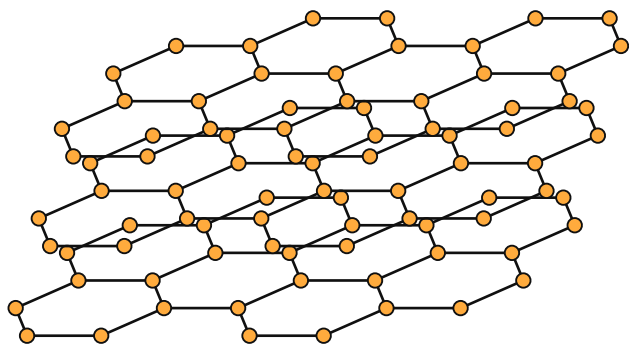


CARBON & DIAMOND

Why Can Black Carbon Become Clear Diamond?

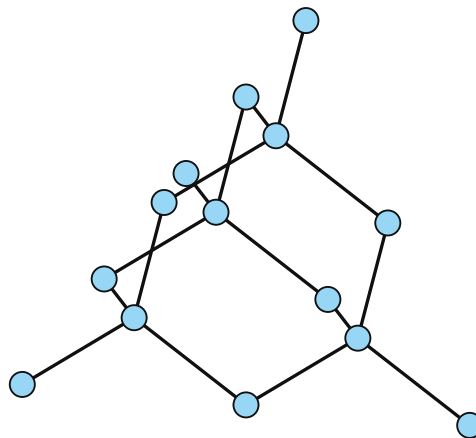
The essential answer: diamond is carbon, too. The element does not change; the arrangement of its atoms and electrons does. Graphite absorbs much visible light, while a sufficiently pure diamond has little visible-light absorption. Neither is a perfect blackbody. [1, 2, 7, 18, 26]

GRAPHITE: LAYERED CARBON



Three bonded neighbors per interior atom

DIAMOND: 3D CARBON NETWORK



Four bonded neighbors per interior atom

Figure 1. Idealized carbon networks. Colored spheres represent carbon atoms, not the visible color of the material. Bond drawings are schematic; real solids contain enormous repeating networks.

“Carbon is black” describes familiar materials such as graphite and soot, not every possible form of the element. “Pressure makes diamond” is also incomplete: crystal growth depends on the pathway, temperature, chemistry, and atomic rearrangement. Industrial diamond can be grown by high-pressure methods or from activated gas at low pressure. [9, 11]

READING ROUTE	PAGES
Articles: atoms, bonds, color, formation, stability, and blackbodies	2–11
Formula reference and twelve worked examples	12–16
Student practice: 30 questions, then a separate teacher answer key	17–22
Safe investigations, glossary, misconceptions, and source directory	23–26

Study levels: core explanations suit secondary-school science; algebra, trigonometry, logarithms, and thermodynamics provide optional extensions. Use a calculator for numerical work. Original illustrations, calculated graphs, and explanatory articles are included throughout.

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Scientific starting points: [1], [2], [7], [9], [11], [18], [26]. Sources are listed on pages 25–26.

Carbon Has No Single Color

A chemical element is defined by the number of protons in its atomic nuclei. Carbon has atomic number 6. Rearranging carbon atoms into graphite or diamond does not change that number. Both ideal crystals consist of the same element, but they are different allotropes: different structural forms of that element. [1, 5, 6]

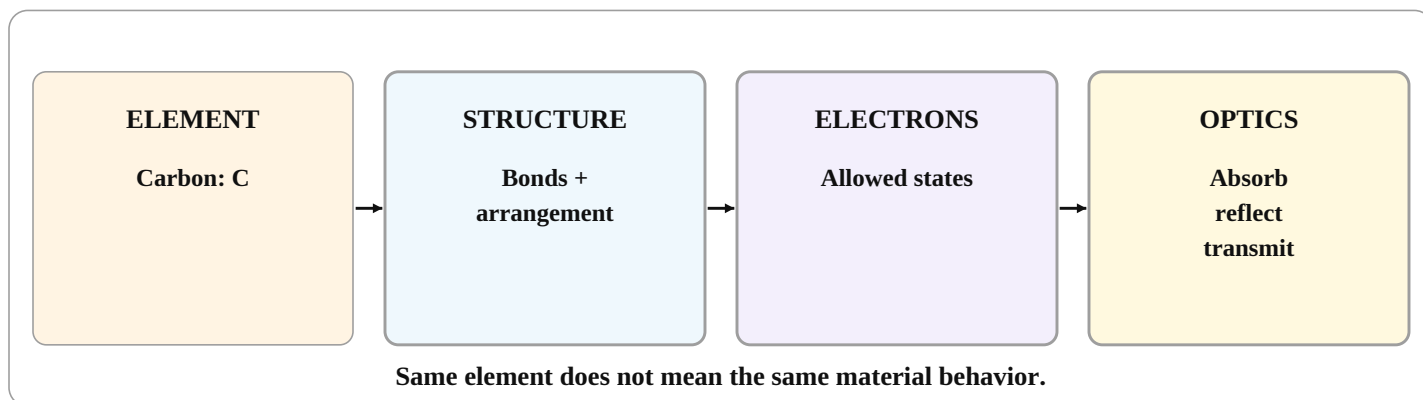


Figure 2. A useful explanation proceeds from elemental identity to structure, electronic behavior, and optical response. A change in appearance does not necessarily indicate a new element.

MATERIAL	CHEMICAL / STRUCTURAL DESCRIPTION	USUAL OPTICAL APPEARANCE
Graphite	An allotrope of carbon; stacked, bonded sheets.	Gray to black; opaque in bulk, often with metallic luster.
Diamond	An allotrope of carbon; a three-dimensional bonded network.	Pure, low-defect material can be colorless and transparent; many diamonds are colored.
Graphene	A single carbon sheet with a honeycomb arrangement.	One suspended layer absorbs only about 2.3% of visible light under the measured conditions.
Soot / charcoal	Carbon-rich, structurally disordered materials; composition and porosity vary.	Commonly black; particles, pores, impurities, and thickness affect appearance.
Coal	A geological carbon-rich mixture, not a pure carbon allotrope.	Commonly dark; not chemically identical to pure graphite or diamond.

The Pencil Is Not a Tiny Diamond Waiting to Be Squeezed

A pencil core is a manufactured material containing graphite and other ingredients. Its mark appears when material transfers to paper. Its ability to write is a property of the material and its layered structure, not a sign that its carbon atoms are a different element from those in diamond. A color comparison alone cannot identify chemical purity. [2, 6]

Conceptual example: transparent window glass, opaque powdered glass, and a frosted glass pane can look very different even when their chemical composition is similar. Structure, interfaces, particle size, and scattering matter as well as composition.

Sources: [1], [2], [5], [6], [9], [26]. Graphene is an experimental counterexample to “all carbon is black.”

The Chemical Construction

An isolated neutral carbon atom has six electrons, commonly written $1s^2 2s^2 2p^2$, with four valence electrons. In solid-state bonding models, carbon can form different arrangements of shared-electron bonds. The labels sp^2 and sp^3 summarize local bonding geometry; they do not describe a change in the nucleus. [1, 5]

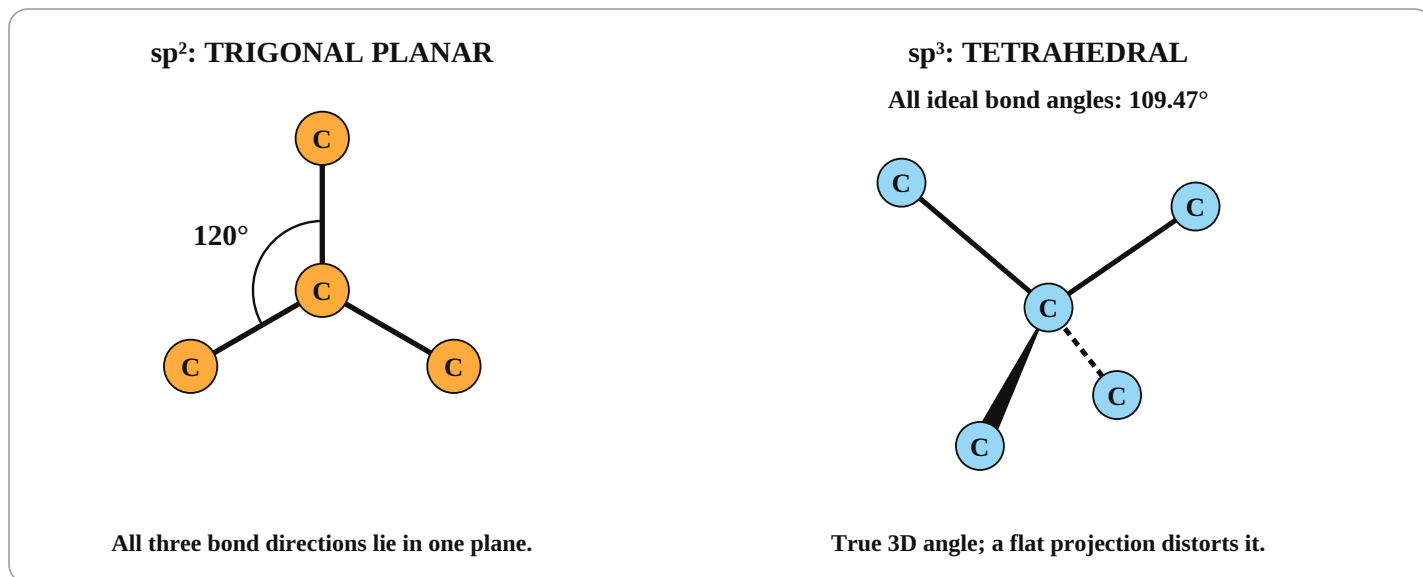


Figure 3. Each central carbon has three neighbors in ideal graphite and four in ideal cubic diamond. A tetrahedron is a three-dimensional object; its bond angles cannot be measured correctly from a flattened drawing.

FEATURE	GRAPHITE	DIAMOND
Local bonding model	sp^2 ; three σ bonds in a plane, with delocalized π electronic states.	sp^3 ; four σ bonds in a three-dimensional network.
Nearest bonded neighbors	3 per interior carbon atom.	4 per interior carbon atom.
Ideal bond angle	120° between in-plane bonds.	$\arccos(-1/3) \approx 109.47^\circ$.
Larger construction	Honeycomb sheets stacked into a crystal.	A continuous tetrahedrally bonded crystal.

Why the Formula Is C, Not C_4 or C_6

A bond count is not a molecular formula. Four neighbors around a diamond carbon do not make diamond a collection of isolated C_4 molecules. A six-membered ring in graphite likewise does not make graphite a collection of separate C_6 molecules. Both are network solids; the chemical formula of an ideal pure sample is C. [6]

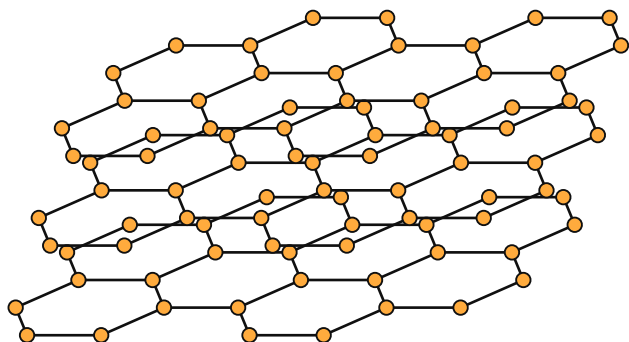
$C(\text{graphite}) \rightleftharpoons C(\text{diamond})$ • Same Element, Different Structure

The double arrow labels possible structural interconversion under appropriate conditions. It does not mean the two forms transform rapidly or coexist in equilibrium in an ordinary classroom.

Sources: [1], [5], [6]. Angles shown are ideal local geometries; defects, surfaces, and strain can alter local values.

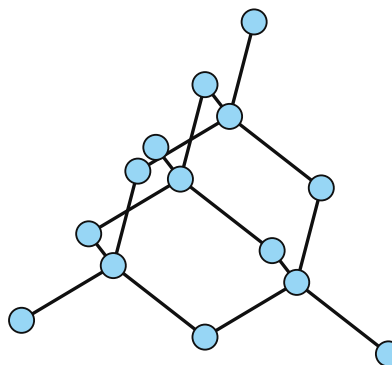
Structure at the Nanometer Scale

GRAPHITE: LAYERED CARBON



Three bonded neighbors per interior atom

DIAMOND: 3D CARBON NETWORK



Four bonded neighbors per interior atom

Figure 4. Graphite has strong in-plane covalent bonding and much weaker bonding between layers. The diamond drawing is a projection of part of a diamond-cubic network, not the shape of a cut gemstone.

QUANTITY	APPROXIMATE VALUE	HOW TO INTERPRET IT
Graphite in-plane C–C distance	0.142 nm	Distance between bonded neighbors within a sheet.
Graphite layer separation	0.335 nm	Spacing between adjacent sheets; not an ordinary in-plane covalent bond.
Diamond nearest C–C distance	0.1545 nm	Distance between tetrahedrally bonded neighbors.
Diamond cubic cell edge a	0.3567 nm	Edge of the conventional cubic unit cell.
Diamond cell population	8 atoms per conventional cell	Shared boundary atoms count fractionally.

A Small Repeating Cell Explains a Large Crystal

The conventional diamond cell has an effective population of eight atoms: corner contributions total one atom, face contributions total three, and four atoms lie inside. It repeats in three dimensions. A drawing of one cell truncates some bonds; interior atoms in the extended solid still have four bonded neighbors. [4, 7]

$$d = (\sqrt{3} / 4)a \text{ and } \rho = 8M / (N_A a^3)$$

The diamond bond distance is slightly longer than the in-plane graphite distance. Nevertheless, diamond is much harder to scratch. Bulk hardness depends on the connected structure and available deformation mechanisms, not on a rule that “the shortest individual bond always makes the hardest material.” Graphite can shear between sheets. [3, 4, 6]

Scale check: 1 nm = 10^{-9} m. The 0.335 nm graphite layer spacing is about 2.36 times its 0.142 nm in-plane bond distance. This ratio compares two different structural distances; it is not a ratio of bond strengths.

Data: [3], [4], [7]. Distances are rounded representative crystal values, not measurements of every sample.

Why One Absorbs and One Transmits

Light can transfer energy to matter when an allowed interaction is available. Graphite has delocalized electronic states and a semimetallic band structure that supports absorption over a broad range of photon energies. Thick graphite therefore transmits little visible light, although it can reflect a noticeable fraction. “Black” does not mean that every incoming photon is absorbed. [2, 3, 10]

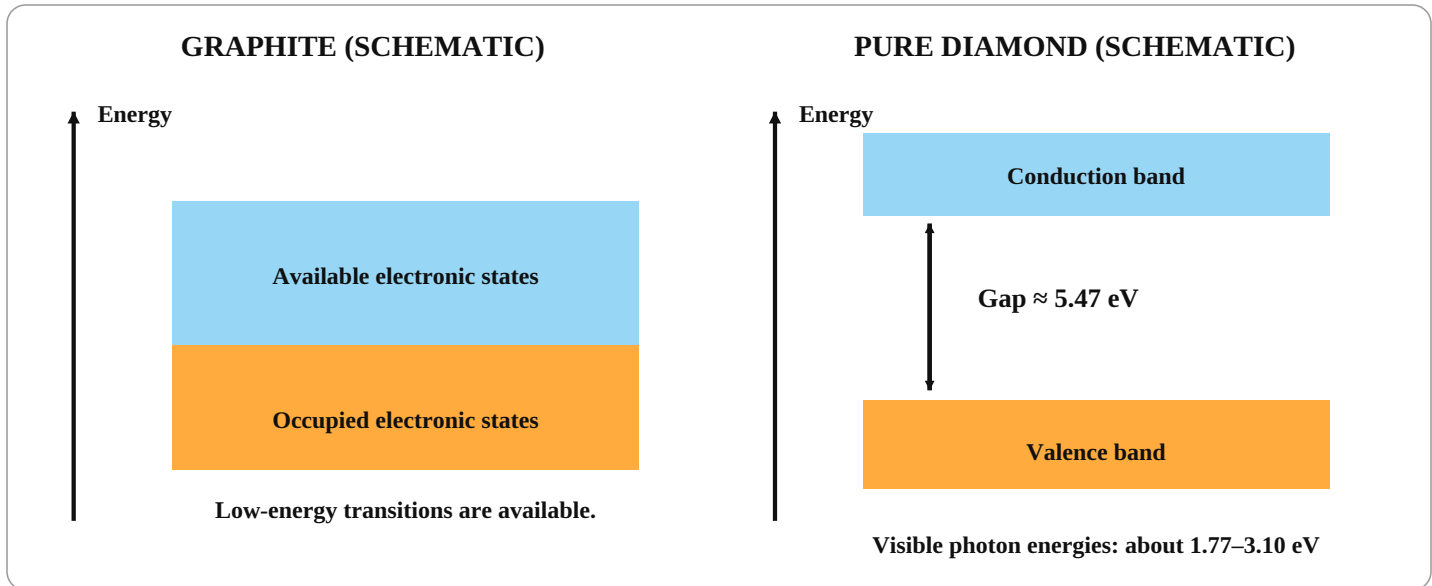


Figure 5. Qualitative electronic-energy sketch, not a calculated band structure. The horizontal positions do not represent electron momentum. Graphite has low-energy electronic transitions; pure diamond has a large forbidden-energy interval.

In high-purity diamond, the valence and conduction bands are separated by an indirect band gap of about 5.47 electronvolts. Visible photons, roughly 400–700 nm, carry about 3.10–1.77 eV each. They cannot bridge that full gap by themselves, so strong intrinsic visible electronic absorption is absent. Light can travel through a sufficiently clear crystal. [7, 8]

$$E = hf = hc/\lambda \cdot E[\text{eV}] \approx 1239.84 / \lambda[\text{nm}]$$

Transparency Is an Electronic Property, Not Empty Space

Diamond is denser than graphite; it does not transmit light because its atoms leave larger holes for light to slip through. Transparency involves how electromagnetic waves interact with the material’s electronic and vibrational states. The light still refracts and partly reflects. Impurities, defects, surfaces, and inclusions can add absorption or scattering. [4, 7, 16]

Important boundary: $1239.84 / 5.47 \approx 227$ nm is an energy-equivalent wavelength. Because diamond has an indirect gap, phonon assistance and other details matter near its absorption edge. This number is not a perfectly sharp, universal optical cutoff.

Clear, Colorless, and Sparkling

Transparent means light can pass through with limited scattering. Colorless means the transmitted or reflected visible light has little selective color bias. Sparkle describes bright flashes created by illumination and the geometry of reflection and refraction. A transparent blue diamond is possible, and a colorless but heavily included diamond can look cloudy. [13–17, 22]

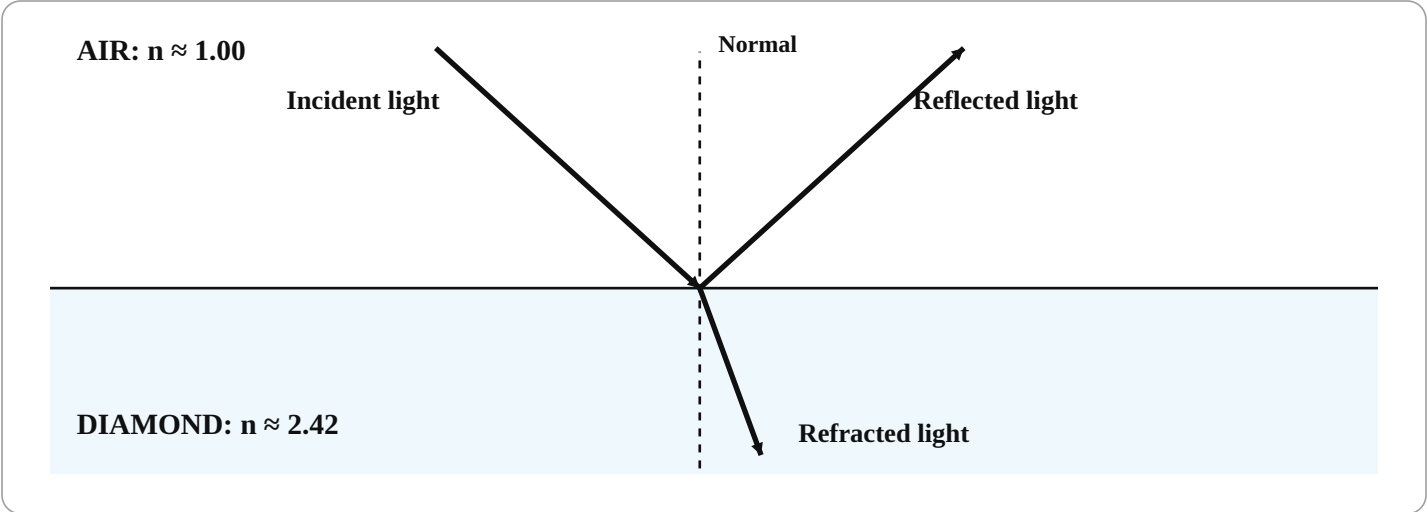


Figure 6. At an air–diamond boundary, some light reflects and some refracts. Angles are measured from the dashed normal, not from the surface. Ray directions are illustrative, not a scale construction.

CAUSE / FEATURE	POSSIBLE RESULT	WHAT IT TEACHES
Certain nitrogen-related defects	Yellow or orange coloration.	Defect states can remove selected wavelengths.
Substitutional boron in some diamonds	Blue coloration; altered electrical behavior.	Trace atoms can change a property without replacing the carbon network.
Dark inclusions / dense defect structures	Black or very dark appearance.	A dark diamond is not automatically a perfect absorber.
Light-scattering inclusions	Cloudy or milky appearance.	Low clarity can result from scattering rather than strong selective color absorption.

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 \cdot \theta_c = \sin^{-1}(n_2/n_1)$$

Diamond’s visible refractive index is approximately 2.42, with wavelength dependence. For light traveling from diamond into air, the critical angle is about 24.4°. Above it, an ideal smooth interface produces total internal reflection. A gemstone’s cut redirects light, while dispersion separates colors. Neither effect requires the diamond to be a blackbody. [7, 16, 17]

The critical-angle formula requires $n_1 > n_2$. Not every diamond color has the same cause, and a color photograph cannot determine a stone’s defect chemistry or authenticity.

Sources: [7], [13], [14], [15], [16], [17], [22]. The table gives examples, not a complete color-classification system.

What Pressure Actually Does

Higher pressure tends to favor denser structures because they occupy less volume. But a favorable final structure does not appear automatically: carbon atoms must move, old bonds must reorganize, and a new crystal must nucleate or grow. Pressure is part of the explanation, not a substance that removes black color. [4, 11, 21]

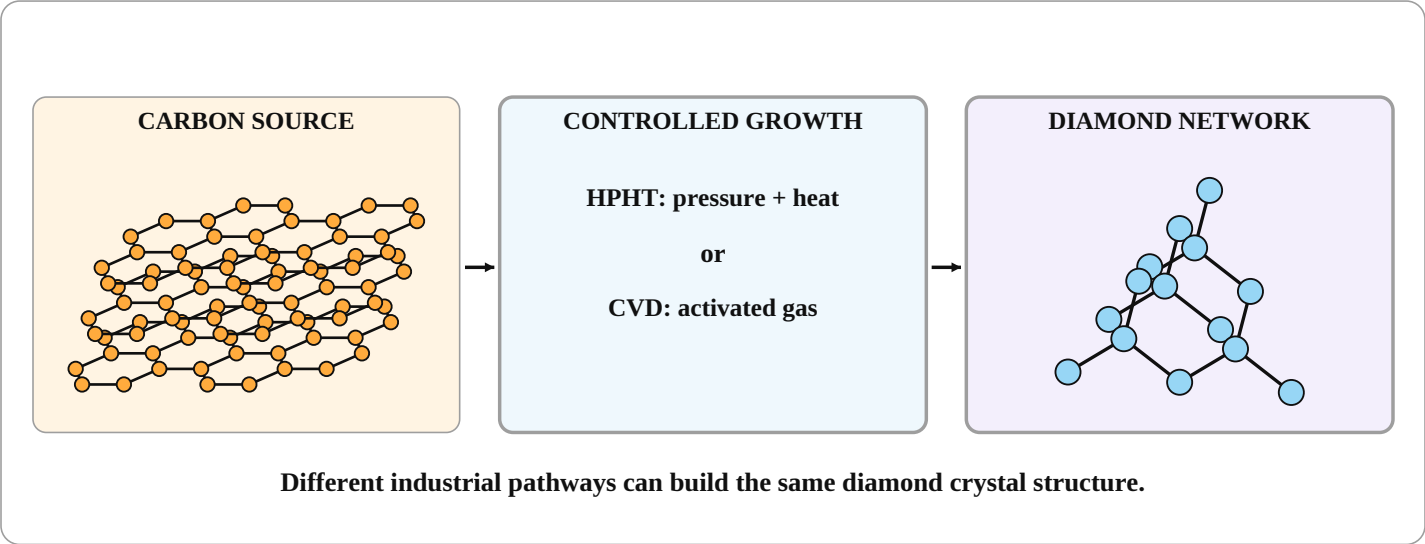


Figure 7. Industrial growth pathways. HPHT means high pressure, high temperature. CVD means chemical vapor deposition. These are scientific process summaries, not instructions for a home experiment.

PATHWAY	TYPICAL FEATURES	KEY CORRECTION
HPHT growth	Common gem-growth conditions are about 5–6 GPa and 1300–1600°C. A metal solvent/catalyst helps supply carbon to a seed.	Not just cold squeezing; often dissolution and recrystallization.
CVD growth	An activated carbon-containing gas supplies carbon to a heated seed at relatively low pressure.	Diamond can grow without bulk high-pressure compression.
Natural growth	Many diamonds form deep in Earth from carbon-bearing fluids or melts under suitable mantle conditions.	Ordinary buried coal is not the general explanation for natural diamonds.

Does the Carbon Change Chemically?

Carbon atoms remain carbon. Their bonding and crystal structure change, and the surrounding growth chemistry can involve solvents, catalysts, or gases. A grown diamond can have the diamond crystal structure while containing impurities, growth sectors, and defects that reflect its production history. [11, 12, 26]

Safety and scope: do not attempt diamond synthesis with household presses, microwaves, flame, sealed vessels, or improvised electrical equipment. Specialized research pathways exist, including shear-driven transformations; “heat is always required in every possible pathway” would also be too absolute. [28]

Sources: [4], [11], [12], [21], [26], [28]. Standard growth ranges are examples, not a universal phase boundary.

Why Diamond Stays Diamond

At ordinary pressure and temperature, graphite is thermodynamically more stable than diamond. Diamond is metastable: it can persist because changing its entire bonding network requires a difficult sequence of rearrangements. A process can be thermodynamically favorable but extraordinarily slow. Stability and reaction speed answer different questions. [6, 21]

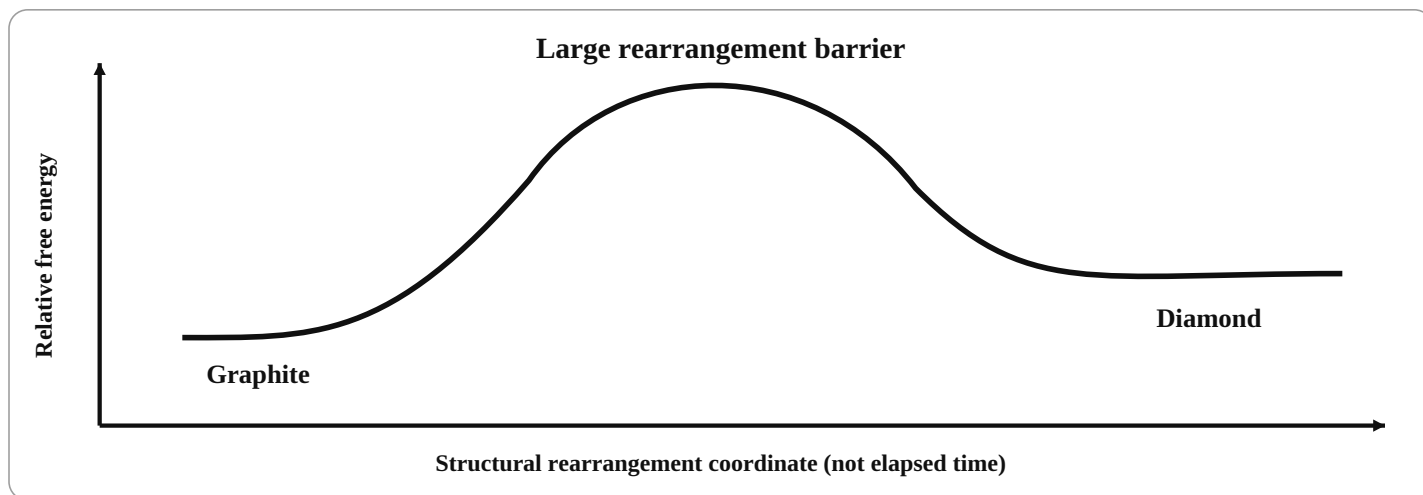


Figure 8. Qualitative ambient-condition free-energy landscape. The graphite endpoint is lower. The high barrier helps explain persistence of diamond. Neither the heights nor the curve are measured numerical data.

$$G = H - TS \quad \Delta G = \Delta H - T\Delta S$$

Here G is Gibbs free energy, H is enthalpy, T is absolute temperature, and S is entropy. The second equation applies to a change at a specified temperature. A negative ΔG favors the specified change thermodynamically; it does not give a reaction rate. A catalyst changes a pathway's kinetics, not the equilibrium free-energy difference. [21]

An Advanced Pressure Connection

$$(\partial \Delta G_m / \partial p)_T = \Delta V_m$$

Define $\Delta V_m = V_{m,\text{diamond}} - V_{m,\text{graphite}}$. Using $M = 12.011$ g/mol and representative densities, these molar volumes are about 3.417 and 5.315 cm³/mol. Their difference is negative. Increasing pressure therefore shifts the free-energy difference in the direction that favors diamond, locally at fixed temperature. [3, 4, 21]

First-order model: $\Delta G_m(p_2) - \Delta G_m(p_1) \approx \Delta V_m \Delta p$. Taking the room-pressure volumes as constant gives about -9.49 kJ/mol for a 5.00 GPa increase. This ignores compression and temperature changes; it does NOT calculate the actual formation threshold.

Conceptual example: a ball can remain in a shallow hollow when a large ridge separates it from a deeper hollow. The analogy illustrates a barrier; atoms do not literally roll across the plotted curve.

Sources: [3], [4], [6], [21]. The molar-volume example is an original calculation with explicitly stated approximations.

Are They Perfect Blackbodies?

A perfect blackbody is an ideal absorber: it absorbs all radiation incident on it at every wavelength and direction. It reflects none and transmits none. In thermal equilibrium its emission follows the ideal blackbody spectrum. “Black” in this definition is stronger than “looks dark to the human eye.” [18, 19, 27]

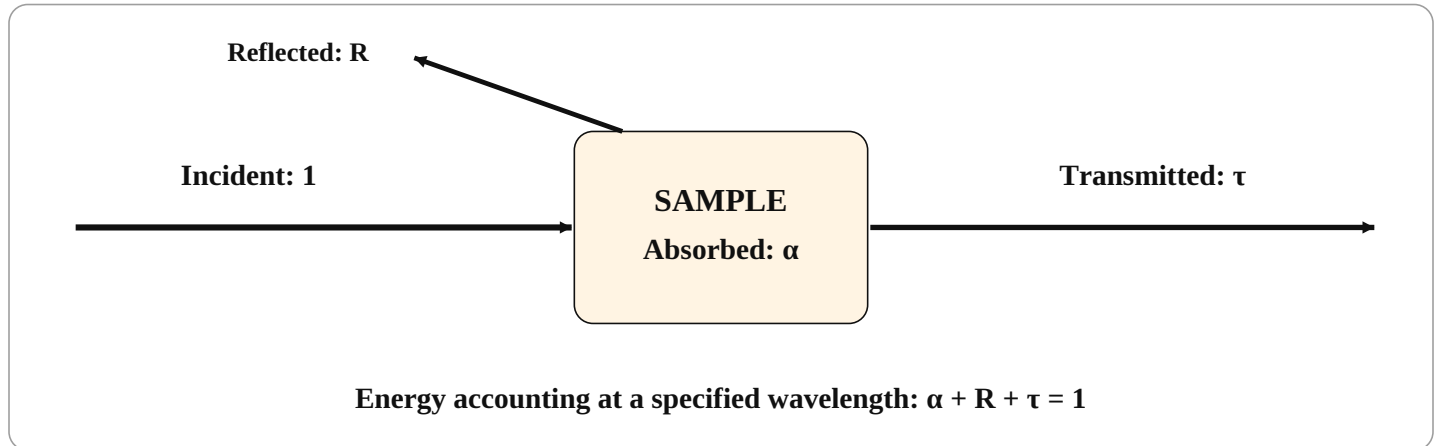


Figure 9. Energy fractions for an incident beam. Include all reflected and transmitted directions, including scattered light. The wavelength-specific fractions must sum to one.

$$\alpha_{\lambda} + R_{\lambda} + \tau_{\lambda} = 1$$

MATERIAL / MODEL	PERFECT BLACKBODY?	REASON
Bulk graphite	No.	It reflects some light; absorption and emission depend on wavelength, surface, orientation, and temperature.
Clear diamond	No.	It transmits visible light and reflects light at its surfaces.
Black diamond or soot	Not automatically.	Visual darkness does not prove unit absorption across the electromagnetic spectrum.
An engineered absorbing cavity	Can be a useful approximation.	Multiple encounters reduce escape; performance must be specified and measured.
Ideal mathematical blackbody	Yes, by definition.	$\alpha = 1$, $R = 0$, $\tau = 0$, and thermal emissivity $\epsilon = 1$.

Absorption and Emission Are Related, But Match the Conditions

Kirchhoff's law gives $\epsilon_{\lambda} = \alpha_{\lambda}$ for the corresponding wavelength, direction, and polarization under the ordinary reciprocal thermal-equilibrium conditions. A large visible absorptivity does not establish the same numerical emissivity in the thermal infrared. A table entry such as $\epsilon = 0.90$ must specify what material and conditions it represents. [19, 27]

In this guide, $\epsilon = 0.90$ is an assigned gray-body model parameter for exercises. It is NOT presented as a universal measured emissivity of graphite, charcoal, or diamond.

Black Objects Can Glow

An object can look black under room lighting while emitting thermal infrared radiation. At 300 K, the ideal blackbody spectrum peaks near 9.66 micrometers, well beyond visible light. Raising the temperature changes the spectrum: sufficiently hot absorbers can glow visibly. A “blackbody” need not look black when hot. [18, 19]

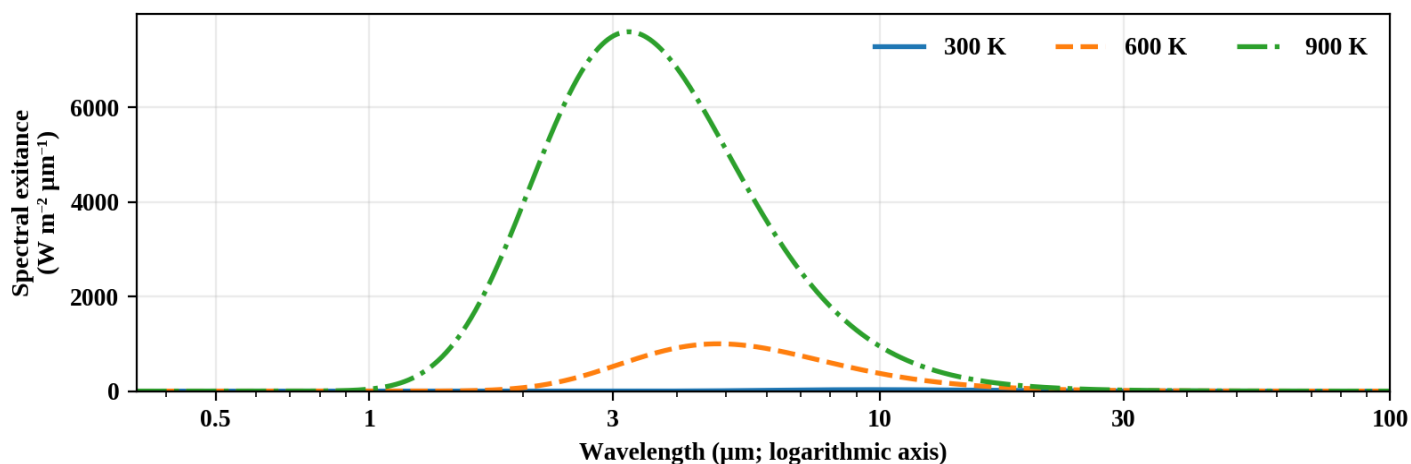


Figure 10. Calculated Planck spectra for ideal blackbodies. The wavelength axis is logarithmic; each curve gives emitted power per unit area per micrometer. These are model curves, not measurements of graphite or diamond.

$$\lambda_{\max} T = b \cdot P_{\text{emit}} = \epsilon \sigma A T^4$$

Wien’s law locates the wavelength peak. The Stefan–Boltzmann expression estimates total emitted power when a gray-body approximation is appropriate. Use kelvins, not Celsius, in both laws. At fixed area and emissivity, doubling absolute temperature multiplies emitted power by 16. Net exchange with a warm environment need not follow that same ratio. [18, 19]

$$P_{\text{net}} = \epsilon \sigma A (T^4 - T_{\text{surr}}^4)$$

The net formula here assumes a uniform, opaque, diffuse-gray object facing a large black isothermal enclosure, with the relevant view factor equal to one. A is the total participating radiating area. A transparent, spectrally complex diamond sample may require a wavelength-dependent treatment rather than one constant emissivity. [7, 19]

Two different questions: “Can I see through it?” concerns visible transmission. “How does it exchange thermal radiation?” concerns the relevant absorption/emission spectrum at its temperature. Diamond has infrared absorption bands even when it is visibly clear. [7]

Thermal emission is not the same as fluorescence. Fluorescence involves excitation by another source and need not have a thermal blackbody spectrum.

MASTER TABLE • PROPERTIES AND PRACTICAL CONSEQUENCES

Comparison and Contrast

PROPERTY	GRAPHITE	DIAMOND
Ideal composition	Carbon, C.	Carbon, C.
Bonding geometry	3 neighbors; sp ² ; 120°; layered.	4 neighbors; sp ³ ; 109.47°; 3D network.
Typical bulk appearance	Gray–black and opaque; can be shiny.	Can be transparent and colorless; many colors and clarity grades exist.
Representative crystal density	2.26 g/cm ³ .	3.515 g/cm ³ .
Mohs scratch hardness	About 1–2.	10 on the conventional Mohs scale.
Mechanical behavior	Sheets shear readily; soft and lubricating.	Very scratch-resistant, but brittle and capable of cleavage.
Electrical behavior	Conductive, with strong directional dependence.	High-purity bulk material is normally insulating; doping can change behavior.
Heat conduction	Strongly anisotropic; often efficient within layers.	Exceptionally high in suitable high-quality material, largely through lattice vibrations.
Visible-light response	Strong bulk absorption plus some reflection.	Low absorption when pure; strong refraction and nonzero surface reflection.
Blackbody status	Not a perfect blackbody.	Not a perfect blackbody.
Typical uses	Electrodes, writing materials, lubrication, and heat-management components.	Cutting / wear components, gemstones, optical windows, and heat spreaders.
Reaction with oxygen	Carbon can oxidize; products depend on conditions.	Carbon can oxidize; products depend on conditions.



The similarities identify the shared element; the contrasts identify the importance of structure. Diamond can conduct heat very well without conducting electric current well, because heat can travel through lattice vibrations. Graphite’s electrical conductivity does not make it an optical mirror at every wavelength. Each property has its own physical mechanism. [2–8, 23, 24]

Do not divide Mohs numbers to claim “diamond is five times harder.” Mohs is an ordinal scratch-ranking scale, not a linear ratio scale. Do not equate hardness with toughness: resisting a scratch and resisting fracture are different tests. [3, 4]

No single universal room-pressure “melting point” is assigned here. Carbon’s transformations, oxidation, and sublimation depend on temperature, pressure, environment, and kinetics. Powder bulk density also differs from crystal density because pores occupy volume.

Sources: [1]–[8], [18], [19], [23], [24], [26]. Numerical properties are representative, not gemstone-authentication tests.

Formula and Constant Reference I

RELATION	SYMBOLS AND USE
$\rho = m/V$; $V = m/\rho$	ρ : density; m : mass; V : volume. Keep units compatible.
$n_{\text{mol}} = m/M$; $N = (m/M)N_A$	M : molar mass; N : number of atoms; n_{mol} : amount in moles.
$p = F/A$; $F = pA$	p : pressure; F : normal force; A : loaded area. $\text{Pa} = \text{N/m}^2$.
Percent change = $100(\text{new} - \text{old})/\text{old}$	The original quantity sets the denominator. State whether the change is an increase or reduction.
$d = (\sqrt{3}/4)a$; $\rho = 8M/(N_A a^3)$	Ideal diamond-cubic cell: edge a , nearest-neighbor distance d , eight atoms per conventional cell.
$\cos \theta = (\mathbf{u} \cdot \mathbf{v})/(\mathbf{u} \mathbf{v})$	Dot product relation. Tetrahedral directions can be chosen to give $\cos \theta = -1/3$.
$V_m = M/\rho$; $\delta(\Delta G_m) \approx \Delta V_m \Delta p$	$\delta(\Delta G_m)$ denotes the pressure-induced change in the phase free-energy difference at fixed T , with constant molar volumes.

CONSTANT / CONVERSION	VALUE USED
Carbon molar mass, M	12.011 g/mol (representative natural composition; not exact).
Avogadro constant, N_A	$6.02214076 \times 10^{23} \text{ mol}^{-1}$ (exact).
Planck constant, h	$6.62607015 \times 10^{-34} \text{ J}\cdot\text{s}$ (exact).
Speed of light in vacuum, c	299792458 m/s (exact).
Boltzmann constant, k_B	$1.380649 \times 10^{-23} \text{ J/K}$ (exact).
Electronvolt	1 eV = $1.602176634 \times 10^{-19} \text{ J}$ (exact).
Temperature; carat	$T[\text{K}] = t[^\circ\text{C}] + 273.15$; 1 carat = 0.200 g.
Pressure and size	1 GPa = 10^9 Pa ; 1 atm = 101325 Pa; 1 nm = 10^{-9} m .
Area and volume	1 mm ² = 10^{-6} m^2 ; 1 cm ³ = 10^{-6} m^3 .

Unit trap: converting millimeters to meters multiplies length by 10^{-3} , but converting square millimeters to square meters multiplies area by $(10^{-3})^2 = 10^{-6}$. Cube the conversion factor for a volume.

Reporting rule: carry extra digits during calculations, then round a final answer to a sensible precision, usually three significant figures for these exercises. The symbol n in optics means refractive index; n_{mol} here means amount of substance.

Formula and Constant Reference II

RELATION	MEANING / CONDITIONS
$E = hf = hc/\lambda$	Photon energy; f is frequency, λ is vacuum wavelength. $E[\text{eV}] \approx 1239.84/\lambda[\text{nm}]$.
$n_1 \sin \theta_1 = n_2 \sin \theta_2$	Snell's law; angles measured from the surface normal.
$\theta_c = \sin^{-1}(n_2/n_1)$	Critical angle only when light travels from n_1 to n_2 with $n_1 > n_2$.
$R = [(n_2 - n_1)/(n_2 + n_1)]^2$	Normal-incidence intensity reflectance at a smooth boundary between nonabsorbing media.
$I/I_0 = \exp(-\beta L)$	Ideal single-pass attenuation model. β is an absorption coefficient, L is path length; ignore scattering and surface reflection.
$\alpha_\lambda + R_\lambda + \tau_\lambda = 1$	Wavelength-resolved energy balance. R , τ include all outgoing directions.
$\epsilon_\lambda = \alpha_\lambda$	Kirchhoff relation under corresponding equilibrium, reciprocal conditions. Do not mix wavelength bands.
$\lambda_{\text{max}} = b/T$	Wien displacement law for the spectrum per unit wavelength.
$P_{\text{emit}} = \epsilon \sigma A T^4$	Total emission in the gray-body approximation; $\epsilon = 1$ for an ideal blackbody.
$P_{\text{net}} = \epsilon \sigma A (T^4 - T_{\text{surr}}^4)$	Use the enclosure, opacity, area, and view-factor assumptions explained on page 10.

The Full Ideal Spectrum: Planck's Law

$$M_\lambda(T) = (2\pi hc^2/\lambda^5) / \{\exp[hc/(\lambda k_B T)] - 1\}$$

M_λ is spectral radiant exitance: emitted power per unit surface area per unit wavelength. With λ in meters, its units are $\text{W}\cdot\text{m}^{-3}$. Multiply by 10^{-6} to express power per micrometer of wavelength. Spectral radiance B_λ instead has the prefactor $2hc^2$ and is per steradian.

REFERENCE VALUE	NUMBER
Stefan–Boltzmann constant, σ	$5.670374419 \times 10^{-8} \text{ W}\cdot\text{m}^{-2}\cdot\text{K}^{-4}$
Wien constant, b	$2.897771955 \times 10^{-3} \text{ m}\cdot\text{K}$
Rounded diamond values for exercises	$n = 2.42$; band gap $E_g = 5.47 \text{ eV}$

Symbol warning: α is absorptivity (a dimensionless fraction); β here is a path-length absorption coefficient. Neither should be confused with thermal conductivity. Planck and Wien expressions refer to thermal radiation, not every kind of emitted light.

Worked Examples: Atoms and Shape

1. Same Mass, Smaller Volume

Question: compare 1.000 g of crystalline graphite and diamond. Using $V = m/\rho$ gives $V_g = 1.000/2.26 = 0.4425 \text{ cm}^3$ and $V_d = 1.000/3.515 = 0.2845 \text{ cm}^3$. The fractional reduction relative to the graphite volume is $(0.4425 - 0.2845)/0.4425 = 0.3570$. **Answer:** about 35.7% less volume for the same mass.

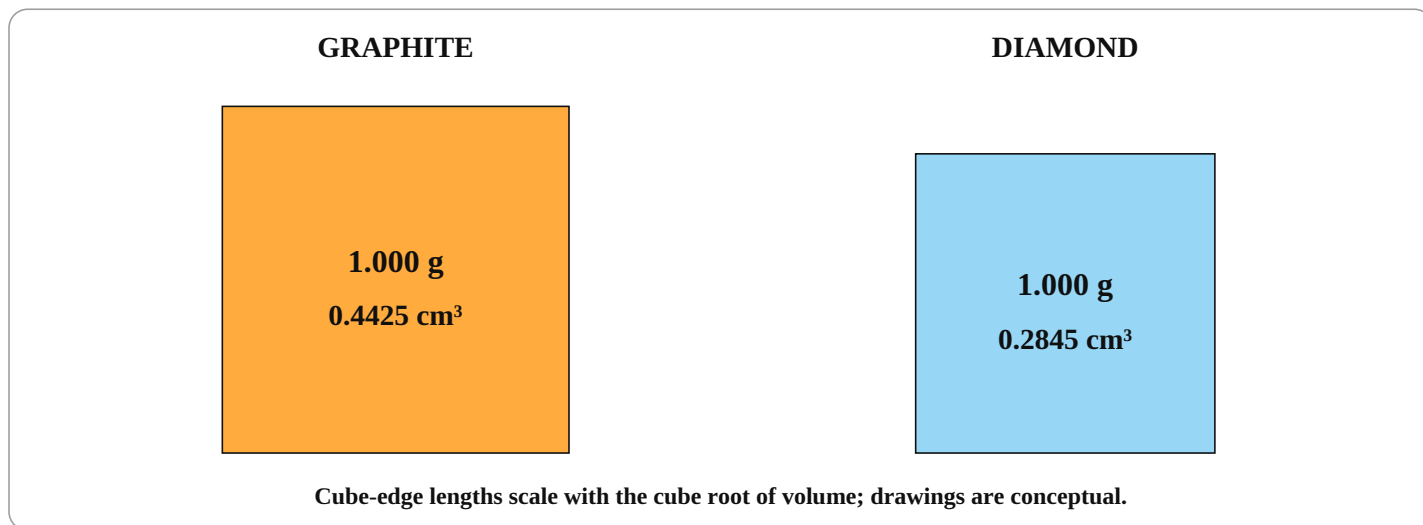


Figure 11. Equal-mass samples at representative crystal densities. The squares depict faces of conceptual cubes; the edge lengths scale with the cube root of their volumes.

2. How Many Atoms Are in One Carat?

$$N = (0.200 \text{ g} / 12.011 \text{ g} \cdot \text{mol}^{-1})(6.02214 \times 10^{23} \text{ mol}^{-1})$$

Answer: $N \approx 1.00 \times 10^{22}$ carbon atoms in an ideal pure one-carat diamond. Its volume is $0.200/3.515 = 0.0569 \text{ cm}^3$. Changing graphite into diamond conserves the number of carbon atoms when no carbon enters or leaves the sample.

3. From a Unit Cell to a Bond Distance

Take $a = 0.3567 \text{ nm}$. Then $d = (\sqrt{3}/4)(0.3567) = 0.154456 \text{ nm} \approx 0.1545 \text{ nm}$. The factor $\sqrt{3}$ comes from a cube's body diagonal. A local tetrahedral bond occupies one quarter of that diagonal in the conventional diamond cell.

4. Derive the Tetrahedral Angle

Choose $u = (1, 1, 1)$ and $v = (1, -1, -1)$. Their dot product is -1 and each length is $\sqrt{3}$. Therefore $\cos \theta = -1/(\sqrt{3}\sqrt{3}) = -1/3$, giving $\theta = \arccos(-1/3) \approx 109.47^\circ$. This is a three-dimensional angle, not 90° or 120° .

Interpretation: density, bond length, and bond angle measure different aspects of structure. None by itself is a direct measurement of visible-light absorption.

Worked Examples: Light and Pressure

5. A Red Photon Compared with the Diamond Gap

For $\lambda = 650 \text{ nm}$, $E = 1239.84/650 = 1.91 \text{ eV}$. That is below 5.47 eV . The gap's energy-equivalent wavelength is $1239.84/5.47 = 226.7 \text{ nm}$, in the ultraviolet. This supports the visible-transparency explanation but does not replace a full indirect-transition absorption model.

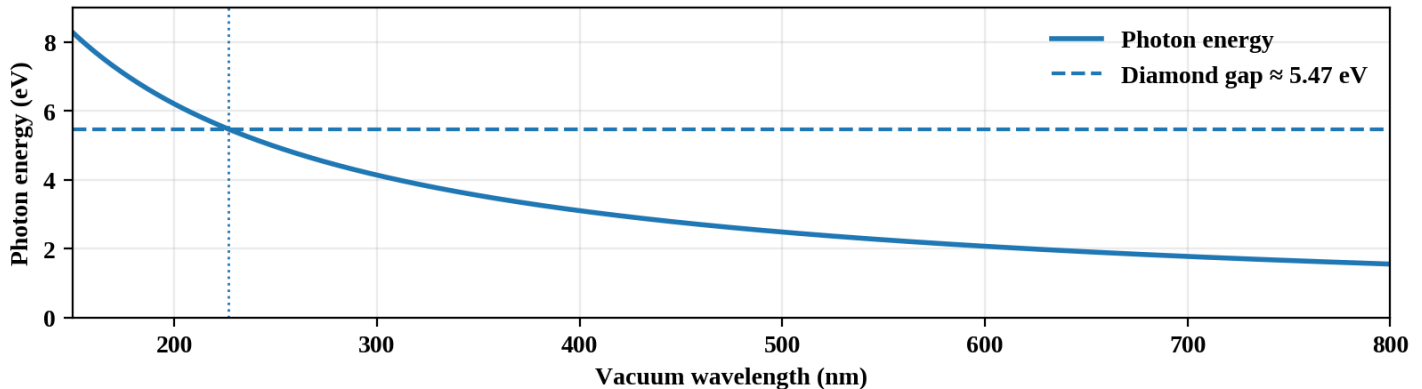


Figure 12. Calculated photon energy versus vacuum wavelength. The horizontal line marks the approximate diamond gap; the crossing is an energy comparison, not a measured absorption spectrum.

6. A Clear Diamond Still Reflects Light

$$R = [(2.42 - 1)/(2.42 + 1)]^2 = 0.1724 \approx 17.2\%$$

This is the reflected intensity fraction at one flat, uncoated air–diamond interface at normal incidence. A nonabsorbing slab's first directly transmitted beam, neglecting all later internal reflections, has fraction $(1 - R)^2 \approx 0.685$. Neither percentage describes every ray in a faceted gemstone.

7. Convert Pressure into Force

For $p = 5.50 \text{ GPa}$ and $A = 1.00 \text{ mm}^2$: $F = (5.50 \times 10^9 \text{ Pa})(1.00 \times 10^{-6} \text{ m}^2) = 5500 \text{ N}$. The pressure is about 54,300 atmospheres. Force over an area is a useful scale comparison, not a safe procedure for building a pressure vessel.

8. Emitted Power Is Not Net Power

Use the assigned model $\varepsilon = 0.90$, $A = 0.0100 \text{ m}^2$, $T = 600 \text{ K}$, and $T_{\text{sur}} = 300 \text{ K}$. Emission is $0.90\sigma(0.0100)(600^4) = 66.1 \text{ W}$. Net outward radiation is $0.90\sigma(0.0100)(600^4 - 300^4) = 62.0 \text{ W}$. The difference is absorbed radiation from the modeled surroundings.

Check: these thermal answers apply to the opaque gray object and black-enclosure model, not automatically to a transparent diamond window. All participating radiating surface area must be included.

Worked Examples: Spectra and Models

9. Where Does the Thermal Spectrum Peak?

At 300 K, $\lambda_{\max} = 2.89777 \times 10^{-3}/300 = 9.66 \times 10^{-6} \text{ m} = 9.66 \text{ }\mu\text{m}$. At 600 K the peak is $4.83 \text{ }\mu\text{m}$, and at 900 K it is $3.22 \text{ }\mu\text{m}$. Doubling T halves this wavelength peak, while increasing total ideal emitted power by $2^4 = 16$ at fixed area.

10. A Simple Attenuation Model

An assigned absorption coefficient is $\beta = 2.00 \text{ mm}^{-1}$ and path length is $L = 0.500 \text{ mm}$. Their product is dimensionless: $\beta L = 1.00$. Thus $I/I_0 = e^{-1} = 0.3679$, or 36.8% transmitted in this idealized single-pass model. Doubling L gives $e^{-2} = 13.5\%$. Surface reflection and scattering have been excluded.

11. A Graphene-Inspired Layer Model

$$\tau_N = (0.977)^N \cdot N = \ln(0.50) / \ln(0.977)$$

Assign each independent layer a transmitted fraction of 0.977. The solution is $N \approx 29.79$, so 30 integer layers would bring the toy model below 50% transmission. Real stacked sheets can interact electronically and optically; this independent-layer model is not a rigorous calculation for bulk graphite.

12. How a Cavity Can Look Very Absorbing

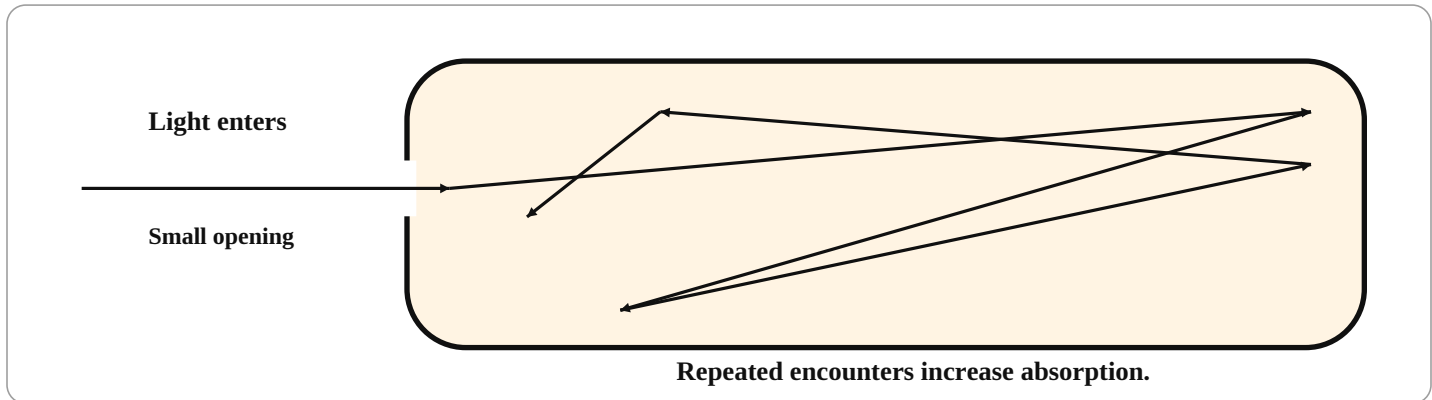


Figure 13. A small opening can reduce the chance that incoming light escapes. The ray path is illustrative. This is not a claim that each real ray experiences the same number of wall encounters.

Suppose each wall encounter absorbs 60% of the surviving energy. After exactly five encounters, the remaining fraction is $(1 - 0.60)^5 = 0.01024$. The absorbed fraction is $1 - 0.01024 = 0.98976$, or about 99.0%. Real cavity performance also depends on the chance of escape and on the spectrum of the walls.

Model-literacy question: which assumption controls each answer? Example 9 uses a wavelength-defined thermal peak; 10 neglects scattering/reflections; 11 assumes independent layers; 12 assigns a fixed encounter count.

Student Practice A

Name / class: _____ Date: _____

Use a separate sheet or notebook for full working. Show a formula, substitution, units, and final interpretation. Use three significant figures unless an exact count is requested.

Data: $M = 12.011 \text{ g/mol}$; $N_A = 6.02214 \times 10^{23} \text{ mol}^{-1}$; $\rho_g = 2.26 \text{ g/cm}^3$; $\rho_d = 3.515 \text{ g/cm}^3$; 1 carat = 0.200 g; 1 nm = 10^{-7} cm . Diamond cell: $a = 0.3567 \text{ nm}$, 8 atoms.

1. Element or Different Substance?

State the ideal chemical formula of graphite and diamond. How many protons does each carbon nucleus contain? What changes when one allotrope becomes the other?

2. Classify the Materials

Classify graphite, diamond, and coal as carbon allotropes or a carbon-rich mixture. Explain why a black appearance alone cannot establish purity.

3. Compare Bond Angles

Give the ideal local bond angle in graphite and diamond. Calculate the difference between those angles in degrees.

4. Count Shared Bonds

In a large periodic model containing 100 carbon atoms, estimate the number of distinct nearest-neighbor bonds for (a) graphite within its sheets and (b) diamond. Every bond is shared by two atoms; ignore surfaces.

5. Compare Bond Distances

Using 0.142 nm and 0.1545 nm, calculate the percentage by which a diamond nearest-neighbor bond distance exceeds graphite's in-plane distance. Does the result mean graphite must be harder?

6. Compare Two Different Separations

Divide graphite's 0.335 nm layer spacing by its 0.142 nm in-plane bond distance. State what the ratio does and does not measure.

7. Volume of One Carat

Calculate the volume in cm^3 of a pure one-carat diamond using the supplied crystal density.

8. Conserve the Carbon

A model sample initially contains 2.00 cm^3 of graphite. Calculate its mass and the final diamond volume if all carbon is retained and the reference densities apply.

9. Count the Atoms

Calculate the number of carbon atoms in a pure one-carat diamond. Explain why an equal mass of pure graphite has the same atom count.

10. Challenge: Derive a Crystal Density

Use $\rho = 8M/(N_A a^3)$ to calculate diamond's density in g/cm^3 . Convert the cell edge to centimeters before cubing it.

Student Practice B

Name / class: _____ Date: _____

Angles are measured from the normal. Use degree mode for trigonometry. State assumptions whenever an idealized formula is applied.

Data: $E[\text{eV}] = 1239.84/\lambda[\text{nm}]$; $E_g = 5.47 \text{ eV}$; $n_{\text{air}} = 1.00$; $n_d = 2.42$; $b = 2.89777 \times 10^{-3} \text{ m}\cdot\text{K}$; $\sigma = 5.67037 \times 10^{-8} \text{ W}\cdot\text{m}^{-2}\cdot\text{K}^{-4}$. Also $1 \text{ mm}^2 = 10^{-6} \text{ m}^2$.

11. Photon Energy

Calculate the energy of a 450 nm photon in eV. Is it enough by itself to bridge a 5.47 eV gap?

12. Energy-Equivalent Wavelength

Calculate the wavelength associated with 5.47 eV. Explain why it should not be called an exact, universal diamond transparency boundary.

13. Refraction

Light enters diamond from air at an incidence angle of 45.0° . Calculate the transmitted angle using Snell's law.

14. Total Internal Reflection

Find the diamond-to-air critical angle. Would an internal ray at 30.0° from the normal undergo total internal reflection at an ideal smooth interface?

15. Reflection from Clear Material

Find the normal-incidence reflectance of one air–diamond boundary. For incident power of 1.00 W, calculate reflected power. Explain why this already rules out a perfect blackbody at that wavelength.

16. Energy Accounting

At a specified wavelength, a sample reflects 25% and transmits 10% of incident power. Find its absorptivity. Is it a perfect blackbody at that wavelength?

17. Pressure and Area

Find the normal force corresponding to 5.00 GPa over 2.00 mm^2 . This is a mathematical scale comparison, not a construction or synthesis instruction.

18. Assigned Gray-Body Emission

An opaque model object has $\epsilon = 0.90$, participating radiating area $A = 0.0100 \text{ m}^2$, and $T = 600 \text{ K}$. Find its total emitted thermal power.

19. Net Radiation

Place the object from Question 18 in a large black isothermal enclosure at 300 K, with view factor one. Calculate net outward radiative power. Why is it smaller than the emitted power?

20. A Room-Temperature Peak

Calculate the ideal wavelength peak at 300 K in μm . Is it inside the approximate $0.400\text{--}0.700 \mu\text{m}$ visible band?

Student Practice C

Name / class: _____ Date: _____

Distinguish measured material facts from ideal models. Use a notebook for paragraphs, diagrams, and numerical working.

21. Temperature-Ratio Reasoning

At fixed area and constant assigned emissivity, by what factor does emitted power change from 300 K to 450 K? Why should you not substitute the corresponding Celsius temperatures into this ratio?

22. Heat versus Electricity

Explain how high-purity diamond can transfer heat efficiently while remaining a poor electrical conductor. Must a good thermal conductor always be a good electrical conductor?

23. Attenuation Model

For $I/I_0 = e^{-\beta L}$, use $\beta = 2.00 \text{ mm}^{-1}$ and $L = 0.500 \text{ mm}$. Find transmission for this thickness and for twice the thickness. Name two effects that this simple calculation neglects.

24. Independent-Layer Model

Using $\tau_N = (0.977)^N$, find the smallest integer N that gives transmission no greater than 50%. State why real stacks need a more detailed model.

25. Cavity Model

A wall absorbs 60% of remaining light at each encounter. In a model with exactly five encounters before any possible escape, calculate the total absorbed fraction. Why does this not prove a real cavity is perfect?

26. The Meaning of Black

A material strongly absorbs visible light. A student concludes that its emissivity is exactly 1 at every infrared wavelength. Identify the error and state the properly matched Kirchhoff relation.

27. Read and Predict a Spectrum

Using $\lambda_{\text{max}} T = 2.89777 \times 10^{-3} \text{ m} \cdot \text{K}$, find the peaks at 600 K and 900 K. Predict which curve has the greater total emitted power per unit area and explain why.

28. Challenge: Pressure and Molar Volume

Use $M = 12.011 \text{ g/mol}$, $\rho_g = 2.26 \text{ g/cm}^3$, and $\rho_d = 3.515 \text{ g/cm}^3$. Find ΔV_m for diamond minus graphite. Estimate $\Delta V_m \Delta p$ for $\Delta p = 5.00 \text{ GPa}$ in kJ/mol. Use $1 \text{ cm}^3 = 10^{-6} \text{ m}^3$ and state the model's limits.

29. Design a Fair Optical Comparison

Propose a safe test comparing visible transmission through a clear sample and a dark sample. Identify the controlled variables, a reference measurement, a measured quantity, and at least one possible source of error.

30. Explain the Original Question

Write a short article answering: “How can black carbon become clear diamond, and are both perfect blackbodies?” Include elemental identity, bonding, electrons, growth conditions, and the difference between visual darkness and perfect absorption.

Self-check before submission: have you labeled every unit, distinguished an ideal model from a real sample, and connected each numerical result to a scientific claim?

Teacher Key A

Teaching use: this begins the answer-key section. Keep pages 20–22 separate from student copies when using the questions for assessment. Accept equivalent reasoning and appropriate rounding.

1–2. Identity and Classification

1. Both ideal formulas are C, and every carbon nucleus has six protons. Atomic arrangement and bonding change, not elemental identity. 2. Graphite and diamond are allotropes; coal is a carbon-rich mixture. Appearance alone cannot establish composition, purity, or crystal structure.

3. Bond-Angle Difference

$$120.00^\circ - 109.4712^\circ = 10.5288^\circ \approx 10.5^\circ$$

The smaller diamond angle belongs to a tetrahedron, not a flattened four-armed cross. Do not compare an apparent angle on a projected diagram with the actual 3D bond angle.

4. Count Each Bond Once

Graphite: $100 \times 3 / 2 = 150$ in-plane bonds. Diamond: $100 \times 4 / 2 = 200$ bonds. Divide by two because counting neighbors at every atom counts each bond at both ends. Exact finite clusters require boundary corrections; the question specifies a periodic interior model.

5–6. Structural Ratios

5. $100(0.1545 - 0.142)/0.142 = 8.80\%$. This does not establish a hardness ordering; graphite's easy interlayer shear contrasts with diamond's 3D network. 6. $0.335/0.142 = 2.36$. It compares a layer separation with a bonded-neighbor distance, not two bond energies.

7–8. Density with Mass Conservation

7. $V = 0.200/3.515 = 0.0569 \text{ cm}^3$. 8. Initial mass $m = (2.26)(2.00) = 4.52 \text{ g}$. Final volume $V = 4.52/3.515 = 1.29 \text{ cm}^3$. The volume changes while the retained mass stays constant.

9. Atom Count

$N = (0.200/12.011)(6.02214 \times 10^{23}) = 1.00 \times 10^{22}$ atoms. Equal masses of pure carbon with the same isotopic composition have the same atom count regardless of allotrope.

10. Density from the Cell

$$a = 0.3567 \times 10^{-7} \text{ cm} = 3.567 \times 10^{-8} \text{ cm}$$

Cell mass = $8(12.011)/(6.02214 \times 10^{23}) \approx 1.596 \times 10^{-22} \text{ g}$. Cell volume $a^3 \approx 4.538 \times 10^{-23} \text{ cm}^3$. Dividing gives $\rho \approx 3.516 \text{ g/cm}^3$, or 3.52 g/cm^3 to three significant figures, consistent with the reference value.

Diagnostic mistakes: using four instead of eight atoms for the conventional cell; failing to cube the length conversion; treating C_4 as diamond's molecular formula; confusing crystal density with a porous powder's bulk density.

Teacher Key B

11–12. Energy and Wavelength

11. $E = 1239.84/450 = 2.76$ eV, below 5.47 eV. It cannot bridge the full gap by itself. 12. $\lambda = 1239.84/5.47 = 226.7$ nm ≈ 227 nm. Diamond's indirect transitions, phonons, defects, and measurement conditions prevent interpreting this as an exact universal transmission step.

13. Snell's Law

$$\theta_2 = \sin^{-1}[(1.00/2.42)\sin 45.0^\circ] \approx 17.0^\circ$$

The transmitted ray bends toward the normal on entering the higher-index medium. An answer larger than 45° should trigger a check of the index ratio.

14. Critical Angle

$\theta_c = \sin^{-1}(1.00/2.42) \approx 24.4^\circ$. An internal incidence angle of 30.0° exceeds it, so total internal reflection occurs in the stated ideal interface model.

15–16. Reflected, Transmitted, Absorbed

15. $R = (1.42/3.42)^2 = 0.1724$. Reflected power = 0.172 W for 1.00 W incident. Nonzero reflection contradicts unit absorption. 16. $\alpha = 1 - 0.25 - 0.10 = 0.65$, or 65%. The sample is not a perfect blackbody at that wavelength.

17. Force under Pressure

$$F = (5.00 \times 10^9 \text{ N/m}^2)(2.00 \times 10^{-6} \text{ m}^2) = 1.00 \times 10^4 \text{ N}$$

The area conversion is squared. The result supplies a scale of force; it says nothing about whether an improvised device can safely contain the stated pressure.

18. Total Emission

$P_{\text{emit}} = (0.90)(5.67037 \times 10^{-8})(0.0100)(600^4) = 66.1$ W. Temperature must be in kelvins. The assigned emissivity is part of the model, not a universal graphite property.

19. Net Outward Radiation

$P_{\text{net}} = (0.90)(5.67037 \times 10^{-8})(0.0100)(600^4 - 300^4) = 62.0$ W. The object also absorbs thermal radiation from the enclosure. With these parameters, that inward contribution is about 4.13 W.

20. Room-Temperature Peak

$$\lambda_{\text{max}} = (2.89777 \times 10^{-3})/300 = 9.66 \text{ } \mu\text{m}$$

The peak lies in the infrared, not the visible band. An object can therefore radiate thermally even though the eye does not see it glow.

Assessment note: reward a correct assumption or unit check even when arithmetic slips. A bare number without its units or physical meaning does not complete these problems.

Teacher Key C

21–22. Distinguish the Transport Mechanisms

21. $(450/300)^4 = 1.5^4 = 5.0625$, about 5.06 times the emitted power. Celsius has an offset from absolute zero and cannot be used in the ratio. 22. Lattice vibrations carry heat in diamond; a wide electronic band gap suppresses ordinary mobile charge carriers. Strong thermal conduction does not require strong electrical conduction.

23–25. Exponentials and Repeated Encounters

23. $e^{-(2.00)(0.500)} = e^{-1} = 0.3679$, or 36.8%. At twice the thickness, $e^{-2} = 0.1353$, or 13.5%. Reflection and scattering are neglected. 24. $N \geq \ln(0.50)/\ln(0.977) = 29.79$; the smallest integer is 30. Layer coupling, interference, and reflection can change the real result. 25. Absorbed fraction = $1 - 0.40^5 = 0.98976 \approx 99.0\%$. It is still below one, and real escape paths and wavelength dependence matter.

26. Correct Use of Kirchhoff's Law

Visible behavior has been extrapolated to every infrared wavelength without evidence. Under the matched reciprocal equilibrium conditions, $\epsilon_\lambda = \alpha_\lambda$ at the same wavelength, direction, and polarization. “Looks black” does not imply $\epsilon = 1$ everywhere.

27. Thermal Peaks and Total Power

At 600 K: 4.83 μm . At 900 K: 3.22 μm . The 900 K ideal curve has greater integrated emitted power per area by $(900/600)^4 = 5.0625$. The area under a wavelength spectrum, not just the height of one plotted point, gives its integrated power.

28. Molar-Volume Pressure Estimate

$$\Delta V_m = 12.011/3.515 - 12.011/2.26 = -1.898 \text{ cm}^3/\text{mol}$$

Convert to $-1.898 \times 10^{-6} \text{ m}^3/\text{mol}$. Multiply by $5.00 \times 10^9 \text{ Pa}$ to obtain $-9490 \text{ J/mol} = -9.49 \text{ kJ/mol}$. A negative pressure contribution favors diamond relative to graphite in this local model. It omits compressibility, changing temperature, and kinetic barriers; it is not a synthesis threshold.

29. Example of a Fair Comparison

Use a low-power LED, fixed holder and detector, equal illuminated areas, and documented sample thicknesses. Measure the dark signal and the unobstructed reference I_0 , then the transmitted signal I . Report a dark-corrected ratio. Control distances and angles. Stray light, scattering outside the detector, unequal thickness, and automatic camera exposure are possible errors.

30. Essential Features of a Successful Article

It identifies diamond as carbon; contrasts graphite's three-neighbor sheets with diamond's four-neighbor network; explains how electronic states affect visible absorption; states that controlled growth is more than ordinary squeezing; and explains why reflection or transmission rules out a perfect blackbody. Credit additional distinctions between transparency, color, and scattering.

Suggested scoring: Questions 1–27, 2 points each; Question 28, 6 points; Question 29, 5 points; Question 30, 10 points. Total = 75 points. Award method and explanation credit, not only final-number credit.

Safe Classroom Investigations

Safety first: these activities do not synthesize diamond. Do not burn carbon, grind unknown powders, heat gemstones, use lasers, pressurize vessels, or connect graphite directly to mains power. Avoid dust and bright-light exposure. Use adult supervision and ordinary classroom materials.

ACTIVITY	METHOD AND OBSERVATION	LIMIT / SCIENTIFIC QUESTION
Build the two networks	Use paper cutouts or blunt craft connectors. Make one three-neighbor planar model and one four-neighbor tetrahedral model.	Does a 2D sketch preserve a true 3D angle? Models show geometry, not actual electron size.
Pencil film and light	Draw regions of increasing graphite-pencil coverage on transparent film. Compare transmission using a diffuse LED and fixed viewing geometry.	Pencil material includes binders. Do not label the film “pure graphene” or infer an exact absorption constant.
A dark cavity	Compare a small opening in a closed, matte-lined cardboard box with an exposed patch of the same lining under room lighting.	Can repeated light encounters explain greater apparent darkness? This is not a calibrated blackbody.
Refraction model	Place a clear acrylic or glass block over a printed grid, or use a classroom ray simulation.	The sample models refraction; it is not diamond and has a different index.
Thermal spectrum graph	Plot λ_{max} for 300, 450, 600, and 900 K; compare T^4 ratios using a spreadsheet or calculator.	No heating is necessary. How do the spectral peak and integrated power change differently?

A Suggested Three-Lesson Sequence

Lesson 1: compare the structures, construct bond models, and solve Questions 1–10. **Lesson 2:** connect structure to electronic states, use the energy plot, and solve Questions 11–17. **Lesson 3:** distinguish black appearance from blackbody behavior, interpret thermal spectra, and complete the remaining questions.

A Better Investigation Question

Instead of “Which carbon is darkest?”, ask: “At a stated wavelength, thickness, and viewing geometry, what fractions are reflected, transmitted, and absorbed?” This makes the claim measurable and reveals why an uncalibrated photograph is not an absorption spectrum.

Accessibility: the diagrams use text labels and geometry as well as color. A black-and-white print still preserves the essential comparisons. A notebook is preferable to repeatedly printing extra answer-space pages.

What to Remember and What to Test

TERM	WORKING DEFINITION
Allotrope	A different structural form of the same element.
Coordination number	Number of specified nearest neighbors; here, directly bonded carbon neighbors.
Band gap	An energy interval without allowed bulk electronic states between relevant bands.
Absorption / scattering	Absorption transfers incident radiation energy into material excitation; scattering redirects radiation.
Metastable	Persistent in a local state even though another state is thermodynamically favored.
Emissivity	Thermal emission relative to an ideal blackbody under specified conditions.
Anisotropy	A property depends on direction within the material.

MISCONCEPTION	MORE ACCURATE STATEMENT
All carbon is black.	Carbon's form, thickness, defects, and optical response determine appearance.
Pressure squeezes the blackness out.	A new bonding network changes the electronic states available to interact with light.
Diamond is clear because it is less dense.	Diamond is denser than graphite; the visible transparency has an electronic explanation.
A black object must be a perfect blackbody.	A perfect blackbody absorbs all incident radiation, not merely much visible light.
Diamond is unbreakable.	Scratch hardness does not guarantee resistance to fracture.
A material has one emissivity for all situations.	Emissivity can depend on wavelength, temperature, direction, and surface condition.

Real Applications: Match the Property to the Job

A graphite electrode uses electrical conduction; a diamond optical window uses appropriate spectral transmission; a diamond heat spreader uses thermal conduction; a cutting edge uses wear and scratch resistance. Specially doped diamond electrodes illustrate that “diamond is an insulator” has an important purity and doping qualification. [2, 23–25]

Exit ticket: “Graphite and diamond are both _____. Their _____ and _____ differ. These differences change how they _____, _____, and _____ light. Neither is a perfect blackbody because _____.” Supply the final clause separately for graphite and diamond.

Next useful extension: compare graphite, diamond, and silicon as electronic materials, or investigate why carbon-rich activated materials can adsorb molecules while diamond serves in optical and electronic devices. Keep adsorption (surface attachment) distinct from optical absorption.

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