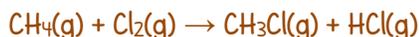


AS 91164 Demonstrate understanding of bonding, structure, properties and energy changes
Help Sheet for the Energy Calculations I

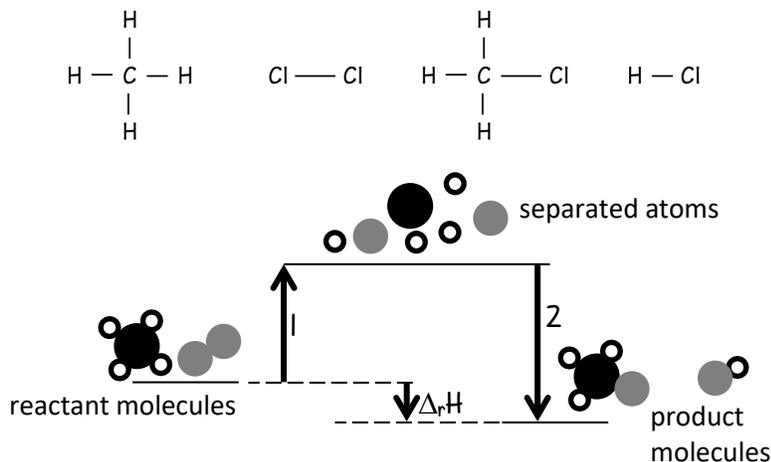
Questions involving bond enthalpies e.g. questions that look like....

Chlorine reacts with methane to form chloromethane and hydrogen chloride, as shown in the equation below.



Use the bond enthalpies opposite to calculate $\Delta_r H^\circ$ for this reaction.

Consider the species involved in the reaction.



1. Bond breaking (endothermic)
2. Bond making (exothermic)

We are trying to find $\Delta_r H$.

Average bond enthalpies have the units of kJ mol^{-1} .

They show the energy required to break 1 mol of a particular bond.

Bond	Bond enthalpy / kJ mol^{-1}
H-Cl	431
C-H	414
C-Cl	324
Cl-Cl	242

Average bond enthalpies are always listed as + numbers.

You will need to decide if the value is + or - depending upon whether bonds are being broken (+) or formed (-).

$$\Delta_r H^\circ = \sum(\text{bonds broken}) + \sum(\text{bonds formed})$$

where \sum means "the sum of"

Before CH_4 and Cl_2 can react, 4 x C-H bonds and 1 x Cl-Cl bond have to be broken. Then 3 x C-H, 1 x C-Cl and 1 x H-Cl bonds need to be made/formed.

Bonds broken (Note: values are positive as bond breaking)

- 4 x C-H 414 x 4
- Cl-Cl 242
- $\sum(\text{bonds broken}) = 1656 + 242 = 1898$

Bonds made/formed (Note: values are negative as bond making; you must include the sign!)

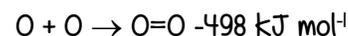
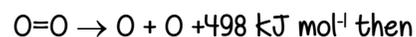
- 3 x C-H -414 x 3
- C-Cl -324
- H-Cl -431
- $\sum(\text{bonds formed}) = -1242 + -324 + -431 = -1997$

$$\Delta_r H^\circ = \sum(\text{bonds broken}) + \sum(\text{bonds formed})$$

$$\Delta_r H^\circ = 1898 + -1997$$

$$\Delta_r H^\circ = -99.0 \text{ kJ mol}^{-1} \text{ (3 s.f.)}$$

To break bonds is endothermic; to make the same bonds is exothermic e.g if



Of course in this example opposite you could also choose to only look at the bonds that are changing in the reaction.

E.g.

- break 1 x C-H and 1 x Cl-Cl
- make 1 x C-Cl and 1 x H-Cl.

It would give you the same answer of $\Delta_r H^\circ = -99.0 \text{ kJ mol}^{-1}$. Either method is fine.

Sometimes we might need to rearrange the formula.

$$\Delta_r H^\circ = \sum(\text{bonds broken}) + \sum(\text{bonds formed})$$

Looking at some past papers.....

2014: Hydrogen gas, $\text{H}_2(\text{g})$, reacts with oxygen gas, $\text{O}_2(\text{g})$, as shown by the following equation



Given the average bond enthalpies in the table below, calculate the average bond enthalpy of the O-H bond in H_2O .

Bond	Average bond enthalpy / kJ mol^{-1}
H - H	436
O = O	498

Rearrange to give; $\sum(\text{bonds formed}) = \Delta_r H^\circ - \sum(\text{bonds broken})$

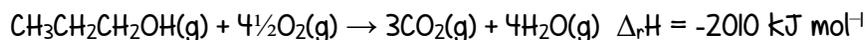
$$\sum(\text{bonds formed}) = -242 - (436 + 498/2) = -927 \text{ kJ}$$

Don't forget the bonds formed are 2 x O-H in H_2O so divide by 2 to find O-H bond enthalpy. $-927 \div 2 = -464$ (3 s.f.)

So the average bond enthalpy of O-H bond is 464 kJ mol^{-1} . (Written as + value like all average bond enthalpies).

Here is a harder one!!

The equation for the combustion of propan-1-ol is:



Calculate the bond enthalpy for the C=O bond, using the enthalpy of the reaction above and the bond enthalpy data in the table.

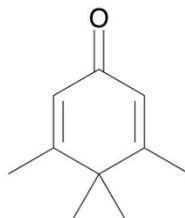
Bond	Bond enthalpy / kJ mol^{-1}
C-H	+414
C-O	+358
O=O	+498
C-C	+346
O-H	+463

Strategy to solve

- Draw out $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ and work out all the bonds broken
- Calculate energy for bonds broken in $4\frac{1}{2}\text{O}_2$ ($4.5 \times +498$)
- $\sum(\text{bonds formed}) = \Delta_r H^\circ - \sum(\text{bonds broken})$
- Calculate energy for bonds made in $4\text{H}_2\text{O}$ ($4 \times \text{H-O-H}$); this will be $8 \times \text{O-H}$ bonds which will be $8 \times -463 \text{ kJ}$
- You have calculated $\sum(\text{bonds formed})$; subtract energy for bonds made in $4\text{H}_2\text{O}$ and you will find energy for bonds made in 3CO_2 ($3 \times \text{O=C=O}$), which is, of course, $6 \times \text{C=O}$ bonds.
- Divide by 6 to find bond energy for one C=O bond. Answer is 826 kJ mol^{-1} (3 s.f.) (Written as + value like all average bond enthalpies).



Penguin



Penguinone