A-Level Chemistry

Bond Enthalpies

Mark Scheme

Time available: 66 minutes
Marks available: 63 marks

1.

(a) Heat (energy) change at constant pressure

allow transfer for change

1

(b) **M1** correctly showing how many of which types of bonds are broken / made

(broken) 2(C–C) + 8(C–H) + 5(O=O) *(5776 + 2(C-C))*

***M1** is for identifying the number and type of bonds broken / made (does not have to explicit if they are broken or made, it is just which bonds and the number of each)*

(made) 6(C=O) + 8(O–H) *(8162)*

1

M2 including 4(41) for vaporisation of water

***M2** is for including 4(41) in some way in the calculation*

1

M3 2(C–C)

= 6(C=O) + 8(O–H) + 4(41) – 2046 – 8(C–H) – 5(O=O)

= 6(743) + 8(463) + 4(41) – 2046 – 8(412) – 5(496)

= 504

***M3** is for calculating total for C-C bonds; allow 340 for 2 marks for omitting 4(41)*

1

M4 (C–C) = $\frac{\mathbf{M3}}{2}$ = 252 (kJ mol^{-1})

***M4** is for dividing their **M3** by two (ie allow ECF from **M3** to **M4**; ECF for 3(C-C) to divide their **M3** by three)*

252 scores 4

170 scores 3 (omits vaporisation of water)

168 scores 3 (3 C-C bonds)

113 scores 2 (3 C-C bonds & omits vaporisation of water)

88 scores 3 (vaporisation of water on wrong side)

Ignore units

1

(c) Oxygen / O_2 is the only substance that has O=O bond

1

[6]

2.

(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 $(3 \times \Delta_f H CO_2) = -19 + (-822) + 3(-111) - 0$

$(3 \times \Delta_f H CO_2) = -1174$

1

M3 $\Delta_f H CO_2 = -391$ 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]

3. (a) $C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$

1 mark for correct formulae and balancing

1

1 mark for all correct state symbols

1

(b) (Standard) enthalpy of formation

1

Difficult to prevent C reacting with O_2 to form some CO_2

1

(c) $\Delta H = \Sigma \Delta H_c$ reactants − $\Sigma \Delta H_c$ products or a correct cycle

1

OR $\Delta H = -393-(-283)$

$\Delta H = -110$ (kJ mol$^{-1)}$

1

(d) Correctly drawn Hess's law cycle

1

4 (Xe–F) = 252 + (2 × 158) = 568

Xe–F = 568 / 4

1

Xe–F = 142 (kJ $mol^{-1)}$)

1

(e) Mean bond enthalpy found by taking an average for Xe–F in a range of compounds

1

[10]

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) The enthalpy (change) to break 1 mol of H—O / bonds

Allow heat energy

1

Averaged over a range of compounds / molecules

Penalise energy but mark on

ignore states

CE = 0 for ionic bonds

1

(b) $H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$

ΔH = (H−H) + $\frac{1}{2}$(O = O) − 2(H−O) / sum of (bonds broken) − sum of (bonds formed)

1

= 436 + 496 / 2 − 2 × 464

1

= −244 (kJ mol^{-1})

Allow 1 mark only for +244 and −488

Units not essential but penalise incorrect units

1

(c) (i) same reaction / same equation / same number / same reactants and same products / same number and type of bonds broken and formed

Do not allow similar

1

(ii) There must be a slight difference between the actual bond enthalpy (in water) and mean bond enthalpies for the O−H bond (in other molecules)

Allow bond enthalpy value for enthalpy of formation may not be under standard conditions.

Allow reference to bond energy rather than bond enthalpy

Do not allow heat loss or experimental error

Do not allow mean bond enthalpies are not accurate

1

[7]

6. (a) (i) ΔH = Σ bonds broken –Σ bonds formed

1

= 944/2 + 3/2 × 436 –3 × 388

1

= –38 (kJ mol^{-1})

ignore units even if incorrect

correct answer scores 3

–76 scores 2/3

+38 scores 1/3

1

(ii) mean / average bond enthalpies are from a range of compounds
or
mean / average bond enthalpies differ from those in a single compound / ammonia

1

(b) $\Delta S = \Sigma S$ products $- \Sigma S$ reactants

1

$= 193 - (192/2 + 131 \times 3/2)$

1

$= -99.5$ J K^{-1} mol^{-1}

units essential for M3

correct answer with units scores 3

–199 J K^{-1} mol^{-1} & –99.5 score 2/3

–199 and + 99.5 J K^{-1} mol^{-1} score 1/3

1

(c) (i) $\Delta G = \Delta H - T\Delta S = -46 + 800 \times 99.5/1000$

mark is for putting in numbers with 1000

if factor of 1000 used incorrectly CE = 0

1

= 33.6 or 33600

allow 33 to 34 (or 33000 to 34000)

1

kJ mol^{-1} with J mol^{-1}

correct units for answer essential

if answer to part (b) is wrong or if -112 used, mark consequentially e.g.

- *–199 gives 113 to 114 kJ mol^{-1} (scores 3/3)*
- *–112 gives 43 to 44 kJ mol^{-1} (scores 3/3)*

1

(ii) If answer to (c) (i) is positive: not feasible / not spontaneous

If answer to (c) (i) is negative: feasible / spontaneous

if no answer to (c) (i) award zero marks

1

[11]

7. (a) Equation $1/2N_2 + 3/2H_2 \rightarrow NH_3$

1

$\Delta Hf = [(945 \times 0.5) + (426 \times 1.5)] - (391 \times 3)$

1

$= -46.5$ kJ mol^{-1}

1

Mark Range	The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of QWC but the candidates' QWC in this answer will be one of the criteria used to assign a level and award the marks for this part of the question **Descriptor** an answer will be expected to meet most of the criteria in the level descriptor
4-5	– claims supported by an appropriate range of evidence – good use of information or ideas about chemistry, going beyond those given in the question – argument well structured with minimal repetition or irrelevant points – accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling
2-3	– claims partially supported by evidence – good use of information or ideas about chemistry given in the question but limited beyond this – the argument shows some attempt at structure – the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling
0-1	– valid points but not clearly linked to an argument structure – limited use of information or ideas about chemistry – unstructured – errors in spelling, punctuation and grammar or lack of fluency

(b) The higher the temperature the faster the reaction QWC

1

but, since the reaction is exothermic

1

the equilibrium yield is lower QWC

1

The higher the pressure the greater the equilibrium yield QWC

1

because there is a reduction in the number of moles of gas in the reaction

1

but higher pressure is expensive to produce or plant is more expensive to build QWC

1

A better catalyst would lessen the time to reach equilibrium

1

and allow more ammonia to be produced in a given time QWC

1

[11]