Allotropes of carbon: factsheet

Education in Chemistry
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Some elements are able to exist in different structural forms, known as allotropes. Carbon does this very well because of its ability to form bonds with other neighbouring carbon atoms – something called catenation.

The way in which carbon atoms are connected to each other makes a big difference to the physical, chemical and electronic properties of the material. Some carbon allotropes have been known for a long time; others have been discovered more recently.

Diamond

Used for ...

- drill bits in oil exploration and for slicing through concrete
- jewellery: naturally-made diamonds are of higher purity and very expensive!

Because ...

- of its tetrahedral structure, diamond is one of the hardest known materials
- it has a high refractive index, light is reflected internally, so it sparkles
- all its electrons are used to create the bonding lattice, leaving none spare, it's a poor conductor of electricity

Structure

Diamond has a tetrahedral structure. Each carbon atom is connected to four other carbon atoms by a covalent bond to form a giant crystal lattice.

4027°C

That's how much you have to heat diamond to break all its bonds and liquefy it into molten carbon. It's so hard to change into a gas because of its tetrahedral structure.

Graphite

Used for ...

- pencil leads
- nuclear reactor cores, to stop or slow the nuclear reaction

Because ...

- its layer-like structure makes it soft and flaky, as a pencil it leaves marks on your paper
- so much energy is needed to break the covalent bonds, graphite is tough enough to be used in a nuclear reactor
- of its soup of spare electrons, graphite is a very good conductor of electricity

3600°C

Heat graphite to this temperature to sublime it. That's how much energy it takes to break its covalent bonds.

Structure

Each carbon atom is covalently bonded to just three others, leaving one electron spare. This results in atoms arranged in flat layers of hexagons, between which is a soup of free, delocalised electrons that's made up from the spare electrons.

Graphene

Graphene was a theoretical concept before it was isolated and studied in 2004 by Andre Geim and Konstantin Novoselov at the University of Manchester, who were awarded the Nobel prize in physics in 2010 for their discovery. It's the thinnest, lightest, strongest, most stretchy material we've ever created.

Used for ...

- solar cells that are both transparent and flexible
- smart windows that can control heat and light transmittance
- electronic displays

Because ...

- of its spare electrons, graphene is an excellent conductor of electricity and heat

1 g

A single sheet of graphene the size of a football pitch would weigh less than 1 g!

Structure

Think of graphene as a single layer extracted from graphite. In its hexagonal lattice, each carbon is bonded with three others, leaving a spare electron.

Fullerenes

Until 1985 it was thought there were only two allotropes of carbon: diamond and graphite. But scientists thought they had detected the presence of another form of carbon in space. That mysterious new allotrope is C_{60}, or buckminsterfullerene. Other fullerenes exist too, like C_{70}, as well as ellipsoids and tubes.

Used for ...

- (potentially) drug delivery– many researchers are currently working on this

Because ...

- buckminsterfullerene's intermolecular forces are weak, its melting point is low
- fullerenes have a sea of free electrons inside, they can conduct electricity

1985

A team headed by Professor Sir Harry Kroto from the University of Sussex discovered and named C_{60}, or buckminsterfullerene.

Structure

Buckminsterfullerene's spherical structure comprises 60 carbon atoms arranged as 10 hexagons and 12 pentagons. The same shape as a football – which is why C_{60} is also sometimes called a 'buckyball'.