

How atoms share electrons in covalent bonds

Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Worksheet answers

Use these answers after you have tried each problem. Check the method, not only the final value. Whenever a property is explained, make sure you named the particles and the forces that are overcome, because that is where most marks are won.

Level: Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** GCSE C2

Problem 1 Define the bond

1. A covalent bond is formed when two atoms share a pair of electrons.
2. Non-metals.
3. One single bond is one shared pair, so **2 electrons**.

Problem 2 How many bonds?

1. Hydrogen needs 1, oxygen 2, nitrogen 3, carbon 4, chlorine 1.
2. Each atom forms as many bonds as the electrons it needs: **H 1, O 2, N 3, C 4, Cl 1**.

Problem 3 Counting shared electrons

Each shared pair is 2 electrons.

1. Double bond: 2 pairs, so 4 electrons.
2. Triple bond: 3 pairs, so 6 electrons.
3. Two double bonds: 4 pairs, so 8 electrons.

O₂: 4, N₂: 6, CO₂: 8 shared electrons.

Problem 4 Sort the substances

1. Chlorine: simple molecular. Silicon dioxide: giant covalent. Iodine: simple molecular. Diamond: giant covalent.
2. Chlorine is a gas, so its forces between molecules are very weak. Silicon dioxide has a very high melting point because a network of strong bonds must be broken. Iodine vaporises easily, so only weak forces hold its molecules. Diamond is hard because every carbon has four strong bonds in a rigid network.

Simple: Cl₂, I₂. Giant: SiO₂, diamond.

Problem 5 Why no current?

1. Wax is made of simple molecules with no free charged particles, so no charge can flow.
2. In graphite each carbon uses three outer electrons in bonds, and the fourth electron can move along the layers and carry charge.

Graphite conducts because of its free electrons; wax has none.

Problem 6 Reading a diagram

1. There is 1 shared pair.
2. Each chlorine atom has 3 lone pairs.
3. Each atom has the shared pair (2 electrons) and 3 lone pairs (6 electrons) around it: $2 + 6 = 8$.

1 shared pair, 3 lone pairs each, 8 outer electrons each.

Problem 7 Uses of carbon

1. Each carbon in diamond forms four strong bonds in a rigid network, so it is extremely hard and can cut rock.
2. The layers of graphite slide off and leave a mark because the forces between layers are weak.
3. The layers slide over each other easily, so graphite reduces friction between moving metal parts.

Diamond: hardness. Graphite: sliding layers.

Problem 8 Hydrogen chloride

1. Hydrogen needs 1 electron and chlorine needs 1, so they share 1 pair.
2. Chlorine has $7 - 1 = 6$ electrons not shared, which makes 3 lone pairs.
3. Chlorine needs only one more electron, so it can form only one bond, and hydrogen also forms one bond.

1 shared pair and 3 lone pairs; one H joins one Cl.

Problem 9 Predict the formula

1. Phosphorus needs 3 electrons: PH_3 . Silicon needs 4: SiCl_4 . Sulfur needs 2: H_2S .
2. Phosphorus has $5 - 3 = 2$ unshared electrons: 1 lone pair. Silicon uses all 4 electrons: 0 lone pairs. Sulfur has $6 - 2 = 4$ unshared electrons: 2 lone pairs.

PH_3 (1 lone pair), SiCl_4 (0), H_2S (2).

Problem 10 Boiling points of the halogens

1. Bromine, Br_2 , has a boiling point of about 59°C .
2. The boiling point rises as the relative formula mass increases.
3. Larger molecules have stronger forces between them, so more energy is needed to separate them. The covalent bonds inside the molecules are not broken.
4. A gas at 25°C must have a boiling point below 25°C : fluorine (-188°C) and chlorine (-34°C).

Br_2 about 59°C ; F_2 and Cl_2 are gases at 25°C .

Problem 11 Carbon dioxide and sand

1. Carbon dioxide is a simple molecular substance, so only the weak forces between separate CO₂ molecules must be overcome, which needs little energy. Silicon dioxide is a giant covalent structure in which every atom is held by strong covalent bonds in a network, and a huge number of these bonds must be broken to melt it.

Weak forces between molecules versus strong bonds throughout a network.

Problem 12 Counting bonds in hydrocarbons

1. Ethane has 6 C-H bonds and 1 C-C bond: $6 + 1 = 7$ bonds.
2. Ethene has 4 C-H pairs and a double bond with 2 pairs: $4 + 2 = 6$ pairs.
3. Each pair has 2 electrons: $6 \times 2 = 12$ electrons.

Ethane 7 bonds; ethene 6 shared pairs, 12 shared electrons.

Problem 13 Diamond versus graphite

1. Each carbon atom forms 3 bonds with neighbours in the layer.
2. Only weak forces hold the layers together, so they slide over each other easily.
3. The fourth outer electron of each carbon in graphite is free to move along the layer and carry charge. In diamond all four outer electrons are used in bonds, so none can move.

3 bonds per carbon; free electrons make graphite conduct.

Problem 14 Four unknown solids

1. A is simple molecular, B is ionic, C is giant covalent, D is metallic.
2. A has a low melting point and does not conduct, so it is made of small molecules with weak forces between them. C has a very high melting point and does not conduct, so strong covalent bonds link all its atoms and it has no mobile charges.

A simple molecular, B ionic, C giant covalent, D metallic.

Problem 15 Spot the errors

1. Wrong: boiling breaks only the weak forces between molecules, and the O-H bonds stay intact.
2. Wrong: diamond does not conduct, because all four outer electrons of each carbon are used in bonds and none can move.
3. Wrong: the C-H bonds are strong and are not broken. Methane boils at a low temperature because the forces between methane molecules are weak.

In each statement the intermolecular forces or lack of free electrons is the key idea.

Problem 16 Bonds in a diamond

1. Each bond is shared by two atoms, so counting four bonds per atom counts every bond

twice.

$$2. \text{ Bonds} = 4 \times 5.0 \times 10^{21} \div 2 = 1.0 \times 10^{22}.$$

$$3. \text{ Bonds} = 3 \times 5.0 \times 10^{21} \div 2 = 7.5 \times 10^{21}.$$

Diamond 1.0×10^{22} bonds; graphite layers 7.5×10^{21} bonds.

Problem 17 Graphite in detail

1. Graphite is made of separate layers with strong bonds inside each layer and weak forces between layers. Diamond is a single rigid network with four bonds on every carbon.
2. Melting would need the strong covalent bonds inside the layers to be broken, which needs a lot of energy, even though the layers slide easily.
3. Graphite conducts because of its free electrons, and it has a high melting point and does not react easily, so it can carry current like a metal.

Soft because of weak forces between layers, high melting point because of strong bonds inside layers.

Problem 18 Silicon carbide

1. Giant covalent structure, like diamond.
2. Each atom has 4 outer electrons and forms 4 bonds, each carbon bonded to four silicon atoms and each silicon to four carbon atoms.
3. The melting point is very high because a huge number of strong bonds must be broken. It is hard because the rigid network resists any movement of atoms. It does not dissolve because water molecules cannot overcome the strong bonds.

Giant covalent, 4 bonds on each atom.

Problem 19 Hydrogen cyanide

1. $1 + 4 + 5 = 10$ outer electrons.
2. One pair between H and C plus three pairs between C and N: $1 + 3 = 4$ shared pairs, which is 8 electrons.
3. The remaining $10 - 8 = 2$ electrons form 1 lone pair, on the nitrogen atom.
4. Hydrogen has 1 shared pair = 2 electrons. Carbon has $1 + 3 = 4$ shared pairs = 8 electrons. Nitrogen has 3 shared pairs + 1 lone pair = 4 pairs = 8 electrons.

10 electrons, 4 shared pairs, 1 lone pair on N.

Problem 20 Boiling points of alkanes

1. Methane to ethane: $-89 - (-162) = 73$ °C. Ethane to propane: $-42 - (-89) = 47$ °C. Propane to butane: $-1 - (-42) = 41$ °C. Butane to pentane: $36 - (-1) = 37$ °C.
2. Larger molecules have stronger forces between them, so more energy is needed to separate them. The covalent bonds are not broken.
3. Butane boils at -1 °C, so it is a gas at 25 °C. Pentane boils at 36 °C, so it is a liquid at 25 °C.
4. The increases are getting smaller (73, 47, 41, 37), so the next increase is about 33 to 35

°C, giving about 69 to 71 °C, which lies in the 60 to 80 °C range.

Butane gas, pentane liquid; hexane about 70 °C.