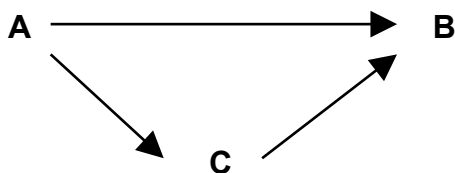




HESS'S LAW 3 – BOND ENTHALPIES

Hess's Law: The enthalpy change for a reaction is independent of the route taken

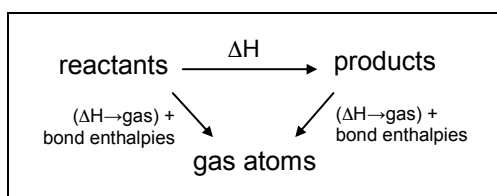


e.g. the enthalpy change to go from A → B direct is the same as going from A → C → B

- This method is for questions involving bond enthalpies (some people called these “type 3 questions”).
- Bond enthalpy is the enthalpy change to break one mole of covalent bonds in the gas phase.
- For most bonds (e.g. C-H, C-C, C=O, O-H, etc.) the value for the bond enthalpy is an average taken from a range of molecules as the exact value varies from compound to compound. For some bond enthalpies (e.g. H-H, H-Cl, O=O, etc) the value is exact as only one molecule contains that bond.
- Enthalpies of reaction that have been calculated using mean bond enthalpies are not as accurate as they might be because the values used are averages and not the specific ones for that compound.

Best method for most students (uses a cycle)

- This cycle works for any question that involves bond enthalpies, whether to find a bond enthalpy or ΔH for a reaction.
- Remember that substances must be in the gas state before bonds are broken, and so ΔH to go to the gas state is needed for solids and liquids. (Note - ΔH vaporisation is the enthalpy change to convert a liquid to a gas)



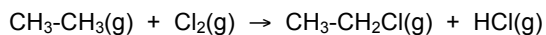
- As with other cycles, the sum of the clockwise arrows equals the sum of the anticlockwise arrows. Be careful to ensure that arrow directions and number of moles are correct.

Simpler method for simple examples

- This is the way you would have done the questions at GCSE.
- The problem is that it only works if all reactants and products are in the gas phase, though this is usually the case at AS (but not at A2).
- In this method, simply
 - add up the energy needed to break all the bonds in the reactants
 - add up the energy released forming bonds in the products
 - enthalpy change is simply:

$$\Delta H = (\text{SUM } \Delta H \text{ bonds broken}) - (\text{SUM } \Delta H \text{ bonds made})$$
 - remember “break – make”
- Sometimes you may be given the overall enthalpy change and all the bond enthalpies except one and will need to find the unknown bond enthalpy.

Example 1 Calculate the enthalpy change for the following reaction given the following bond enthalpies.



Bond enthalpies: C-C 348, C-H 412, Cl-Cl 242, C-Cl 338, H-Cl 431 kJ/mol

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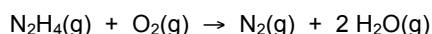
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Example 2 Hydrazine has the formula N_2H_4 and is used as a rocket fuel (e.g. for the Apollo moon rockets). It burns in the following reaction for which the enthalpy change is -583 kJ/mol.



Calculate the N-N bond enthalpy in hydrazine given the following bond enthalpies.

Bond enthalpies: N-H 388, O=O 498, N≡N 944, O-H 463 kJ/mol

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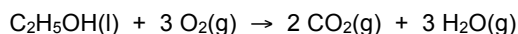
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Example 3 Ethanol has the formula $\text{C}_2\text{H}_5\text{OH}$ and is used as a fuel (e.g. for cars in Brazil). It burns in the following reaction for which the enthalpy change is -1015 kJ/mol.



Calculate the C-C bond enthalpy in ethanol given the following bond enthalpies and enthalpy of vaporisation of ethanol.

Bond enthalpies: C-H 412, O-H 463, C-O 360, C=O 743, O=O 498 kJ/mol

Enthalpy of vaporisation of ethanol, $\text{C}_2\text{H}_5\text{OH}(\text{l}) = 44 \text{ kJ/mol}$

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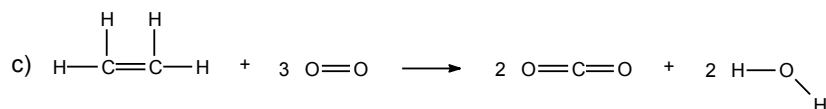
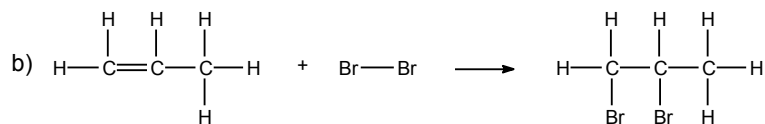
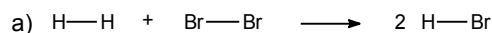
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- 1) Use the following bond enthalpies to calculate ΔH^\ominus for the following reactions. You may assume that all species are in the gaseous state.

Bond	H-H	O=O	C-C	C=C	C-H	F-F	H-O	Br-Br	C-Br	H-Br	C=O
kJ mol^{-1}	436	496	348	612	412	158	463	193	276	366	743



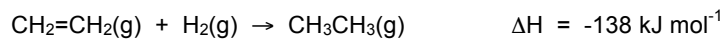
d) $\Delta_c H$ of methane

- 2) Calculate the average N-H bond energy in $\text{NH}_3(\text{g})$ using the data below.

$$\Delta H_f^\ominus \text{ of } \text{NH}_3(\text{g}) = -46 \text{ kJ mol}^{-1}$$

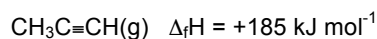
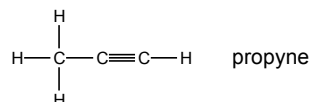
$$\text{Bond enthalpies: } \text{N}=\text{N} = 944; \text{H}-\text{H} = 436 \text{ kJ mol}^{-1}$$

- 3) Calculate the C=C bond energy in ethene using the data below.



$$\text{Bond enthalpies: } \text{C}-\text{C} = 348; \text{H}-\text{H} = 436; \text{C}-\text{H} = 412 \text{ kJ mol}^{-1}$$

- 4) Calculate the C≡C bond enthalpy in the gas propyne using the bond enthalpy values in the table above and the enthalpy changes for the reactions shown below.



- 5) Calculate the average S-F bond energy in $\text{SF}_6(\text{g})$ using the bond data in the table, the $\Delta_f H$ of $\text{SF}_6(\text{g})$ which is $-1100 \text{ kJ mol}^{-1}$, and



- 6) Calculate $\Delta_f H$ for bromomethane, $\text{CH}_3\text{Br}(\text{g})$, given the bond data in the table and

