Access Tuition

A-Level Chemistry

Hess's Law

Mark Scheme

Time available: 61 minutes
Marks available: 58 marks

1. (a) **M1** The enthalpy / heat energy change when 1 mol (of a substance / compound / product) is formed from its (constituent) elements

__M1__ energy change is not sufficient – must refer to enthalpy change or heat energy change

1

M2 with (all) reactants and products / all substances in standard states

__M2__ or with (all) reactants and products / substances in normal states under standard conditions / 100 kPa and any specified temperature (usually 298 K)

Ignore reference to 1 atmosphere

If enthalpy of combustion given rather than formation, then mark __M1__ and __M2__ independently, and __M2__ could score.

1

(b) **M1** ΔH = [sum $\Delta_f H$ products] **–** [sum $\Delta_f H$ reactants]

or –114 = [3(–130) – 972] – [3X – 339]

or 3X = 3(–130) – 972 + 339 + 114

–303 scores 3 marks (+303 scores 2 marks)

–909 scores 2 marks (+909 scores 1 mark)

ignore units

1

M2 3X = –909

__M2__ No ECF from __M1__ __(__except +909 or arithmetic error)

1

M3 X = –303 (kJ mol^{-1})

__M3__ ECF from __M2__, ie __M3__ ÷ 3

1

(c) **M1** provides energy to break (covalent) bond in chlorine / Cl_2 or to form chlorine free radicals

1

M2 $CH_3CH_2CH_3$ + •Cl → •$CH_2CH_2CH_3$ + HCl

1

M3 $\bullet CH_2CH_2CH_3 + Cl_2 \rightarrow ClCH_2CH_2CH_3 + \bullet Cl$

__M2__ and __M3__:

- *must show structure of $\bullet CH_2CH_2CH_3$ in at least one of the equations to score both marks (dot must be on or around the end CH_2 group), but only penalise $\bullet C_3H_7$ once across both equations if both equations otherwise correct*
- *on this occasion, molecular formula of propane can be allowed for __M2__*
- *on this occasion, molecular formula of 1-chloropropane can be allowed for __M3__*
- *penalise absence of radical dots once*
- *allow equations in either order*

1

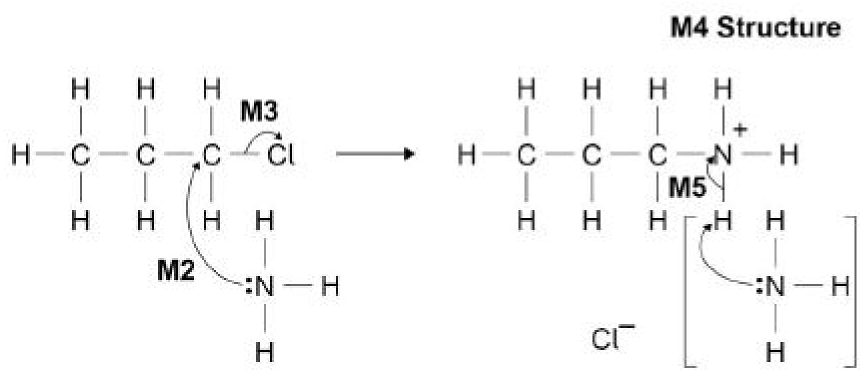
(d) the ability/power of atom to attract/withdraw the 2/pair of electrons in a covalent bond

allow nucleus in place of atom

1

(e) **M1** nucleophilic substitution

1



M2 curly arrow from lone pair on N of NH_3 to the correct C atom

Penalise __M2__ if negative charge on ammonia

1

M3 must show the movement of a pair of electrons from the C−Cl bond to the Cl atom; mark **M3** independently provided it is from their original molecule

Penalise __M3__ for formal charge on C and/or Cl of C–Cl or incorrect partial charges on C–Cl; ignore other partial charges on uncharged atoms

Penalise __M3__ for any additional arrow(s) to/from the Cl to/from anything else

1

M4 is for the structure of the alkylammonium ion, which could be a condensed formula; a positive charge must be shown on, or close to, the N atom

1

M5 is for an arrow from the N−H bond to the N atom

*The second molecule of NH_3 is not essential for **M5**, but penalise **M5** if used incorrectly (but only penalise once in **M2** and **M5** for negative charge on ammonia)*

1

<u>SN1 mechanism alternative</u> (loss of Cl first followed by attack by NH_3) :

***M2** curly arrow from C–Cl bond to the Cl*

***M3** curly arrow from lone pair of NH_3 to correct C on the correct carbocation*

[14]

2. (a)

M1 moles cyclohexane = $\frac{192.730-192.100}{84(.0)}$ or $\frac{0.630}{84(.0)}$ (= 0.00750)

Correct answer scores 4 marks

1

M2 heat released = 1216 x 1000 x 0.0075 (= 9120) (J)
[or 1216 x 0.0075 = (9.12) (kJ)]

*0.0075 scores **M1** with or without working*

*9120 or 9.12 scores **M1** and **M2** with or without working*

1

M3 $\Delta T \left(= \frac{q}{mc} = \frac{9120}{50(.0) x 4.18}\right)$ = 43.6

Allow ECF at each stage

*correct **M3** scores **M1** and **M2***

1

M4 final temperature = 19.1 + **M3** = 62.7 or 63 (°C)

1

Alternative **M3/4**

M3 9120 = 50 × 4.18 × (Final T – 19.1)

M4 Final T = 62.7 or 63 (°C)

*Ignore negative sign for q in **M2** and/or ΔT in **M3**, but penalise if used as a temperature fall in **M4** (if alternative method used for **M3/4** and negative value for q is used, allow **M3** for expression with negative q value but do not allow **M4**)*

(temperatures to at least 2sf)

*If candidates use a value in kJ rather than J to find ΔT / final T then they lose **M3**, but ECF to **M4** [e.g. 9.12 rather than 9120 giving ΔT = 0.0436 and final temperature = 19.1(436) – this would give 3 marks]*

*If candidates use 0.63 g for m in **M3**, they will get ΔT = 3.46 and final temperature = 22.56 – this would give 3 marks]*

*Cannot score **M2** using moles = 1*

(b) thermal energy / heat loss or

or idea of heat being transferred to calorimeter

incomplete combustion or

allow idea that it is not under standard conditions

evaporation

allow no lid / poor/no insulation

1

(c) **M1** 6 × (–394), 6 × (–286) and –3920

1

M2 (ΔH =) [6 × (–394)] + [6 × (–286)] + 3920
(or (ΔH =) [–2364)] + [–1716)] + 3920)
(or (ΔH =) –4080 + 3920)

1

M3 = –160 (kJ mol–1)

1

–160 scores 3 marks; +160 scores 2 marks

–8000 scores 2 marks; +8000 scores 1 mark

–1876 scores 2 marks; +1876 scores 1 mark

***M1** is for correct coefficients, i.e. 6 × $\Delta_c H$ H_2 & 6 × $\Delta_c H$ C & 1 x $\Delta_c H$ C_6H_{12} (ignore whether + or –)*

*ECF from **M1** to **M2**/3 for incorrect coefficients / arithmetic error / transposition*

*ECF from **M2** to **M3** for use of products – reactants*

Ignore any cycle

[8]

3. (a) $2Fe(s) + \frac{3}{2}O_2(g) \longrightarrow Fe_2O_3(s)$ ONLY

Don't allow multiples. States must be shown

1

(b) M1 Correct cycle or equation

If M1 and M2 not awarded then M3 can be awarded for their M2 divided by 3

1

M2 $(3 \times \Delta_f HCO_2) = -19 + (-822) + 3(-111) - 0$

$(3 \times \Delta_f HCO_2) = -1174$

1

M3 $\Delta_f HCO_2 = -391$ kJ mol^{-1}

−317 for 1 mark

+391 for 1 mark

1

Allow 2 sig fig or more

(c) M1 Correct Hess's law cycle or equation

If M1 and M2 not awarded then M3 can be awarded for their M2 divided by 6

1

M2 (6(N−H)) = 944 + 3(+436) + 92

(6(N−H)) = 2344

−391 for 1 mark

1

M3 N−H = (+)391 kJ mol^{-1}

1

Allow 2 sig fig or more

(d) Data book value derived from (a number of) different compounds (not just different NH_3 molecules)

1

[8]

4. (a) $C(s) + 2F_2(g) \longrightarrow CF_4(g)$

State symbols essential

1

(b) Around carbon there are 4 bonding pairs of electrons (and no lone pairs)

1

Therefore, these repel equally and spread as far apart as possible

1

(c) $\Delta H = \Sigma\ \Delta_f H$ products – $\Sigma\ \Delta_f H$ reactants or a correct cycle

1

Hence = (2 × –680) + (6 × –269) – (x) = –2889

1

x = 2889 – 1360 – 1614 = –85 (kJ mol^{-1})

1

Score 1 mark only for +85 (kJ mol^{-1})

(d) Bonds broken = 4(C–H) + 4(F–F) = 4 × 412 + 4 × F–F

Bonds formed = 4(C–F) + 4(H–F) = 4 × 484 + 4 × 562

Both required

1

–1904 = [4 × 412 + 4(F–F)] – [4 × 484 + 4 × 562]

4(F–F) = –1904 – 4 × 412 + [4 × 484 + 4 × 562] = 632

1

F–F = 632 / 4 = 158 (kJ mol^{-1})

1

The student is correct because the F–F bond energy is much less than the C–H or other covalent bonds, therefore the F–F bond is weak / easily broken

Relevant comment comparing to other bonds

(Low activation energy needed to break the F–F bond)

1

[10]

5. (a) (i) **M1 (could be scored by a correct mathematical expression which <u>must</u> have <u>all</u> Δ*H* symbols and the ∑ or SUM)**

Correct answer gains full marks

Credit 1 mark ONLY if ***–122*** *(kJ mol^{-1})*

M1 $\underline{\Delta H = \sum \Delta H_f\ (\textbf{products}) - \sum \Delta H_f\ (\textbf{reactants})}$

OR a <u>correct cycle of balanced equations</u>

M2 $\underline{\Delta H}$ = 3(−394) − 3(−111) − (−971)
(This also scores M1)

M3 = **<u>(+) 122</u>**(kJ mol^{-1})

Award 1 mark ONLY for –122

For other incorrect or incomplete answers, proceed as follows

- *check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**)*
- *If no AE, check for correct method; this requires either a correct cycle of balanced equations OR a clear statement of **M1** which could be in words and scores **<u>M1 only</u>***

3

(ii) By definition

Ignore reference to "standard state"

OR

Because it is an element / elemental

1

(b) (i) $TiO_2 + \mathbf{2}Cl_2 + \mathbf{2}C \longrightarrow TiCl_4 + \mathbf{2}CO$

Allow multiples

OR

$TiO_2 + \mathbf{2}Cl_2 + C \longrightarrow TiCl_4CO_2$

Ignore state symbols

M1 use of Cl_2 <u>and</u> C

M2 a correct balanced equation

2

(ii) $TiCl_4 + \mathbf{4}Na \longrightarrow Ti + \mathbf{4}NaCl$

Allow multiples

OR

$TiCl_4 + \mathbf{2}Mg \longrightarrow Ti + \mathbf{2}MgCl_2$

Ignore state symbols

M1 use of Na ***OR*** Mg

M2 a correct balanced equation

2

(c) (i) $\mathbf{4}\ FeCr_2O_4 + \mathbf{8}\ Na_2CO_3 + \mathbf{7}O_2 \longrightarrow \mathbf{8}Na_2CrO_4 + 2Fe_2O_3 + 8CO_2$

Allow multiples

Ignore state symbols

1

(ii) $Cr_2O_3 + \mathbf{2}Al \longrightarrow Al_2O_3 + \mathbf{2}Cr$

Allow multiples

Ignore state symbols

1

[10]

6. (a) They are elements **(1)**

Ignore irrelevant comments

1

(b) Enthalpy <u>change</u> **(1)**

or heat energy change or heat change or ΔH or any named enthalpy change C.E. if change not mentioned

Independent of route **(1)**

OR depends on initial and final <u>states</u>
Only give second mark if first mark awarded except allow if energy used instead of enthalpy

2

(c) $\Delta H = \Sigma\Delta H_f^{\ominus}(\text{products}) - \Sigma\Delta H_f^{\ominus}(\text{reactants})$ **(1) (Or a cycle)**

$= 2 \times -242 + \frac{1}{2} \times -394 - (-365)$ **(1) (also implies first mark)**

$= -316\ \text{kJ mol}^{-1}$ **(1)**

3

Ignore no units penalise wrong units
+316 scores 1/3

[6]