

# Getting the most from this book

## Examiner tips

Advice from the examiner on key points in the text to help you learn and recall unit content, avoid pitfalls, and polish your exam technique in order to boost your grade.

## Knowledge check

Rapid-fire questions throughout the Content Guidance section to check your understanding.

## Knowledge check answers

- 1 Turn to the back of the book for the Knowledge check answers.

## Summary


## Summaries

- Each core topic is rounded off by a bullet-list summary for quick-check reference of what you need to know.

## Questions & Answers

### Exam-style questions

### Examiner comments on the questions

Tips on what you need to do to gain full marks, indicated by the icon .

### Sample student answers

Practise the questions, then look at the student answers that follow each set of questions.

Structured questions

Structured questions

### Question 11

Crude oil contains a large proportion of alkanes, which form a homologous series.

(a) (i) Explain the meaning of the term 'homologous series', using the alkanes as your example. (2 marks)

(ii) Note that the question requires a reference to the homologous series of alkanes.

(b) Alkanes exhibit structural isomerism. Draw the displayed formulae of the three structural isomers of the alkane  $C_5H_{12}$ . (3 marks)

Make sure that you write in all the hydrogen atoms. Using 'sticks' will not score full marks.

(b) Methane reacts with chlorine in the presence of UV light to give chloromethane and hydrogen chloride:

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

(i) What type of reaction is this? (1 mark)

(ii) The first step of the mechanism involves homolytic fission. Explain the meaning of this term. (1 mark)

(iii) Give the mechanism for the reaction between methane and chlorine, making clear which are the initiation, propagation and termination steps. (6 marks)

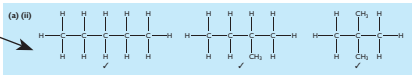
The initiation step should be shown using the correct type of curly arrow. The other steps do not require curly arrows, but radicals must be shown with a  $\cdot$ .

Total: 13 marks

Student answer

(a) (i) A series of compounds with the same general formula, in this case  $C_nH_{2n+2}$ , and showing similar chemical properties. ✓


(ii) The inclusion of the particular general formula is necessary to make the answer refer to the alkanes, as required by the question. If asked about a specific type of compound, make sure that your answer is specific, not general.

(a) (ii) 

(b) (i) free radical substitution ✓

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### Examiner commentary on sample student answers

Find out how many marks each answer would be awarded in the exam and then read the examiner comments (preceded by the icon ) following each student answer. Annotations that link back to points made in the student answers show exactly how and where marks are gained or lost.

# Bonding

## Ionic bonding

### The formation of ions

An **ionic bond** is the attraction between a positive and a negative ion.

- Positive ions or **cations** are formed by loss of electron(s) from atoms or groups of atoms. The ions are usually metal ions, but can be non-metallic — for example, the ammonium ion,  $\text{NH}_4^+$ .
- Negative ions or **anions** are formed when atoms or groups of atoms gain electrons.
- The ions formed may have octets of electrons, but many *d*-block metal ions do not. The ion that forms gives the strongest bonding in a resulting compound.
- The driving force for ion formation lies in the lower energy of the compound formed, compared with the constituent elements.

### Evidence for the existence of ions

The evidence for the existence of ions in compounds comes from electrolysis. The passage of a current through a molten salt or aqueous salt solution relies on the movement of the ions, which then lose electrons at the anode or gain them at the cathode to form the constituent elements.

This movement can be seen if the ions are coloured. Copper(II) chromate,  $\text{CuCrO}_4$ , contains blue  $\text{Cu}^{2+}$  and yellow  $\text{CrO}_4^{2-}$  ions. If a small crystal is placed at the middle of a strip of wetted filter paper attached at each end to a power supply, a yellow colour spreads to the positive electrode and a blue colour to the negative electrode.

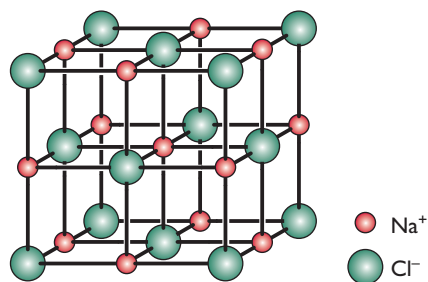
### Ionic crystals

An ionic crystal consists of a giant three-dimensional lattice of ions. The structure depends on the relative size of the anion and cation, and on the stoichiometry of the substance. Clearly,  $\text{NaCl}$  (shown below) cannot have the same crystal structure as  $\text{MgCl}_2$ .

The crystal is held together by a *net* attractive force between oppositely charged cations and anions. There are also longer-range repulsive forces between ions of the same charge. However, because these ions are more widely separated the repulsive forces are not as large as the attractive forces between ions of different charge. Because the attractive forces are uniform over the whole crystal:

- ionic substances have high melting and boiling temperatures
- there are no individual molecules in the solid that have the formula of the crystal (e.g.  $\text{NaCl}$ ) — the formula simply shows the relative proportions of the ions in the crystal

The attractive force between two ions is described by Coulomb's law:



#### Examiner tip

The larger the charge and the smaller the radius of the ions, the stronger the bond.

#### Knowledge check 18

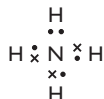
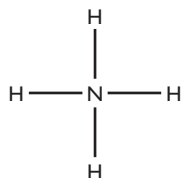
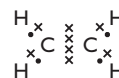
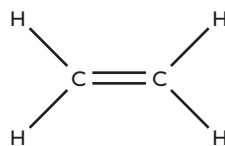
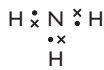
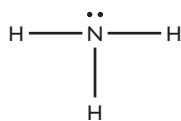
Draw a dot or cross diagram, showing all electrons and the charge on (a) a magnesium ion and (b) a chloride ion.

#### Examiner tip

Remember that anions ( $-$ ) go to the positive anode where they are oxidised by electron loss.

#### Knowledge check 19

Explain why ionic solids have high melting temperatures.



## Metallic bonding

The Drude–Lorentz model of a metallic crystal shows the following features:

- Metal ions are usually held in a close-packed lattice, the exception being group 1 metals, which are not close-packed.
- The outer (valence) electrons are delocalised throughout the metal crystal.
- The bonding is not particularly directional. This means the lattice can be distorted without breaking, so the metal is malleable and ductile.
- The delocalised electrons are mobile and enable conduction of electricity in the solid.
- The more delocalised electrons there are, the stronger the bonding and the higher the melting temperature.
- The smaller the metal ion, the closer the packing and the higher the melting temperature is.

### Examiner tip

Metals conduct electricity by movement of *electrons*, whereas ionic compounds conduct, when molten only, by movement of *ions*.

### Knowledge check 28

Explain why magnesium has a higher melting temperature than sodium.

### Summary

After studying this topic, you should be able to:

- explain an ionic bond, a covalent bond, a dative covalent bond and a metallic bond
- give evidence for the existence of ions
- explain why ionic compounds have high melting temperatures
- explain why the lattice energy of NaCl is more exothermic than that of KCl
- calculate the lattice energy from Born–Haber data
- explain why theoretical and experimental lattice energies may differ
- draw dot-and-cross diagrams for covalent molecules
- explain why metals conduct electricity and why potassium has a lower melting temperature than calcium

## Structured questions

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e Note that the question requires a reference to the homologous series of alkanes.

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e Make sure that you write in all the hydrogen atoms. Using 'sticks' will not score full marks.

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(i) What type of reaction is this? (1 mark)

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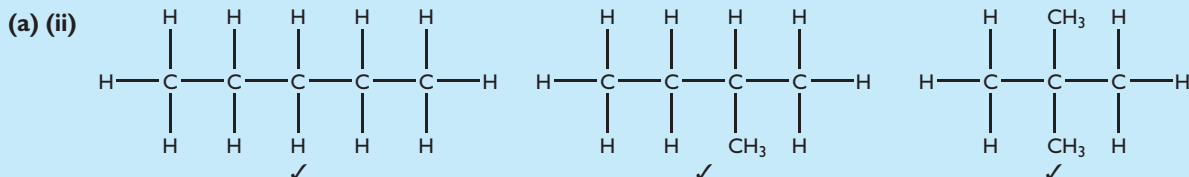
e The initiation step should be shown using the correct type of curly arrow. The other steps do not require curly arrows, but radicals must be shown with a  $\cdot$ .

**Total: 13 marks**

## Student answer

(a) (i) A series of compounds with the same general formula, in this case  $C_nH_{2n+2}$  ✓, and showing similar chemical properties ✓.

e The inclusion of the particular general formula is necessary to make the answer refer to the alkanes, as required by the question. If asked about a specific type of compound, make sure that your answer is specific, not general.

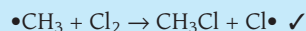


(b) (i) (Free) radical substitution ✓

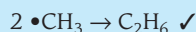
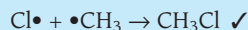
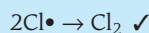
(b) (ii) Breaking a covalent bond so that one electron goes to each of the two species formed, which are radicals ✓

(b) (iii) Initiation:  $\text{Cl}-\text{Cl} \longrightarrow 2\text{Cl}\cdot$  ✓

Propagation:



Termination:



e A common error is to have an impossible propagation step such as  $\text{CH}_4 + \text{Cl}\cdot \rightarrow \text{CH}_3\text{Cl} + \text{H}\cdot$ . Not only are the bond energies unfavourable, but also the mechanism is the removal of an H radical by a Cl radical.

## Question 12

(a) State Hess's law.

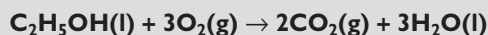
(2 marks)

(b) Define the term 'standard enthalpy of combustion'.

(3 marks)

e Do not forget to state what is meant by 'standard conditions'.

(c) The equation for the combustion of ethanol in air is:



Calculate the enthalpy change for this reaction using the average bond enthalpy values given in the table.

(3 marks)

Bond	Average bond enthalpy/kJ mol <sup>-1</sup>	Bond	Average bond enthalpy/kJ mol <sup>-1</sup>
C-H	+412	C-C	+348
C-O	+360	O-H	+463
O=O	+496	C=O	+743

e Make sure that you give a sign and units with your answer.

**Total: 8 marks**

### Student answer

(a) The heat energy/enthalpy change in a chemical reaction is independent of the route used to go from the reagents to the products ✓ provided that the initial and final states are the same ✓.