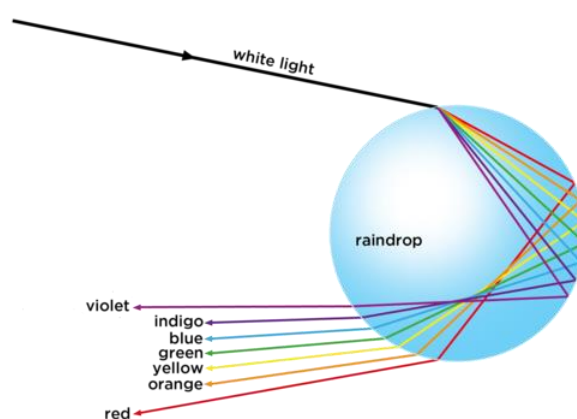


Figure-2: Spectrum of seven light.

1. A **primary rainbow** forms when sunlight is refracted, dispersed, internally reflected once, and refracted again inside airborne water droplets at an angle of 42 degrees.

The Physics Steps

- **First Refraction & Dispersion:** Sunlight enters a spherical raindrop, bending (refracting) at the air-water boundary. Because different wavelengths of light travel at different speeds in water, white light splits into its

component colours. Violet light bends the most, and red light bends the least.

- **Internal Reflection:** The separated light rays hit the inner back surface of the water droplet and reflect back inside the drop instead of passing straight through.

- **Second Refraction (Exit):** When the light reaches the front surface of the droplet again, it bends as it exits back into the air toward the observer. This second refraction further spreads the colours.

2. A **secondary rainbow** forms when sunlight undergoes a four-step path of refraction, two internal reflections, and a final refraction inside spherical raindrops.

The Four-Step Optical Pathway

- **First Refraction & Dispersion:** Sunlight enters the front surface of a raindrop, bending (refracting) and splitting (dispersing) into individual component wavelengths (colours) because each colour has a different refractive index.

- **First Internal Reflection:** The light strikes the back inner surface of the droplet and reflects internally.

- **Second Internal Reflection:** Instead of exiting immediately (which would form a primary bow), the light bounces a second time off the inner wall of the droplet.

- **Final Refraction & Exit:** The light strikes the front surface again and refracts out into the air toward the observer.

Key Characteristics & Physics Differences

- **Reversed Colour Order:** Because of the extra internal reflection, the emerging angle for red light is steeper than

for violet light. This places red on the inner edge (bottom of the arc) and violet on the outer edge (top of the arc), which is the exact reverse of a primary rainbow.

- **Larger Viewing Angle:** The secondary bow appears at an angle of roughly 50° to 53° from the anti-solar point, meaning it sits higher and wider in the sky than the primary bow (which sits at 40° to 42°).

- **Lower Intensity:** Each internal reflection loses a significant portion of light energy through transmission out of the droplet. As a result, the secondary rainbow is only about 1/10th as intense (much fainter) than the primary bow.

- **Alexander's Dark Band:** The unlit, dark region of the sky situated between the bright primary bow and the fainter secondary bow is called Alexander's dark band, caused by the optical cut-off angles of deviated light rays.

The 7 colours of the rainbow in order from top to bottom are Red, Orange, Yellow, Green, Blue, Indigo, and Violet.

The Order (ROYGBIV)

You can remember this sequence using the popular mnemonic device ROYGBIV:

R - Red (outer edge of the arc)

O - Orange

Y - Yellow

G - Green

B - Blue

I - Indigo

V - Violet (inner edge of the arc)

Read backward as VIBGYOR, the colours go from the inner edge to the outer edge.

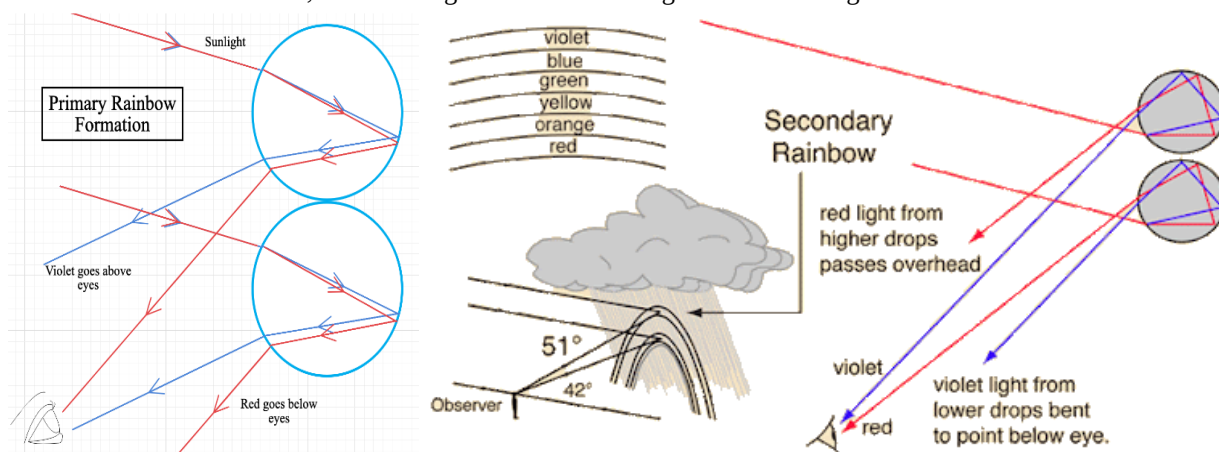


Figure-3: Primary & Secondary Rainbow.

When we talk about the "chemistry" of a natural rainbow, the direct answer is surprising: a literal rainbow in the sky is not a chemical reaction—it is purely a phenomenon of physics and optics.

However, nature is filled with "chemical rainbows" through organic pigments, structural colors, and pH-driven transformations. Below is a breakdown of how the

physical rainbow works alongside the true chemistry behind nature's vivid colours.



Figure-4: 12 Different types of Rainbow.

The 12 Types of Rainbows

1. Primary Rainbow: The classic, most common arch with red on the outside and violet on the inside, formed by one internal reflection.
2. Secondary (Double) Rainbow: A fainter second arch outside the main one with reversed colours (red on the bottom) caused by two internal reflections.
3. Twinned Rainbow: Two distinct rainbow arcs that split upward from a single shared base, caused by a mix of differently sized water droplets.
4. Tertiary and Quaternary Rainbows: Rare rainbows formed by three or four internal reflections of light, typically appearing back toward the sun.
5. Higher-Order Rainbows: Extremely faint arcs produced by five or more internal light reflections inside water droplets.
6. Supernumerary Rainbow: Soft, faint pastel coloured extra bands clinging to the inner edge of a primary rainbow, created by light wave interference.
7. Reflected (Reflection) Rainbow: A separate bow formed when sunlight reflects off a body of water before hitting the falling raindrops.
8. Full-Circle Rainbow: A complete 360-degree ring of a rainbow, usually only visible from high-altitude locations like airplanes.
9. Monochrome Rainbow: A rare, single-colour red arc seen during sunrise or sunset when the lower sun scatters away all other short light wavelengths.
10. Rainbow under Moonlight (Moonbow): A dim, often whitish bow created when moonlight refracts through moisture in the air.

11. Fogbow: A pale, nearly colourless wide bow formed when sunlight hits tiny micro-droplets in fog rather than large raindrops.
12. Circumhorizontal Arc: A brilliant, horizontal "fire rainbow" sheet of spectral colours high in cirrus clouds, which is technically an ice halo rather than a true liquid-droplet rainbow.

The Sky Rainbow

The Physics of Light & Water: Atmospheric rainbows are generated when sunlight interacts with suspended water droplets. No chemical bonds are altered. Instead, water droplets act as miniature prisms via three distinct physical steps.

Process Scientific Explanation

- **Refraction:** Sunlight slows down and bends as it passes from the air into a denser water droplet.
- **Dispersion:** White light is a mixture of all visible wavelengths. Shorter wavelengths (violet/blue) slow down and bend more than longer wavelengths (red). This breaks the light into its constituent colours.
- **Reflection:** The separated light waves bounce off the back wall of the water droplet (internal reflection) and refract a second time as they exit back into the air toward your eyes.

CONCLUSION

A rainbow is a multi-coloured circular arc in the sky caused by the refraction, internal reflection, and dispersion of light in water droplets.

How a Rainbow Forms

- Sunlight and Rain: You need both rain in front of you and the sun shining from behind you to see a rainbow.
- Bending Light: When white sunlight enters a water drop, it slows down and bends (refraction).
- Splitting Colours: The light reflects off the back of the drop and splits into individual colours because different wavelengths bend at different angles.
- Optical Illusion: Billions of droplets work together to project a coloured circle of light, but you only see an arc from the ground.

REFERENCE

1. <https://en.wikipedia.org/wiki/Rainbow>