

# AS and A LEVEL CHEMISTRY B (SALTERS)

## Lesson Element

### Intermolecular bonding

#### Instructions and answers for teachers

These instructions should accompany the OCR resource 'Intermolecular bonding' activity which supports OCR AS and A Level Chemistry B.

**AS and A LEVEL  
CHEMISTRY B (SALTERS)**

**Lesson Element**

**Intermolecular bonding**

Plotting boiling point against  $M_r$   
Here are the boiling points of several homologous series:


No of C atoms	Alkanes		Ketones		Alcohols	
	$M_r$	Bpt/K	$M_r$	Bpt/K	$M_r$	Bpt/K
1	16	109			32	338
2	30	185			46	352
3	44	231	58	329	60	371
4		273	72	353		390
5		309		375		411

Note that these data are for straight-chain alkanes and ketones and primary alcohols.

**Task 1**  
Work out the missing  $M_r$  values.

**Task 2**  
Using the grid on the following page, plot graphs of these three series on the same axes, with the boiling point on the y-axis and the  $M_r$  (not the number of carbon atoms) on the x-axis.

Version 1



#### The Activity:

Associated learning outcome:

Learners should be able to demonstrate and apply their knowledge and understanding of: OZ(d) the relative boiling points of substances in terms of intermolecular bonds



*This activity offers an opportunity for maths skills development.*

#### Associated materials:

'Intermolecular bonding' Lesson Element learner activity sheet.

#### Suggested timings:

**Starter – Introduction:** 10 minutes

**Discussion – Hydrogen bonding:** 30 minutes

**Activity – Variation of boiling point with  $M_r$ :** 20 minutes



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## Teacher guidance

In this activity learners plot a graph of boiling point against  $M_r$  for alkanes, ketones and alcohols. This paves the way to an understanding of instantaneous dipole–induced dipole bonding and how this is present in all molecules, the strength increasing with the  $M_r$ . The relative strengths of the three types of intermolecular bond can be seen from the graph.

This activity also offers an opportunity to revisit some of the concepts presented earlier in the course: alkanes, alcohols and homologous series. Examining the intermolecular bonding in organic compounds helps learners to appreciate that intermolecular bonding is a relevant concept across chemistry, not just in relation to inorganic small molecules.

Misconceptions learners may show are:

- that hydrogen bonds are formed by any hydrogen atom in a molecule, not just those attached to a strongly electron-withdrawing group.
- that the breaking of covalent bonds occurs when a liquid boils.

## Starter – Introduction

A possible start is to show this video on the properties of water

[www.youtube.com/watch?v=aVmU3CLxvgU](http://www.youtube.com/watch?v=aVmU3CLxvgU).

## Discussion – Hydrogen bonding

This leads on to a class discussion of hydrogen bonding and the unusual properties of water.

## Activity – Variation of boiling point with $M_r$

Learners plot boiling point against  $M_r$  for the homologous series: alkanes, ketones, alcohols. (See learner activity sheet). They discuss the answers to the questions in groups.

*If you are offering this activity during teaching of The ozone story, learners will need an introduction to ketones as they will not have met them before.*



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Get together in groups to answer the following questions:

1. Why do the  $M_r$  values in all the series differ by the same number?

Each member of a homologous series differs by  $\text{CH}_2$  (=14) from the last.

2. Why are there no ketones listed with 1 or 2 carbon atoms?

The smallest possible ketone is propanone with 3C.

3. How is the strength of the intermolecular bonds related to the boiling point?

The stronger the intermolecular bonds, the more energy is required to separate the molecules and thus the higher the boiling point.

4. Draw the structure of ethanol and decide which type of intermolecular bonds it has.

Ethanol has hydrogen bonds between the molecules. These are clearly the strongest intermolecular bonds because more energy is required to break them.



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5. Draw the structure of propanone and decide which type of intermolecular bonds it has.

Propanone has permanent dipole–permanent dipole bonds. These are clearly stronger (for the same  $M_r$ ) than the intermolecular bonds in the alkanes, but not as strong as hydrogen bonds.

6. What evidence is there that alkanes have intermolecular bonds and how do these bonds vary with  $M_r$ ?

If they had no intermolecular bonding, they would never become liquids, however low the temperature. The boiling point increases with  $M_r$  (but not proportionally).

*Learners may additionally suggest plotting the boiling points of chloroalkanes. These points are close to the alkane line. The extra strength of the permanent dipole–permanent dipole bond is counteracted by weaker instantaneous dipole–induced dipole bonds in the smaller molecules. Teachers may feel that this is too complicated at this stage.*

## Extension activities

### Instantaneous dipole–induced dipole bonding

After an explanation of how this type of bonding occurs ask the following questions relating to the learners' graphs:

1. Why do the boiling points of the alkanes increase with increasing  $M_r$ ? Instantaneous dipole–induced dipole bonds increase in strength as the  $M_r$  increases, since there are more electrons in the molecule and more chance of polarisation.
2. Why do the boiling points of the other two series also increase with  $M_r$  at about the same rate? All molecules have instantaneous dipole–induced dipole bonds, as well as permanent dipole–permanent dipole or hydrogen bonds. The instantaneous dipole–induced dipole bonds get stronger as the  $M_r$  increases, whereas the contribution from permanent dipoles and hydrogen bonds stays roughly the same.



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## The effect of molecular shape on instantaneous dipole–induced dipole bonds

Learners can also plot more points on their graphs for branched alkanes and secondary alcohols, to show that the boiling points are lower because the molecules do not fit together so well.

## Conclusion

At the end of the lesson, summarise:

There are three types of intermolecular bond. For the same  $M_r$  (and for small molecules): hydrogen bonds are stronger than permanent dipole–permanent dipole bonds which are stronger than instantaneous dipole–induced dipole bonds (though the latter increase with  $M_r$ ).

## Teacher preparation

Teachers need to have:

- ensured that supplies of graph paper (and pencils and erasers) are available
- plotted the graph in advance to better advise the pupils (e.g. on choice of scale)
- revised intermolecular bonding, if necessary.



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