InkChemistry

ANSWER BOOK

Shapes of molecules and ions

Bonding and structure · Unit C03

AQA 3.1.3.5 · OCR A 2.2.2

20 questions · 61 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 SM-Q1

B1 pairs of electrons round a central atom repel each other. **B1** they arrange themselves as far apart as possible, which fixes the shape. [2]

A2 SM-Q4

B1 pyramidal, with three bonding pairs and one lone pair on oxygen. **B1** a bond angle of about 107°. [2]

A3 SM-Q13

B1 sulfur has six outer electrons and the two chlorine atoms add one each: eight electrons, four pairs, two bonding and two lone. **B1** the molecule is bent, with a Cl–S–Cl angle of about 104.5°; allow 100° to 105°. [2]

A4 SM-Q21

B1 the nitrogen has three regions of electron density and no lone pair, as boron does in BF_3. **B1** the ion is trigonal planar, with O–N–O angles of 120°. [2]

A5 SM-Q2

B1 lone pair–lone pair repulsion is greater than lone pair–bonding pair, which is greater than bonding pair–bonding pair. [1]

SECTION B · Standard, 3 to 5 marks

B1 SM-Q5

B1 nitrogen has three bonding pairs and one lone pair. **B1** the four pairs repel and get as far apart as possible, in a roughly tetrahedral arrangement. **B1** the lone pair repels more strongly than the bonding pairs, pushing them closer together than 109.5°. **B1** the shape of the atoms is pyramidal with an angle of 107°. [4]

B2 SM-Q7

B1 phosphorus has five outer electrons and five chlorine atoms add one each: ten electrons, five pairs. **B1** all five are bonding pairs, and they repel to be as far apart as possible. **B1** the shape is trigonal bipyramidal. **B1** angles of 120° between the equatorial bonds and 90° between axial and equatorial bonds. [4]

B3 SM-Q14

B1 both molecules have two double bonds to oxygen, each counting as one region of electron density. **B1** carbon uses all four outer electrons in bonding and has no lone pair, so CO_2 is linear, 180°. **B1** sulfur uses four of its six outer electrons in bonding and keeps one lone pair, giving three regions. **B1** so SO_2 is bent, with an angle of about 119°. [4]

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B4 SM-Q17 **M1** iodine has seven outer electrons; four fluorine atoms add one each; subtract one for the positive charge: 7 + 4 - 1 = 10. **M1** 10 ÷ 2 = 5 pairs: four bonding pairs, one for each bond, and one lone pair. **B1** five pairs are based on a trigonal bipyramid, and the lone pair takes an equatorial position, where it has fewest neighbours at 90°. **B1** the ion is a seesaw, a distorted tetrahedron, with angles a little under 120° and 180°; reject tetrahedral. [4]

B5 SM-Q6 **B1** NH_4^+ has four bonding pairs and no lone pair, so it is tetrahedral, 109.5°. **B1** NH_3 has three bonding pairs and one lone pair. **B1** the lone pair repels more than a bonding pair, closing the angle in NH_3 to 107°. [3]

B6 SM-Q8 **B1** xenon has eight outer electrons and four fluorine atoms add four: twelve electrons, six pairs, four bonding and two lone. **B1** six pairs are based on an octahedron. **B1** the two lone pairs repel most strongly so they take positions opposite each other, at 180°, leaving the four fluorine atoms in a square plane at 90°. [3]

B7 SM-Q9 **B1** chlorine has seven outer electrons and three fluorine atoms add three: ten electrons, five pairs, three bonding and two lone. **B1** five pairs are based on a trigonal bipyramid, and the lone pairs take equatorial positions, where they have fewest neighbours at 90°. **B1** the three fluorine atoms, two axial and one equatorial, form a T-shape with angles a little under 90°. [3]

B8 SM-Q10 **B1** two C–H bonds are drawn as plain lines in the plane of the paper. **B1** one C–H bond is drawn as a solid wedge, coming towards the viewer, and one as a hatched wedge or dashed line, going away. **B1** a bond angle of 109.5° is labelled between two bonds. [3]

B9 SM-Q11 **B1** bromine has seven outer electrons and five fluorine atoms add five: twelve electrons, six pairs, five bonding and one lone. **B1** six pairs are based on an octahedron with one position taken by the lone pair, so the shape is square pyramidal. **B1** the lone pair repels the bonding pairs more strongly, so the angles are a little under 90°. [3]

B10 SM-Q12 **B1** the central iodine has seven outer electrons, two iodine atoms add two, and the charge adds one: ten electrons, five pairs. **B1** two are bonding pairs and three are lone pairs, which take the three equatorial positions of a trigonal bipyramid. **B1** the ion is linear, with an angle of 180°. [3]

B11 SM-Q15 **B1** xenon has eight outer electrons plus two from the fluorine atoms: ten electrons, five pairs, two bonding and three lone. **B1** the three lone pairs take the equatorial positions of a trigonal bipyramid, leaving the two fluorine atoms axial. **B1** XeF_2 is therefore linear, 180°, so the prediction is wrong: water has four pairs, not five, and only two lone pairs. [3]

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B12 SM-Q18 **B1** nitrogen has five outer electrons, the two hydrogen atoms add two and the charge adds one: eight electrons, four pairs. **B1** two are bonding pairs and two are lone pairs, which repel more strongly. **B1** the ion is bent, with an angle of about 104.5°, like the isoelectronic water molecule. [3]

B13 SM-Q19 **B1** in BF_3 boron has three bonding pairs and no lone pair, so it is trigonal planar with angles of 120°. **B1** the lone pair on nitrogen forms a dative bond to boron, giving boron four bonding pairs. **B1** four bonding pairs repel equally and get as far apart as possible, so the bonds round boron become tetrahedral, about 109.5°. [3]

B14 SM-Q20 **B1** each carbon atom is bonded to two carbon atoms and one hydrogen atom and has no lone pair, so it has three regions of electron density. **B1** the three regions repel and get as far apart as possible, so each carbon is trigonal planar with angles of 120°. **B1** six trigonal planar carbons joined in a ring form a flat regular hexagon, with all twelve atoms in one plane. [3]

SECTION C · Long, 6 marks or more

C1 SM-Q16 **Indicative content** [6]

B1 each central atom has four pairs of electrons, which repel and get as far apart as possible in a tetrahedral arrangement. **B1** methane has four bonding pairs, all repelling equally, so its angle is 109.5°. **B1** lone pairs repel more strongly than bonding pairs, because they are held by one nucleus and sit closer to it. **B1** ammonia has three bonding pairs and one lone pair, so its bonding pairs are pushed together to 107°. **B1** water has two bonding pairs and two lone pairs, so its angle is closed further to 104.5°. **B1** the shapes are tetrahedral, pyramidal and bent, named from the positions of the atoms.

Levels

Level 3 (5–6 marks) all three molecules are explained from four electron pairs in a tetrahedral arrangement, the greater repulsion of lone pairs is stated with the reason, and the three angles and three shape names are correct.

Level 2 (3–4 marks) two or three angles are correct and lone pairs are said to repel more; the reason lone pairs repel more, the tetrahedral starting point, or a shape name is absent.

Level 1 (1–2 marks) one angle or shape is right; the usual error is to call NH_3 or H_2O tetrahedral, or to say the hydrogen atoms repel each other.

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