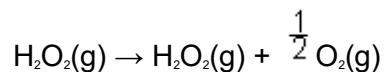


Q1. (a) The table below contains some mean bond enthalpy data.

Bond	H–O	O–O	O=O
Mean bond enthalpy/kJ mol ⁻¹	463	146	496

The bonding in hydrogen peroxide, H₂O₂, can be represented by H–O–O–H. Use these data to calculate the enthalpy change for the following reaction.



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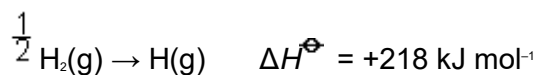
(3)

(b) The standard enthalpy of formation, ΔH_f^\ominus for methane, is $-74.9 \text{ kJ mol}^{-1}$. Write an equation, including state symbols, for the reaction to which this enthalpy change applies.

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(2)

(c) The enthalpy changes for the formation of atomic hydrogen and atomic carbon from their respective elements in their standard states are as follows.

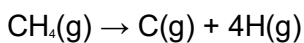


(i) By reference to its structure, suggest why a large amount of heat energy is required to produce free carbon atoms from solid carbon.

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- (ii) Parts (b) and (c) give enthalpy data for the formation of CH₄(g), H(g) and C(g). Use these data and Hess's Law to calculate the value of the enthalpy change for the following reaction.



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- (iii) Use your answer from part (c)(ii) to calculate a value for the mean bond enthalpy of a C–H bond in methane.

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(5)
(Total 10 marks)

- Q2.** (a) Define the term *standard enthalpy of combustion*, ΔH_c^\ominus

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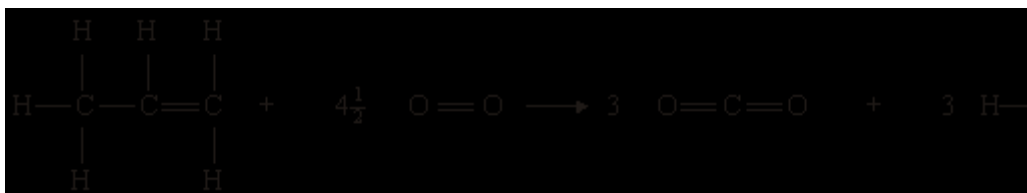
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(3)

- (b) Use the mean bond enthalpy data from the table and the equation given below to calculate a value for the standard enthalpy of combustion of propene. All substances are in the gaseous state.

Bond	C = C	C—C	C—H	O = O	O = C	O—H
Mean bond enthalpy/ kJ mol ⁻¹	612	348	412	496	743	463



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(3)

(c) State why the standard enthalpy of formation, ΔH_f^\ominus , of oxygen is zero.

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(1)

(d) Use the data from the table below to calculate a more accurate value for the standard enthalpy of combustion of propene.

Compound	$\text{C}_3\text{H}_6(\text{g})$	$\text{CO}_2(\text{g})$	$\text{H}_2\text{O}(\text{g})$
Standard enthalpy of formation, $\Delta H_f^\ominus / \text{kJ mol}^{-1}$	+20	-394	-242

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(3)

(e) Explain why your answer to part (b) is a less accurate value than your answer to part (d).

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(2)
(Total 12 marks)

Q3. (a) Explain the meaning of the terms *mean bond enthalpy* and *standard enthalpy of formation*.

Mean bond enthalpy

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Standard enthalpy of formation

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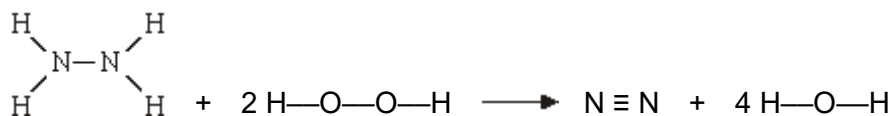
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(5)

(b) Some mean bond enthalpies are given below.

Bond	N-H	N-N	N≡N	H-O	O-O
Mean bond enthalpy/kJ mol ⁻¹	388	163	944	463	146

Use these data to calculate the enthalpy change for the following gas-phase reaction between hydrazine, N₂H₄, and hydrogen peroxide, H₂O₂



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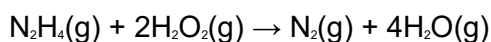
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(3)

(c) Some standard enthalpies of formation are given below.

	$\text{N}_2\text{H}_4(\text{g})$	$\text{H}_2\text{O}_2(\text{g})$	$\text{H}_2\text{O}(\text{g})$
$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	+75	-133	-242

These data can be used to calculate the enthalpy change for the reaction in part (b).



(i) State the value of ΔH_f^\ominus for $\text{N}_2(\text{g})$.

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(ii) Use the ΔH_f^\ominus values from the table to calculate the enthalpy change for this reaction.

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(4)

(d) Explain why the value obtained in part (b) is different from that obtained in part (c)(ii).

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(1)

(Total 13 marks)

Q4. Use the information below to answer this question.



The standard enthalpy of combustion of butane, in kJ mol^{-1} , is

- A** -2880
- B** -2590
- C** -806
- D** -554

(Total 1 mark)

Q5. This question is about the reaction given below.



Enthalpy data for the reacting species are given in the table below.

Substance	CO(g)	H ₂ O(g)	CO ₂ (g)	H ₂ (g)
$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	-110	-242	-394	0

The standard enthalpy change for this reaction of carbon monoxide and steam is

- A** +42 kJ mol^{-1}
- B** -42 kJ mol^{-1}
- C** +262 kJ mol^{-1}
- D** -262 kJ mol^{-1}

(Total 1 mark)

Q6. Methanol, CH₃OH, is a convenient liquid fuel.

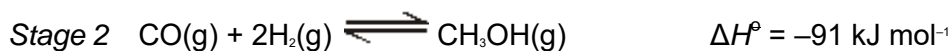
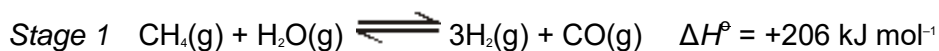
(a) An experiment was conducted to determine the enthalpy of combustion of liquid methanol. The energy obtained from burning 2.12 g of methanol was used to heat 150 g of water. The temperature of the water rose from 298 K to 362 K. (The specific heat capacity of water is 4.18 J K⁻¹ g⁻¹)

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

(ii) Use the data above to calculate a value for the enthalpy of combustion of one mole of liquid methanol.

(7)

(b) Methanol can be synthesised from methane and steam by a process that occurs in two stages.



(i) Explain why, in *Stage 1*, a higher yield of hydrogen and carbon monoxide is **not** obtained if the pressure is increased.

(ii) *Stage 2* is carried out at a compromise temperature of 500K. By considering what would happen at higher and lower temperatures, explain why 500 K is considered to be a compromise for *Stage 2*.

(5)

(c) The standard enthalpies of combustion of carbon monoxide and of hydrogen are -283 kJ mol⁻¹ and -286 kJ mol⁻¹, respectively. Use these data and the enthalpy change for *Stage 2* to calculate a value for the standard enthalpy of combustion of gaseous methanol.

(3)

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(Total 15 marks)