Determining the approximate strength of H-bond

Objective

To determine the approximate strength of hydrogen bond formed between ethanol molecules by measuring the enthalpy change on mixing it with cyclohexane.

Principle

Ethanol contains —OH group which can form hydrogen bond among its molecules but cyclohexane hasn't. On mixing, cyclohexane will break the hydrogen bond among ethanol molecules. Breakage of hydrogen bond consumes energy thus the temperature lowers and hydrogen bond strength of ethanol can hence be calculated.

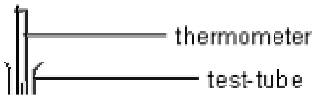
Chemicals

ethanol, cyclohexane

Apparatus

10ml pipette, pipette filler, test-tube, cotton wool, thermometer, beaker

Experimental set-up



Procedure

1.> Weigh a test-tube and the weight is recorded.
2.> The initial temperature of ethanol, cyclohexane and test-tube are recorded in Table 1.
3.> A test-tube is placed into a beaker and is surrounded with cotton wool.
4.> A thermometer is then put into the test-tube.
5.> Pipette 4 cm^3 of ethanol into the test-tube.
6.> Pipette about 9 cm^3 of cyclohexane into the same test-tube.

7.> The mixture is stirred gently & carefully with the thermometer and the lowest temperature is recorded.

Results

Mass of the test-tube: 14.44 g

Table 1 shows the temperature change after mixing two substances:

	ethanol	cyclohexane	test-tube
Initial temperature / ℃	15.5	16.5	18
Lowest temp. after mixing /℃	13.8		
△**T** /℃	- 1.7	- 2.7	- 4.2

Table 2 shows the data of the substances:

	Molecular mass	Density /kgdm^{-3}	Specific heat capacity kJkg^{-1}K^{-1}	Volume of solution added /cm^3
ethanol	46	0.81	2.44	4
cyclohexane	84	0.78	1.83	9
test-tube	/	/	0.78	/

Energy absorbed to break hydrogen bond

= energy absorbed from test-tube (E_1) + energy absorbed from ethanol (E_2) + energy absorbed from cyclohexane (E_3)

Energy = mc△T

$$E_1 = [14.44 \div 1000] \cdot [0.78] \cdot [4.2] \text{ kJ}$$
$$= 0.04731 \text{ kJ}$$
$$E_2 = [(0.81 \cdot 4) \div 1000] \cdot [2.44] \cdot [1.7] \text{ kJ}$$
$$= 0.01344 \text{ kJ}$$
$$E_3 = [(0.78 \cdot 9) \div 1000] \cdot [1.83] \cdot [2.7] \text{ kJ}$$
$$= 0.03469 \text{ kJ}$$

$$E = E_1 + E_2 + E_3$$
$$= 0.09544 \text{ kJ}$$

Strength of hydrogen bond of ethanol = E ÷ no. of moles of ethanol

$= E \div [(0.81 \cdot 4) \div 46]$

$= 1.36\ kJmol^{-1}$

Precaution

1.> The test-tube should be used instead of beaker because the smaller in size of test-tube can reduce heat loss or heat gain from surroundings. For same reason, there is cotton wool between test-tube and beaker.

2.> Since both ethanol and cyclohexane are easily vapourize, the volume of substances added may be affected, so the transfer process and the experiment should be done as fast as possible.

3.> The ethanol - cyclohexane mixture should be stirred gently & carefully with the thermometer, to ensure heat is evenly distributed.

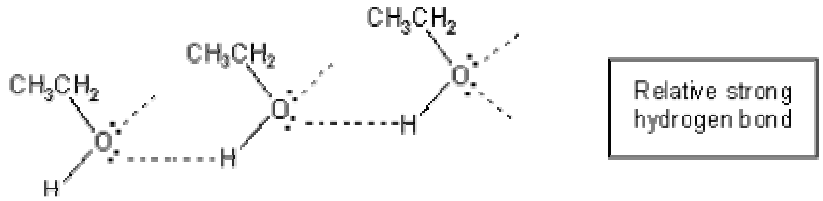
4.> Ethanol & cyclohexane are flammable, it should be ensure that there is no fire around.

Discussion

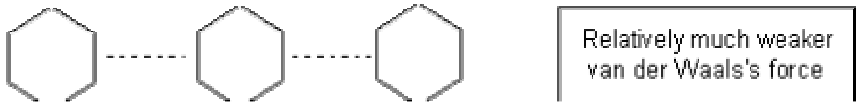
Hydrogen bond is defined as the the intermolecular force (or intramolecular force) formed between H atom attached to F, O, or N and the lone pair electrons on F, O or N. The more electropositive (δ+) on H, the stronger is the hydrogen bond.

In this experiment, there are 2 assumptions made - it is assumed that no heat loss to (or gain from) the surroundings and all hydrogen bonds between ethanol molecules are broken.

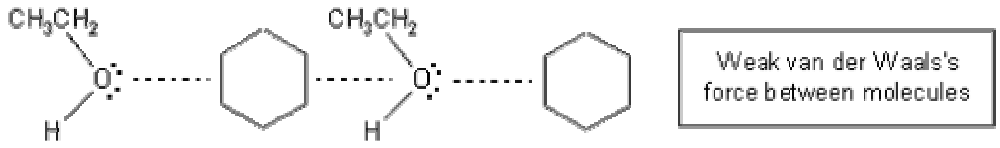
It should be noticed that among ethanol molecules, hydrogen bonds can be present due to the presence of lone pair electrons on O attached to H:



However, among cyclohexane molecules, there is only relatively much weaker van der Waal's force but no H-bond:



After mixing these two substances, hydrogen bonds formed between ethanol molecules are broken because cyclohexane molecules separate ethanol molecules and hence interrupt its hydrogen bonds from forming:



To ensure that all the hydrogen bonds are broken, excess cyclohexane is added.

However, in this experiment, hydrogen bond strength obtained is not reliable because we can't ensure that all hydrogen bonds are broken. If we want to have a more reliable result, we can improve the experiment by several methods:

< 1.> Repeat the experiment by adding more cyclohexane until the temperature becomes constant which indicates hydrogen bonds are no longer present.

< 2.> Since ethanol is a polar molecule whereas cyclohexane is non-polar, they are immiscible. To ensure all hydrogen bonds are broken, it's better to use 2 substances which are miscible, with only ethanol can form hydrogen bond.

< 3.> Ethanol used should be as pure as possible, say, 99% to eliminate the effect of hydrogen bonds formed between water molecules.

When hydrogen bonds are broken, energy is absorbed, temperature drops. Since hydrogen bond is much stronger than van der Waal's force, the slightly increase in temperature caused by formation of van der Waal's force between ethanol & cyclohexane molecules can be compensated by the highly decrease in temperature caused by breaking of hydrogen bond among ethanol molecules. Hence, the approximate value of hydrogen bond strength of ethanol can be obtained by this calorimetric method.

Conclusion

From this experiment, we can conclude that hydrogen bond is present between ethanol molecules due to the presence of hydroxyl group, —OH. The approximate strength of hydrogen bond of ethanol can be measured by using simple calorimetric method.