

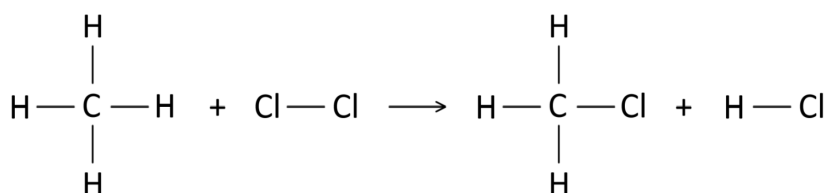
Bond Energy Calculations

Mark Scheme



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1. Methane gas CH_4 (g), reacts with chlorine gas Cl_2 (g), in the presence of ultraviolet light to produce chloromethane CH_3Cl (g) and hydrogen chloride HCl (g).



The table below gives the bond energies for the bonds in the equation.

Bond	H-C	Cl-Cl	C-Cl	H-Cl
Bond energy	413	243	346	432

- a) Calculate the energy needed to break the bonds in the reactant molecules.

Bond energy = $4(413) + 243$	Bond energy = 1895	1 mark
		Total: 1 mark

- b) Calculate the energy released when the bonds are formed in the product molecules.

Bond energy = $3(413) + 346 + 432$	Bond energy = 2017	1 mark
		Total: 1 mark

- c) Calculate the overall energy change for the reaction between the methane gas and chlorine gas.

$\Delta H = \text{reactants} - \text{products}$	$\Delta H = 1895 - 2017$	1 mark
$\Delta H = -122$		1 mark
Unit = kJ/ mol		1 mark
Correct answer with correct unit scores full marks. Working out is not required.		
		Total: 3 marks

- d) State whether the overall energy change is endothermic or exothermic and give a reason for your answer.

Exothermic	1 mark
A reason to include the following:	
More energy is given out making bonds than is required to break them.	1 mark
Accept answers that are differently worded but that convey the same understanding.	
Total: 2 marks	

(Total for Question 1 is 7 marks)

2. Hydrogen gas, H₂ (g) reacts with oxygen gas, O₂ (g) to form water vapour, H₂O (g).

The figure below shows the displayed formula equation for the reaction.



The table below gives the bond energies for the bonds in the equation.

Bond	H-H	O=O	O-H
Bond energy	436	498	464

- a) Calculate the energy needed to break the bonds in the reactant molecules.

Bond energy = 2(436) + 498	Bond energy = 1370	1 mark
		Total: 1 mark

- b) Calculate the energy released when the bonds are formed in the product molecules.

Bond energy = 4(464)	Bond energy = 1856	1 mark
		Total: 1 mark

- c) Calculate the overall energy change for the reaction between the hydrogen gas and oxygen gas.

$\Delta H = \text{reactants} - \text{products}$	$\Delta H = 1370 - 1856$	1 mark
$\Delta H = -486$		1 mark
Unit = kJ/ mol		1 mark
Correct answer with correct unit scores full marks. Working out is not required.		
		Total: 3 marks

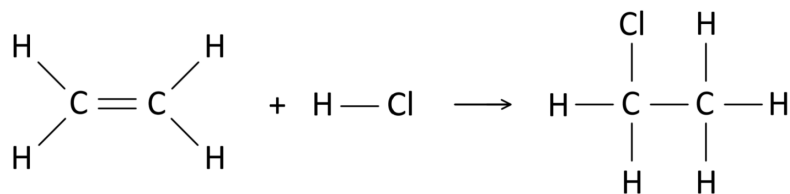
- d) State whether the overall energy change is endothermic or exothermic and give a reason for your answer.

<u>Exothermic</u>	1 mark
A reason to include the following:	
More energy is given out making bonds than is required to break them.	1 mark
Accept answers that are differently worded but that convey the same understanding.	
	Total: 2 marks

(Total for Question 2 is 7 marks)

3. Ethene gas, C₂H₄ (g) reacts with hydrogen chloride gas, HCl (g) to produce chloroethane, C₂H₄Cl₂.

The figure below shows the displayed formula equation for the reaction.



The table below gives the bond energies for the bonds in the equation.

Bond	H–C	C=C	H–Cl	C–Cl	C–C
Bond energy	413	612	431	338	347

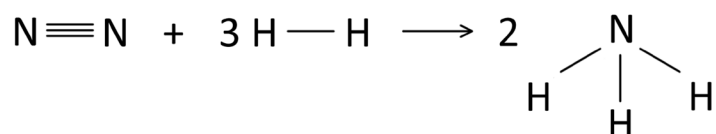
Use the bond energies to calculate the energy change for the reaction.

$\Delta H = \text{reactants} - \text{products}$	1 mark
$\Delta H = 4(413) + 612 + 431 - 5(413) + 338 + 347$	
$\Delta H = 2695 - 2750$	1 mark
$\Delta H = -55$	1 mark
Unit = kJ/ mol	1 mark
	Total: 4 marks

(Total for Question 3 is 4 marks)

4. The Haber process is the reaction between nitrogen, N₂ and hydrogen, H₂ which produces ammonia NH₃.

The figure below shows the displayed formula equation for the reaction.



The table below gives the bond energies for the bonds in the equation.

Bond	N≡N	H–H	N–H
Bond energy	944	436	388

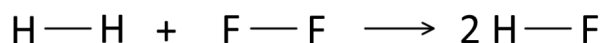
Use the bond energies to calculate the energy change for the reaction.

$\Delta H = \text{reactants} - \text{products}$	1 mark
$\Delta H = 944 + 3(436) - 6(388)$	
$\Delta H = 2252 - 2328$	1 mark
$\Delta H = -76$	1 mark
Unit = kJ/ mol	1 mark
	Total: 4 marks

(Total for Question 4 is 4 marks)

5. Hydrogen gas, $\text{H}_2(\text{g})$, reacts with fluorine gas $\text{F}_2(\text{g})$ to produce hydrogen fluoride. Hydrogen fluoride can be used in the production of Teflon for nonstick coatings on cooking pans.

The figure below shows the displayed formula equation for the reaction.



The table below gives the bond energies for the bonds in the equation.

Bond	H-H	F-F	H-F
Bond energy	436	158	562

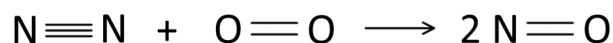
Use the bond energies to calculate the energy change for the reaction.

$\Delta H = \text{reactants} - \text{products}$	1 mark
$\Delta H = 436 + 158 - 2(562)$	1 mark
$\Delta H = 594 - 1124$	1 mark
$\Delta H = -530$	1 mark
Unit = kJ/ mol	1 mark
	Total: 4 marks

(Total for Question 5 is 4 marks)

6. Nitrogen gas, $\text{N}_2(\text{g})$ reacts with oxygen gas $\text{O}_2(\text{g})$ to produce nitrogen monoxide $\text{NO}(\text{g})$.

The figure below shows the displayed formula equation for the reaction.



The table below gives the bond energies for the bonds in the equation.

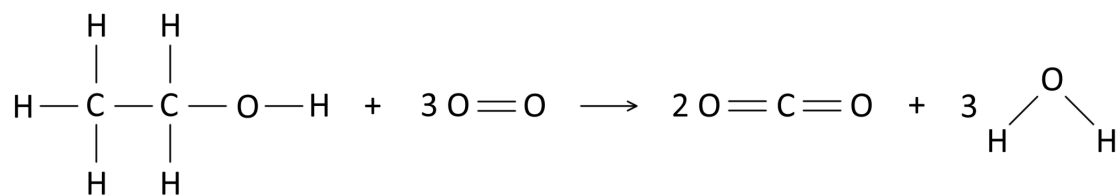
Bond	$\text{N} \equiv \text{N}$	$\text{O} = \text{O}$	$\text{N} = \text{O}$
Bond energy	944	498	607

Use the bond energies to calculate the energy change for the reaction.

$\Delta H = \text{reactants} - \text{products}$	1 mark
$\Delta H = 944 + 498 - 2(607)$	1 mark
$\Delta H = 1442 - 1214$	1 mark
$\Delta H = 228$	1 mark
Unit = kJ/ mol	1 mark
	Total: 4 marks

(Total for Question 6 is 4 marks)

7. Ethanol is often used as a fuel. The combustion of ethanol, $\text{C}_2\text{H}_5\text{OH}$, is an exothermic reaction. The figure below shows the displayed formula equation for the reaction.



The table below gives the bond energies for the bonds in the equation.

Bond	C-H	C-C	C=O	C-O	O=O	O-H
Bond energy	413	347	x	358	498	464

In the reaction the energy released forming new bonds was -1270 kJ/mol .

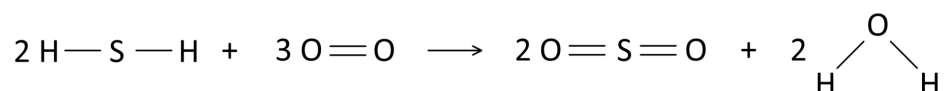
Use this information and the bond energies above to calculate the bond energy x for the C=O bond. Give your answer to three significant figures.

Reactants = $5(413) + 347 + 358 + 464 + 3(498)$	
Reactants = 4728	1 mark
Products = $4(x) + 6(464)$	
Products = $4x + 2784$	1 mark
$-1270 = 4728 - (4x + 2784)$ $-1270 = 4728 - 4x - 2784$ $-1270 = 1944 - 4x$ $-3214 = -4x$ $x = -3214 \div -4$ $x = 803.5$	1 mark
To 3 significant figures $x = 804$	1 mark
Unit = kJ/mol	1 mark
	Total: 5 marks

(Total for Question 7 is 5 marks)

8. Hydrogen sulfide reacts with oxygen to produce sulfur dioxide and water.

The figure below shows the displayed formula equation for the reaction.



The table below gives the bond energies for the bonds in the equation.

Bond	H-S	O=O	S=O	O-H
Bond energy	364	498	x	464

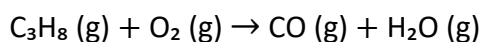
In the reaction the energy released forming new bonds was 1034 kJ/mol more than the energy required to break the bonds of the reactant molecules.

Use this information and the bond energies above to calculate the bond energy x for the S=O bond.

Reactants = $4(364) + 3(498)$	
Reactants = 2950	1 mark
Products = $4(x) + 4(464)$	
Products = $4x + 1856$	1 mark
$\Delta H = 2950 + 1034$	
$\Delta H = 3984$	1 mark
$4x + 1856 = 3984$	
$4x + 1856 = 3984$	
$x = 2128 \div 4$	
$x = 532$	1 mark
Unit = kJ/ mol	1 mark
	Total: 5 marks

(Total for Question 8 is 5 marks)

9. The incomplete combustion of propane, C₃H₈, can produce carbon monoxide, CO, and water, H₂O, as shown in the following **unbalanced** equation:



- a) Balance the equation for the reaction.

Correct reactants 2C₃H₈ (g) + 7O₂ (g)	1 mark
Correct products 6CO (g) + 8H₂O (g)	1 mark
	Total: 2 marks

- b) Draw the displayed formula equation for this reaction.

$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ 2 \text{ H}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \end{array} + 7 \text{ O}=\text{O} \longrightarrow 6 \text{ C}\equiv\text{O} + 8 \begin{array}{c} \text{O} \\ / \quad \backslash \\ \text{H} \quad \text{H} \end{array} $	
Correct displayed scores 4 marks. 1 mark for each correct balanced formula.	4 marks
	Total: 4 marks

The table below gives the bond energies for the bonds in the equation.

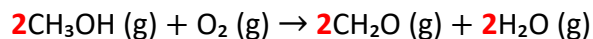
Bond	C–C	C–H	O=O	C≡O	O–H
Bond energy	347	413	498	1077	464

- c) Use the bond energies to calculate the energy change for the reaction.

Reactants = 16(413) + 7(498) + 4(347)	
Reactants = 11482	1 mark
Products = 6(1077) + 16(464)	
Products = 13886	1 mark
ΔH = 11482 – 13886	
ΔH = –2404	1 mark
Unit = kJ/ mol	1 mark
	Total: 4 marks

(Total for Question 9 is 10 marks)

10. The reaction of methanol, CH₃OH, and oxygen ,O₂, produces methanal, CH₂O, and water, H₂O, as shown in the following **unbalanced** equation:



a) Balance the equation for the reaction.

Correct reactants $2\text{CH}_3\text{OH (g)} + \text{O}_2 \text{ (g)}$	1 mark
Correct products $2\text{CH}_2\text{O (g)} + 2\text{H}_2\text{O (g)}$	1 mark
	Total: 2 marks

b) Draw the displayed formula equation for this reaction.

$ \begin{array}{c} \text{H} \\ \\ 2 \text{ H}-\text{C}-\text{O}-\text{H} \\ \\ \text{H} \end{array} + \text{O}=\text{O} \rightarrow 2 \begin{array}{c} \text{H} \\ \diagdown \\ \text{C}=\text{O} \\ \diagup \\ \text{H} \end{array} + 2 \begin{array}{c} \text{O} \\ \diagup \quad \diagdown \\ \text{H} \quad \text{H} \end{array} $	
Correct displayed scores 4 marks. 1 mark for each correct balanced formula.	4 marks
	Total: 4 marks

The table below gives the bond energies for the bonds in the equation.

Bond	C-H	C-O	O-H	O=O	C=O
Bond energy	413	358	464	498	x

c) The overall energy change for this reaction is -328 kJ/mol.

Use the overall energy change and the bond energies above to calculate the bond energy x for the C=O bond.

Reactants = $6(413) + 498 + 358 + 464$	
Reactants = 4620	1 mark
Products = $4(413) + 2(x) + 4(464)$	
Products = $3508 + 2x$	1 mark
$-328 = 4620 - (2x + 3508)$	
$-328 = 4620 - 2x - 3508$	
$-328 = 1112 - 2x$	
$2x = 1440$	
$x = 720$	1 mark
Unit = kJ/ mol	1 mark
	Total: 4 marks

(Total for Question 10 is 10 marks)