Chem Factsheet

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Why Students Lose Marks : Bonding

First, try deciding which of the following statements are true and which are false.

Statement	True	False
Intramolecular bonding occurs between molecules		
Intermolecular bonding occurs between ions		
Bonding involves all of the electrons of the atoms concerned		
The sideways overlap of π-orbitals can result in a π-bond		
The smaller the electronegativity difference between atoms the greater the polarisation of a bond		
Delocalisation of electrons results in a higher energy level and increased stability		
The high electron density of a π-bond always causes reactions with electrophiles		

You should have appreciated that **all** of the statements above are **false**.

Points to remember:
Some terms refer to 'bonding' and some to 'structure'. Interchanging the two incorrectly does not gain credit. For example a 'giant structure' is *not* a 'giant bond' and a 'covalent bond' is *not* a 'covalent structure', although the phrase 'covalently bonded giant structure' is perfectly correct and acceptable. "Bonding" is about *how* and "structure" is about *what results*.

Make sure your answers have **no contradictions**.

> ***Extract from examiners report**: 'Contradictions abounded. Many candidates lost marks through careless use of language, where **ionic/covalent/molecular/macromolecular** were used indiscriminately'.*

When drawing diagrams to show bonding make sure that you show everything the question asks for (normally a diagram showing the final bond is essential). When indicating dipoles use δ^+ and δ^- as full charges will be penalised.

When describing polarisation, the greater the difference in electronegativity of the elements concerned the greater the degree of polarisation. However, no two different elements have exactly the same electronegativity.

Every factor needs to be considered.

(i) Polarisation of a bond may result in centres of charge density which are the controlling factor in the way a compound reacts, and so these centres of charge may be considered as integral to the bond itself in that compound. For example a highly polarised π-bond may not attract electrophiles as the resulting centre of positive charge will repel them.

(ii) It is important to differentiate between this and the increased stability of a conjugated π-system, which results in electrophilic attack needing more robust conditions and more rigorous reagents .

> ***Remember:** to distinguish clearly bonding **between** molecules (intermolecular) which is generally weaker and bonding between **atoms within** molecules (intramolecular) which is strong.*

Work through the following by seeing if you can find the faults in the students' answers, then compare your ideas with the comments and mark scheme.

Sample Student's Worked Question Number 1

a) Explain why sodium chloride has a very high melting point. (2 marks)

b) Name the two types of bonding that occur in graphite and state where they occur. (2 marks)

c) Name the type of bond that exists in solid diamond. (1 mark)

d) Explain the difference in density between graphite and diamond. (2 marks)

e) Double bonds consist of σ (sigma) and π (pi) bonds. Explain how orbital overlap results in the formation of these two types of bond. (You may use diagrams to clarify your explanation (2 marks)

Student's Answer

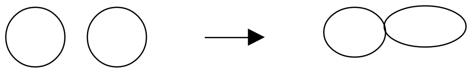
a) The ions in the lattice are held together by strong intermolecular forces of attraction between ions, so all the bonds need to be broken.

b) There are giant covalent bonds between carbon atoms and delocalised electron bonding between the planes of carbon atoms.

c) Giant covalent.

d) The delocalised electron bonding is different to the purely giant covalent bonding which occurs in both. There are lots more bonds in diamond and diamond is a lot harder and does not conduct electricity.

e) σ-bonds are formed when s and p orbitals overlap



π-bonds are formed when two p orbitals overlap.

Comments on these answers

a) The correct idea of ions being held together by strong forces is negated by the use of the incorrect term "intermolecular". Inter-atomic might be condoned although, at GCE level, *inter-ionic* or *electrostatic* are the correct terms. The idea of bonds being broken is too vague. Thus the student gains no marks.

b) The bonds between the carbon atoms are *covalent* ; "giant covalent" is not acceptable as it refers to the structure. Bonding cannot be named as "delocalised electron" type as this again refers to structure. Thus the student gains no marks.

c) "Giant covalent" is accepted here as it has already been penalised in part b). However, "giant" should not be there since it refers to structure, not bonding.

d) The answer restates the student's previous answers to parts b and c, and then adds irrelevant information ("hardness" and "conductivity), so is not credit worthy.

e) The student fails to gain any marks because he has not explained how the orbitals overlap in either his diagram or his explanations.

Compare theMark Scheme

(a) The strong force of attraction between ions (1 mark)
a lot of energy is needed to separate the ions/break the ionic bonds. (1 mark)

(b) The bonds are covalent between carbon atoms in planes. (1 mark)
There are Van der Waals'/induced dipole/dispersion/temporary dipole forces between the planes of carbon atoms. (1 mark)

(c) Covalent. (1 mark)

(d) The distance between the layers in graphite is greater than the length of the covalent bond in diamond. (1 mark)
The atoms in diamond are more closely packed. (1 mark)

(e) The sigma bond is formed from end on overlap between s and s (or s and p or p and p) orbitals. (1 mark)
The πbond is formed by sideways overlap between p and p orbitals. (1 mark)

Diagrams are only credit worthy if they show how the two orbitals are overlapping. The shape of the initial orbitals and the final orbital is not asked for.

Sample Student's Worked Question Number 2

The carbonyl group has a π-bond which reacts readily with nucleophiles but does not react readily with electrophiles. Explain this. (2 marks)

Student's answer
The π-bond has a lower electron density than usual due to polarisation.

Comments on this answer
The student has begun to answer the question by implying that the electrons have been withdrawn away from the bond by polarisation and so would gain one mark.

Compare the Mark Scheme
The carbon is δ^+or a description of the C=O bond polarisation (1 mark)

so nucleophiles are attracted / electrophiles are repelled by the $C^{\delta+}$ *or* so the π-bond electrons are not available due to the polarisation of the bond (1 mark)

Sample Student's Worked Question Number 3

The melting point of sodium chloride is much higher than that of sodium metal. Explain this difference in melting point. (3 marks)

Student's Answer
The bonding in sodium is metallic that is positive ions in a sea of electrons, whereas the bonding in sodium chloride is ionic as only ions are involved and no electrons. Ionic bonding is stronger than metallic bonding.

Comments on this answer
The answer is purely descriptive and does not 'explain' the bonding. The last sentence is a general statement which is not related to the question. The student has failed to gain any marks.

Compare the Mark Scheme
Sodium metal: Attraction due to electrostatic forces between positive ions in a lattice and delocalised or free electrons (1 mark)

Sodium chloride: Electrostatic attractions between Na^+ and Cl^- ions (1 mark)

Ionic bonding in NaCl is stronger than the metallic bonding in Na. (1 mark)

Sample Student's Worked Question Number 4

Two common forms of phosphorus are known as white phosphorus (P_4), melting point 44°C and red phosphorus, melting point 550°C. With reference to their structure and bonding explain why the melting points are so different. (5 marks)

Student's Answer
The white phosphorus is held together by hydrogen bonding and dipole-dipole interactions.

Red phosphorus is a giant molecule, like diamond and graphite which have high melting points. The bonds between the molecules of the red phosphorus need to be weakened before melting can occur, and the intermolecular forces are strong as there are so many bonds.

In summary, the different melting points are due to the fact that a lot more bonds need to be broken in the red phosphorus than in the white phosphorus so naturally the melting point of the red is higher.

Comments on this answer
White phosphorus: Hydrogen bonding and dipole-dipole interactions are not applicable to non-polar substances. Intramolecular bonds are not broken when a simple molecular substance melts. (Zero marks)

***Red phosphorus*:** No reference is made to covalent bonding so zero credit.

Also the other points made are wrong. Red phosphorus is a giant covalent structure so no individual molecules exist and hence, no bonds between molecules exist. Also, bonds must be broken not weakened and intermolecular forces is a redundant term as there are no individual molecules.

Compare the Mark Scheme

White phosphorus: consists of individual molecules (1 mark)
weak intermolecular/van der Waals forces between them (1 mark)

Red phosphorus: is a giant covalent structure (1 mark)
the covalent bonds must be broken (1 mark)
covalent bonds are strong (1 mark)

Notes
Mention of ionic bonding in either allotrope ? zero marks for that allotrope.

Mention of intermolecular forces in red phosphorus ? zero marks for that allotrope.

If there is no mention of covalent bonding for red phosphorus ? zero marks for that allotrope.

Sample Student's Worked Question Number 5

State the type of bonding present in (i) $BeCl_2$ (ii) $BaCl_2$. Explain the difference in bonding type for these two compounds. (3 marks)

Student's Answer

(i) simple molecular

(ii) ionic

The ions in beryllium chloride attract less strongly so it acquires some covalent character, whereas the barium and chloride ions attract much more strongly, making the compound purely ionic.

Comments on this answer

Simple molecular is not a type of bonding but a structure.
Ionic is correct and gains one mark.
The idea of 'some covalent character' is incorrect here and the rest of the answer is only descriptive rather than explanatory.

Compare the Mark Scheme

(i) covalent (1 mark)

(ii) ionic (1 mark)

Be and Cl electronegativity difference is small; Ba and Cl electronegativity difference is large. (1 mark)

Sample Student's Worked Question Number 6

By considering the different types of intermolecular attraction present, explain why the boiling point of pure water (H_2O) is 373K whereas that of pure hydrogen sulphide (H_2S) is 212K. (4 marks)

Student's Answer

There is hydrogen bonding between the water molecules which results from the differing electronegativities of the hydrogen and oxygen, causing the water molecules to have a permanent dipole and to arrange themselves so that the positive hydrogen end of the dipole attracts the negative. This is strong and so needs energy to overcome this attraction.

The intermolecular forces in hydrogen sulphide are due to van der Waal forces.

Comments on this answer

Only the first mark is gained. There is no comparison so the last two marks are also lost.

Compare the Mark Scheme

Hydrogen bonding in water (1 mark)

Dipole-dipole forces in hydrogen sulphide (1 mark)

Hydrogen bonding is strong<u>er</u> (1 mark)

so <u>more</u> energy or a high<u>er</u> energy is needed (1 mark)

Sample Student's Worked Question Number 7

The boiling point of hydrogen fluoride is higher than expected. Name the force responsible for this and draw a diagram to show how two hydrogen fluoride molecules are attracted to each other. Show partial charges on your diagram and explain their origin. (5 marks)

Student's Answer

Hydrogen bonding

$\overset{+}{H}$——$\overset{-}{F}$: – – – $\overset{+}{H}$——$\overset{-}{F}$:

The fluorine is more electronegative and so attracts the hydrogen atom.

Comments on this answer

Hydrogen bonding is correct and gains one mark.
The diagram correctly shows the hydrogen bond.

However, the partial charges are shown as full charges and only one lone pair rather than three is shown on each fluorine, so only one mark for the diagram.

The explanation confuses the intramolecular and intermolecular bonding so no marks (although if it had stopped before the word 'and' the answer would have gained a mark).

Compare the Mark Scheme

Hydrogen bonding (1 mark)
hydrogen bond between lone pair on F and H (1 mark)
3 lone pairs shown on F (1 mark)
correct partial charges on atoms (1 mark)

$^{\delta+}H—\ddot{\underset{..}{F}}^{\delta-}$: - - - $^{\delta+}H—\ddot{\underset{..}{F}}^{\delta-}$:

The fluorine attracts the bonding electrons much more strongly than the hydrogen. (1 mark)

Practice Questions

1. Describe the bonding between Cu and H_2O within the complex ion $[Cu(H_2O)_6]^{2+}$(aq). (2 marks)
2. Suggest a reason, in terms of polarisation, why aluminium carbonate does not exist at room temperature. (2 marks)
3. Magnesium oxide has a very high melting point. Explain this. (2 marks)
4. Explain the meaning of the term 'delocalised π-bond electrons' (2 marks)
5. Explain what is meant by a polar covalent bond.
   Which of the molecules NH_3, HF, and H_2O contains the least polar bond. Explain why this bond is less polar. (4 marks)
6. The boiling point of NH_3 is higher than one would expect for a molecule of its size. Identify the force which is responsible for this. Draw a diagram to show how two molecules of ammonia are attracted together by this force, showing partial charges and all lone pairs of electrons on your diagram. (4 marks)

Answers

1. Lone pair on the water molecule/ligand (1 mark)
   Donated to copper(II) ion (1 mark)
   Dative covalent/coordinate bond alone = 1 mark only

2. Aluminium ion: high charge density/highly polarising/very small (1 mark)
   So aluminium ion polarises/distorts the electron cloud around the carbonate ion (1 mark)

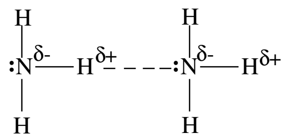
   Reference to carbonate molecule is penalised.

3. MgO has <u>very strong</u> (1 mark)
   electrostatic <u>attraction</u> between ions (1 mark)

4. π-bond is formed by the sideways overlap of p-orbitals (1 mark)
   delocalised electrons are spread over <u>more than two atoms</u> (1 mark)

5. Covalent bond two atoms share a pair of electrons (1 mark)
   Polar bond is a covalent bond in which the electron distribution is not symmetrical/equal or a bond with δ^+ and δ^- on the ends (1 mark)
   NH_3 (1 mark)

6. Nitrogen has a smaller electronegativity than oxygen or fluorine (1 mark)
   Hydrogen bonding (1 mark)



   Hydrogen bond between lone pair and H (1 mark)
   Pair of correct charges on both molecules (1 mark)
   Lone pair on both molecules (1mark)

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