Formation and Properties

The Diamond Course
Progress Evaluation Reminder

If you have not yet completed Progress Evaluation 2, please do so before continuing further with your coursework.

Lessons 2, 8, and 15. Each one has three separate components – a Learning Evaluation, a Training Evaluation, and a Satisfaction Evaluation.

Detailed instructions for Learning Evaluations are in the Testing Center section of the DCA’s website. Instructions for Training and Satisfaction Evaluations are in the Evaluations section.

If you have other questions or need help, please contact us. You can use this website – just click on Help.

You can also email studenthelp@diamondcouncil.org or phone 615-385-5301 / toll free 877-283-5669.
Formation
and Properties

In This Lesson:
• An Expanded Look
• Amazing Origins
• Crystals of Carbon
• Diamond Properties
• Another Perspective

AN EXPANDED LOOK

With this lesson you begin an expanded look at the world of diamonds. In the first main section of the course – Lessons 2 through 8 – you gained essential knowledge that you can use every day in diamond retailing. You learned about the 4Cs and how to present them. You surveyed the diamond jewelry that’s available to customers today. You examined the lab-created processes and products that are making the diamond industry more complex.

This lesson and those that follow will present information that you may use less frequently. It’s still important to your success, however. Knowing more than the bare essentials will make you more confident, more interesting, and more effective when selling diamonds.

This section of the course will give you answers to questions discerning customers may ask: Where do diamonds come from? What makes them so special? How do economic factors like supply and demand affect their value? Will they maintain their value in the future?
The facts and explanations you collect from these lessons will provide extra information you need to help customers fully understand diamond’s beauty, rarity, and value. There’s a natural logic that underlies the 4Cs, which this lesson and those that follow will make clear. If you can communicate the logic, you remove the mystery from the purchase decision and place it where it ought to be – with the diamond itself.

Back in Lesson 1 you learned that diamond is a mineral made of carbon, and it formed deep within Earth. Your expanded look at diamonds starts with when, where, and how this happened.

**Lesson Objectives**

*When you have completed this lesson you will be able to:*

- Share interesting facts about diamond formation.
- Discuss diamond’s chemical and crystal nature.
- Explain diamond’s remarkable characteristics.
- Use diamond’s origin to present the 4Cs.
Amazing Origins

Nature still holds secrets concerning the origins of diamonds, but science has discovered a number of amazing facts about this subject:

- **Diamonds are very old.** They also formed over a long period in our planet’s history. Geologists estimate Earth’s age to be about 4.54 billion years. The oldest diamonds crystallized around 3.3 billion years ago. Even the youngest are almost 1 billion years old. This is a span of more than 2 billion years, and it represents about half the entire time Earth has existed.

- **Diamonds formed under extreme conditions.** The temperatures ranged from about 1,700° to 2,400° Fahrenheit. The pressures were between 650,000 and 870,000 pounds per square inch. To put these numbers into perspective, consider that water vaporizes at 212° Fahrenheit. Silver melts at 1,764°, and gold at 1,947°. The average pressure on the floor of the Pacific Ocean is only about 6,000 pounds per square inch. (This is at a depth of about 14,000 feet.) Modern technology has created super-strong presses that recreate conditions similar to those of natural diamond formation. These devices are used to produce synthetic diamonds and high-pressure high-temperature (HPHT) treatments.

- **Diamonds formed deep inside Earth.** Most diamonds crystallized 90 to 120 miles beneath the surface. Some originated at even greater depths. The region where this occurred is called the **diamond stability field**. It lies under the ancient rock platforms, called cratons, which form the cores of continents. This region is the only area within Earth where the right combinations of heat and pressure exist.

- **The carbon in diamonds came from two sources.** Most of the carbon that made diamonds was trapped deep in Earth as it formed. A small percentage was later carried down from the surface by the geologic process known as subduction. This happens when one section of Earth’s crust slips under another and moves downward until it melts. The carbon was carried down in rocks from the upper crust. Some may have come from the remains of very early plants and animals.
• **Diamond crystals grew at different rates.**

  They often waited a long time to reach the surface. Under laboratory conditions, it takes a day or two to manufacture a 1-carat synthetic diamond. Many natural diamonds could have grown that quickly, but large high quality crystals may have taken centuries to form. Some diamonds were carried upward soon after formation. Others remained stored inside Earth for millions of years. (You’ll learn about diamonds’ journey to the surface in the next lesson.)

  The picture of diamond formation is like a scientific puzzle. Over the past century – and especially the last 50 years – the pieces have come together from a wide range of research. Knowledge of Earth’s structure and dynamics created the framework. In-depth studies of diamond deposits filled in the background. Sophisticated analysis of natural diamonds and experience in diamond synthesis provided key details. Customers might be interested to hear that some of the most useful information has come from diamond inclusions, which can act as geologic thermometers, barometers, or clocks.

  The puzzle is still missing a few pieces. For example, no one knows exactly what triggered diamond formation.

  The knowledge gained thus far has led to discoveries of important new diamond sources. It has also added new dimensions to the fascination diamonds have always inspired.
CRYSTALS OF CARBON

The facts and theories of diamond formation are truly remarkable. They’re just the beginning of the story, however. The gems born deep within Earth so long ago are extraordinary in even the most fundamental ways:

• **Diamond’s chemical composition – its “atomic recipe” – is carbon.** Laboratory tests have shown that gem quality diamonds are typically 99.95% carbon – and they can be more than 99.99% pure. This makes diamond one of the purest of all materials found in nature.

• **Diamond is the only gem that’s composed of just one element.** All other gems are chemical combinations. For example, ruby and sapphire are made primarily of aluminum and oxygen. Tourmaline is one of the most chemically complex gemstones. It can include 15 different elements.

• **Carbon atoms build diamond crystals by sharing electrons.** This is called covalent (ko-VAY-lent) bonding. (In many other gems, the atoms gain or lose electrons.) Each carbon atom bonds with four neighbors to form a tetrahedron. This is the simplest and strongest of all three dimensional configurations. The distance between each pair of bonded atoms is only 6 hundred-millionths of an inch!

• **The arrangement of carbon atoms in gem quality diamond crystals is almost perfectly symmetrical in every direction.** This is due to the uniform chemical composition and covalent bonding. The orderly arrangement of atoms is known as crystal structure. The pattern in diamonds is described as isometric or cubic. (The first term comes from Greek words that mean “equal measure.”) Sometimes the structure produces crystals of great beauty and perfect geometry. These outwardly manifest the internal symmetry. More often, the external shapes aren’t perfect. Many crystals are distorted or broken. The internal order is always there, however, because it exists at the atomic level.
CRYSTAL FORMS

Like a child’s toy blocks, the carbon atoms in diamonds can build a variety of crystal forms. Despite external differences, all the forms reflect fixed geometric patterns that exist within the crystal structure.

Three forms are particularly important – the cube, octahedron, and dodecahedron:

- **Cube** – This box-like form with 6 square sides has the simplest geometry of all diamond crystals. Very few gem quality diamonds take this crystal form (external shape). The internal cubic pattern exists in every diamond, however, and plays a key role in the cutting process.

- **Octahedron** – This form has 8 sides, and resembles two pyramids joined base-to-base. The octahedron is the most common crystal form for gem quality diamonds. For that reason, it’s considered diamond’s crystal habit. Octahedrons are ideal for making round brilliants and princess cuts.
• **Dodecahedron** – After the octahedron, this 12-sided form is the most frequent for gem quality diamonds. Dodecahedral crystals are usually rounded. They rarely have flat, well-defined crystal faces. Dodecahedrons are usually made into round brilliants.

Because of the complex conditions in which they grow, diamond crystals often occur as modifications or combinations of basic forms. Flattened and elongated crystals are common as well.

When crystal growth along octahedral planes reverses itself, a **macle** is created.

A macle - a flat, triangular crystal resulting from twinning.
DIAMOND PROPERTIES

The combination of chemical composition and crystal structure produces diamond’s inherent characteristics. These are known as properties. To emphasize the importance of the combination, you might contrast diamond with graphite and salt.

Graphite is a soft black mineral that’s used to make pencil leads. It’s composed of pure carbon, but has a different crystal structure than diamond. On the other hand, salt has an isometric structure like a diamond but a different composition. (Graphite’s structure is hexagonal, and salt is made of sodium chloride.)

It takes both chemistry and structure to create the unique and lasting beauty of a diamond. Over decades of study, scientists have identified a long list of diamond properties. Many are only of technical interest, but there are a few you might mention in presentations:

- **Hardness:** This property is defined as resistance to scratching. Diamond is the hardest material that has yet been discovered. The Mohs Hardness Scale rates hardness from 1 to 10, based on whether one material can scratch another. On the Mohs Scale, diamond is 10, corundum (ruby and sapphire) is 9, and topaz is 8. More precise tests show that diamond is 140 times harder than ruby or sapphire, and 300 times harder than topaz. Superior hardness is the reason diamond can take and keep a polish far better than any other gemstone. However, you may need to explain that superior hardness does not make a diamond indestructible.
• **Toughness:** This is *resistance to breaking*. It’s usually rated as exceptional, excellent, good, fair, or poor. Overall, diamond’s toughness is good. It would be excellent if not for another diamond property known as *cleavage*. That’s the potential to break in certain crystal directions. (As you learned in Lesson 3, an actual break in one of these directions is also called a cleavage.) Diamond’s hardness and toughness make it one of the most durable and wearable of all gems. Even diamonds require proper care, though. You’ll examine this topic in Lesson 15.

• **Density:** The *relationship between size and weight*. One way of expressing density is *specific gravity* (SG). This is a number that indicates the weight of a material compared to the weight of an equal volume of water. Gem quality diamond’s SG is typically very close to 3.52. (This means, for example, that a 1-carat diamond will weigh about 3 1/2 times more than a drop of water that’s the same physical size.) SG is one of the properties gemologists can use to separate unset diamonds from simulants.

• **Transparency:** The *ability of a material to transmit light* (or other forms of energy) without blocking or distorting it. Many gemstones are transparent, but none rival diamond in this regard. Diamond is exceptionally transparent to visible light. It also transmits energy all the way from the deep ultraviolet to the far infrared part of the spectrum.

*The density of every gemstone is different. A one-carat ruby or sapphire would be smaller (because they’re more dense) than a one-carat diamond. A one-carat emerald is much larger.*

*Photo courtesy LF Industries.*
Formation and Properties

- **Refraction**: The *slowing and bending of light* in a transparent material. Refraction is what makes a drinking straw appear to bend in a glass of water. It’s measured by *refractive index* (RI), which compares the speed of light in air to its speed in the material. Diamond’s RI is 2.417. This means that light slows to about 40% of its normal speed inside a diamond. (When light leaves the diamond, it bursts back to its original speed.) High RI and hardness contribute to diamond’s unrivaled brilliance and scintillation.

- **Dispersion**: As you learned in Lesson 5, this is the *spreading of white light into spectral colors*. It’s caused by different colors of light being refracted differently. (Violet is refracted most and red least.) Diamond’s dispersion is 0.044. That’s higher than any other natural gem you’re likely to see. It is, however, surpassed by simulants such as CZ and moissanite. This is the factual basis for ads claiming that these materials display more fire than diamond.
ANOTHER PERSPECTIVE

A big part of diamond’s mystique lies in the fact that it’s a natural product. It wasn’t made in a laboratory or a factory under controlled conditions. You might say that diamonds were born in the most extreme of all environments on (or in) Earth. Amid the massive and violent forces of our planet’s interior, many things could’ve gone wrong. It’s almost a miracle that diamonds exist at all.

Many (perhaps most) diamonds perished before they reached the light of day. Of those that survived, only a fraction is gem quality. The rest are so small, so included, or so imperfectly crystallized that they can be used only for abrasives or other industrial purposes.

Even minor variations in composition, structure, or the growth environment could have big impacts on the factors that affect a diamond’s value. You’ve already examined these factors – the 4Cs – in the final product.

Let’s take another look at them from the perspective of formation:

• **Carat Weight** – Every diamond crystal’s size was limited by time, or how long the right temperature-pressure conditions existed. Growing room (space) was also essential. So were nutrients in the form of available carbon atoms. As a result, only one gem quality crystal in a thousand grew large enough to yield a high quality finished diamond weighing 1 carat or more.

Photo courtesy JCK.
Formation and Properties

High clarity diamonds also originated in optimal environments.

- **Clarity** – High clarity diamonds formed under very favorable conditions. As they were forming, diamonds often engulfed smaller crystals of other minerals (or even other diamonds) that became inclusions. Crystal structure distortions created graining. The immense stresses involved in formation frequently caused fractures and cleavage breaks.

- **Color** – Colorless diamonds must have formed under conditions that were close to ideal. Minute amounts of nitrogen tinted most diamonds various shades of yellow. More rarely, traces of boron produced blue diamonds. Distortions in the crystal structure often resulted in brownish tints. They also created the pinks and reds that command astronomical prices. Most other colors of the diamond palette came from combinations of trace elements and structural irregularities.

*The various colors of the diamond palette come from trace elements and irregularities in crystal structure.*

*Photo courtesy JCK.*
• **Cut** – Diamond’s crystal structure dictates how it can be cut. The crystal form or significant clarity characteristics often determine the shape the cutter chooses.

   From this viewpoint, it’s clear that the 4Cs don’t have much to do with “good” or “bad.” They’re simply outcomes of the astonishing process through which nature shaped each diamond’s potential for beauty and value. Explaining this can help some customers overcome reservations about a diamond that has inclusions or a tint of color. For others it can underscore the rarity of large, high quality diamonds.

As a sales professional, it’s important to recognize that every diamond you show came from an almost unbelievable set of circumstances. Compared to any other gem – or any other material that’s known – diamond’s properties are exceptional in every way. The factors that determine its value are reflections of its unique history. And it may have waited billions of years for you to present the secrets of its beauty.
DIAMOND TYPES

Although diamonds are essentially pure carbon, they can contain traces of more than 25 different elements. The most common of these is nitrogen. Others include aluminum, barium, boron, calcium, chromium, copper, hydrogen, iron, magnesium, manganese, silicon, sodium, and titanium.

Based mainly on the presence or absence of nitrogen, scientists divide gem quality diamonds into two types. Each type is also subdivided. Diamond types are important because of how they relate to high pressure high-temperature (HPHT) treatment and diamond synthesis.

• **Type Ia** – These diamonds contain groups of nitrogen atoms that cause yellow tints in the normal color range. The more nitrogen atoms and groups, the darker the color will be. Most natural gem quality diamonds are Type Ia. HPHT treatment can turn some Type Ia diamonds intense yellow, green, or orange.

• **Type Ib** – Diamonds containing isolated atoms of nitrogen dispersed throughout the crystal structure. In sufficient quantities, these isolated atoms create a vivid “canary” yellow color. Natural diamonds of this type are rare, but most synthetic diamonds are Type Ib.

• **Type IIa** – Diamonds of this type are exceptionally pure in composition. They contain almost no nitrogen. Although they’re very rare, Type IIa diamonds are significant because they’re frequently large, colorless, and flawless. Those that are tinted brown by crystal structure distortion can be lightened by HPHT treatment. Some other Type IIa diamonds will turn pink with HPHT treatment.

• **Type IIb** – Instead of nitrogen, these extremely rare diamonds contain traces of boron. The boron can impart a blue color if it’s present in large enough amounts. HPHT treatment can sometimes deepen or intensify the color.

Based on the trace elements that diamonds contain, they are divided into different types.
Formation and Properties

RECAP OF KEY POINTS

• Knowing more than just the bare essentials about diamonds will help you answer customer questions and present value more effectively.

• Diamonds range in age from about 1 billion to 3.3 billion years. They formed under conditions of immense heat and pressure deep inside Earth. Large, high quality crystals may have taken centuries to grow.

• Diamond is essentially pure carbon with an isometric, or cubic, crystal structure. It’s the only gem composed of a single element.

• The combination of chemical composition and crystal structure produces diamond’s properties. These include superior hardness, good toughness, exceptional transparency, and high refraction and dispersion.

• The 4Cs are natural outcomes of the formation process. Every diamond is a miracle of nature has waited billions of years for you to present it.
LESSON 9 FOLLOW-UP CHECKLIST

____ With a coworker, role-play using facts about diamond formation to put the 4Cs in a positive light for customers.

____ Take a look at the diamonds in your showcases. Think about the fact that they’re more than a billion years old. Then develop two or three benefit statements based on this feature. For example: “This diamond’s great age makes it a perfect symbol of enduring love.”

____ Make a list of other important features presented in this lesson and brainstorm benefit statements for each one.
Lesson 9 Self-Test

This lesson also includes a Self-Test that’s designed to help you gauge your comprehension of the lesson material. The test is an important part of the learning process, so be sure to complete it.

When you’re ready to take the test, go to the Course Materials page (the one that lists all the lessons) and click on “Self-Test.” Make certain you select the test for this lesson.

All questions in the test are based on Lesson 9. More than one answer for a question might seem correct, but you should select the one best answer based on the lesson discussion.

As you take the test, you may refer to the lesson. To do this, you’ll need to have the lesson loaded in a separate window of your browser.

If you feel certain about a question, try answering it without looking at the lesson. If you’re not sure, check the lesson before answering.

After you answer a question, you’ll receive immediate results and feedback. You’ll find out whether you answered correctly, what the correct answer was (in case you missed it), and also the page number in the lesson where the information can be found. Take time to review any material you’re not completely clear on.

At the end of the test, you’ll receive your overall results. Then you’ll be able to continue to the next step in your coursework.

If you have questions or need help, please contact us. You can use this website – just click on “Help.” You can also email studenthelp@diamondcouncil.org or phone 615-385-5301 / toll free 877-283-5669.