Chem Factsheet

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Why Students Lose Marks: AS Energetics

This Factsheet analyses students' answers to AS exam questions on Energetics. By the end of this Factsheet, you should be more confident about:

- What the examiners want
- The kinds of things you are likely to be asked
- Common mistakes and misunderstandings

As you read the students' answers to the questions and the comments, try to work out what the student should have done - using the hints and comments if necessary - before you read the markscheme. NB: this Factsheet is **not** intended to teach you energetics for the first time - this is covered in Factsheets 8 and 65.

What do you have to know?

In this type of question, the examiner is trying to assess whether you can:

- understand and explain what is meant by the various enthalpy changes;
- recall definitions accurately and precisely;
- understand and apply Hess's law;
- calculate $\Delta H^{\ominus}$ directly from experimental results, and understand why the value may be different to theoretical results,

For some examination boards, you will also have to

- draw enthalpy level diagrams and reaction profiles.

In any question involving **calculation**, there are likely to be marks available for showing a clear **method.** If you have to use one answer in the next part of the question, there are likely to be "error carried forward" marks available - so you are only penalised once for a wrong answer. Also note that you may be asked to use other skills such as writing balanced equations and simple moles calculations.

(a) Define *standard enthalpy of formation*

The enthalpy change when a compound is formed from its elements [3]

×✓× The student understands what the term means, and gains 1 mark for "formed from its elements". S/he should have realised that this was not enough for 3 marks - there is no real attempt to be precise in giving the definition - how much of the compound is formed? what state are the elements in? what conditions are used?

The table below gives some data on enthalpies of formation

Substance	O_2(g)	CO_2(g)	H_2O (l)	C_2H_6(g)
$\Delta H^{\ominus}_f$ /kJmol^{-1}	0	-394	-286	-85

(b) Why is the enthalpy of formation of oxygen gas zero?

Because it is an element [1]

*✓ Correct - an element in its standard state always has zero enthalpy of formation. Although the mark was awarded, the candidate should really have referred to "standard state" as well - for example, the enthalpy of formation of **gaseous** carbon would not be zero.*

(c) Use the data from the table to calculate the enthalpy change for the following reaction:

$$2C_2H_6(g) + 7\,O_2(g) \rightarrow 4CO_2(g) + 6H_2O\,(l)$$

$\Delta H^{\ominus}_f$ (reactants) = 2 × -85 = -170

$\Delta H^{\ominus}_f$ (products) = 4 × -394 + 6 × -286 = -3292

$\Delta H^{\ominus}$ = -170 – -3292 = 3122 kJ mol [3]

××× The calculations of $\Sigma\Delta H^{\ominus}_f$ for products and reactants were correct, but the correct equation to calculate $\Delta H^{\ominus}$ is $\Delta H^{\ominus} = \Sigma\Delta H^{\ominus}_f$ (products) - $\Sigma\Delta H^{\ominus}_f$ (reactants)
The student would have lost two of the three marks for using this the wrong way round (and hence getting the wrong sign for $\Delta H^{\ominus}$).
The final mark is lost for incorrect units - it is kJ mol^{-1}, not kJmol.

(d) Hence write down the standard enthalpy of combustion of ethane 3122 [1]

× This equation and value refer to 2 moles of ethane, not 1. If the student had halved his/her incorrect answer to (c), this mark would have been awarded as a "follow through". However, the student should have realised at this stage that the sign of their answer could not be correct - the enthalpy of combustion of a fuel like ethane must be negative.

Markscheme

(a) the enthalpy change when one mole of a compound (1) is formed from its constituent elements (1) in their standard state (1) under standard conditions

(b) because it is an element (1)

(c) $\Delta H^{\ominus} = \Sigma\Delta H^{\ominus}_f$(products) - $\Sigma\Delta H^{\ominus}_f$(reactants) (or enthalpy cycle) (1)
4 × -394 + 6 × -286 – 2 × -85 (1 - also award first mark if this is seen)
=-3122 kJ mol^{-1} (1)
Max 1 mark for incorrect sign. Penalise incorrect units; ignore no units

(a) State Hess's Law

energy change in a reaction only depends on the initial and final states, not the route taken .... [2]

✗✓ *The student has the general idea, but has made one crucial mistake - you must refer to "enthalpy change" or "heat energy change" rather than "energy change".*

Sucrose ($C_{12}H_{22}O_{11}$) reacts with oxygen to form carbon dioxide and water

$$C_{12}H_{22}O_{11}\,(s) + 12\,O_2(g) \rightarrow 12CO_2(g) + 11H_2O\,(l)$$

(b) Write a balanced chemical equation to represent the formation of 1 mole of sucrose from its constituent elements in their standard states

$12C + 11H_2 + 5½O_2 \rightarrow C_{12}H_{22}O_{11}$ .... [2]

✓✗ *This is the correct equation, correctly balanced - but state symbols were needed to indicate that the elements were in their standard states.*
Note that "follow through" marks would have been awarded in part (c) if an incorrect equation had been produced here.

(c) Use the enthalpy of combustion data given below to determine the enthalpy of formation of sucrose

Substance	C(s)	H_2(g)	$C_{12}H_{22}O_{11}$ (s)
$\Delta H^\ominus_c$ / kJmol^{-1}	-393.5	-285.8	-4098

$$\begin{tikzcd}
12C + 11H_2 + 5½O_2 \arrow[rr, "\Delta H^\ominus_f"] \arrow[dr, "12\,\Delta H^\ominus_c(C) + 11\Delta H^\ominus_c(H_2)"'] & & C_{12}H_{22}O_{11} \arrow[dl, "\Delta H^\ominus_c(C_{12}H_{22}O_{11})"] \\
& 12CO_2 + 11H_2O &
\end{tikzcd}$$

$\Delta H^\ominus_f = 12\,(-393.5) + 11(-285.8) -4098 = -11963.8\ kJmol^{-1}$ .... [3]

✓✗✗ *The first mark is awarded for the correctly drawn enthalpy cycle. Unfortunately the remaining two marks are lost due to the mistake in writing "–4098" rather than "– -4098" as is required, as we are going against the direction of the arrow. This could just be an arithmetic slip, but it could also indicate a lack of understanding of how to use the enthalpy cycle.*
The implausibly large negative value of $\Delta H^\ominus_f$ should have alerted the student to the fact there was something wrong

Markscheme

(a) the enthalpy change (1) for a reaction is independent of the route taken (1) (or depends only on initial and final state)

(b) $12C(s) + 11H_2(g) + 5½O_2(g) \rightarrow C_{12}H_{22}O_{11}\,(s)$ (1) correct formulae and balanced (1) correct state symbols

(c) $\Delta H = \Sigma\Delta H^\ominus_c$(reactants) - $\Sigma\Delta H^\ominus_c$ (products) (1) (or enthalpy cycle)

$\Delta H = 12 \times -393.5 + 11 \times -285.8 - -4098$ (1 - also award first mark if this is seen)

= -3767.8 kJmol^{-1} (1)

Positive answer scores 2 marks; if other incorrect answer given, correct signs and multipliers score 2 marks.

A student added 30cm^3 of sodium hydroxide to 30 cm^3 of hydrochloric acid in a polystyrene cup. The concentration of each solution was 2 mol dm^{-3}. The temperature rose by 6.3° C.

(a) Calculate the enthalpy change for this reaction. (The final solution has a specific heat capacity of 4.18 J g^{-1}K^{-1} and a density of 1.00 g cm^{-3}.)

$\Delta H^\ominus = mc\Delta T = 60 \times 4.18 \times 6.3 = 1580$ .... [2]

✓✗ *The calculation is correct (although the units - joules - were not given). However, the sign is incorrect - since the reaction is exothemic, the enthalpy change is negative*

(b) Calculate the molar enthalpy change for this reaction

moles of NaOH = $0.03 \times 2 = 0.06$

molar enthalpy change = $1580 \div 0.06 = 26333$ kJmol^{-1} .... [3]

✓✓✗ *The calculation is largely correct, and no marks are deducted for carrying forward the sign error from part (a). However, the units given in the final answer are incorrect - since the answer in (a) was given in joules, this answer is also in joules. To convert to kJ, it should be divided by 1000.*

(c) Explain why this is likely to be less than the theoretical value given in data books

Some heat will be lost from the cup .... [1]

✓ *Correct. This is a common question; the other possible answer in many cases is that the reaction may not have completed.*

Markscheme

(a) $\Delta H^\ominus = -60 \times 4.2 \times 6.3 = -1580$ J (or -1.580 kJ) (1 - value 1 - sign)

(b) Moles of NaOH or HCl = $0.03 \times 2 = 0.06$ (1)

Molar enthalpy change = answer to (a)/ 0.06 (1 ecf) = -26.33 kJ mol^{-1} (1 ecf - penalise incorrect units)

(c) Heat loss (1)

(a) Explain the term *mean bond enthalpy*

the average energy required to break a covalent bond [2]

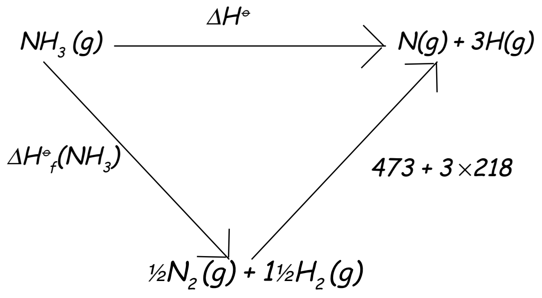
✓✗ *Since the question says "Explain", it is necessary to say that the actual energy required varies between compounds, and hence an average is used*

(b) (i) Use the data given below to find the enthalpy change for the reaction $NH_3(g) \rightarrow N(g) + 3H(g)$

Data: $\frac{1}{2}H_2(g) \rightarrow H(g) \quad \Delta H^\ominus = +218\ kJmol^{-1}$

$\frac{1}{2}N_2(g) \rightarrow N(g) \quad \Delta H^\ominus = +473\ kJmol^{-1}$

$\Delta H_f(NH_3) = -46\ kJmol^{-1}$



✓✗✓✗ *First mark awarded for correct species in the cycle. However, the arrow for $\Delta H^\ominus_f$ of ammonia is in the wrong direction, losing the second mark for the cycle. The first mark for calculation is given for the correct multipliers (473 + 3 × 218) but the final mark is not awarded, as it should be +46 not -46*

$\Delta H^\ominus = -46 + 473 + 3 \times 218 = 1081\ kJ\ mol^{-1}$ [4]

(ii) Deduce a value for the mean bond enthalpy of an N - H bond in ammonia

$1081 \div 3 = 360\ kJ\ mol^{-1}$ ✓ *Mark awarded (error carried forward)* [1]

(c) The mean bond enthalpy for the N - H bond given in data books is 391 $kJmol^{-1}$. Comment on this.

There are errors in the calculations ✗ [1]

This is never a sensible answer! The key point is that the bond enthalpy has slightly different values in different compounds - the data book figure is a mean across all compounds containing N - H bonds - so it is surprising if it is exactly the same as the answer obtained

Markscheme

(a) The energy required to break a specific covalent bond (1) varies between compounds, so an average is used (1)

(b) (i) Enthalpy cycle (or equivalent) with correct species (1)

Entire cycle correct (1)

$\Delta H^\ominus = 46 + 473 + 3 \times 218$ (1)

$= 1173\ kJ\ mol^{-1}$ (1)

(ii) $1173/3 = 391\ kJmol^{-1}$ (1 ecf)

(c) Would expect it to be slightly different from the calculated value for the bond in ammonia, as it is an average across all compounds (1)

(*allow reasonable comment explaining difference if (b) (ii) is incorrect)*

Practice Question

(a) What is the meaning of the term *enthalpy change?* [2]

(b) (i) Define the *standard enthalpy of combustion* [3]

(ii) Write an equation corresponding to the standard enthalpy of combustion of ethanol (C_2H_5OH) [2]

(c) Using the mean bond enthalpy data below, calculate a value for the enthalpy of combustion of ethanol [4]

Bond	Mean bond enthalpy
C–H	$+412\ kJmol^{-1}$
C–C	$+348kJmol^{-1}$
C=O	$+805kJmol^{-1}$
O=O	$+496kJmol^{-1}$
O–H	$+463kJmol^{-1}$
C–O	$+360kJmol^{-1}$

(d) In an experiment, the combustion of 0.36 grammes of ethanol produced a temperature rise of 17°C in 100cm³ of water. Use these data to calculate a value for the standard enthalpy of combustion of ethanol [4] (density of water=$1gcm^{-3}$. Specific heat capacity of water = $4.2\ Jg^{-1}K^{-1}$)

(e) Comment on the difference between your two calculated values

Markscheme

(a) heat energy change (1) measured at constant pressure (1)

(b) (i) the enthalpy change when one mole of a compound (1) is completely burnt in oxygen (1) under standard conditions (1)

(ii) $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

(1 correct balanced equation, 1 state symbols)

(c) $\Delta H^\ominus = \Sigma$ bonds broken - Σ bonds formed (1)

Bonds broken: 348 + 5(412) + 360 + 463 + 3(496) (1)

Bonds formed: 4(805) + 6(463) (1)

$\Delta H^\ominus = 4719 - 5998 = -1279\ kJmol^{-1}$ (1)

(d) $\Delta H^\ominus = mc\Delta T = 100 \times 4.2 \times 17$ (1) = 7140J = 7.14 kJ

Moles of ethanol = 0.36/46 = 0.00783 (1)

Standard enthalpy of combustion = 7.14/0.00783 (1)

$= 910\ kJmol^{-1}$(1)

(e) Difference due to heat loss in experiment (1)

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