An Extended Problem Using Enthalpy Changes from Y12

Introduction

This problem will involve the use of ***Enthalpies of Combustion,*** $\Delta_c H$, to obtain ***Enthalpies of Formation,*** $\Delta_f H$.

The Enthalpies of Formation will then be used to calculate the $\Delta_r H$ for an esterification reaction.

The problem is associated with a simple **esterification reaction**. Many of you will be familiar with this reaction from GCSE. Esters are organic molecules made by the reaction of a carboxylic acid with an alcohol. A common example is shown in the box below:

ethanoic acid	+	ethanol	→	ethyl ethanoate	+	water
$CH_3COOH_{(l)}$	+	$CH_3CH_2OH_{(l)}$	→	$CH_3COOCH_2CH_{3(l)}$	+	$H_2O_{(l)}$

Enthalpies of Combustion are typically quite straight forward to obtain directly **by experiment** in a simple **combustion calorimeter** or a more accurate **bomb calorimeter**.

Enthalpies of combustion of these molecules are presented in the table below. Enthalpies of combustion of carbon and hydrogen are also given.

Chemical	Enthalpy of Combustion $\Delta_c H$ / $kJmol^{-1}$
C (s)	-394
$H_{2(g)}$	-286
CH_3COOH (*l*)	-874
CH_3CH_2OH (*l*)	-1368
$CH_3COOCH_2CH_3$ (*l*)	-2238

Task 1

Draw **Hess Cycles** involving the **enthalpies of combustion** $\Delta_c H$ that will allow you to calculate the **enthalpies of formation** $\Delta_f H$ for the following compounds:

a) **ethanoic acid,** $CH_3COOH_{(l)}$

$\Delta_f H\ (CH_3COOH)$=.....kJ mol^{-1}

b) **ethanol,** $CH_3CH_2OH_{(l)}$

$\Delta_f H\ (CH_3CH_2OH)$ =.....kJ mol^{-1}

c) ethyl ethanoate, $CH_3COOCH_2CH_{3(l)}$

$\Delta_f H\ (CH_3COOCH_2CH_3)$=.....kJ mol^{-1}

Task 2

Using the enthalpies of formation calculated in Task 1, calculate the enthalpy of reaction $\Delta_r H$ for the esterification reaction between ethanoic acid and ethanol.

You may be thinking that you haven't been given a value for $\Delta_f H\ (H_2O)$. But, if you think about it carefully, the value for $\Delta_f H\ (H_2O)$ is shown somewhere in the data that you have been given.

Clue: In the case of hydrogen and carbon (and a few others) the value of ΔH_f is also the same value as another enthalpy change.