

1. Enthalpy changes of reaction can be determined indirectly from average bond enthalpies and standard enthalpy changes.

The table below shows the values of some average bond enthalpies.

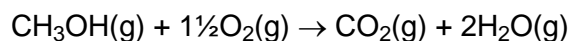
bond	average bond enthalpy /kJ mol ⁻¹
C-H	+410
O-H	+465
O=O	+500
C=O	+805
C-O	+336

- (i) Why do bond enthalpies have positive values?

.....

[1]

- (ii) The equation below shows the combustion of methanol, CH₃OH, in the gaseous state.



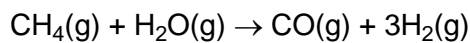
Using the average bond enthalpies in the table above, calculate the enthalpy change of combustion, ΔH_c , of gaseous methanol.

$$\Delta H_c = \dots\dots\dots \text{kJ mol}^{-1}$$

[3]

[Total 4 marks]

2. (a) Methane reacts with steam to produce carbon monoxide and hydrogen. The equation for this process is given below.



The table below shows the standard enthalpy changes of formation for CH_4 , H_2O and CO .

compound	$\Delta H_f^\ominus/\text{kJ mol}^{-1}$
CH_4	-75
H_2O	-242
CO	-110

- (i) Define the term *enthalpy change of formation*.

.....

.....

.....

[2]

- (ii) In ΔH_f^\ominus , what are the conditions indicated by the symbol $^\ominus$?

.....

.....

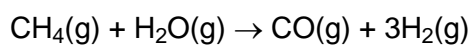
[1]

- (iii) Write the equation, including state symbols, that represents the standard enthalpy change of formation for carbon monoxide, CO .

.....

[2]

- (iv) Using the ΔH_f^\ominus values in the table above, calculate the enthalpy change for the reaction of methane with steam.



$$\Delta H = \dots\dots\dots \text{kJ mol}^{-1}$$

[3]

- (b) State one important manufacturing process in which hydrogen is used.

.....

[1]

[Total 9 marks]

3. Propane, C_3H_8 , is a gas at room temperature and pressure. It is used in blow torches to melt the bitumen needed to apply the felt to flat roofs.

Write the equation for the complete combustion of propane.

[Total 2 marks]

4. Define the term *standard enthalpy change of combustion*.

.....

[Total 3 marks]

5. Alkanes are important hydrocarbons since they are used as fuels in homes and in industry. It is important that the enthalpy changes involved in alkane reactions are known.

(i) Define the term *enthalpy change of formation of a compound*.

.....
.....
.....

[2]

(ii) Write the equation, including state symbols, that accompanies the enthalpy change of formation of hexane, $C_6H_{14}(l)$.

[2]

(iii) What conditions of temperature and pressure are used when measuring the **standard** enthalpy change of formation?

temperature

pressure

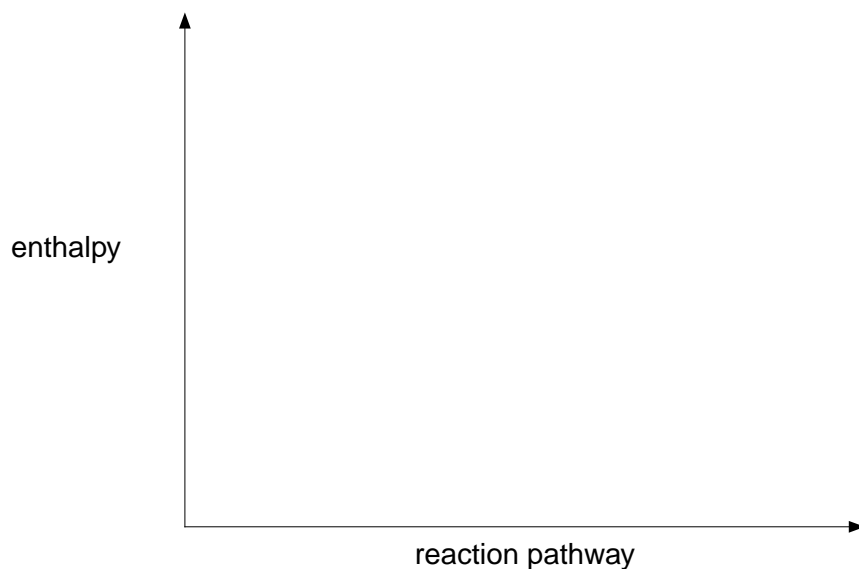
[1]

[Total 5 marks]

6. The standard enthalpy change of formation of hexane is -199 kJ mol^{-1} .

Using the axes below, show the enthalpy profile diagram for the formation of hexane.

On your diagram label the enthalpy change of reaction, ΔH , and the activation energy, E_a .

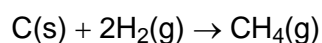


[Total 3 marks]

7. Enthalpy changes can be calculated using enthalpy changes of combustion. The table below shows some values for standard enthalpy changes of combustion.

substance	$\Delta H_c^\ominus / \text{kJ mol}^{-1}$
C(s)	-394
H ₂ (g)	-286
CH ₄ (g)	-890

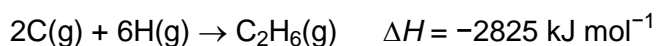
Use these values to calculate the standard enthalpy change of the reaction below.



standard enthalpy change = kJ mol^{-1}

[Total 3 marks]

8. The equations for the combination of gaseous atoms of carbon and hydrogen to form methane, CH_4 , and ethane, C_2H_6 , are shown below.



Use these data to calculate:

- (i) the bond enthalpy of a C–H bond,

bond enthalpy = kJ mol^{-1}

[1]

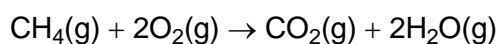
- (ii) the bond enthalpy of a C–C bond.

bond enthalpy = kJ mol^{-1}

[2]

[Total 3 marks]

9. Methane reacts with oxygen to produce carbon dioxide and water. The equation for this reaction is given below.



Gas cookers use methane as a fuel because this reaction is exothermic and takes place at a fairly fast rate.

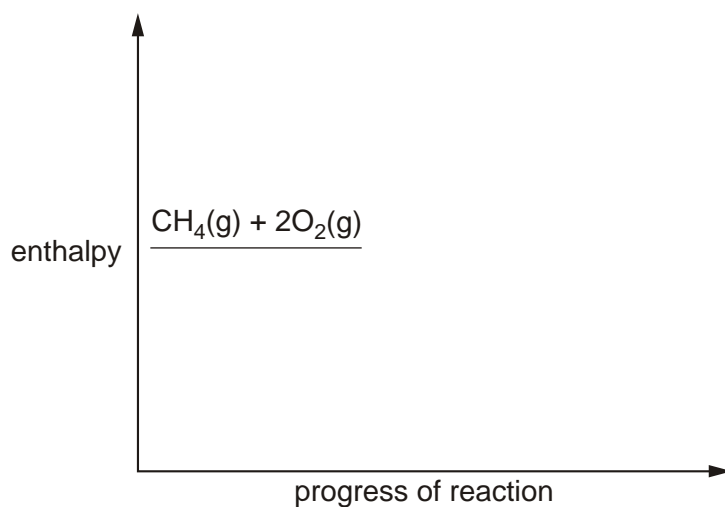
Activation energy is important in considering the conditions needed to change the rate of a reaction.

- (a) What is meant by the term *exothermic*?

.....

[1]

- (b) The figure below is an incomplete enthalpy profile diagram for the reaction between methane and oxygen.



- (i) Complete the figure to show the complete enthalpy profile for the reaction.

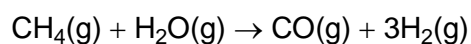
[2]

- (ii) Label the activation energy, E_a , on the figure above.

[1]

[Total 4 marks]

10. Methane can be reacted with steam to produce carbon monoxide and hydrogen. The equation for this process is given below.



The table below shows the enthalpy changes of formation for methane, steam and carbon monoxide.

compound	$\Delta H_f / \text{kJ mol}^{-1}$
CH ₄	-75
H ₂ O	-242
CO	-110

- (a) Define the term *enthalpy change of formation*.

.....
.....
.....

[2]

- (b) Write the equation, including state symbols, representing the enthalpy change of formation for methane, CH₄.

.....

[2]

- (c) Use the ΔH_f values in the table to calculate the enthalpy change for the reaction shown in the equation shown above.

..... kJ mol⁻¹

[3]

- (d) State one important manufacturing process in which hydrogen is used.

.....
.....

[1]

[Total 8 marks]

11. Energy changes during reactions can be considered using several different enthalpy changes. These include average bond enthalpies and enthalpy changes of combustion.

Table below shows the values of some average bond enthalpies.

bond	average bond enthalpy / kJ mol^{-1}
C — H	+ 410
O — H	+ 465
O == O	+ 500
C == O	+ 805
C — O	+ 336

- (i) Why do bond enthalpies have positive values?

.....

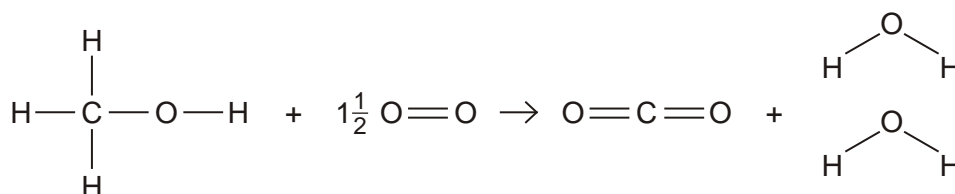
[1]

- (ii) Define the term *bond enthalpy*.

.....

[2]

- (iii) The equation below shows the combustion of methanol, CH_3OH , in the gaseous state.



Use the average bond enthalpies from the table above to calculate the enthalpy change of combustion of gaseous methanol, ΔH_c .

$$\Delta H_c = \dots\dots\dots \text{kJ mol}^{-1}$$

[3]

- (iv) Suggest **two** reasons why the **standard** enthalpy change of combustion of methanol will be different from that calculated in part (iii).

reason 1

.....

reason 2

.....

[2]

[Total 8 marks]

12. The changes in energy during reactions are often considered using enthalpy changes of reaction. One such enthalpy change is the standard enthalpy change of formation.

- (i) Define the term *standard enthalpy change of formation*.

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.....

[3]

- (ii) Write the equation for the reaction corresponding to the standard enthalpy change of formation of magnesium nitrate, $\text{Mg}(\text{NO}_3)_2$. Include state symbols.

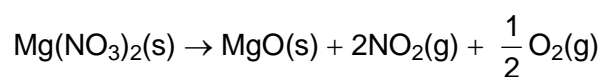
[2]

- (iii) When magnesium nitrate is heated, it decomposes to give magnesium oxide, nitrogen dioxide and oxygen.

Use the standard enthalpy changes of formation to find the enthalpy change of reaction for this decomposition.

substance	standard enthalpy change of formation / kJ mol^{-1}
$\text{Mg}(\text{NO}_3)_2$	-791
MgO	-602
NO_2	-33

The equation for this reaction is shown below.

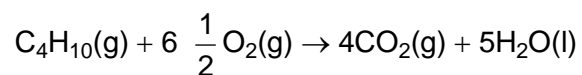


enthalpy change = kJ mol^{-1}

[3]

[Total 8 marks]

¶ CE13. The combustion of butane is shown in the equation below.



- (i) The standard enthalpy change of combustion of butane is $-2877 \text{ kJ mol}^{-1}$. What does *standard* mean in this context?

.....

.....

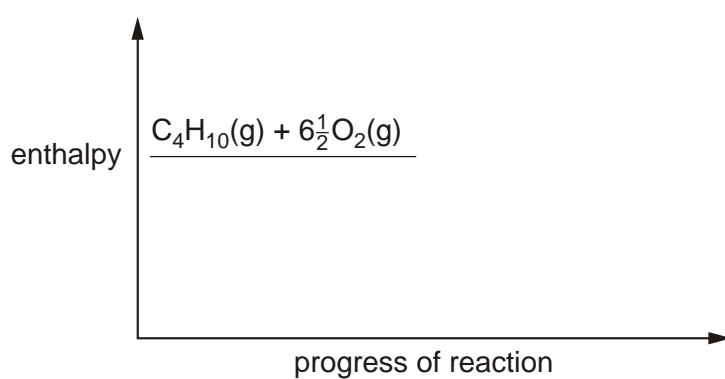
[1]

- (ii) Define the term *enthalpy change of combustion*.

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.....
.....

[2]

- (iii) Complete the enthalpy profile diagram for the combustion of butane. Label the activation energy, E_a , and the enthalpy change, ΔH .



[3]

[Total 6 marks]

14. Enthalpy changes of combustion can be used to determine enthalpy changes of formation.

- (i) Write the equation for the standard enthalpy change of formation of butane, C_4H_{10} . Include state symbols in your answer.

.....

[2]

- (ii) Use the following data to calculate the standard enthalpy change of formation of butane.

	standard enthalpy change of combustion / kJ mol^{-1}
carbon	-394
hydrogen	-286
butane	-2877

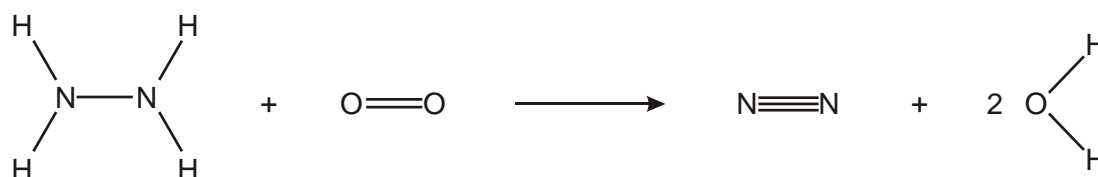
answer kJ mol^{-1}

[3]

[Total 5 marks]

15. This question is about hydrazine, N_2H_4 , and ammonia, NH_3 . These are both compounds of nitrogen and hydrogen.

- (a) Hydrazine can be oxidised and used as a rocket fuel. The equation for one possible reaction taking place is shown below.



Some average bond enthalpies are given below.

bond	bond enthalpy / kJ mol^{-1}
N-N	+163
N≡N	+945
N-H	+390
O=O	+497
O-H	+463

- (i) Use these data to calculate the enthalpy change for the reaction of hydrazine with oxygen, as shown.

answer kJ mol^{-1}

[4]

- (ii) Calculate the enthalpy change for one gram of hydrazine in this reaction.

answer kJ

[1]

- (b) Ammonia reacts with oxygen in a very similar way to that shown for hydrazine. The enthalpy change for one gram of ammonia is approximately the same as that for one gram of hydrazine.

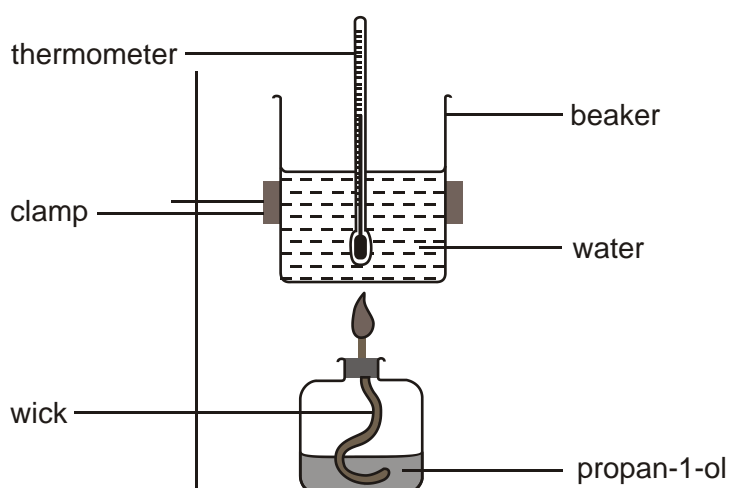
Using the table above, suggest a reason why hydrazine is used as a rocket fuel and ammonia is not.

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[1]

[Total 6 marks]

16. In an experiment to determine the standard enthalpy change of combustion of propan-1-ol, $\text{C}_3\text{H}_7\text{OH}$, a student used the apparatus shown below.



- (a) Define the term *enthalpy change of combustion*.

.....

[2]

- (b) Write the equation for the standard enthalpy change of combustion of propan-1-ol, C₃H₇OH.

.....

[2]

- (c) The student measured 50.0 cm³ of water into the beaker and lit the burner. When the temperature of the water had gone up by 12.8 °C, he found that 0.100 g of propan-1-ol had been burnt.

- (i) Calculate the energy, in kJ, produced by burning 0.100 g of propan-1-ol. The specific heat capacity of water is 4.18 J g⁻¹ K⁻¹.

energy = kJ

[2]

- (ii) Calculate the number of moles of propan-1-ol in 0.100 g.

number of moles =

[2]

- (iii) Calculate the enthalpy change of combustion, in kJ mol⁻¹, of propan-1-ol.

enthalpy change kJ mol⁻¹

[1]

- (d) The student looked in a text book and found that the actual value for the standard enthalpy change of combustion of propan-1-ol was more exothermic than the experimental value.

Suggest **two** reasons for the difference between this value and the one he obtained experimentally.

1

.....

2

.....

[2]

[Total 11 marks]

17. There are several oxides of lead. This question is about the enthalpy changes that occur during the reactions of some of these oxides.

- (i) Define the term *enthalpy change of formation*.

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[2]

- (ii) What are the standard conditions of temperature and pressure used in enthalpy calculations?

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[1]

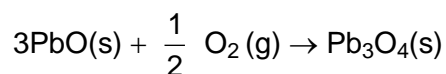
[Total 3 marks]

18. Write an equation, including state symbols, representing the standard enthalpy change of formation of PbO.

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[Total 2 marks]

19. Metal priming paints often contain 'red lead', Pb₃O₄. Red lead can be made by heating PbO in the presence of air.



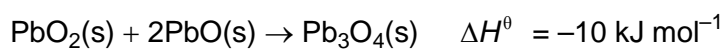
- (i) Use the ΔH_f^θ values in Table below to calculate the standard enthalpy change for the above reaction.

compound	ΔH_f^θ /kJ mol ⁻¹
PbO(s)	-217
Pb ₃ O ₄ (s)	-718

$$\Delta H^\theta = \dots\dots\dots \text{kJ mol}^{-1}$$

[3]

- (ii) Red lead can also be obtained by reacting PbO₂ with PbO.



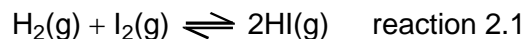
Use the value of ΔH^θ for this reaction, together with the values of ΔH_f^θ in the table above, to calculate a value for the enthalpy change of formation of PbO₂(s).

$$\Delta H_f^\theta = \dots\dots\dots \text{kJ mol}^{-1}$$

[3]

[Total 6 marks]

20. In the vapour state, hydrogen and iodine undergo the following reaction.



Write an equation, including state symbols, for the bond enthalpy of I – I.

.....

[Total 2 marks]

21. This question is about the relationship between bond enthalpies and enthalpy changes of combustion.

Define the term *bond enthalpy*.

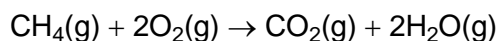
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[Total 2 marks]

22. Methane burns in air according to the following equation.



- (i) Use the average bond enthalpies given in the table below to calculate a value for the enthalpy change of combustion of methane, ΔH_{C} .

bond	average bond enthalpy / kJ mol ⁻¹
C–H	+410
O–H	+465
O=O	+500
C=O	+805

$$\Delta H_{\text{C}} = \dots\dots\dots \text{kJ mol}^{-1}$$

[3]

- (ii) The standard enthalpy change of combustion of methane is -890 kJ mol^{-1}

Suggest why your calculated value differs from this value.

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[1]

[Total 4 marks]

23. The Table below gives values for the standard enthalpy changes of combustion for the first three alkanes.

alkane	formula	$\Delta H_c^\theta / \text{kJ mol}^{-1}$
methane	CH_4	-890
ethane	C_2H_6	-1560
propane	C_3H_8	-2220

- (i) Write a balanced equation, including state symbols, illustrating the standard enthalpy change of combustion of propane gas.

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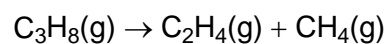
[2]

- (ii) As the chain length in the alkanes increases, the value of ΔH_c^θ becomes more negative. Use your understanding of bond breaking and bond making to explain this trend.

.....

[2]

- (iii) Propane can be cracked to form ethene and methane.



The standard enthalpy change of combustion of ethene, $\Delta H_c^\theta = -1410 \text{ kJ mol}^{-1}$.

Use this value together with relevant values in Table above to calculate the enthalpy change of this reaction.

$$\Delta H_c^\theta = \dots\dots\dots \text{ kJmol}^{-1}$$

[3]

[Total 7 marks]