Graphene and fullerenes

4.2.3.3 · Bonding, structure and the properties of matter · revision notes

Graphene (a single layer of graphite) and fullerenes (hollow carbon molecules such as buckminsterfullerene and carbon nanotubes). You need to recognise them from diagrams and descriptions, explain the properties of graphene, and give uses of fullerenes and nanotubes.

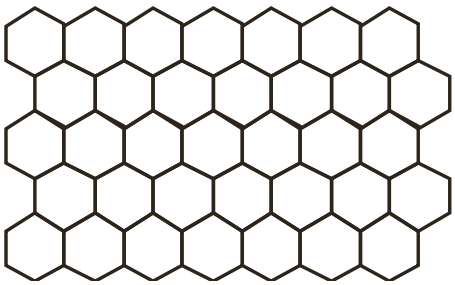
Key facts

- Graphene = a single layer of graphite (one atom thick)
- Fullerenes = hollow molecules of carbon; hexagonal rings, sometimes rings of 5 or 7 atoms
- Carbon nanotubes = cylindrical fullerenes with a very high length to diameter ratio
- Fullerene uses: drug delivery, lubricants, catalysts
- Graphene: very strong (covalent bonds), conducts (delocalised electrons) → electronics, composites
- Buckminsterfullerene: C_{60}, spherical, the first fullerene discovered
- Nanotubes: very strong, conduct → nanotechnology, electronics, materials
- Grade 8+ only C_{60} is molecular: weak intermolecular forces → much lower melting point than graphite

Notes

Graphene

- Graphene is a **single layer of graphite**: carbon atoms in hexagonal rings, just **one atom thick**.

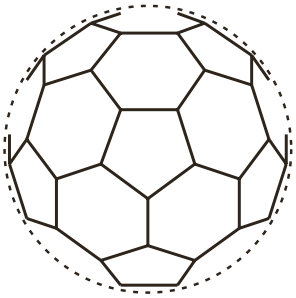


Graphene: a single layer of graphite.

- Each carbon atom forms three strong covalent bonds, and one electron from each atom is **delocalised**.
- It is **very strong**, because the atoms are held together by strong covalent bonds across the whole layer.
- It **conducts electricity**, because the delocalised electrons can move across the layer.
- These properties, and the fact that it is so thin and light, make graphene useful in **electronics** and in **composites** (adding graphene to another material can make it much stronger).

Fullerenes

- **Fullerenes** are **molecules** of carbon atoms with **hollow shapes**.
- Their structure is based on **hexagonal rings** of carbon atoms, but they may also contain rings of **five or seven** carbon atoms.
- The first fullerene to be discovered was **buckminsterfullerene, C_{60}**. Its molecules are **spherical**, made of rings of five and six carbon atoms, like the pattern on a football.



hollow sphere of 60 carbon atoms in rings of 5 and 6 atoms

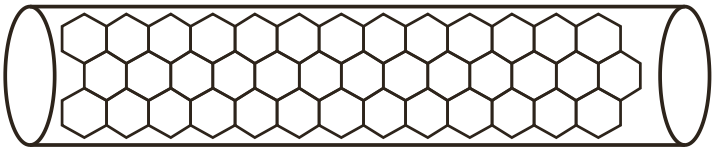
buckminsterfullerene, C_{60}

C_{60}: the front half of the ball is drawn. Like a football.

- Uses of fullerenes: carrying **drugs** into the body (the hollow cage can hold a drug molecule), **lubricants** (the spherical molecules help surfaces slide), and **catalysts** (they have a large surface area).
- C_{60} is made of separate molecules with weak intermolecular forces between them, so it has a much lower melting point than diamond or graphite. Grade 8+ only

Carbon nanotubes

- **Carbon nanotubes** are **cylindrical fullerenes**: tubes of carbon atoms with a very high **length to diameter ratio** (very long compared with their width).



a cylinder of hexagons: very long, very narrow

Nanotubes have a very high length to diameter ratio.

- They are very strong (high tensile strength) because of their strong covalent bonds, and they conduct electricity because each carbon atom forms three covalent bonds, so one electron per atom is delocalised and carries charge.
- Their properties make them useful in **nanotechnology**, **electronics** and **materials**, e.g. reinforcing the frames of tennis rackets.

How to answer each type of question

Recognise and describe fullerenes

1 to 3 marks | Grade 4

1. A closed, hollow cage is a fullerene such as C_{60}; a long hollow tube is a nanotube; a flat single sheet of hexagons is graphene.
2. Learn the key facts: C_{60}, spherical, rings of five and six (fullerenes can also have rings of seven).

Example. (a) Give the formula of buckminsterfullerene.
(b) Describe the shape of a molecule of buckminsterfullerene.
(c) Fullerenes contain rings of six carbon atoms. Give one other size of ring that fullerenes can contain.

Model answer.

(a) C_{60} (1)

(b) A hollow sphere / ball (1)

(c) Five (or seven) carbon atoms (1)

Give uses of fullerenes and nanotubes

1 to 2 marks | Grade 5

1. Nanotubes: nanotechnology, electronics, reinforcing materials.
2. Other fullerenes: drug delivery, lubricants, catalysts.
3. Give one clear use per mark.

Example. Give one use of carbon nanotubes and one use of other fullerenes.

Model answer.

Nanotubes, any one from: reinforcing materials such as tennis rackets; electronics; nanotechnology (1).

Fullerenes, any one from: delivering drugs in the body; lubricants; catalysts (1).

Explain the properties of graphene 3 to 4 marks **Grade 5**

1. Describe the structure: a single layer of carbon atoms, each bonded to three others.
2. Strength: strong covalent bonds.
3. Conductivity: one delocalised electron per carbon atom, free to move.

Example. Graphene is being developed for flexible touch screens. It is very strong and conducts electricity.
Explain these two properties in terms of its structure and bonding.

Model answer. Graphene is a single layer of carbon atoms, each bonded to three others (1). It is strong because the atoms are joined by strong covalent bonds (1). It conducts because one electron from each carbon atom is delocalised (1), so these electrons can move across the layer and carry charge (1).

Explain why C_{60} has a lower melting point than graphite 4 marks **Grade 8**

1. Say C_{60} is made of separate molecules.
2. Weak intermolecular forces between them need little energy to overcome.
3. Graphite is a giant covalent structure: many strong covalent bonds must be broken, needing much more energy.

Example. Buckminsterfullerene has a much lower melting point than graphite.
Explain why.

Model answer. Buckminsterfullerene is made of separate C_{60} molecules (1) with weak intermolecular forces between them, which need little energy to overcome (1). Graphite has a giant covalent structure (1), so many strong covalent bonds must be broken to melt it, which needs much more energy (1).

Don’t lose marks

- Calling fullerenes giant covalent structures. They are molecules (hollow cages or tubes).
- Saying graphene conducts because it is a metal or because it has free ions.
- Saying fullerenes contain only hexagonal rings: they can also contain rings of five or seven carbon atoms.
- Mixing up the shapes: buckminsterfullerene is a sphere; nanotubes are cylinders.
- Forgetting that graphene is only one atom thick.

More tips

Memory tricks

- Graphene = graphite with only one layer. Same bonding (3 bonds + 1 delocalised electron per atom), so it is strong and conducts.
- C_{60}: 60 carbon atoms shaped like a football. Buckyball = sphere; nanotube = cylinder.
- Nanotube uses: tiny tech (nanotechnology), electronics and tough materials.

Exam technique

- To explain a property of graphene, use the same ideas as for graphite: covalent bonds for strength, delocalised electrons for conductivity.
- In 'give a use' questions, one clear use per mark is enough; extra wrong answers can cancel out a right one.
- Read diagrams carefully: a closed hollow cage is a fullerene, a long tube is a nanotube, and a flat single sheet of hexagons is graphene.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3

Describe graphene as one layer of graphite

Graphene is a single layer of carbon atoms in hexagonal rings, one atom thick.

Grade 4

Describe fullerenes as hollow carbon molecules

They are based on hexagonal rings of carbon atoms, sometimes with rings of five or seven atoms.

Grade 4

Name buckminsterfullerene and give its formula

The first fullerene discovered: C_{60}, a hollow, spherical molecule.

Grade 5

Give uses of fullerenes and nanotubes

Fullerenes: drug delivery, lubricants, catalysts; nanotubes: nanotechnology, electronics and strengthening materials.

Grade 5

Explain the properties of graphene

Strong covalent bonds make it very strong; delocalised electrons let it conduct electricity.

Grade 5

Describe carbon nanotubes and their properties

Cylindrical fullerenes with a very high length to diameter ratio; very strong and conduct electricity.

Grade 8

Explain why C_{60} has a lower melting point

C_{60} is molecular, so melting overcomes weak intermolecular forces, not covalent bonds.

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