Energy changes

Question Paper 2

Level	Pre U
Subject	Chemistry
Exam Board	Cambridge International Examinations
Topic	Energy changes- Physical Chemistry
Booklet	Question Paper 2

Time Allowed: **61 minutes**

Score: **/51**

Percentage: **/100**

Grade Boundaries:

1. **(a)** In theory, the reaction shown in equation 2.1 could be used to prepare SiF_4.

equation 2.1 $CF_4(g) + SiH_4(g) \longrightarrow CH_4(g) + SiF_4(g)$

Bond enthalpy data is shown in Table 2.1.

Table 2.1

gas-phase bond	average bond enthalpy / $kJ\,mol^{-1}$
C–H	413
C–F	467
Si–H	318
Si–F	553

Calculate the enthalpy change of the reaction shown in equation 2.1. Include a sign and units in your answer. You are advised to show your working.

$\Delta_r H^\ominus$ = ... [3]

(b) The reaction shown in equation 2.1 is not observed to take place at room temperature and pressure. However, recent research (*Science*, 2008) has revealed a method of exchanging a fluorine atom bonded to carbon with a hydrogen atom bonded to silicon at room temperature and pressure. This was accomplished by introducing triethylsilyl cations, $(C_2H_5)_3Si^+$. The proposed mechanism contains the following steps.

step 1 $(C_2H_5)_3Si^+ + C_6F_5CF_3 \rightarrow (C_2H_5)_3SiF + C_6F_5CF_2^+$

step 2 $(C_2H_5)_3SiH + C_6F_5CF_2^+ \rightarrow (C_2H_5)_3Si^+ + C_6F_5CF_2H$

(i) Write down the overall equation shown by the reaction steps above.

....[1]

(ii) State and explain the role of $(C_2H_5)_3Si^+$ in this process.

....

....

....[2]

(c) Suggest why Si−F bonds have a higher average bond enthalpy than C−F bonds.

....

....[1]

(d) Suggest why, despite the stronger Si−F bond, SiF_4 is more reactive than CF_4.

....

....[1]

[Total: 8]

2. **(a)** Simple esters are flammable liquids. Flammability is affected by volatility. Write the following homologous series in order of boiling point, assuming molecular masses are similar.

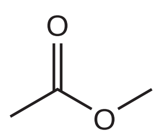
alcohols **s**

highest boiling point ....

↑ ....

lowest boiling point .... [1]

(b) **(i)** The structure of methyl ethanoate, $C_3H_6O_2$, is shown below.



Write an equation for the complete combustion of methyl ethanoate.

.... [1]

(ii) Define *standard enthalpy change of formation*.

....

....

.... [3]

(iii) Use the standard enthalpy changes of combustion, $\Delta_c H^{\ominus}$, in Table 7.1 to calculate the standard enthalpy change of formation of methyl ethanoate.

Table 7.1

	$\Delta_c H^{\ominus}$ / kJ mol^{-1}
carbon	–393.5
hydrogen	–285.8
methyl ethanoate	–1592.1

.... kJ mol^{-1} [3]

(c) A student used the apparatus shown in Figure 7.1 to carry out experiments to determine the standard enthalpy change of combustion for ethyl ethanoate.

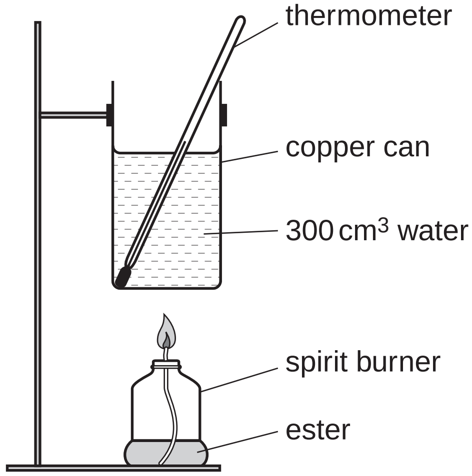


Fig. 7.1

- mass of copper pot is 250 g
- volume of water is 300 cm^3

An initial experiment was carried out using methyl ethanoate. This ester was combusted in a spirit burner underneath a copper can so that the flame from the burner heated 300 cm^3 of water in the can. It was found that 0.980 g of ester was required to raise the temperature of the water in the can by 10.0 °C.

(i) Describe how this initial experiment was carried out to collect the data that gave these results.

....

....

....

....

....

....

....

....

....

.... [6]

(ii) Calculate the total thermal energy in kJ gained by the water and the copper can in this initial experiment. The specific heat capacities of water and copper are 4.18 and 0.384 $J\,g^{-1}\,K^{-1}$, respectively.

Take the density of water to be 1.00 $g\,cm^{-3}$. Assume that the water and copper are in thermal equilibrium with each other. Express your answer to the appropriate number of significant figures.

.... [3]

(iii) Using the $\Delta_c H^{\ominus}$ value in Table 7.1, calculate the total theoretical thermal energy in kJ released by the mass of methyl ethanoate combusted in this initial experiment.

.... kJ [2]

(iv) Heat losses are significant but can be taken into account by using the known value of $\Delta_c H^{\ominus}$ of −1592.1 $kJ\,mol^{-1}$ for methyl ethanoate. A similar experiment with ethyl ethanoate produced the following results.

mass of ethyl ethanoate combusted = 0.948 g

increase in temperature of 300 cm^3 water = 11.5 °C

Calculate the most accurate possible value for the standard enthalpy change of combustion for ethyl ethanoate.

.... $kJ\,mol^{-1}$ [4]

(d) Outline **four** improvements that could increase the accuracy of the raw data recorded in these experiments.

....

....

....

....

....

....

....

....

....

....[4]

(e) In terms of the ease of lighting and the appearance of the flame how does methyl ethanoate compare to decyl ethanoate ($CH_3COOC_{10}H_{21}$)?

ease of lighting ....

....[1]

appearance of flame ....

....[1]

[Total: 29]

3.

Table 1.1 gives some data on four fuel sources: methanol, ethanol, hydrogen and octane.

Octane can serve as a rough approximation of petrol.

Table 1.1

name	formula	molar mass / g mol^{-1}	density / g cm^{-3}	$\Delta_c H^{\ominus}$ (298 K) / kJ mol^{-1}	$\Delta_f H^{\ominus}$ (298 K) / kJ mol^{-1}
methanol	CH_3OH	32	0.793^a	–726.0	–239.1
ethanol	C_2H_5OH		0.789^a	–1367.3	–277.1
liquid hydrogen	H_2	2	0.0711^b		
octane	C_8H_{18}		0.703^a		–250.0

^{a} At 298 K and 1 bar pressure.
^{b} At 20 K and 1 bar pressure.

(a) Insert the missing molar mass values in the table. [1]

(b) Calculate the density of **gaseous** hydrogen at 298 K and 1 bar pressure.
Assume 1 mol of any gas occupies 24 dm^3 at 298 K and 1 bar pressure. Give your answer in g cm^{-3}.

.... g cm^{-3} [1]

(c) What is the value of the standard enthalpy of formation of hydrogen **gas**, H_2?

.... [1]

(d) Use the information in Table 1.2 to give the value of the standard enthalpy of combustion of hydrogen.

Table 1.2

name	$\Delta_f H^{\ominus}$ (298 K) / kJ mol^{-1}
water	–285.8
carbon dioxide	–393.5

.... [1]

(e) Write down the chemical equation that represents the standard enthalpy of combustion of octane. Include state symbols.

.... [2]

(f) Use the enthalpy of formation data in Table 1.1 and Table 1.2 to calculate the standard enthalpy of combustion of octane.

.... [3]

(g) An important property of a fuel, especially when the fuel has to be lifted (such as in aviation), is the energy released on combustion *per gram* of fuel.

Calculate the enthalpy change of combustion per gram of fuel at 1 bar pressure and 298 K for methanol and hydrogen gas.

(i) methanol

....

(ii) hydrogen gas

.... [2]

(h) Another important characteristic of a fuel, especially when there is a fuel tank of limited size, is the energy released on combustion *per* cm^3 of fuel.

Calculate the enthalpy change of combustion per cm^3 of fuel for ethanol and octane.

(i) ethanol

....

(ii) octane

.... [2]

(i) Explain why, given the data in the question, it is not strictly possible to make a fair comparison of the energy released per cm^3 of liquid hydrogen with the other fuels.

....

.... [1]

[Total: 14]