

Zometool Project Series: the world's most powerful (and fun!) modeling system. Kids, educators, and Nobel-prize winning scientists all love Zometool:

- it's unique, brilliant, beautiful
- all kits are compatible—more parts, more power!
- guaranteed for life!

"The mind, once stretched by a new idea, never regains its original dimensions." —Oliver Wendell Holmes

BUCKYBALLS! Hailed as a breakthrough, buckyballs have exciting uses in everything from medical research to optics, metallurgy, electronics and energy. Find out how they stimulate human research and imagination:

- Molecule of the Year in 1991!
- Lighter than plastic; stronger than steel!
- How will this beautiful molecule change your future?

Have a ball with this Wild Science Discovery!

MADE IN USA
from kid-safe materials

US Patents RE 33,785; 6,840,699 B2. Zometool is a registered trademark of Zometool Inc. Based on the 31-zone system, discovered by Steve Baer, Zomeworks Corp., USA © 2010

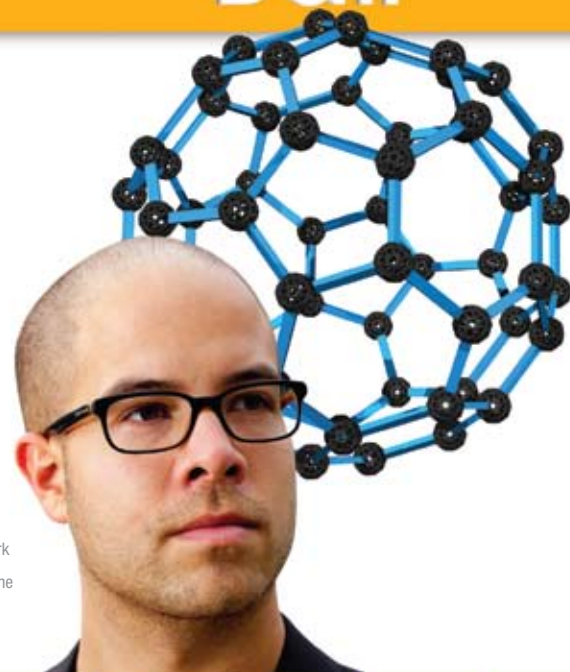


WARNING:
Choking Hazard
SMALL PARTS. NOT for children under 3 years.



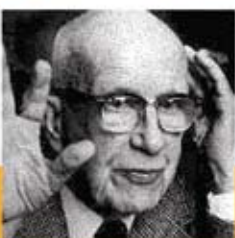
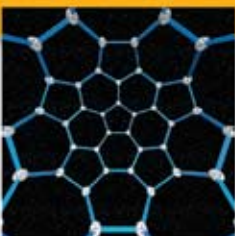
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Bucky Ball

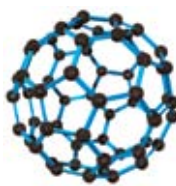


Includes detailed instructions by Dr. Steve Yoshinaga

Parts: 60 150 90



START HERE!



A buckyball is a spherical molecule made entirely of carbon atoms—the roundest and (some say) most beautiful of all known molecules. Scientists believe it may be one of the most useful, too.

It's for kicks



Although there are many sizes, the most common buckyball consists of 60 carbon atoms (C60). Like a soccer ball (*a truncated icosahedron*), it's made of 32 “flat” shapes (*polygons*): 20 hexagons and 12 pentagons. It has 60 corners (*vertices*)

WHAT IS A BUCKYBALL?

made of carbon atoms, and 90 edges, the bonds between the carbons.



Slicing 12 “points” truncates the icosahedron

A buckyball has much more in common with a soccer ball than just looks. It spins, bounces against hard surfaces, and when squeezed and released, springs back to its original shape. Buckyballs are so strong, they've survived 15,000 mph collisions!

Why bucky?



Buckyballs were named after the visionary design scientist R. Buckminster Fuller, because they resemble the geodesic domes he popularized, like the Biosphere in Montreal. Fuller died in 1983, two years before Harold Kroto, Richard Smalley, Robert Curl and colleagues

discovered buckyballs, but his name lives on: a whole class of molecules related to buckyballs are now called *fullerenes*.

Fullerenes



After the C60¹ buckyball was discovered in 1985, scientists found more fullerenes. Made entirely of carbon, they form spheres (buckyballs), ellipsoids (C70) or tubes (buckytubes, or nanotubes²), and have chemical properties more similar to graphite (pencil lead) than diamond—both of which are also different forms of pure carbon!

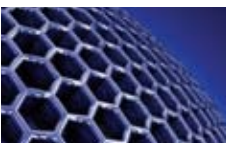
¹Prof. Eiji Osawa of Toyohashi University of Technology, Japan, theorized soccer ball-shaped C60 in *Chemistry*, vol. 25, 1970

²Electron micrographs of tubular carbon filaments were published in 1952 by Radushkevich and Lukyanovich in the *Russian Journal of Physical Chemistry*.

How it's put together

Allotropes are different forms of the same element, due to chemical bonding (Greek: *allos* “variation” + *tropos* “manner or form”). Diamond and graphite are two of the most well-known allotropes of carbon.

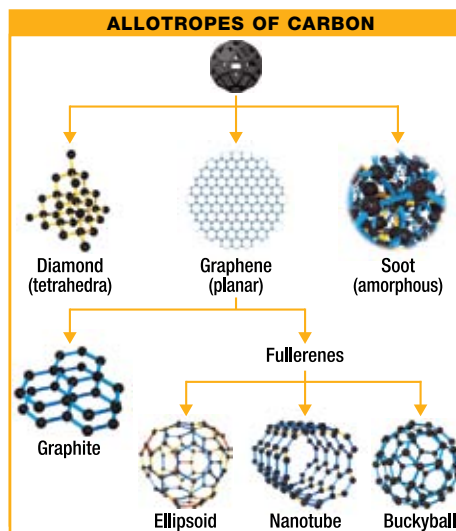
In a diamond, each carbon atom is bonded to four neighboring carbons by single bonds in a tetrahedral formation (right). This *structure* creates a strong 3-D molecular lattice: diamond is the hardest naturally occurring substance on earth.



Like diamond, graphite is pure carbon, but its form and properties are completely different.

The atoms arrange like hexagonal bathroom tiles, in sheets, one atom thick! Within each sheet, carbons are tightly bonded, but between sheets only loosely attracted. So *graphene* sheets slide over each other, making graphite useful for things like lubrication, and writing: pencil “lead” is really carbon. Use a pencil, and you're spreading chunks of graphite on cellulose (paper).

Just as you could use the same Zometool parts to build different models that are strong or weak, the different structures of diamond and graphite cause one to be hard and the other soft. It's not what it's made of, it's how it's put together.



Buckyballs are another allotrope of carbon. They are much more related to graphite than diamonds, since buckyballs and buckytubes are essentially sheets of graphene folded or wrapped into different 3D shapes.

Primordial buckyballs



Another carbon allotrope is *amorphous* (Greek: “without-form”). Unlike crystalline graphite or diamond, candle soot is mostly amorphous carbon, but some of it forms buckyballs. Not just strange round molecules dreamed up by mad scientists, buckyballs have been around for billions of years—at least since the first forest fire.

Oops, I made a buckyball



A few buckyballs form when a candle burns, but under experimental conditions, scientists make larger amounts, by vaporizing carbon. Since oxygen and nitrogen inhibit buckyball formation, they

zap carbon using lasers or electricity in an all-helium atmosphere, causing the free atoms to form rings of buckyballs and nanotubes.

Drs. Kroto, Smalley and Curl made buckyballs while trying to understand carbon molecule formation around red giant stars. There's no air in outer space, so to simulate those conditions, they created an ideal environment for making buckyballs. Like many scientific advances, buckyballs were discovered by accident!

Revolution in progress

Buckyballs have tremendous potential as a building block in the nanoworld:

- squashed buckyballs, 2x as hard as diamond, may be used in commercial drilling
- superconducting potassium-doped buckyballs could be used in nano-electronics
- buckyballs filled with taxol and attached to antibodies may act as anti-cancer drugs

Buckyballs offer a tool to enter the nanoworld, because they can act as scaffolds or carriers of chemicals with unique properties.

How close are we?

Uses for the buckyball are being explored all around the world. Scientists in government and industry are characterizing its dynamic properties and safety profile. Beyond peppering soot, buckyballs may soon be a household item—in cosmetics, cleaning products, medicine and more. By learning about buckyballs today, you might find a cure for cancer tomorrow!

LANGUAGE OF THE BUCKY-VERSE

Allotrope—one of several forms of the same element
Buckybabies—Buckyballs with fewer than 60 carbon atoms
Buckybowl—half of a buckyball
Buckyeggs—when two pentagons next to each other in a buckyball form a pointy end, causing it to look like an egg
Buckytube, or nanotube—fullerene tube with buckyball-domed ends
C60—most common buckyball, 60 carbons shaped like a soccer ball
Dopeyballs—made by replacing one or two C60 carbon atoms with metal atoms. Potassium “doped” buckyballs are superconductors. Others may function as catalysts. Dopeyballs can be used as scaffolds to make designer buckyballs. Insomnia? Try Sleepyballs. Still can't get to sleep? Call Grumpyballs. You get the idea!
Fullerene—molecule of pure carbon formed as sphere, ellipsoid, or tube
Fuzzyballs—buckyballs with atoms covalently attached to the carbons, creating a “fuzz” outside. Fluorinated fuzzyballs (C60/F60) may act as a superlubricant.
Giant Fullerenes—Buckyballs with more than 60 carbon atoms
Graphene—single layer of carbon atoms bonded in a hexagonal tiling
Polygon—closed, 2D shape of line segments joined end-to-end
Structure—systematic arrangement of parts or components in a substance, body, or whole
Truncated Icosahedron—3D shape with 20 hexagonal and 12 pentagonal faces, made by slicing the “points” off an icosahedron
Vertices—corners, where 2 lines (in 2D) or 3(+) faces (in 3D) meet

A FULLER VISION



As a 5-year old, R. Buckminster Fuller found “the triangle held it's shape when nothing else did,”³ using toothpicks and peas⁴ in kindergarten. His love affair with the triangle led to inventions like the geodesic dome and oct-tet truss.

Obsessed with efficiency, form and functionality, Fuller adopted a “more for less” philosophy. Waldo Warren⁵ derived the word *dymaxion* from the terms *dynamic*, *maximum* and *tension* to christen Fuller's inventions, like the Dymaxion Car, Dymaxion House and Dymaxion Map.



The 4th dimension—Fuller was the original “out of the box” (or “into the dome”) thinker. He visualized physical *form* in x, y, and z, but also *function* over time. His 4D designs maximized utility, with minimum stress on “spaceship earth.” Fuller knew that we must respect our planet.

Born in 1895, Bucky's fresh ideas challenge us to build a better



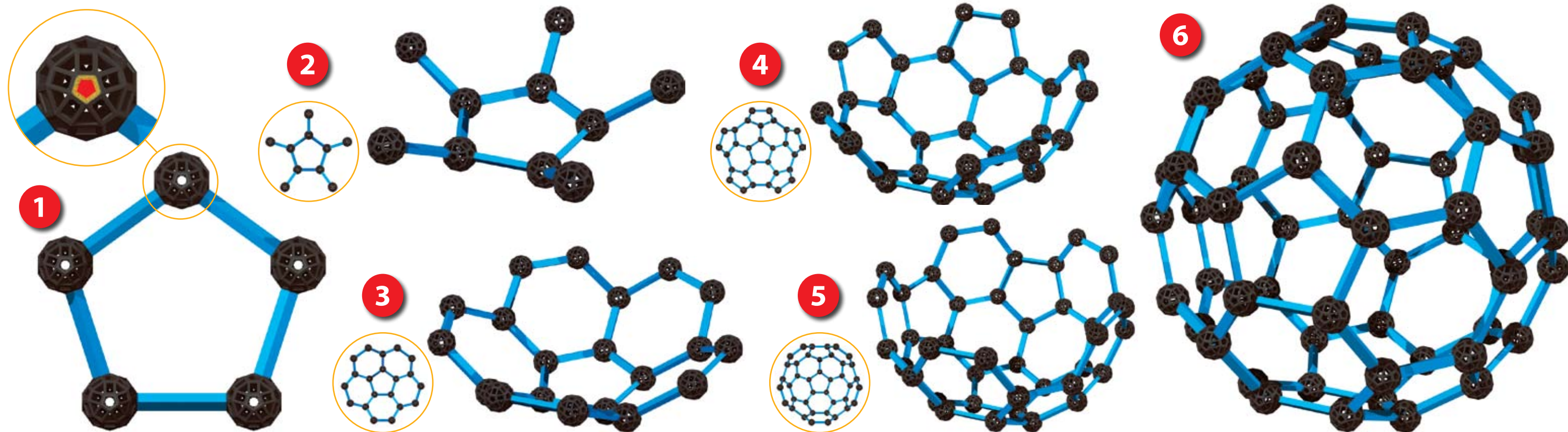
world in 21st century. Visit the Buckminster Fuller Institute at www.bfi.org for more information.

³*Buckminster Fuller: Thinking Out Loud*, video recording, New York: Zeitgeist Films, 1996.

⁴A Fröbel “gift,” precursor of Zometool.

⁵Advertising expert Warren also coined the term “radio”

Bucky Steps



Shadows

How to Make Shadows

1. Place a blue, yellow or red strut* in any hole.
2. Point the strut at the sun.
3. Cast shadow on a white board at 90° to sun's rays.

4D Buckyball

Rules

Related Projects