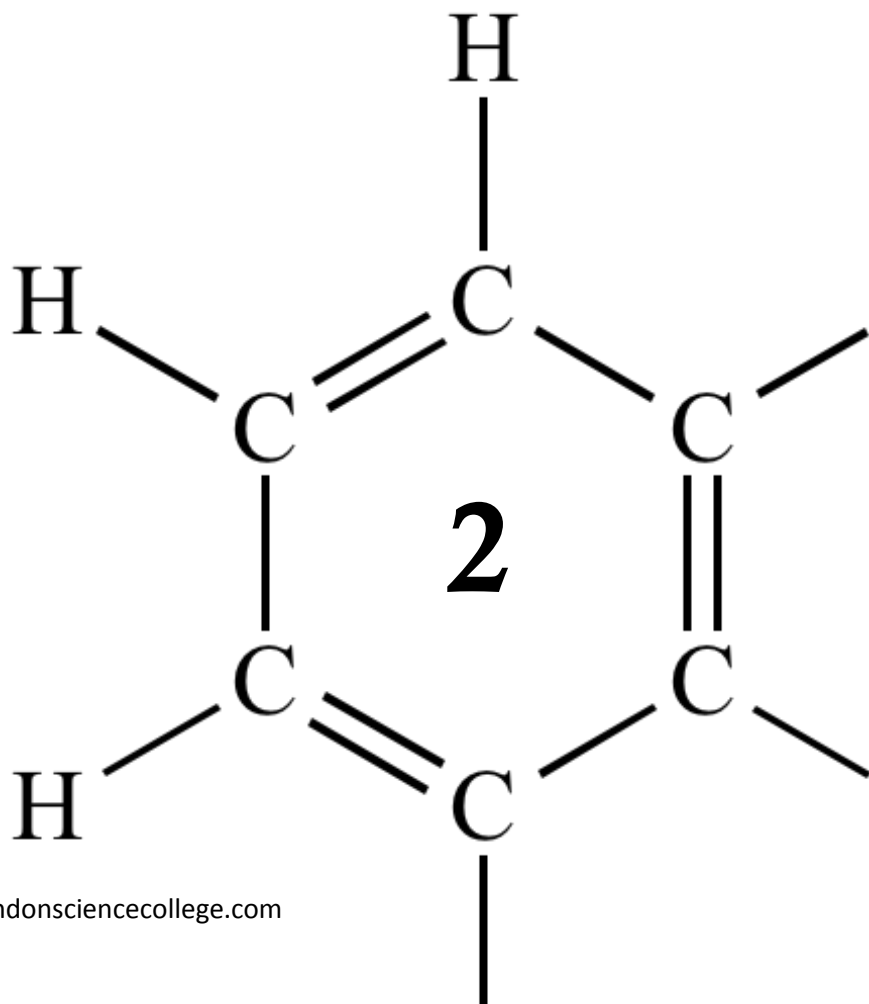


OCR AS CHEMISTRY

MODULE 3

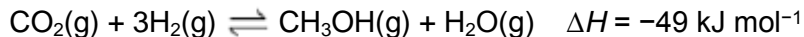
ENTHALPY



1

Many chemical processes release waste products into the atmosphere. Scientists are developing new solid catalysts to convert more efficiently these emissions into useful products, such as fuels. One example is a catalyst to convert these emissions into methanol. The catalyst is thought to work by breaking a H–H bond.

An equation for this formation of methanol is given below.



Some mean bond enthalpies are shown in the following table.

Bond	C=O	C–H	C–O	O–H
Mean bond enthalpy / kJ mol ⁻¹	743	412	360	463

- (a) Use the enthalpy change for the reaction and data from the table to calculate a value for the H–H bond enthalpy.

H–H bond enthalpy = kJ mol⁻¹

(3)

- (b) A data book value for the H–H bond enthalpy is 436 kJ mol⁻¹.

Suggest **one** reason why this value is different from your answer to part (a).

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(1)

- (c) Suggest **one** environmental advantage of manufacturing methanol fuel by this reaction.

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(1)

(d) Use Le Chatelier's principle to justify why the reaction is carried out at a high pressure rather than at atmospheric pressure.

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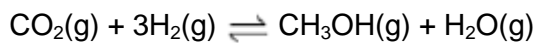
(3)

(e) Suggest why the catalyst used in this process may become less efficient if the carbon dioxide and hydrogen contain impurities.

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(1)

- (f) In a laboratory experiment to investigate the reaction shown in the equation below, 1.0 mol of carbon dioxide and 3.0 mol of hydrogen were sealed into a container. After the mixture had reached equilibrium, at a pressure of 500 kPa, the yield of methanol was 0.86 mol.



Calculate a value for K_p

Give your answer to the appropriate number of significant figures.

Give units with your answer.

$K_p = \dots\dots\dots$ Units = $\dots\dots\dots$

(7)

(Total 16 marks)

2

A 5.00 g sample of potassium chloride was added to 50.0 g of water initially at 20.0 °C. The mixture was stirred and as the potassium chloride dissolved, the temperature of the solution decreased.

- (a) Describe the steps you would take to determine an accurate minimum temperature that is **not** influenced by heat from the surroundings.

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(4)

- (b) The temperature of the water decreased to 14.6 °C.

Calculate a value, in kJ mol^{-1} , for the enthalpy of solution of potassium chloride.

You should assume that only the 50.0 g of water changes in temperature and that the specific heat capacity of water is $4.18 \text{ J K}^{-1} \text{ g}^{-1}$.

Give your answer to the appropriate number of significant figures.

Enthalpy of solution = kJ mol^{-1}

(4)

- (c) The enthalpy of solution of calcium chloride is $-82.9 \text{ kJ mol}^{-1}$.
The enthalpies of hydration for calcium ions and chloride ions are -1650 and -364 kJ mol^{-1} , respectively.

Use these values to calculate a value for the lattice enthalpy of dissociation of calcium chloride.

Lattice enthalpy of dissociation = kJ mol^{-1}

(2)

- (d) Explain why your answer to part (c) is different from the lattice enthalpy of dissociation for magnesium chloride.

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(2)

(Total 12 marks)

3

- (a) Propanone can be formed when glucose comes into contact with bacteria in the absence of air.

- (i) Balance the following equation for this reaction of glucose to form propanone, carbon dioxide and water.



(1)

- (ii) Deduce the role of the bacteria in this reaction.

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(1)

(b) Propanone is also formed by the oxidation of propan-2-ol.

(i) Write an equation for this reaction using [O] to represent the oxidising agent.

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(1)

(ii) State the class of alcohols to which propan-2-ol belongs.

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(1)

(c) A student determined a value for the enthalpy change when a sample of propanone was burned. The heat produced was used to warm some water in a copper calorimeter. The student found that the temperature of 150 g of water increased by 8.0 °C when 4.50×10^{-3} mol of pure propanone was burned in air.

Use the student's results to calculate a value, in kJ mol^{-1} , for the enthalpy change when one mole of propanone is burned.

(The specific heat capacity of water is $4.18 \text{ J K}^{-1} \text{ g}^{-1}$)

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(3)

(d) Define the term **standard enthalpy of combustion**.

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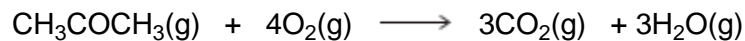
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(3)

(e) Use the mean bond enthalpy data in the table and the equation given below the table to calculate a value for the standard enthalpy change when gaseous propanone is burned.

	C-H	C-C	C-O	O-H	C=O	O=O
Mean bond enthalpy / kJ mol⁻¹	412	348	360	463	805	496



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(3)

- (f) Suggest **two** reasons why the value obtained by the student in part (c) is different from the value calculated in part (e).

Reason 1

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Reason 2

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(2)
(Total 15 marks)

4

Vanadium is an important metal. Ferrovandium, an alloy of iron and vanadium, is used to make a strong type of vanadium-steel. Pure vanadium is used in nuclear reactors.

- (a) The table shows some standard enthalpy of formation data.

	$V_2O_5(s)$	$CaO(s)$
$\Delta H_f^\theta / \text{kJ mol}^{-1}$	-1560	-635

In the oldest method of extraction of vanadium, V_2O_5 is reacted with calcium at a high temperature.



Use data from the table and the equation to calculate the standard enthalpy change for this reaction.

State the type of reaction that V_2O_5 has undergone.

Suggest **one** major reason why this method of extracting vanadium is expensive, other than the cost of heating the reaction mixture.

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(5)

- (b) Ferrovandium is produced by the reaction of aluminium with a mixture of V_2O_5 and iron(III) oxide.

Write an equation for the reaction of aluminium with iron(III) oxide.

State the change in oxidation state of aluminium in this reaction.

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(2)

- (c) Pure vanadium, for nuclear reactors, is formed by the reaction of hydrogen with purified VCl_2

Write an equation for this reaction in which the only other product is HCl gas.

Identify **two** hazards in this process, other than the fact that it operates at a high temperature.

Deduce why this process produces **pure** vanadium, other than the fact that purified VCl_2 is used.

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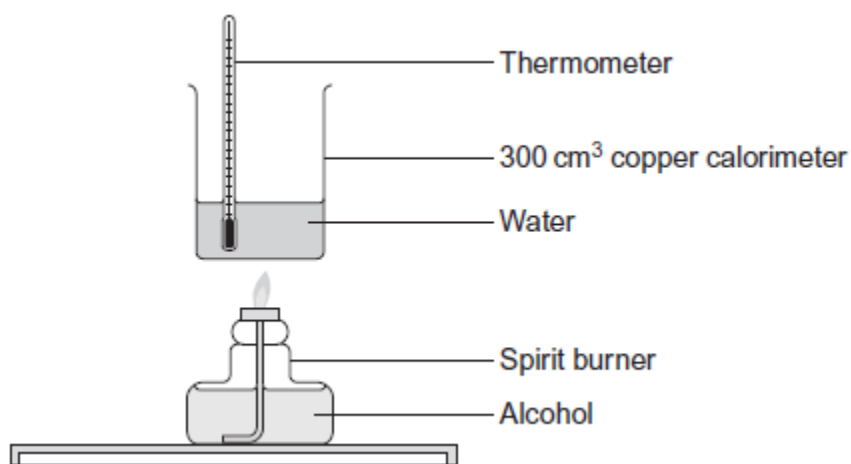
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(4)
(Total 11 marks)

5

A value for the enthalpy of combustion of an alcohol can be determined using the apparatus shown in the diagram. The calorimeter is held in position by a clamp.



This experiment can be repeated by using a different volume of water that would result in a more accurate value for the enthalpy of combustion because there would be a reduction in the heat lost.

State a change in the volume of water that would cause a reduction in heat loss and explain your answer.

Change in volume:

Explanation:

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(Total 2 marks)

6

The table contains some bond enthalpy data.

Bond	H-H	O=O	H-O
Bond enthalpy / kJ mol ⁻¹	436	496	464

(a) The value for the H-O bond enthalpy in the table is a mean bond enthalpy.

State the meaning of the term **mean bond enthalpy** for the H-O bond.

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(2)

(b) Use the bond enthalpies in the table to calculate a value for the enthalpy of formation of water in the gas phase.

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(3)

- (c) The standard enthalpy of combustion of hydrogen, forming water in the gas phase, is almost the same as the correct answer to part (b).
- (i) Suggest **one** reason why you would expect the standard enthalpy of combustion of hydrogen to be the same as the answer to part (b).

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(1)

- (ii) Suggest **one** reason why you would expect the standard enthalpy of combustion of hydrogen to differ slightly from the answer to part (b).

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(1)

(Total 7 marks)

7

Antimony is a solid element that is used in industry. The method used for the extraction of antimony depends on the grade of the ore.

- (a) Antimony can be extracted by reacting scrap iron with low-grade ores that contain antimony sulfide (Sb_2S_3).

- (i) Write an equation for the reaction of iron with antimony sulfide to form antimony and iron(II) sulfide.

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(1)

- (ii) Write a half-equation to show what happens to the iron atoms in this reaction.

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(1)

- (b) In the first stage of the extraction of antimony from a high-grade ore, antimony sulfide is roasted in air to convert it into antimony(III) oxide (Sb_2O_3) and sulfur dioxide.

- (i) Write an equation for this reaction.

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(1)

- (ii) Identify **one** substance that is manufactured directly from the sulfur dioxide formed in this reaction.

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(1)

- (c) In the second stage of the extraction of antimony from a high-grade ore, antimony(III) oxide is reacted with carbon monoxide at high temperature.

- (i) Use the standard enthalpies of formation in the table and the equation given below the table to calculate a value for the standard enthalpy change for this reaction.

	Sb₂O₃(s)	CO(g)	Sb(l)	CO₂(g)
$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	-705	-111	+20	-394



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(3)

- (ii) Suggest why the value for the standard enthalpy of formation of liquid antimony, given in the table above, is **not** zero.

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(1)

- (iii) State the type of reaction that antimony(III) oxide has undergone in this reaction.

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(1)

- (d) Deduce **one** reason why the method of extraction of antimony from a low-grade ore, described in part (a), is a low-cost process. Do **not** include the cost of the ore.

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(1)

(Total 10 marks)

8

Ethanol is an important fuel.

- (a) A dilute aqueous solution of ethanol can be produced by the fermentation of an aqueous solution of glucose.
It is claimed that the ethanol obtained from this solution is a carbon-neutral biofuel.

Write an equation for this fermentation reaction.

Give **two** other essential conditions for this reaction to produce a good yield of ethanol.

Name a process used to produce a much more concentrated solution of ethanol from a dilute aqueous solution.

State the meaning of the term **carbon-neutral** in the context of this biofuel.

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(5)

- (b) A student carried out a laboratory experiment to determine the enthalpy change when a sample of ethanol was burned. The heat produced was used to warm some water in a copper calorimeter. The student found that the temperature of 75.0 g of water increased by 5.50 °C when 2.40×10^{-3} mol of pure ethanol was burned in air.

Use the student's results to calculate a value, in kJ mol^{-1} , for the enthalpy change when one mole of ethanol is burned.

(The specific heat capacity of water is $4.18 \text{ J K}^{-1} \text{ g}^{-1}$)

Deduce **two** reasons why the student's value for the standard enthalpy of combustion of ethanol is different from a Data Book value of $-1279 \text{ kJ mol}^{-1}$.

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(Extra space).....

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(5)

(c) Mean bond enthalpies can be used to calculate enthalpies of reaction.

(i) Give the meaning of the term **mean bond enthalpy**.

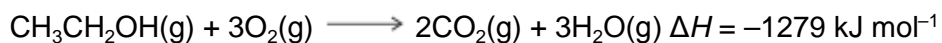
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(2)

(ii) Consider the mean bond enthalpy data in the following table.

	C—H	C—C	C—O	O=O	C=O	O—H
Mean bond enthalpy / kJ mol⁻¹	412	348	360	to be calculated	805	463

Use the data in the table above and the equation shown to calculate a value for the bond enthalpy for the O=O double bond in an oxygen molecule.



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(3)
(Total 15 marks)