

2.3 Structure and bonding of carbon

Name: _____ Class: _____ Date: _____

Total: 24 marks

KEY WORDS diamond • graphite • graphene

Objective

Explain diamond, graphite, graphene and fullerenes from structure. Original questions for spec statements 4.2.3.1–4.2.3.3.

1 Key knowledge and worked examples

Form of carbon	Bonding	Properties explained
diamond	each C forms 4 covalent bonds in a giant covalent network	very hard; very high melting point; does not conduct
graphite	each C forms 3 bonds – layers of hexagonal rings; no covalent bonds between layers; one delocalised electron per atom	soft/slippery (layers slide – lubricant); high melting point; conducts like a metal
graphene	a single layer of graphite	one atom thick, very strong, conducts – electronics, composites
fullerenes	hollow molecules of hexagons (+ 5/7 rings); C₆₀ Buckminsterfullerene spherical	delivery of medicines, catalysts, lubricants
carbon nanotubes	cylindrical fullerenes, huge length : diameter ratio	nanotechnology, electronics, strong materials

Worked example (4 marks). Explain two properties of graphite from its bonding.

Each carbon forms only three covalent bonds, arranged in layers with no covalent bonds between layers; the layers slide over each other, so graphite is soft and slippery – used as a lubricant. One electron from each carbon is delocalised; these electrons

move through the structure, so graphite conducts electricity.

2 Practice

2.1 How many covalent bonds does each carbon atom form in diamond? [1]

2.2 Why can graphite be used as a lubricant? [2]

2.3 What is graphene? [1]

2.4 Graphene is proposed for a conducting sheet in a composite material. Explain two suitable properties in terms of its structure. [4]

3 Exam-style questions

3.1 Explain why diamond is hard and does not conduct electricity. [4]

3.2 Graphite conducts electricity but diamond does not. Explain the difference. [4]

3.3 Describe the structure of a carbon nanotube and give two uses of fullerenes. [4]

3.4 A carbon material contains separate hollow cages. A second is a continuous network with four bonds per carbon. Classify both and explain why the cages are not fragments of diamond. [4]

Solutions

2.1 Four.

2.2 The layers of hexagonal rings have no covalent bonds between them; so the layers slide easily over one another.

2.3 A single layer of graphite, one atom thick.

2.4

Graphene has strong covalent bonds between carbon atoms in one layer, giving high strength useful in composites. Delocalised electrons carry charge, allowing electrical conduction. One-atom thickness is also a relevant structural property, but alone does not explain conductivity.

3.1 In diamond every carbon atom is joined to four others by strong covalent bonds in a rigid giant covalent network; a lot of energy is needed to break the many strong bonds, making diamond very hard; there are no free/delocalised electrons to carry charge.

3.2 In graphite each carbon forms only three bonds, leaving one electron per atom delocalised; these free electrons move through the structure and carry charge. In diamond all four outer electrons form covalent bonds; none is free, so there is no charge carrier and no conduction.

3.3 A carbon nanotube is a cylindrical fullerene, with a very high length-to-diameter ratio. Uses of fullerenes – any two: carriers for targeted drug delivery in medicine; catalysts; lubricants; strengthening composite materials; electronics/semiconductors.

3.4

The first is a fullerene molecular material; the second is giant covalent diamond. Cages are finite, separate molecules, whereas diamond bonds extend through a continuous network, not separate cage molecules.