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How boiling points change as the number of carbons change

Aim:

The aim is to find out how the boiling point changes as the number of carbons in an alcohol increases.

Scientific Knowledge:

Molecules exist as distinct, separate collections of matter. The bonds within a molecule are typically quite strong, such that it's usually necessary to heat a molecule to very high energies before the bonds begin to break. For example, water is stable to decomposition to hydrogen and oxygen up to temperatures well above 500 C. In contrast, the forces between molecules tend to be relatively weak. If we chose an arbitrary scale in which the bonds between atoms within a molecule are set at 100, then the forces between molecules range between 0.001 and 15. In other words it generally takes far less energy to separate molecules from one another than it does to take molecules apart. The forces between molecules are called **intermolecular forces.**

Intermolecular forces are the forces of attractions that exist between molecules in a compound. These cause the compound to exist in a certain state of matter: solid, liquid, or gas; and affect the melting and boiling points of compounds as well as the solubility of one substance in another. Intermolecular forces are generally ***much weaker*** than covalent bonds. As the number of carbons increase the intermolecular force increases. However the more branches there are the weaker the intermolecular forces become. Isomers can also affect intermolecular forces; different physical properties of isomers can make the intermolecular forces stronger. The boiling points are determined by the strength of the intermolecular forces. So the stronger the intermolecular force, the higher the boiling point is.

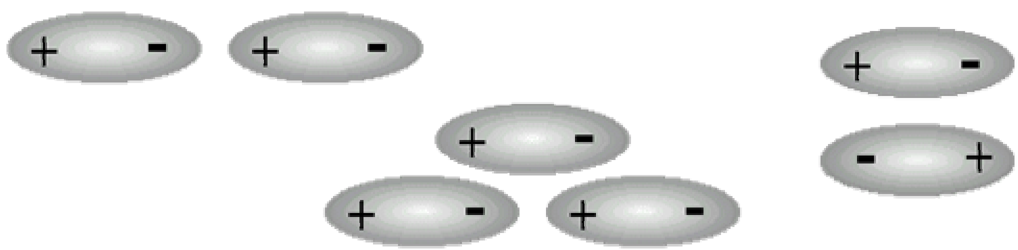
In alcohols, as the carbons increase then the intermolecular force should also increase. This basically means that the alcohols with the most carbons should have higher boiling points then the alcohols with the least carbons. As you get more and more carbons in an alcohol then the boiling point should increase.

Many molecules contain bonds that fall between the extremes of ionic and covalent bonds. The difference between the electro-negativities of the atoms in these molecules is large enough that the electrons aren't shared equally, and yet small enough that the electrons aren't drawn exclusively to one of the atoms to form positive and negative ions. The bonds in these molecules are said to be *polar*, because they have positive and negative ends, or poles, and the molecules are often said to have a *dipole moment*. HCl molecules, for example, have a dipole moment because the hydrogen atom has a slight positive charge and the chlorine atom has a slight negative charge. Because of the force of attraction between oppositely charged particles, there is a small dipole-dipole force of attraction between adjacent HCl molecules. The dipole-dipole interaction in HCl is relatively weak; only 3.3 kJ/mol. (The covalent bonds between the hydrogen and chlorine atoms in HCl are 130 times as strong.) The force of attraction between HCl molecules is so small that hydrogen chloride boils at -85.0°C.

A dipole-dipole force exists between neutral polar molecules

- Polar molecules attract one another when the partial positive charge on one molecule is near the partial negative charge on the other molecule
- The polar molecules must be in close proximity for the dipole-dipole forces to be significant
- Dipole-dipole forces are characteristically weaker than ion-dipole forces
- Dipole-dipole forces increase with an increase in the polarity of the molecule

Typically, dipole-dipole and dispersion forces are grouped together and termed ***van der Waal forces*** (sometimes the hydrogen bonding forces are also included with this group).



Attractive Dipole-Dipole Interactions

Prediction:

My overall prediction will be that the method 2 will produce more accurate results compared to the preliminary work. This is because method 2 uses a heating mantle, rather then a common bunsen burner. My prediction is as the number of carbons increase the boiling points (temperature) will also increase. This relates to my scientific knowledge of the more carbons, the stronger the intermolecular force will be, this in turn creates higher boiling points. This means that the hexanol will have the highest boiling point, which will be in 3 figures, methanol will have the lowest boiling point because it contains the least amount of carbons. I predict as the carbons increase by one, the boiling points will increase by 10 c. So if Methanol has a boiling point of 65 c then ethanol will have a boiling point of 75 c, in turn propanol will have a boiling point of around 85 c (estimates). Alcohols like propan-2-ol and 2 methyl propan-2-ol will not follow this pattern because they are branched alcohols. The branched alcohols cause the intermolecular force to become weaker, causing lower boiling points. So propan-2-ol and 2 methyl propan-2-ol will have lower boiling points, I predict around 82 c for propan-2-ol and 85 c for 2 methyl propan-2-ol.

Preliminary work:

Apparatus:

Thermometer	Beaker	Alcohols
Tongs	Tripod	Paraffin
Bunsen Burner	Goggles	
Boiling tube	Heat Proof Mat	

Diagram:

Method:

1. Collect and set up all apparatus including goggles.
2. Fill the boiling tube with 50ml of alcohol, place a thermometer in it and put it to one side.
3. Fill a beaker with 100ml of Paraffin, place the beaker on the tripod.
4. Put the boiling tube, (with thermometer in it) in the beaker.
5. Light a Bunsen burner and place it under the tripod.
6. Let the experiment take place by letting the paraffin boil
7. Check the thermometer and record the temperature, once the experiment has taken place.
8. Remove the boiling tube from the beaker using tongs and let it cool down.
9. Repeat all of this again with a different alcohol.
10. Once all alcohols have been used, clear up.

Method 2:

Apparatus:

Thermometer	Beaker
Test tube	heating mantle
Goggles	Alcohols
Round bottom flask	
Stand	

Diagram:

Method:

1. Collect and set up all apparatus including goggles.
2. Get an alcohol and pour 50ml of it in the round bottom flask
3. Switch on the Heating Mantle for 5-10 seconds
4. Keep switching it on and off otherwise it will get too hot
5. Wait until the first drop of alcohol comes out of the tube into the beaker
6. Record the reading on the thermometer
7. Remove the alcohol from the experiment.
8. Let everything cool down
9. Repeat all of the above with a different alcohol.
10. Once all alcohols have been used, clear up.

Actual results from chemistry book:

Alcohol	No. Of carbons	Boiling point (c)
Methanol	1	65.1
Ethanol	2	78.6
Propanol	3	105.5
Propan-2-ol	3	82.5
2 Methyl propan-2-ol	4	82.4
Butanol	4	117.3
Pentanol	5	138.1
Hexanol	6	158.1

Results:

Alcohol	No. Of carbons	Preliminary work (c)	Method 2 (c)
Methanol	**1**	**70**	**64**
Ethanol	**2**	**80**	**82**
Propanol	**3**	**95**	**102**
Propan-2-ol	**3**	**98**	**85**
2 Methyl propan-2-ol	**4**	**115**	**85**
Butanol	**4**	**98**	**115**
Pentanol	**5**	**110**	**135**
Hexanol	**6**	**110**	**155**

Fair test:

To make it a fair test I should use the same amount of alcohol for each method. For method two I should make sure each alcohol receives the same amount of heat.

Safety:

For safety I have to wear goggles. You should tie back any long hair. You should not touch the heating mantle when on or hot – do not touch any hot equipment.

Conclusion:

On both my graphs there is a line of best fit that goes in an upwardly direction. My lines of best fit go through most of the alcohols. On preliminary work and actual work (method 2) there are no clear anomalous results, for the normal alcohols, however my alcohols with branching (propan-2-ol and 2 methyl propan-2-ol) were far away from the line of best fit. One in particular was very far from the line, that was the 2 methyl propan-2-ol. I have circled that alcohol as anomalous. As I compare my lines of best fit I notice that the method 2 results contained higher boiling points. As I compare my results table to the results taken from the chemistry book I notice that my method 2 results match better then the preliminary work. I also notice that in the graphs, as the method 2 line of best fit is very close to the actual results line of best fit. I had stated this in my prediction.

My main prediction stated that the actual work would produce more accurate results, closer to the best-fit line. I had predicted this because the actual work uses a heating mantle, known to give more accurate results compared to Bunsen burner. This prediction was correct, because all of my actual work results are less then a millimetre away from the line of best fit, and very close to actual results. So it has a very small gradient of 0.5/1. I made a very simple prediction of boiling points increasing as carbons increase, my graphs and tables clearly show this as methanol has a boiling point of 70/64 c with 1 carbon and hexanol has boiling points of 110/155 c with 6 carbons.

In my prediction I made an estimate of boiling points increasing by 10 c as the carbons increased by one. Both of my methods kind of support this. At the beginning of my preliminary work the boiling points increase by 10 c, however this does not happen near to the end. It does happen at the end of my actual work, but it does not happen at the beginning of it.

The anomalous results that I have circled in my graphs are of the alcohols with branching. I had made it clear in my scientific knowledge and my prediction that branching causes weaker intermolecular forces that make the boiling point decrease in temperature. My graphs and results tables support this because on both methods the branched alcohols were below the line of best fit.

Evaluation:

The accuracy of my results is varied; although the preliminary work results follow a pattern they are still below the results taken from the chemistry book. A reason for these inaccurate results is because of the equipment used. The heating equipment was a bunsen burner, this is fine although it cannot grantee accurate results. My method 2 uses a heating mantle. A heating mantle is a device with which the heat can be controlled with time. This would be an ideal device to use, because you can make sure that the heat applied on each alcohol is the same, however the heating mantle used in my experiment was faulty. The time was not working properly so I had to make sure that the heating mantle was on 10 seconds, then off for 5 seconds. A couple of seconds either way could cause inaccurate results.

The quality of my results are high, all my results come very close to their line of best fit. The only two results on every method that do not come near the line of best fit are the branched alcohols. As stated in conclusion, branched alcohols give low boiling points so this is why they are below the line of best fit. Results that are generally higher then the line of best fit could also occur because of the equipment. Because the same equipment was used over and over again, the equipment may still have been very hot. So already there may have been around 10 c on the thermometer before the alcohol is even heated.

The purity of the alcohols could also affect the results obtained. If the equipment was not properly cleaned then the alcohols could mix. This would cause high or low boiling points. Another way the alcohols could become impure is by them mixing with water. After every alcohol was used the equipment will have been washed. If the equipment was not properly dried using some kind of towel the water could easily mix with the alcohol. This would also cause high or low boiling points.

Further work:

Apparatus:

Thermometer
Heating mantle
Beaker
Test tubes
Goggles
Boiling tube
Alcohols
Paraffin

Diagram:

Method:

1. Collect all apparatus including goggles.
2. Fill the boiling tube with 50ml of alcohol, place a thermometer in it and put it to one side.
3. Fill a beaker with 100ml of paraffin, clip it in the stand and place it above the heating mantle.
4. Place the boiling tube containing the thermometer within the beaker.
5. Start up the heating mantle
6. Let the experiment take place until the paraffin boils.
7. Check thermometer and record the results.
8. Clean boiling tube, thermometer and beaker.
9. Repeat all of the above with a different alcohol.
10. Once all eight alcohols have been used, clear the equipment up.

Fair test:

To make it a fair test I should use the same amount of alcohol for each method. For method two I should make sure each alcohol receives the same amount of heat.

Safety:

For safety I have to wear goggles. You should tie back any long hair. You should not touch the heating mantle when on or hot – do not touch any hot equipment.