AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



MARK SCHEME

3.1.4 ENERGETICS

SCORE	PERCENTAGE
/1178	%

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Q1.

(a) $2Fe(s) + \frac{3}{2}O_2(g) \rightarrow Fe_2O_3(s)$ 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]

Q2.

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

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

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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]

Q3.

(a) The <u>enthalpy / heat energy change</u> when <u>1 mol</u> (of a substance)

If enthalpy of formation definition given CE=O

***NOT** just 'energy'*

***ALLOW** alternatives for substance e.g. molecule/compound/element*

1

Is <u>burned/reacts completely in oxygen</u>

***ALLOW** reacts in excess oxygen*

1

With all reactants and products in their <u>standard states</u>
OR
With all reactants and products in their normal states at 298K/given temp & 100kPa

***ALLOW** 'everything' for 'reactants and products'*

Penalise incorrect conditions if given

***ALLOW** 'normal states under standard conditions'*

1

(b) $\Delta H = \Sigma\Delta H_c$(reactants) - $\Sigma\Delta H_c$ (products)
OR
Correctly and fully balanced cycle

Correct answer scores 3

1

$\Delta H = [3(-394) + 4(-286)] – (-2010)$
OR
$\Delta H = -2326 + 2010$

M2 also scores M1

1

$\Delta H = -316$ (kJ mol^{-1})
+316 scores 1 mark only

***IGNORE** units*

Check for AE in working – can award M3 as ecf (error carried

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forward) from M2 if M2 not given due to AE

1

(c) ΔH/-1893 = ΣB(reactants) - ΣB(products)
OR
ΔH/-1893 = ΣBonds broken - ΣBonds formed
OR
ΔH/-1893 = 2B(C-C) + 7B(C-H) + B(C-O) + B(O-H) + 4½ B(O=O) – 6B(C=O) – 8B(O-H)

Correct answer scores 3

1

-1893= 2B(C-C) + 7(412) + 360 + 463 + 4½(496) – 6(805) – 8(463)
OR
-1893= 2B(C-C) +5939 – 8534
OR
-1893= 2B(C-C) -2595
OR
2B(C-C) = 702

M2 also scores M1

May see no 463 in bonds broken and 7x463 in made (gives 5476 – 8071)

1

B(C-C) = (+)351(kJ mol^{-1})

*If **NOT** 351 check for AE. This would lose M2, but could gain M1 and M3*

(+)234 scores 1 (due to 3(C-C))

***NOT** M3 from incorrect M2 unless incorrect M2 is due to AE*

***IGNORE** units*

If no other mark awarded then

***ALLOW** 1 if 5939 or 5476 or 8534 or 8071 seen*

1

[9]

Q4.

(a) (i) $\mathbf{2}C_6H_{12}O_6 \longrightarrow \mathbf{3}CH_3COCH_3 + \mathbf{3}CO_2 + \mathbf{3}H_2O$

Or multiples

1

(ii) to speed up the reaction
OR
(provide a) catalyst or catalyses the reaction or biological catalyst
OR
release / contain / provides an enzyme

Ignore "fermentation"

Ignore "to break down the glucose"

Not simply "enzyme" on its own

1

(b) (i) $CH_3CH(OH)CH_3 + [O] \longrightarrow CH_3COCH_3 + H_2O$

Any correct representation for the two organic structures. Brackets not essential.

Not "sticks" for the structures in this case

1

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(ii) Secondary (alcohol) OR 2° (alcohol)

1

(c) **M1** $q = m\ c\ \Delta T$

OR $q = 150 \times 4.18 \times 8.0$

Award full marks for correct answer

*In **M1**, do not penalise incorrect cases in the formula*

M2 = (±) 5016 (J) ***OR*** 5.016 (kJ) ***OR*** 5.02 (kJ)
(also scores M1)

M3 This mark is for dividing correctly the number of kJ by the number of moles and arriving at a final answer in the range shown.
Using 0.00450 mol

therefore ΔH = **− 1115** (kJ mol^{-1})

OR **− 1114.6 to − 1120** (kJ mol^{-1})

Range (+)1114.6 to (+)1120 gains 2 marks

BUT − 1110 gains 3 marks and +1110 gains 2 marks

AND − 1100 gains 3 marks and +1100 gains 2 marks

Award full marks for correct answer

*In **M1**, do not penalise incorrect cases in the formula*

*Penalise **M3** ONLY if correct numerical answer but sign is incorrect; **(+)1114.6 to (+)1120 gains 2 marks***

*Penalise **M2** for arithmetic error and mark on*

If $\Delta T = 281$; score $q = m\ c\ \Delta T$ only

*If c = 4.81 (leads to 5772) penalise **M2** ONLY and mark on for **M3** = − 1283*

*Ignore incorrect units in **M2***

*If units are given in **M3** they must be either kJ or kJ mol^{-1} in this case*

3

(d) **M1** The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / element

M2 is burned / combusts / reacts completely in oxygen
OR
burned / combusted / reacted in excess oxygen

M3 with (all) reactants and products / (all) substances in standard / specified states

OR
(all) reactants and products / (all) *substances in normal states under standard conditions* / 100 kPa / 1 bar and specified T / 298 K

*For **M3***

Ignore reference to 1 atmosphere

3

(e) **M1**

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$\underline{\Sigma \text{ B } \textbf{(reactants)} - \Sigma \text{ B } \textbf{(products)} = \Delta H}$

OR

$\underline{\text{Sum of bonds broken} - \text{Sum of bonds formed} = \Delta H}$

OR

2B(C−C) + B(C=O) + 6B(C−H) + 4B(O=O) (LHS)

− 6B(C=O) − 6B(O−H) (RHS) = $\underline{\Delta H}$

M2 (also scores **M1**)

2(348)+805+6(412)+4(496) [LHS = **5957**]

(696) (2472) (1984)

− 6(805) − 6(463) [RHS = (−) **7608**] = Δ*H*

(4830) (2778)

OR using only bonds broken and formed (**5152 − 6803**)

M3

Δ*H*= $\underline{\textbf{− 1651}}$ (kJ mol^{-1})

Candidates may use a cycle and gain full marks.

Correct answer gains full marks

Credit 1 mark for (+) 1651 (kJ mol^{-1})

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 / addition error; this would score 2 marks (**M1** and **M2**)*
- *If no AE, check for a correct method; this requires either a correct cycle with $4O_2$, $3CO_2$ and $3H_2O$ OR a clear statement of **M1** which could be in words and scores **only M1***

Allow a maximum of one mark if the only scoring point is LHS = 5957 (or 5152) OR RHS = 7608 (or 6803)

Award 1 mark for + 1651

3

(f) **For the two marks M1 and M2, any two from**

- heat loss or not all heat transferred to the apparatus or heat absorbed by the apparatus or (specific) heat capacity of the apparatus not considered
- incomplete combustion / not completely burned / reaction is not complete
- The idea that the water may end up in the gaseous state (rather than liquid)
- reactants and / or products may not be in standard states.
- MBE data refers to gaseous species but the enthalpy of combustion refers to liquids in their standard states / liquid propanone and liquid water in standard states
- MBE do not refer to specific compounds OR MBE values vary with different compounds / molecules OR are average / mean values taken from a range of compounds / molecules

Apply the list principle but ignore incomplete reasons that contain correct chemistry

Ignore "evaporation"

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Ignore "faulty equipment"

Ignore "human error"

Not enough simply to state that "MBE are mean / average values"

2

[15]

Q5.

(a) (i) M1 <u>c(oncentrated) phosphoric acid / c(onc.) H_3PO_4</u>
OR <u>c(oncentrated) sulfuric acid / c(onc.) H_2SO_4</u>

*In **M1**, the acid must be concentrated.*
Ignore an incorrect attempt at the correct formula that is written in addition to the correct name.

M2 Re-circulate / re-cycle the (unreacted) ethene (and steam) / the reactants
OR pass the gases over the catalyst several / many times

*In **M2**, ignore "remove the ethanol".*
Credit "re-use".

2

(ii) M1
(By Le Chatelier's principle) the equilibrium is <u>driven / shifts / moves to the right / L to R / forwards / in the forward direction</u>

M2 depends on a correct statement of M1
The <u>equilibrium moves / shifts to</u>

- <u>oppose the addition of / increased concentration of / increased moles / increased amount of water / steam</u>
- to <u>decrease the amount of steam / water</u>

Mark M3 independently
M3 Yield of product / conversion increase ***OR*** ethanol increases / goes up / gets more

3

(iii) M1 Poly(ethene) / polyethene / polythene / HDPE / LDPE

M2 At higher pressures
More / higher <u>cost</u> of electrical <u>energy to pump</u> / <u>pumping cost</u>
OR
<u>Cost</u> of higher pressure <u>equipment / valves / gaskets / piping etc</u>.
OR <u>expensive equipment</u>

*Credit all converse arguments for **M2***

2

(b) M1 for balanced equation

M2 for state symbols in a <u>correctly balanced equation</u>

$2C(s / graphite) + 3H_2(g) + ½O_2(g) \longrightarrow CH_3CH_2OH(l)$ (C_2H_5OH)

Not multiples but credit correct state symbols in a correctly balanced equation.

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Penalise C_2H_6O but credit correct state symbols in a correctly balanced equation.

2

(c) (i) M1 The <u>enthalpy change</u> / <u>heat change at constant pressure</u> when <u>1 mol</u> of a compound / substance / element

*If standard enthalpy of formation **CE=0***

M2 is <u>burned / combusts / reacts completely</u> in <u>oxygen</u>
OR <u>burned / combusted / reacted in excess oxygen</u>

M3 with (all) <u>reactants and products /</u> (all) <u>substances in standard / specified states</u>
OR (all) <u>reactants and products /</u> (all) <u>substances in normal states under standard conditions</u> / 100 kPa / 1 bar <u>and</u> specified T / 298 K

*For **M3***
Ignore reference to 1 atmosphere

3

(ii) M1

Correct answer gains full marks

<u>ΣB(**reactants**) − ΣB(**products**) = *ΔH*</u>

Credit 1 mark for (+) 1279 (kJ mol^{-1})

OR
<u>Sum of bonds broken − Sum of bonds formed = ΔH</u>
OR
B(C-C) + B(C-O) + B(O-H) + 5B(C-H) + 3B(O=O) (LHS)
− 4B(C=O) − 6B(O−H) (RHS) = <u>*ΔH*</u>

M2 (also scores **M1**)
348+360+463+5(412)+3(496) [LHS = **4719**]
(2060) (1488)
− 4(805) − 6(463) [RHS = − **5998**] = *ΔH*
(3220) (2778)
OR using only bonds broken and formed (**4256 − 5535**)

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 a correct method; this requires either a correct cycle with 2C and 6H and 7O OR a clear statement of **M1** which could be in words and scores **<u>only M1</u>***

M3
ΔH= **<u>− 1279</u>** (kJ mol^{-1})

*Allow a maximum of one mark if the only scoring point is LHS = 4719 **OR** RHS = 5998*

Award 1 mark for +1279

Candidates may use a cycle and gain full marks

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3

(d) (i) Reducing agent ***OR*** reductant ***OR*** electron donor ***OR*** to reduce the copper oxide

Not "reduction".

Not "oxidation".

Not "electron pair donor".

1

(ii) CH_3COOH

1

[17]

Q6.

(a) q = 500 × 4.18 × 40

Do not penalise precision.

1

= 83600 J

Accept this answer only.

Ignore conversion to 83.6 kJ if 83600 J shown.

Unit not required but penalise if wrong unit given.

Ignore the sign of the heat change.

An answer of 83.6 with no working scores one mark only.

An answer of 83600 with no working scores both marks.

1

(b) Moles (= 83.6 / 51.2) = 1.63

Using 77400 alternative gives 1.51 mol

Allow (a) in kJ / 51.2

Do not penalise precision.

1

Mass = 1.63 × 40(.0) = 65.2 (g)

Allow 65.3 (g)

Using 77400 alternative gives 60.4 to 60.5

Allow consequential answer on M1.

1 mark for M_r (shown, not implied) and 1 for calculation.

Do not penalise precision.

2

(c) Molarity = 1.63 / 0.500 = 3.26 mol dm–3

Allow (b) M1 × 2

Using 1.51 gives 3.02

1

(d) Container splitting and releasing irritant / corrosive chemicals

*Must have reference to both aspects; splitting or leaking (can be implied such as contact with body / hands) **and** hazardous chemicals.*

Allow 'burns skin / hands' as covering both points

Ignore any reference to 'harmful'.

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Do not allow 'toxic'.

1

(e) (i) $4Fe + 3O_2 \rightarrow 2Fe_2O_3$

Allow fractions / multiples in equation.

Ignore state symbols.

1

(ii) Iron powder particle size could be increased / surface area lessened

Decrease in particle size, chemical error = 0 / 3

Change in oxygen, chemical error = 0 / 3

1

Not all the iron reacts / less reaction / not all energy released / slower release of energy / lower rate of reaction

Mark points M2 and M3 independently.

1

Correct consequence of M2

An appropriate consequence, for example

- *too slow to warm the pouch effectively*
- *lower temperature reached*
- *waste of materials*

1

(f) (i) Conserves resources / fewer disposal problems / less use of landfill / fewer waste products

Must give a specific point.

Do not allow 'does not need to be thrown away' without qualification.

Do not accept 'no waste'.

1

(ii) Heat to / or above 80 °C (to allow thiosulfate to redissolve)

Accept 'heat in boiling water'.

If steps are transposed, max 1 mark.

1

Allow to cool before using again

Reference to crystallisation here loses this mark.

1

[14]

Q7.

(a) (i) reduction **OR** reduced **OR** redox ***OR*** reduction–oxidation

Not "oxidation" alone

1

(ii) $Fe^{3+} + \mathbf{3}e^- \longrightarrow Fe$

Ignore state symbols

Do not penalise absence of charge on electron

Credit $Fe^{3+} \longrightarrow Fe - \mathbf{3}e^-$

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Credit multiples

1

(b) (i) **Because (one of the following)**

CO is not the only product ***OR***

Reference to "incomplete combustion to form CO" does not answer the question

(Some) complete combustion (also)occurs ***OR***

CO_2 is (also) formed

Further oxidation occurs

1

(ii) The <u>enthalpy change</u> / <u>heat (energy) change at constant pressure</u> in a reaction is <u>independent of the route / path taken</u> (and depends only on the initial and final states)

1

(iii) **M1** The <u>enthalpy change</u> / <u>heat change at constant pressure</u> when <u>1 mol</u> of a compound / substance / element

For M1, credit correct reference to molecule/s or atom/s

M2 is <u>burned completely</u> / <u>undergoes complete combustion</u> in (excess) <u>oxygen</u>

M3 with <u>all reactants and products / all substances in standard states</u>

For M3

Ignore reference to 1 atmosphere

OR <u>all reactants and products / all substances in normal / specified states under standard conditions</u> / 100 kPa / 1 bar <u>and</u> specified T / 298 K

3

(c) **M1 (could be scored by a correct mathematical expression which <u>must</u> have <u>all</u> <u>ΔH</u> symbols and the ∑)**

Correct answer gains full marks

Credit 1 mark ONLY for –1 (kJ mol^{-1})

M1 $\Delta H_r = \sum \Delta H_f$ (**products**) – $\sum \Delta H_f$ (**reactants**)

Credit 1 mark ONLY for – 27 (kJ mol^{-1}) i.e. assuming value for Fe(l) = 0

OR <u>correct cycle of balanced equations with 2Fe, 3C and $3O_2$</u>

M2 ΔH_r = 2(+14) + 3(– 394) – (– 822) – 3(–111)

= 28 –1182 + 822 + 333

(This also scores M1)

M3 = **(+) 1** (kJ mol^{-1})

(Award 1 mark ONLY for – 1)

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(Award 1 mark ONLY for – 27)

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 a correct method; this requires either a correct cycle with 2Fe, 3C and $3O_2$ OR a clear statement of M1 which could be in words and scores <u>only M1</u>*

3

(d) (i) $C(s) + O_2(g) \quad CO_2(g)$

State symbols essential

Possible to include C(s, graphite)

1

(ii) These two enthalpy changes are for <u>the same reaction / same equation / same reactants and products</u>

Penalise reference to CO_2 being produced by a different route

OR

They <u>both make one mole of carbon dioxide only from carbon and oxygen</u> (or this idea clearly implied)

"both form CO_2" is not sufficient (since other products might occur e.g.CO)

OR

The <u>same number and same type of bonds are broken and formed</u>

1

[12]

Q8.

(a) One from

- Ti is not produced
- TiC / <u>carbide</u> is produced OR titanium reacts with carbon
- Product is brittle
- Product is a poor engineering material

Penalise ''titanium carbonate''

Ignore ''impure titanium''

Credit ''titanium is brittle''

1

(b) <u>Heat</u> (energy) <u>change at constant pressure</u>

QoL

1

(c) The <u>enthalpy change</u> in a reaction is independent of

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the route taken (and depends only on the initial and final states)

Credit ''heat change at constant pressure" as an alternative to ''enthalpy change''

1

(d) **M1** The <u>enthalpy change</u> / <u>heat change at constant pressure</u> when <u>1 mol</u> of a compound / substance / product

For M1, credit correct reference to molecule/s or atom/s

M2 is formed from its (constituent) <u>elements</u>

M3 with <u>all reactants and products / all substances in standard states</u>

OR all <u>reactants and products / all substances in normal states under standard conditions</u> / 100 kPa / 1 bar <u>and</u> any specified T (usually 298 K)

Ignore reference to 1 atmosphere

3

(e) (i) Na / it is not in its <u>standard state</u> / <u>normal state under standard conditions</u>

OR

<u>Standard state</u> / <u>normal state under standard conditions</u> for Na is solid / (s)

QoL

Ignore ''sodium is a liquid or sodium is not a solid''

1

(ii) **M1** $\Delta H_r = \sum \Delta H_f$ **(products)** $- \sum \Delta H_f$ **(reactants)**

M2 $\Delta H_r = 4(-411) - (-720) - 4(+3)$
$= -1644 + 720 - 12$
(This also scores M1)

M3 = **−936** (kJ mol^{-1})

Correct answer gains full marks

Credit 1 mark for + 936 *(kJ mol^{-1})*

Credit 1 mark for – 924 *(kJ mol^{-1})*
i.e. assuming value for Na(l) = 0

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 a correct method; this requires* ***either*** *a correct cycle with $2Cl_2$ and 4Na OR a* ***clear complete statement*** *of M1 which could be in words and scores <u>only M1</u>*

3

(iii) Reducing agent

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Ignore "reduces titanium"

OR reductant OR reduces $TiCl_4$

OR electron donor

1

[7]

Q9.

(a) Enthalpy change for the formation of 1 mol of gaseous atoms

allow heat energy change for enthalpy change

1

From the element (in its standard state)

ignore reference to conditions

1

Enthalpy change to separate 1 mol of an ionic lattice/solid/compound

enthalpy change not required but penalise energy

1

Into (its component) gaseous ions

mark all points independently

1

(b) $\Delta H_L = {}^{-}\Delta H_f + \Delta H_a$ + I.E. + 1/2E(Cl-Cl) + EA

Or correct Born-Haber cycle drawn out

1

= +411 + 109 + 494 + 121 – 364

1

= +771 (kJ mol^{-1})

–771 scores 2/3
+892 scores 1/3
–51 scores 1/3
–892 scores zero
+51 scores zero *ignore units*

1

(c) (i) Ions are perfect spheres (or point charges)

1

Only electrostatic attraction/no covalent interaction

mention of molecules/intermolecular forces/covalent bonds CE = 0
allow ionic bonding only
If mention of atoms CE = 0 for M2

1

(ii) Ionic

Allow no covalent character/bonding

1

(iii) Ionic with additional covalent bonding

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Or has covalent character/partially covalent

Allow mention of polarisation of ions or description of polarisation

1

[11]

Q10.

(a) The molecular ion is

- The molecule with one/an electron knocked off/lost

  Ignore the highest or biggest m/z peak

OR

- The molecule with a (single) positive charge

OR

- the ion with/it has the largest/highest/biggest m/z (value/ratio)

  Ignore "the peak to the right"

OR

- the ion with/it has an m/z equal to the M_r

  Ignore "compound"

1

(b) (i) 2(14.00307) + 15.99491 = 44.00105

A sum is needed to show this

1

(ii) Propane/C_3H_8 and carbon dioxide/CO_2 (and N_2O) or they or both the gases/molecules or all three gases/molecules have an (imprecise) M_r of 44.0 (OR 44)

OR

they have the same $\boldsymbol{M_r}$ or molecular mass (to one d.p)

This could be shown in a calculation of relative masses for propane and carbon dioxide

1

(iii) By definition

OR

The standard/reference (value/isotope)

Ignore "element"

Ignore "atom"

1

(c) (i) **M1 (could be scored by a correct mathematical expression)**

$\Delta H = \Sigma\Delta H_{products} - \Sigma\Delta H_{reactants}$

OR a correct cycle of balanced equations

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M1 and M2 can be scored with correct moles as follows
$\Delta H + 2(-46) = +82 + 3(-286)$

$\Delta H - 92 = -776$

$\Delta H = 92 - 776$ OR $92 + 82 - 858$

M3
$\Delta H =$ <u>– 684</u> (kJ mol^{-1}) (This is worth 3 marks)

Award 1 mark ONLY for + 684

Full marks for correct answer.

Ignore units.

Deduct one mark for an arithmetic error.

3

(ii) The value is quoted at a pressure of <u>100 kPa</u> OR <u>1 bar</u> or <u>10^5 Pa</u>

OR

<u>All reactants and products</u> are in their <u>standard states/their normal states at 100 kPa or 1 bar</u>

Ignore 1 atmosphere/101 kPa

Ignore "constant pressure"

1

[8]

Q11.

(a) <u>Heat (energy) change at constant pressure</u>

Ignore references to standard conditions, but credit specified pressure.

1

(b) The <u>enthalpy change</u>/<u>heat (energy) change</u> (at constant pressure) in a reaction is independent of the route/path taken (and depends only on the initial and final states)

1

(c) $\Delta H + 963 = -75 - 432$ OR $\Delta H + 963 = -507$ (**M1**)

$\Delta H = -75 - 432 - 963$ (**M1** and **M2**)

$\Delta H =$ **<u>–1470</u>** (kJ mol^{-1})

Award 1 mark for + 1470

<u>Award full marks for correct answer</u>

Ignore units.

Ignore numbers on the cycle

***M1** and **M2** can score for an arithmetic error*

3

[5]

Q12.

(a) (i) **M1** The enthalpy change / heat change at constant pressure

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when 1 mol of a compound / substance / product

1

M2 Is formed from its (constituent) elements

1

M3 With all reactants and products / all substances in standard states
OR
All reactants and products / all substances in normal states under standard conditions / 100 kPa / 1 bar and specified T / 298 K
Ignore reference to 1 atmosphere

1

(ii) By definition
OR
Because they are elements

1

(iii) **M1** $\Delta H_f = \Sigma\Delta H_f$ **(products)** – $\Sigma\Delta H_f$**(reactants)**

1

M2 = –1669 – 3(–558)
(This also scores M1)

1

M3 = **(+) 5** (kJ mol^{-1})
Correct answer gains full marks.
Assume the value is positive unless specifically stated as negative.
Credit 1 mark if – 5 (kJ mol^{-1}).
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 a correct method; this requires either a correct cycle with 3BaO OR a clear statement of M1 which could be in words and scores only M1*

1

(b) (i) *One from*

- Aluminium is expensive (to extract *OR* due to electrolysis)
- High energy cost
- The cost of heating strongly
  This requires a clear statement about cost

1

(ii) *One from*

- increase collision frequency
- OR more collisions

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- OR <u>more chance of colliding</u>

  The answer MUST refer to <u>more collisions</u>.

  Ignore "more available to collide"

1

(c) (i) $Ba + \mathbf{2}H_2O \rightarrow Ba(OH)_2 + H_2$

Ignore state symbols
Allow multiples and correct ionic equations

1

(ii) **M1** $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$
(or the ions together)

Allow crossed out Na^+ ions, but penalise if not crossed out

1

M2 <u>White precipitate</u> / <u>white solid</u>

Ignore state symbols
Ignore "milky"

1

(iii) **M1** Barium meal or (internal) X-ray or to block X-rays

1

M2 <u>$BaSO_4$ / barium sulfate is insoluble</u> (and therefore not toxic)

Accept a correct reference to M1 written in the explanation in M2, unless contradictory.

For M2 NOT barium ions
NOT barium
NOT barium meal and NOT "It".

Ignore radio-tracing.

1

[14]

Q13.

(a) The enthalpy change when 1 mol of a compound

1

is completely burnt in oxygen

1

under standard conditions, or 298K and 100kPA

1

(b) (i) $C_2H_6 + 3½O_2 \rightarrow 2CO_2 + 3H_2O$

1

(ii) $\Delta H = 2 \times \Delta H_f^{\ominus} (CO_2) + 3 \times \Delta H_f^{\ominus} (H_2O) - \Delta H_f^{\ominus} (C_2H_6)$

1

$= -788 - 858 - (-85)$

1

$= -1561 \text{ kJ mol}^{-1}$

1

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(c) moles methane = $\frac{0.10}{16}$ = 6.25×10^{-3}

1

kJ evolved = $6.25 \times 10^{-3} \times 890 = 5.56$

1

5.56×10^3 joules = (mc)ΔT

1

$\Delta T = \frac{5.56 \times 10^3}{120}$ = 46.4 K

1

[11]

Q14.

(a) Enthalpy change when 1 mol of compound (1)

Is formed from it's elements (1)

All substances in their standard state (1)

3

(b) $\Delta H = \Sigma \Delta H^{\ominus}c$ (reactants) – $\Sigma \Delta H^{\ominus}c$ (products) (1)

= (7*x* – 394) + (4 *x* – 286) – (– 3909) (1)

= + 7 $kJmol^{-1}$ (1)

3

(c) Heat change = m c Δ*T* (1)

= 250 × 4.18 × 60 = 62700J = 62.7kJ (1)

Moles C_7H_8 = 2.5 /92 = 0.0272 (1)

ΔH = 62.7 / 0.0272 = – 2307 kJ mol^{-1} (1)
(allow –2300 to –2323)

4

(d) Mass of water heated = 25 + 50 = 75g
Temp rise = 26.5 – 18 = 8.5 °C
*both for **(1)** mark*

Heat change = 75 × 4.18 × 8.5 = 2665 J = 2.665 kJ (1)

Moles HCl = <u>0.05</u> (1)

Δ*H* = – 2.665 / 0.05 = –53.3 $kJmol^{-1}$ (1)
(allow –53 to –54)

4

(e) Less heat loss (1)

1

[15]

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Q15.

(a) enthalpy (or energy) to break (or dissociate) a bond;

1

averaged over different molecules (environments);

1

enthalpy (or heat energy) change when one mole of a compound;

1

is formed from its elements;

1

in their standard states;

1

(b) enthalpy change = Σ(bonds broken) – Σ(bonds formed) or cycle;

1

= 4 × 388 +163 + 2 × 146 + 4 × 463 – (944 + 8 × 463);
(or similar)

1

= –789;
(+ 789 scores 1 only)

1

(c) (i) zero;

1

(ii) *AH* = Σ (enthalpies of formation of products)
–Σ (enthalpies of formation of reactants)

1

= 4 × –242-(75 + 2 × –133);

1

= –777;
(+ 777 scores one only)

1

(d) mean bond enthalpies are not exact
(or indication that actual values are different from real values)

1

[13]

Q16.

(a) enthalpy change/ heat energy change when 1 mol of a substance

1

is completely burned in oxygen

1

at 298K and 100 kPa or standard conditions

1

(not 1atm)

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(b) $\Delta H = \sum$ bonds broken – $\sum$ bonds formed

1

= (6 × 412) + 612 +348 + (4.5 × 496) – ((6 × 743) + (6 × 463))

1

= – 1572 kJ mol^{-1}

1

(c) by definition ΔH_f is formation from an element

1

(d) $\Delta H_c = \sum \Delta H_f$ products -$\sum \Delta H_f$ reactants or cycle

1

= (3 × – 394) + (3 × –242) – (+20)

1

= − 1928 kJ mol^{-1}

1

(e) bond enthalpies are mean/average values

1

from a range of compounds

1

[12]

Q17.

C

[1]

Q18.

(a) $\Delta H = \Sigma$(bonds broken) – Σ(bonds formed) (or cycle)

1

= +146 – 496/2 (or 2 × 463 + 146 –(2 × 463 + 496/2)

1

= – 102 (kJ mol^{-1}) **(1)**

*(accept no units, wrong units loses a mark; +102 scores **(1)** only)*

1

(b) $C(s) + 2H_2(g) \rightarrow CH_4(g)$ equation **(1)** Correct state symbols **(1)**

2

(c) (i) Macromolecular

(accept giant molecule or carbon has many (4) bonds)

1

(ii) $\Delta H = \Sigma \Delta H_f$(products) – $\Sigma \Delta H_f$(reactants) (or cycle)

1

= 715 + 4 × 218 – (–74.9)

1

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= 1662 (kJ mol^{-1})

(accept no units, wrong units loses one mark, allow 1660 to 1663, –1662 scores one mark only)

1

(iii) 1662/4 = 415.5

(mark is for divide by four, allow if answer to (c)(ii) is wrong)

1

[10]

Q19.

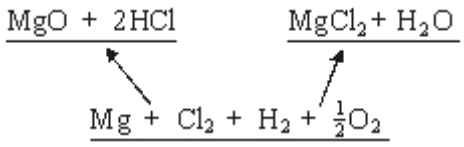
(a) (i) enthalpy (or heat or heat energy) change when 1 mol of a substance **(1)** (QL mark) is formed from its elements **(1)** all substances in their standard states **(1)** (or normal states at 298K, 100 kPa or std condits)

***not** STP, NTP*

3

(b) enthalpy change (or enthalpy of reaction) is independent of route **(1)**

$\Delta H = \Sigma\Delta H_f^{\ominus}$ prods - $\Sigma\Delta H_f^{\ominus}$ reactants (or cycle) **(1)**
minimum correct cycle is:



ΔH = -642 – 286 – (–602 + 2 × –92) **(1)**
= –142 (kJ mol^{-1}) **(1)**

penalise this mark for wrong units

+142 scores 1 mark out of the last three

4

(c) $\Delta H = mcT$ **(1)** (or $mc\Delta T$)
= 50 × 4.2 × 32 = 6720 J = 6.72J **(1)**

mark is for 6720 J or 6.72 kJ

moles HCl = $\frac{\text{vol}}{1000}$ × conc = $\frac{50}{1000}$ × 3 **(1)**

= 0.15 **(1)**

if error here mark on conseq.

Therefore moles of MgO reacted = moles HCl/2 **(1)**
(mark is for/2, CE if not/2)
= 0.15/2 = 0.075

Therefore ΔH = 6.72/0.075 **(1)**
= –90 kJ (mol^{-1})

kJ must be given, allow 89 to 91

*value **(1)***

*sign **(1)**; this mark can be given despite CE for /2*

8

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Note various combinations of answers to part (c) score as follows:

–89 to –91 kJ **(8)** (or –89000 to 91000J)
*no units **(7)***

+89 to +91 kJ **(7)** (or + 89000 to +91000J)
*no units **(6)***

–44 to –46 kJ **(5)** (or -44000 to -46000J)
*no units **(4)** if units after 6.72 or 6720 (5)*

+44 to +46 kJ **(4)** (or +44000 to + 46000)
if no units and
*if no units after 6.72 or 6720 **(3)***
*otherwise check, could be **(4)***

[15]

Q20.

(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) $\Delta H = \Sigma \Delta H_f^{\ominus}$(products) - $\Sigma \Delta H_f^{\ominus}$(reactants) **(1) (Or a cycle)**
$= 2 \times -242 + ½ \times -394 - (-365)$ **(1) (also implies first mark)**
$= -316$ kJ mol^{-1} **(1)**

3

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

[6]

Q21.

(a) Heat energy change **(1)**
Not energy on its own

measured at constant pressure **(1)**
Mark separately, ignore constant temperature statements

2

(b) (i) Enthalpy change when 1 mol of a substance (or compound / product) **(1)** is formed from its constituent elements **(1)** in their standard states **(1)** under standard conditions **(1)**
Mark separately

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(ii) $2Na(s) + S(s) + 2O_2(g) \rightarrow Na_2SO_4(s)$

Balanced (1) State symbols (1), but only if all species are correct

Allow $\frac{1}{8} S_8(s)$

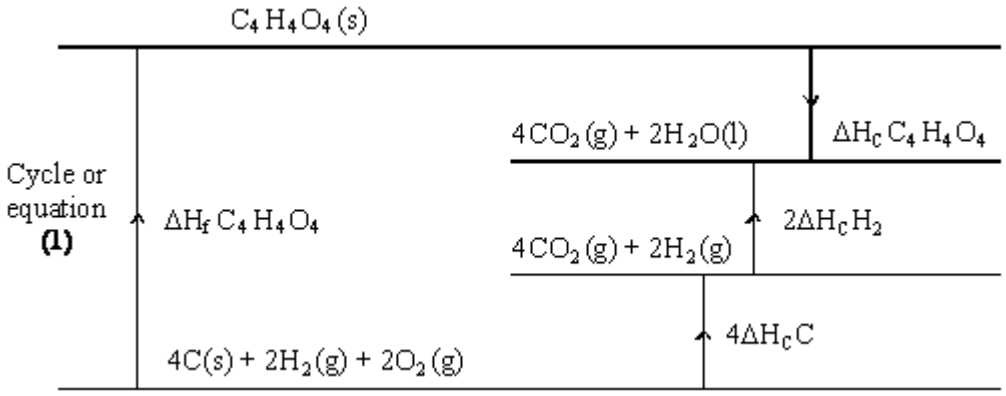
5

(c) Enthalpy change is independent of reaction route **(1)**

Penalise incorrect additional statements

1

(d)



$-1356 + (2 \times 285.8) + (4 \times 393.5) + \Delta H_f C_4H_4O_4 = 0$

$\Delta H_f = -789.6$ kJ mol^{-1}

If answer is incorrect:

Score +789.6 two marks

Score (× 1); (× 2) and (× 4) for species - one mark

If an incorrect negative answer given check for AE for loss of one mark

3

[11]

Q22.

(a) (Enthalpy change) when 1 mol **(1)** of a compound is formed from its constituent elements **(1)** in their standard states **(1)**

3

Allow energy or heat, Ignore evolved or absorbed
Mark each point independently

(b) (The enthalpy change for a reaction is) independent of the route **(1)**

1

(c) $\Delta H_R = \Sigma\Delta H_f$ products - $\Sigma\Delta H_f$ reactants **(1)**
= [(3 × -286) + (3 × -394)] - (-248) **(1)**
= -1792 **(1)** (kJ mol^{-1})

Deduct one mark for each error to zero

3

[7]

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Q23.

C

[1]

Q24.

B

[1]

Q25.

D

[1]

Q1.

(a) This was poorly answered, with many students missing state symbols and balancing the equation incorrectly. Only the best students (24.6%) gained the mark here.

(b) This proved challenging compared to questions set in the previous specification from this topic area. 34.3% of students failed to pick up even one mark.

(c) Again challenging for all but the best students, only 26.3% scored more than one mark.

(d) This was not as well answered as might have been expected. The fact that mean bond enthalpies are calculated using a range of compounds was not well understood.

Q3.

Two-thirds of the marks in this enthalpy-based question involved students being able to carry out calculations based on Hess' Law and, as always, there was a divide between those who could cope with such questions and those who couldn't.

In part (a) the importance of learning definitions was illustrated. Many students failed to make clear that all reactants and products need to be in their standard states.

In questions such as part (b) students are strongly advised to start with a clear and complete indication of the expression relating the enthalpy change of the reaction to the data given or to draw out a clearly labelled cycle. Students who relied on the use of a learned expression often got this wrong way round, possibly due to confusion with the use of enthalpies of formation whereas, in this case, the data provided were enthalpies of combustion.

In a question like part (c) students are strongly advised to sketch out the displayed formulae of all reactants and products when working with bond energies. Failing to do so in many cases meant that bonds were omitted or miscounted (3 × C-C in propan-1-ol was often seen) by students.

Q4.

This question was answered well. Balancing the equation in part (a)i looks straightforward when you know the answer, but it is quite demanding if you have to work it out, and impressively half the students gave the correct answer. In part (b)i, it was necessary to draw unambiguous structures both for propan-2-ol (not given in the question) and propanone (given in part (a)i). The calculation in part (c) was well answered with the focus on correct chemistry rather than on the number of significant figures and the mathematics of rounding the final answer. The definition in part (d) was expected to be straightforward and yet still resulted in only 40% gaining all three marks. As many as 45% gained all three marks and 80% gained at least one mark from the very straightforward calculation in part (e), with errors occurring because some students did not know the bonding either in propanone or in carbon dioxide and used the unnecessary C−O that was given in the data set. It was decided that the very straightforward idea of "heat loss", in whatever context, was worth only one mark in part (f) and that students needed to come up with other reasons why the values in part (c) and part (e) differed; many were able to do so and this led to 54% scoring both marks.

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Q5.

In part (a)(i), some students missed either the fact that the catalyst has to be a concentrated strong acid or that the unreacted ethene is re-circulated to achieve an overall yield of 95% and this meant that only a small number of students scored both marks. Considerable latitude was allowed in the responses for part (a)(ii), since it was clear that many students did not really understand what was happening in this process and this approach to the marking enabled the majority of students to gain at least two marks out of three. In part (a)(iii), some students recognised the possibility of poly(ethene) being formed and approximately 17% of students gained both marks.

It has been a while since a question like part (b) has been asked and it was not well answered with few students gaining full marks and over half scoring zero. Balancing the correct equation and then including the correct state symbols were both needed for full marks. Parts (c) and (d) proved straightforward for many and full marks were seen from over a third of students in each of parts (c)(i) and (c)(ii), respectively.

Q6.

Section B proved more demanding. In part (a), the calculation had similar faults to Question 5 but some students failed to read that the answer was to be in Joules - an answer in kJ was penalized unless there was a clear correct answer in the working. Part (b) and part (c) were well done though the alternative answer to part (a) was frequently used in these. In part (d), only a few students failed to highlight the need for the bag to split or the chemicals to come into contact with skin / hands. Part (e)(i) indicated that a considerable number of students found difficulties with the equation; common errors were the wrong formula for iron (III) oxide, the inclusion of ions on the reagent side of the equation and using Fe2 for the metal. Part (e)(ii) contained many good partial answers but there was a significant failure to focus finally on why longer times might not be an advantage. In part (f)(i), the main errors were to re-state the question about being reusable or to indicate that there would be no waste following use of these handwarmers. There were some vague answers to part (f)(ii) which referred to 'heating' the bag or 'keeping it in a warm place' and, for some, the contents were removed before further treatment. Nevertheless, sensible answers were frequently seen.

Q7.

The thinking required in part (b)(i) proved too much for many and only a few were able to state that, in practice, CO is not the only product and that some complete combustion to form CO_2 would occur. The answer of +1 kJ mol^{-1} was seen frequently in part (c), but some were disconcerted by this value and sought to find an alternative. State symbols were often missed in part (d)(i) and a clear statement in part (d)(ii) that the same reaction occurs for the two specified standard enthalpies was not well understood.

Q8.

Overall, this was a relatively high-scoring question although only 26% of the candidates stated that enthalpy change is the heat change at constant pressure in part (b). Definitions continue to be learned poorly by a proportion of candidates and 15% of candidates failed to score any marks in part (d).

Q9.

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Answers to part (a) were disappointing. Very few candidates scored all four marks and the average score was less than half marks. Typical errors were a failure to mention the formation of one mole of atoms and also to omit to state that the atoms and ions formed should be gaseous. In part (b), only the best candidates gained full marks. Most candidates either failed to use the correct enthalpy change for the formation of one mole of chlorine atoms, using the bond enthalpy without halving it, or incorrectly doubled the electron affinity of chlorine. In part (c)(i), very few candidates were able to give a full explanation of the term perfect ionic model but answers to parts (c)(ii) and (c)(iii) were usually correct.

Q10.

In part (a), candidates rarely knew the meaning of the term molecular ion. In part (b), most could show why the answer for the precise M_r of N_2O was 44.00105, but the fact that both propane and carbon dioxide could be confused with N_2O using M_r values to one decimal place, was not always explained. In part (b)(iii), the idea that the precise M_r for the ^{12}C isotope is defined as exactly 12.00000 was poorly understood. The calculation proved straightforward for many candidates with 65% gaining full marks. The common mistake was an answer of +684 kJ mol^{-1}. Only half of the candidates knew about a standard pressure of 100 kPa in part (c)(ii).

Q11.

Only 20% of the candidates stated that enthalpy change is the heat change at constant pressure, even though this is stated clearly in the specification. It was pleasing to see that more than half the candidates could correctly apply Hess's Law to an unfamiliar cycle and arrive at the right answer for the specified enthalpy change.

Q12.

The range of answers given to the meaning of the term *standard enthalpy of formation* in part (a)(i) indicated the variation in the ability of the candidates to learn basic information. Application of that information in the remainder of part (a) was generally well done, although too many candidates had their data the wrong way around in part (a)(iii).

Part (b) was answered correctly by approximately half of the candidates and there were some good answers in each section of part (c). The ability to construct and balance equations, including the simplest ionic equation in part (c)(ii), was made impossible for those candidates who did not know that Ba^{2+} is the formula of the barium ion.

Q14.

Part (a) was generally well done by most candidates. The most common error was not referring to standard states. The calculation in part (b) proved more demanding for students than some previous enthalpy calculations with many candidates giving the incorrect answer of –7kJmor\ A large number of candidates did not give the correct mass or correct temperature rise in part (c) and therefore only scored the mark for the $Q = mc\Delta t$ equation. Many of the candidates who did calculate the heat evolved then failed to calculate molar quantities. The calculation in part (d) proved very difficult for candidates with very few scoring full marks. Common errors were incorrect mass, incorrect temperature rise and lack of conversion to molar quantities. Candidates should know that exothermic reactions are shown by a negative sign e.g. –53.3kJmol^{-1}. In part (e) many candidates failed to make the comparison regarding heat loss between the two experiments.

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Q15.

More able candidates were able to obtain high marks for this question but less able candidates found the calculations hard. In part (a) candidates lost a mark if they referred to bond-formation instead of bond-breaking. Less able candidates were unable to explain that mean bond enthalpy refers to an average of bonds where the environment is different, usually due to existence in different molecules. In part (b) many candidates provided incorrect answers because they did not work out the correct number of bonds being broken or formed. For example, only the best candidates recognised that two O—O bonds were broken. It was disappointing in part (c) (i) that many candidates did not understand the question. It was quite common to find candidates attempting a calculation using the equation, the enthalpy of formation values given in the table and an assumption that the enthalpy change for the equation was zero. Answers to part (c) (ii) were more usually correct though weaker candidates failed to take account of the two moles of hydrogen peroxide and the four moles of water. Answers to part (d) were usually incorrect. A common wrong answer was the statement 'Heat loss'.

Q16.

More able candidates were able to obtain high marks in this question but the weaker candidates found the calculations difficult. The definition in (a) was usually attempted well with the majority of candidates scoring 3 marks. Answers to (b) discriminated between candidates. There were several arithmetic errors in the calculation, and a few candidates who did not know to subtract the sum of the bonds made from the sum of the bonds broken leading to an incorrect sign in the final answer. Most candidates realised that oxygen was an element in (c). Again the calculation in (d) discriminated well. A common incorrect answer was 1888 $kJmol^{-1}$ which was usually due to doing the calculation the wrong way round. Weaker candidates also failed to take account of the 3 moles of water and carbon dioxide in their calculation. The explanation of why answers to (b) were less accurate than (a) was not done as well as expected with many candidates scoring one out of the 2 marks. Candidates should know that mean bond enthalpies are averaged over a range of compounds which contain the same bond, or from the same compound which contains several of the same type of bond. A common incorrect answer here was ‘heat loss’.

Q18.

Good candidates were able to obtain high marks for this question but weak candidates found it very difficult and marks of zero out of ten were not unusual. In part (a), a common mistake was to use the O—O single bond enthalpy rather than the correct value for the O=O double bond and also to use one mole of oxygen rather than half a mole. In part (b) the balanced equation was usually correct but the state symbol for carbon was frequently shown as gaseous rather than solid (or graphite). In Part (c) (i) only the best candidates appeared to notice the wording in the question which required a reference to the structure of solid carbon. Part (c) (ii) also proved to be a difficult question for weaker candidates who rarely multiplied the enthalpy of formation of hydrogen atoms by the factor four. Also, the enthalpy of formation of methane (–74.9 kJ mol^{-1}) was usually added rather than subtracted. Incorrect cycles and equations involving combustion of methane were also common errors. Part (c) (iii) was answered well; the mark was awarded for dividing the answer to part (c) (ii) by four.

Q19.

Most candidates answered this question well though it proved to be difficult to score maximum marks. The definition of standard enthalpy of formation in part (a) was usually correct though some candidates lost one mark because they did not make it clear that reactants and products should be in their standard states. In part (b) good candidates

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were able to score maximum marks but weaker candidates sometimes referred to energy rather than enthalpy when stating Hess's Law and such candidates often predicted an endothermic enthalpy change (+142 kJ mol^{-1}) rather than an exothermic one. Part (c) proved to be the most difficult part of this question. The major error was in the number of moles of magnesium oxide. Most candidates assumed that the number of moles of MgO would be the same as that of hydrochloric acid whereas it should have been half of that. This error led to a value for the enthalpy change that was too small by a factor of two. Such an answer resulted in the loss of three marks.

Q20.

This question was answered well by many candidates. Answers to part (a) were usually correct. Most candidates provided good answers to part (b) but some lost marks because they referred to energy or to enthalpy alone rather than to enthalpy change. In part (c) the most common error was to invert signs leading to an answer of 316 kJ mol-1 rather than to –316 kJ mol^{-1}.

Q21.

The meaning of the term enthalpy change, required in part (a), was not well stated and whilst many correctly referred to the heat energy change, most failed to state that this was measured at constant pressure. Part (b) was well answered with many correct definitions of the term standard enthalpy of formation of a compound though slightly fewer candidates gave a correct equation with state symbols in section (ii). Hess's Law was correctly stated by many candidates and it is particularly pleasing to report that the calculation required in part (d) was very well done.

Q22.

This question was very well answered and many candidates were able to score full marks. Happily, as candidates showed working in part (c), part marks could be awarded when incorrect answers were given.

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Q1.

(a) **M1** moles (= $\frac{25}{1000}$ × 2.0) = 0.050

1

M2 heat released = 0.050 × 56.1 (= 2.805 kJ or 2805 J)

1

M3 $\Delta T = \frac{q}{mc}$

1

M4 $\Delta T = \frac{2805}{50 \times 4.18}$ or $\frac{1000 \times 0.050 \times 56.1}{50 \times 4.18}$ = 13(.4) (°C)

Correct answer (to at least 2 sig fig) scores 4 marks

*27 or 26.8°C (from moles of two reagents being added together for **M2**, or use of 25 cm^3 in **M4**) scores 3 marks*

*0.013(.4)°C (from not converting kJ to J) scores 3 marks (loses **M4**) [0.027 or 0.0268°C would score 2 marks (loses **M2** and **M4**)*

M1** moles can be shown for either substance or without specifying the substance; if it is shown for both substances, must be correct for both for **M1

*Allow ECF from **M1** to **M2***

*Allow ECF from **M2** to **M4** (providing an attempt to calculate q has been made – no ECF if 56100 or 56.1 is used as q)*

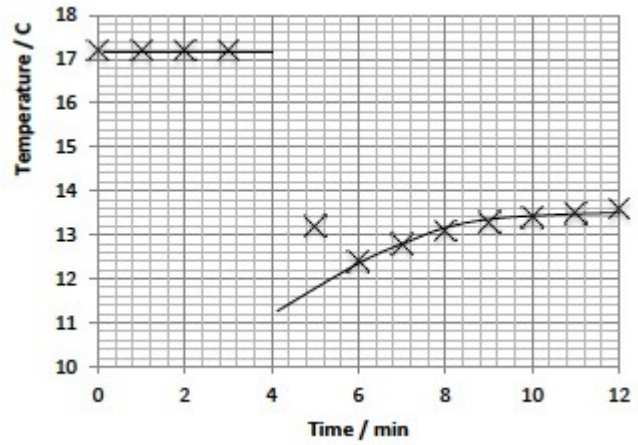
*Correct **M4** scores **M3**. If error made in **M4**, **M3** could score from substituted values in this expression in **M4***

***M4** final answer to at least 2 sig fig.*

*Penalise **M4** for negative temperature rise*

1

(b) **M1** draws suitable best fit curve to 4 minutes



***M1** line must be a curve and ignore value at 5 minutes*

***M1** line should not go to times before 4 minutes*

1

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M2 (17.2 – value read from graph line at 4 minutes) ± 0.2 (°C)

M2 *allow use of any curved or straight line that is an attempt to draw a line through the values after 4 minutes (that may include the point at 5 minutes)*

M2 *allow negative values*

1

[6]

Q2.

(a) Aldehyde/propanal has dipole-dipole forces (between molecules)

If any 'covalent bonds broken' CE=0 for clip.

Ignore Van der Waal forces

M1

Alcohol/propan-1-ol AND Carboxylic acid/ propanoic acid have hydrogen bonding (between molecules).

Ignore reference to energy

M2

The forces between the molecules in aldehyde are weaker (than those in alcohol and acid so it will evaporate first.)

M3 only awarded following correct M1 OR M2

Allow converse for M3

M3

(b) Keep the temperature of the reaction mixture below the boiling point of propan-1-ol/below 97 °C

Allow temperature in range 49-96 inclusive

Allow description of cooling the vessel

M1

Cool the distillate / collecting vessel

Ignore reference to oxidising agents

Penalise lid / sealed container

M2

(c) Add named carbonate/hydrogencarbonate OR magnesium to a sample of the distillate.

Incorrect chemical CE=0

Allow formula (mark on for incorrect formula)

Allow blue litmus or correct named indicator

M1

Effervescence/fizz/bubbles would confirm presence of acid or converse

Blue litmus turns red confirms acid present or converse

Allow gas/CO_2 produced which turns lime water cloudy OR gas/H_2 produced which burns with a squeaky pop

M2

(d) (Temperature difference = 15.1 °C)

If ΔT wrong – AE mark on otherwise can only award M2

If use 457 in M1, can only score M2

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q = 150 × 4.18 × 15.1 or 9467.7 J or 9.4677kJ

M1

amount ethanol burned = 0.457/46.0 = 9.93×10^{-3} mol

If use 457 in M2 can score 2 for - 0.953 kJ mol-1

M2

Heat change per mole = (M1/1000)/M2 = 952.99 kJ mol-1

ΔH = – 953 kJ mol^{-1} must be 3sfs and must be negative

(allow range -953 to -954)

BEWARE if they miss conversion to kJ and also miss conversion to g, they get answer = - 953 which scores 1
+953 can score M1 and M2
Allow -950 or -960 for rounding to 2sf

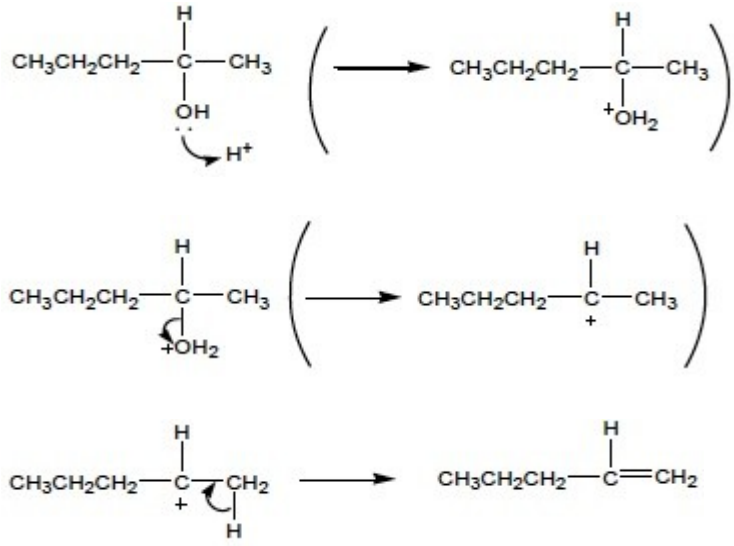
M3

(e) Elimination

Penalise base elimination

M1

Mechanism : Either (E1)

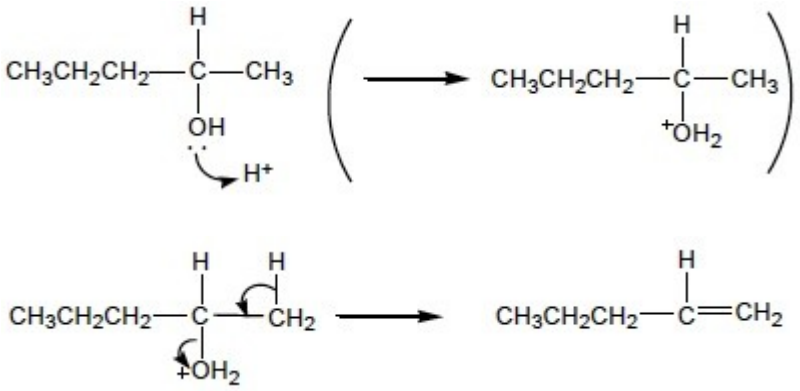


M2 for protonation of alcohol, i.e. lp plus arrow to H^+
or to H of H–O– in H_2SO_4 and from H-O bond to O
M3 for protonated alcohol plus arrow showing loss of water
M4 for arrow showing loss of H^+
From correct carbocation (E1)
wrong alcohol used / alkene formed loses M4

3

OR (E2)

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M2 for protonation of alcohol, i.e. lp plus arrow to H^+ or to H of H–O– in H_2SO_4 and from H-O bond to O
M3 for protonated alcohol plus arrow showing loss of water
M4 for arrow showing simultaneous loss of H^+
wrong alcohol used / alkene formed loses M4

3

(f) *E*-pent-2-ene

Allow trans

M1

C=C bond cannot rotate **and**

Each carbon in the double bond has (2) different groups attached.

Allow (two) different groups on each/either side of the double bond.

M2

[16]

Q3.

(a) **M1** Temperature on the y-axis and uses sensible scales (i.e. minimum 20 little squares for each °C on y-axis)

Lose mark if temperature scale starts at 0°C

*This mark scores if all points fit on the grid. Do not penalise M1 if extrapolation to 4 mins goes off the grid – this is penalised in **M3**.*

1

M2 Plots all the points correctly (± half a small square)

Lose mark if the points go off the grid Ignore a plotted point at 4 mins used to work out ΔT

1

M3 Draws two best fit lines (0-3 mins) and (6-12 mins)

Both lines must be straight and through all points except 5th minute; lose mark if the lines are kinked/doubled. Any line through 5th minute loses mark

*"S-shaped curve" through points loses **M3** and **M4***

1

M4 Extrapolates both lines to at least the 4th minute

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Lose mark if the extrapolation goes off the grid.

1

M5 21.9 – 19.8 = 2.1 (°C)

Allow calculation of ∆T from S-shaped curve as: Value at 4th minute – 19.8 but not if 0 (°C)

∆T value ecf from incorrect lines/extrapolation

∆T must be to at least 1dp

If value of ∆T = 2.1, then award M5

1

(b) 0.2 / 2.1 × 100 = 9.5 %

Conseq on (a)

Ignore no of sfs.

1

(c) Replace the glass beaker with a polystyrene cup / insulate the glass beaker / use a lid

Ignore use more dilute solutions

Ignore suggested materials for insulation

Do not allow copper calorimeter / bomb calorimeter

1

(d) Increase magnitude of temperature change

Ignore references to volume changes

1

by increasing the <u>concentration</u> of the acid/alkali

Mark independently

1

(e) **M1** $HOOCCOOH + 2KOH \rightarrow K_2(OOCCOO) + 2H_2O$

***M1** – equation (allow ionic KOH / $_2C_2O_4$)*

$H_2C_2O_4 + 2KOH \rightarrow K_2C_2O_4 + 2H_2O$

ignore state symbols

allow multiples

Mark independently

M2 q (= mc∆T) = 100 × 4.2 × 3.2 = 1344 J

***M2** – process*

(ignore sign here)

(allow calculations involving 4.18 which leads to 1338 J)

1

M3 n HOOCCOOH = 25 × 0.800 / 1000 = <u>0.020</u>
n KOH = 75 × 0.6 / 1000 = <u>0.045</u>

M3 – calculations of amounts, in moles, of both the ethanedioic acid and potassium hydroxide (both calculations needed)

1

M4 Moles of water = <u>0.040</u> moles

***M4** – answer (stated or used in calculation of ∆H)*

1

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M5 $\Delta H = -1.344/0.04$

$= -33.6$ (kJ mol^{-1})

M5 *– ecf on* ***M2*** *and* ***M4***

Answer must be negative and to at least 2sf

ΔH = – ***M2*** *(in kJ) / M4*

*–32.5 - –34 scores 4/4 (****M2-M5*** *+ equation)*

*+32.5 - +34 scores 3/4 (****M2****,* ***M3****,* ***M4*** *+ equation)*

–65 - –68 scores 3/4 (+ equation)

+65 - +68 scores 2/4 (+ equation)

–52 - –54 scores 3/4 (+ equation)

+52 - +54 scores 2/4 (+ equation)

2

(f) HOOCCOOH is a weak acid / not fully dissociated

H_2SO_4 is a strong(er)acid / fully dissociated / dissociates more

1

(more) energy needed to break bonds/complete dissociation / dissociation is endothermic

So less energy is needed for dissociation of sulfuric acid

Ignore references to heat loss

1

[16]

Q4.

(a) M1 Amount $ZnSO_4 = 1.0 \times \frac{50}{1000}$ mol or Amount $ZnSO_4 = 0.050$ mol

Mark M1 and M2 independently

1

M2 Amount Mg = $\frac{2.08}{24.3}$ mol or Amount Mg = 0.0856 mol
(Hence Mg in excess)

1

M3 $Q = mc\Delta T$

M3 could be scored in M4

1

M4 $Q = 50.0 \times 4.18 \times 37.3$
or $Q = 7795.7$ J

If an error in M4, lose M4 and M5 and only award M6 for correct use of their incorrect M4 and division by their correct limiting reagent

1

M5 (Energy released per mole) $\frac{7.796}{0.05}$ kJ mol^{-1} or $\frac{7.796}{0.05}$ J mol^{-1}

M5 division by their limiting reagent

1

M6 $\Delta H = -156$ kJ mol^{-1}

1

(b) Heat loss (from the apparatus would mean the experimental value is smaller / lower / less exothermic than the data source)

1

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(c) Marks awarded for this answer will be determined by the quality of the communication as well as the standard of the scientific response. Examiners should apply a 'best-fit' approach to the marking.

Level 3 (5 – 6 marks)
Covers 3 Stages with matching justifications
Answer is full and detailed and is supported by an appropriate range of relevant points such as those given below:
- argument is well structured with minimum repetition or irrelevant points
- accurate and clear expression of ideas with only minor errors in the use of technical terms, spelling and punctuation and grammar

Level 2 (3 – 4 marks)
Covers 2 Stages with matching justification. OR covers 3 Stages with incomplete justification
Answer has some omissions but is generally supported by some of the relevant points below:
- the argument shows some attempt at structure
- the ideas are expressed with reasonable clarity but with a few errors in the use of technical terms, spelling, punctuation and grammar

Level 1 (1 – 2 marks)
Covers 1 Stage with matching justification. OR covers 2 Stages with incomplete justification
Answer is largely incomplete. It may contain valid points which are not clearly linked to an argument structure. Unstructured answer. Errors in the use of technical terms, spelling, punctuation and grammar or lack of fluency

Level 0 (0 marks)

Insufficient correct chemistry

Indicative Chemistry Content

Stage 1 Improved insulation
1a Insulate the beaker or use a polystyrene cup or a lid
1b To reduce heat loss

Stage 2 Improved temperature recording
2a Record the temperature for a suitable time before adding the metal
2b To establish an accurate initial temperature
OR
2c Record temperature values at regular time intervals
2d To plot the temperature results against time on a graph

Stage 3 Improved analysis of results
3a Extrapolate the cooling back to the point of addition
3b To establish a (theoretical) maximum temperature OR temperature change (e.g. at the 4^{th} minute) OR adjust for the cooling /apply a cooling correction
3a and 3b could be seen on an extrapolated sketch graph

(Note– IGNORE use of measuring equipment with greater precision)

6

[13]

Q5.

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(a) Not possible to prevent some dissolving

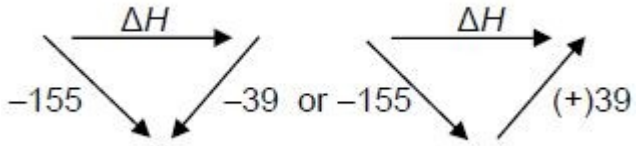
ALLOW It is soluble / dissolves / other hydrates may form / suggestions related to difficulty of measuring T (change) of a solid

1

(b) ($\Delta_{hyd}H$ =) –155 – (–39)

OR labelled cycle

Minimum needed for 'labelled cycle'



1

–116 (kJ mol^{-1})

1/2 for (+)116 or for –29 or for seeing –116 that has then be processed further

1

(c) This question is marked using levels of response. Refer to the Mark Scheme Instructions for examiners for guidance on how to mark this question

Level 3 (5 – 6 marks)

All stages are covered and the explanation of each stage is correct and virtually complete.
Stage 2 must include use of a graphical method for Level 3 (i.e. 'highest T reached' method is max Level 2)

Answer communicates the whole explanation, including reference to enthalpy, coherently and shows a logical progression through all three stages.Answer is full and detailed and is supported by an appropriate range of relevant points such as those given below:
For the answer to be coherent there must be some indication of **how** the graph is used to find ΔT

Level 2 (3 – 4 marks)

All stages are covered (NB 'covered' means min 2 from each of stage 1 and 3) but the explanation of each stage may be incomplete or may contain inaccuracies
OR two stages covered and the explanations are generally correct and virtually complete

Answer is coherent and shows some progression through all three stages. Some steps in each stage may be out of order and incomplete

Level 1 (1 – 2 marks)

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies
OR only one stage is covered but the explanation is generally correct and virtually complete

Answer shows some progression between two stages

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Level 0 (0 marks)

Insufficient correct Chemistry to warrant a mark

Indicative Chemistry Content

Stage 1 Method

(1a) Measures water with named appropriate apparatus
(1b) Suitable volume/mass / volume/mass in range 10 – 200 cm^3/g
(1c) Into insulated container / polystyrene cup (NOT just 'lid')
(1d) Add known mass of $MgCl_2(s)$
(1e) Use of 'before and after' weighing method. NOT 'added with washings'

Stage 2 Measurements (could mark from diagram)

(2a) Record initial temperature (min 2 measurements)
(2b) Record T at regular timed intervals for 5+ mins / until trend seen
(2c) Plot T vs time

Stage 3 Use of Results (3a and 3b could come from diagram)

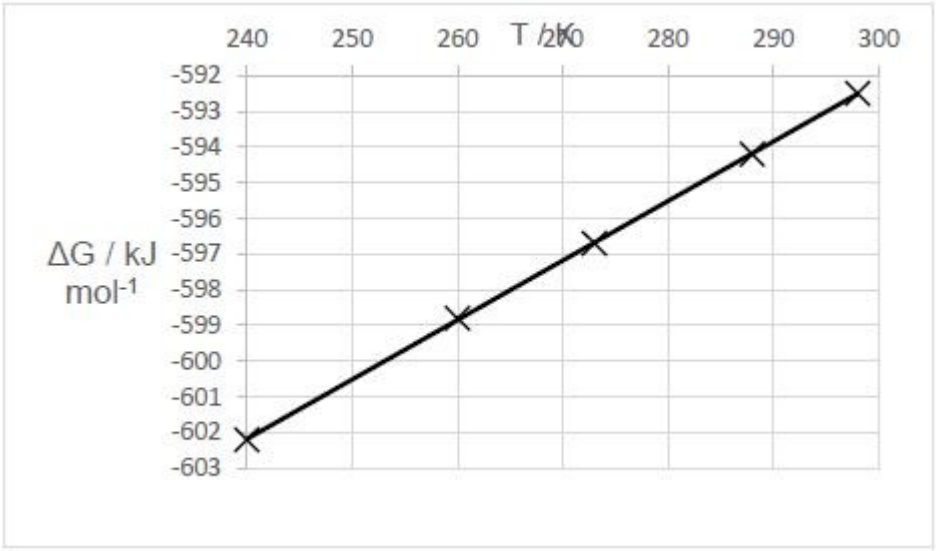
(3a) Extrapolate lines to when solid added (to find initial and final T)
(3b) $T_{final} - T_{initial} = \Delta T$ / idea of finding ΔT from graph at point of addition
(3c) $q = mc\Delta T$
(3d) amount = mass/Mr ($0.80/95.3 = 8.39 \times 10^{-3}$ mol)
(3e) ΔH_{soln} = –q/8.39×10^{-3} or in words

This could all be described in words without showing actual calculations but describing stages

If method based on 'combustion' Max Level 1

6

(d)



M1 *= 5 points correctly plotted*
M2 *= line drawn correctly (NOT if curved, doubled or kinked)*
(Check line of best fit –
if through 250, -600.5 and 280, -595.5 +/- one small square

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*then award **M2**, if all crosses on line award **M1** as well)*

2

Gradient = $\Delta(\Delta G)/\Delta T$ = 0.167 (kJ K^{-1} mol^{-1})

1

($\Delta G = \Delta H - T\Delta S$ so gradient = $-\Delta S$)

ΔS = –167 (J K^{-1} mol^{-1})

***M4** = unit conversion i.e. **M3** × 1000; M5 = –sign (process marks)*

*Correct answer with sign gets **M3**, **M4** and M5*

ALLOW –163 to –171

1+1

[14]

Q6.

TWO correct extrapolations of best fit straight lines

***Max 5/7** if no extrapolations or best fit straight lines drawn*

1

Use of their lines to calculate the temperature change at the 4th minute

1

(17 °C)

Q = mcΔT

Q = 10 × 4.18 × [student's temperature change]

Q = [710.6 J]

Correct numbers inserted into expression.

1

Moles of Mg = 0.24 / 24.3 = 0.00988 mol

1

ΔH = 710.6 / 0.00988 = 71923.07 J mol^{-1}

1

ΔH = –72 (kJ mol^{-1})

Must be negative to score M6

1

Answer to 2 significant figures

1

[7]

Q7.

B

[1]

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Q8.

(a) $C_6H_{11}OH + 8\frac{1}{2}O_2 \longrightarrow 6CO_2 + 6H_2O$

1

(b) Temperature rise = 20.1

$q = 50.0 \times 4.18 \times 20.1 = 4201$ (J)

1

Mass of alcohol burned = 0.54 g and M_r alcohol = 100.0

$\therefore$ mol of alcohol = $n = 0.54 / 100 = 0.0054$

1

Heat change per mole = $q / 1000n$ **OR** q / n

= 778 kJ mol^{-1} **OR** 778 000 J mol^{-1}

1

ΔH = –778 kJ mol^{-1} **OR** –778 000 J mol^{-1}

M4 is for answer with negative sign for exothermic reaction
Units are tied to the final answer and must match

1

(c) Less negative than the reference

1

Heat loss **OR** incomplete combustion **OR** evaporation of alcohol **OR** heat transferred to beaker not taken into account

1

(d) Water has a known density (of 1.0 g cm^{-3})

1

Therefore, a volume of 50.0 cm^3 could be measured out

1

[9]

Q9.

(a) Start a clock when KCl is added to water

1

Record the temperature every subsequent minute for about 5 minutes

Allow record the temperature at regular time intervals until some time after all the solid has dissolved for M2

1

Plot a graph of temperature vs time

1

Extrapolate back to time of mixing = 0 and determine the temperature

1

(b) Heat taken in = $m \times c \times \Delta T = 50 \times 4.18 \times 5.4 = 1128.6$ J

Max 2 if 14.6 °C used as ΔT

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1

Moles of KCl = 5.00 / 74.6 = 0.0670

1

Enthalpy change per mole = +1128.6 / 0.0670 = 16 839 J mol^{-1}

1

= +16.8 (kJ mol^{-1})

Answer must be given to this precision

1

(c) $\Delta H_{solution} = \Delta H_{lattice} + \Delta H$(hydration of calcium ions) + 2 × ΔH(hydration of chloride ions)

$\Delta H_{lattice} = \Delta H_{solution} - \Delta H$(hydration of calcium ions) –2 ×ΔH(hydration of chloride ions)

1

$\Delta H_{lattice}$ = –82–9 – (–1650 + 2 × –364) = +2295 (kJ mol^{-1})

1

(d) Magnesium ion is smaller than the calcium ion

1

Therefore, it attracts the chloride ion more strongly / stronger ionic bonding

1

[12]

Q10.

(a) Weigh the spirit burner (alcohol) before and after combustion **M1**

Do not allow "a known mass of alcohol" owtte

1

Water in a calorimeter / beaker **M2**

1

Measure volume of water (or mass) **M3**

1

Burn the alcohol to heat the water **M4**

1

Measure temperature rise <u>in water</u> **M5**

1

(b) Incomplete combustion

Evaporation of alcohol

Heat capacity of / heat absorption by the apparatus

Inadequate stirring

Any two correct

1
1

(c) Acidified potassium dichromate / manganate(VII) (Heat)

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Allow sodium in place of potassium with appropriate colour change)

If reagent incomplete lose M1 but mark on.

If reagent incorrect, CE = 0/3

1

butan-1-ol orange to green / purple to colourless

1

2-methylpropan-2-ol NVC / orange / purple

1

(d) $C_4H_9OH + 2O_2 \rightarrow 4C + 5H_2O$
OR
$C_4H_9OH + 4O_2 \rightarrow 4CO + 5H_2O$

Allow any correct balanced equations which include combinations of C, CO and/or CO_2 in the products but must be incomplete combustion.

1

Engine would not run as efficiently / would need to use more fuel / would release less energy

Allow build-up of carbon in engine costly to remove

1

CO / Particulates of carbon toxic

Allow global dimming if carbon given as product

1

[13]

Q11.

(a) M1 ($q = mc\Delta T = 100 \times 4.18 \times 38(.0)$)
= 15 884 / 15 880 / 15 900 / 16 000 (J)
(OR 15.884 / 15.88 / 15.9 / 16 (kJ))

Award full marks for correct answer

Mark is for value not expression (at least 2sf); penalise incorrect units here only if M1 is the only potential scoring point in M1-M3

1

M2 Moles (methanol = 1.65 / 32.0) = 0.0516 or 0.052

At least 2sf

1

M3 Heat change per moles = M1/M2
(15 884 / 0.0516 / 1000 = 308 (kJ mol^{-1})
(allow 305 to 310)

At least 2sf; answer must be in kJ mol^{-1}

1

M4 Answer = −308 (kJ mol^{-1}) (allow −305 to −310)

This mark is for – sign (mark independently)

1

(b) Heating up copper / calorimeter / container / thermometer /
heat capacity of copper / calorimeter / thermometer not taken into account

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OR
Evaporation of alcohol/methanol
OR
Experiment not done under standard conditions

Not human errors (e.g. misreading scales)

Not impure methanol

Allow evaporation of water

1

(c) (100 × 0.5 / 38 =) 1.3 or 1.32 or 1.316% (minimum 2 sf)

Allow correct answer to at least 2sf;

Allow 1.31 or 1.315%

1

(d) Idea that heat loss is more significant issue OR
Idea that temperature change/rise is (significantly / much) bigger than uncertainty

One of these two ideas only and each one must involve a comparison

1

(e) M1 Mass of ethanol = 500 × 0.789 (= 394.5 or 395 (g))

1

M2 Moles of ethanol = M1 / 46.0 (= 8.576 or 8.58)

1

M3 Heat released = M2 × 1371 = 11800 (kJ) must be 3 sf

1

Correct answer to 3sf scores 3; correct value to 2sf or more than 3sf scores 2

Answers that are a factor of 10^x out score 2 if given to 3sf or 1 if given to a different number of sf

M3 ignore units, but penalise incorrect units

M3 ignore sign

M2 and M3 – allow consequential marking

[10]

Q12.

(a) (i) $\mathbf{2}C_6H_{12}O_6 \longrightarrow \mathbf{3}CH_3COCH_3 + \mathbf{3}CO_2 + \mathbf{3}H_2O$

Or multiples

1

(ii) to speed up the reaction
OR
(provide a) catalyst or catalyses the reaction or biological catalyst
OR
release / contain / provides an enzyme

Ignore "fermentation"

Ignore "to break down the glucose"

Not simply "enzyme" on its own

1

(b) (i) $CH_3CH(OH)CH_3 + [O] \longrightarrow CH_3COCH_3 + H_2O$

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Any <u>correct</u> representation for the two organic structures.
Brackets not essential.
Not "sticks" for the structures in this case

1

(ii) Secondary (alcohol) OR 2° (alcohol)

1

(c) **M1** q = m c ΔT

OR q =150 × 4.18 × 8.0

Award full marks for <u>correct answer</u>
*In **M1**, do not penalise incorrect cases in the formula*

M2 = (±) 5016 (J) ***OR*** 5.016 (kJ) ***OR*** 5.02 (kJ)
(also scores M1)

M3 This mark is for dividing correctly the number of kJ by the number of moles and arriving at a final answer in the range shown.
Using 0.00450 mol

therefore ΔH = **<u>− 1115</u>** (kJ mol^{-1})

OR **<u>− 1114.6</u> to <u>− 1120</u>** (kJ mol^{-1})

Range (+)1114.6 to (+)1120 gains 2 marks

BUT − 1110 gains 3 marks and +1110 gains 2 marks

AND − 1100 gains 3 marks and +1100 gains 2 marks

Award full marks for correct answer
*In **M1**, do not penalise incorrect cases in the formula*
*Penalise **M3** ONLY if correct numerical answer but sign is incorrect; **(+)1114.6 to (+)1120 gains 2 marks***
*Penalise **M2** for arithmetic error and mark on*
If ΔT = 281; score q = m c ΔT only
*If c = 4.81 (leads to 5772) penalise **M2** ONLY and mark on for **M3** = − 1283*
*Ignore incorrect units in **M2***
*If units are given in **M3** they <u>must be either kJ or kJ mol^{-1}</u> in this case*

3

(d) **M1** The <u>enthalpy change</u> / <u>heat change at constant pressure</u> when <u>1 mol</u> of a compound / substance / element

M2 is <u>burned / combusts / reacts</u> <u>completely</u> in <u>oxygen</u>
OR
<u>burned / combusted / reacted in excess oxygen</u>

M3 with (all) <u>reactants and products /</u> (all) <u>substances in standard / specified states</u>

OR
(all) <u>reactants and products /</u> (all) <u>*substances in normal states under standard conditions*</u> / 100 kPa / 1 bar <u>and</u> specified T / 298 K

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*For **M3***

Ignore reference to 1 atmosphere

3

(e) **M1**

$\sum$ B **(reactants)** − $\sum$ B **(products)** = Δ*H*

OR

Sum of bonds broken − Sum of bonds formed = Δ*H*

OR

2B(C−C) + B(C=O) + 6B(C−H) + 4B(O=O) (LHS)

− 6B(C=O) − 6B(O−H) (RHS) = Δ*H*

M2 (also scores **M1**)

2(348)+805+6(412)+4(496) [LHS = **5957**]

(696) (2472) (1984)

− 6(805) − 6(463) [RHS = (−) **7608**] = Δ*H*

(4830) (2778)

OR using only bonds broken and formed (**5152 − 6803**)

M3

Δ*H*= **− 1651** (kJ mol^{-1})

Candidates may use a cycle and gain full marks.

Correct answer gains full marks

Credit 1 mark for (+) 1651 (kJ mol^{-1})

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 / addition error; this would score 2 marks (**M1** and **M2**)*
- *If no AE, check for a correct method; this requires either a correct cycle with $4O_2$, $3CO_2$ and $3H_2O$ OR a clear statement of **M1** which could be in words and scores **only M1***

Allow a maximum of one mark if the only scoring point is LHS = 5957 (or 5152) OR RHS = 7608 (or 6803)

Award 1 mark for + 1651

3

(f) **For the two marks M1 and M2, any two from**

- heat loss or not all heat transferred to the apparatus or heat absorbed by the apparatus or (specific) heat capacity of the apparatus not considered
- incomplete combustion / not completely burned / reaction is not complete
- The idea that the water may end up in the gaseous state (rather than liquid)
- reactants and / or products may not be in standard states.
- MBE data refers to gaseous species but the enthalpy of combustion refers to liquids in their standard states / liquid propanone and liquid water in standard states
- MBE do not refer to specific compounds OR MBE values vary with different compounds / molecules OR are average / mean values taken

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from a range of compounds / molecules

Apply the list principle but ignore incomplete reasons that contain correct chemistry

Ignore "evaporation"

Ignore "faulty equipment"

Ignore "human error"

Not enough simply to state that "MBE are mean / average values"

2

[15]

Q13.

Increase in volume

If a volume is quoted it must be less than 300

1

Smaller increase in T above room temperature
Or increased contact between calorimeter and water
Or smaller heat loss by evaporation / from the surface

1

[2]

Q14.

(a)

M1 $C_6H_{12}O_6 \longrightarrow$ **2**CH_3CH_2OH ($2C_2H_5OH$) + **2**CO_2

*Penalise C_2H_6O for ethanol in **M1**.*

M2 and **M3**

*Mark **M2** and **M3** independently.*

Any **two** conditions **in any order** for **M2** and **M3** from

- (enzymes from) yeast or zymase
- 25 °C ≤ T ≤ 42 °C OR 298 K ≤ T ≤ 315 K
- anaerobic / no oxygen / no air OR neutral pH

  A lack of oxygen can mean either without oxygen or not having enough oxygen and does not ensure no oxygen, therefore only credit "lack of oxygen" if it is qualified.

  Penalise 'bacteria', 'phosphoric acid', 'high pressure' using the list principle.

M4 (fractional) distillation or GLC

Ignore reference to 'aqueous' or 'water' (ie not part of the list principle).

M5 Carbon-neutral **in this context** means

There is no net / overall (annual) carbon dioxide / CO_2 emission to the atmosphere

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OR

There is no change in the <u>total amount / level</u> of <u>carbon dioxide / CO_2</u> present <u>in the atmosphere</u>

*For **M5** – must be about CO_2 <u>and</u> the atmosphere.*

The idea that the <u>carbon dioxide / CO_2</u> given out equals the <u>carbon dioxide / CO_2</u> that was taken in from <u>the atmosphere.</u>

5

(b) **M1** q = m c ∆T (this mark for correct mathematical formula)

*Full marks for **M1**, **M2** and **M3** for the <u>correct answer</u>.*

*In **M1**, do not penalise incorrect cases in the formula.*

M2 = (75 × 4.18 × 5.5)

1724 (J) **OR** 1.724 (kJ) **OR** 1.72 (kJ) **OR** 1.7 (kJ)

(also scores **M1**)

*Ignore incorrect units in **M2**.*

M3 Using 0.0024 mol

therefore ∆H = **<u>− 718</u>** (kJ mol^{-1})

(Accept a range from −708 to −719 but do not penalise more than 3 significant figures)

*Penalise **M3** ONLY if correct numerical answer but sign is incorrect. Therefore **+718 gains two marks**.*

*If units are quoted in **M3** they must be correct.*

*If ∆T = 278.5, CE for the calculation and penalise **M2** and **M3**.*

M4 and **M5** in any order

Any **two** from

- incomplete combustion
- heat loss
- heat capacity of Cu not included
- some ethanol lost by evaporation
- not all of the (2.40 × 10^{-3} mol) ethanol is burned / reaction is incomplete

*If c = 4.81 (leads to 1984) penalise **M2** ONLY and mark on for **M3** = − 827*

5

(c) (i) **M1** enthalpy / heat / energy change (at constant pressure) or enthalpy / heat / energy needed in <u>breaking / dissociating (a) covalent bond(s)</u>

Ignore bond making.

M2 <u>averaged</u> for that type of bond over <u>different / a range of molecules / compounds</u>

Ignore reference to moles.

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2

(ii) **M1**

∑ B(**reactants**) − ∑ B(**products**) = ΔH

OR

Sum of bonds broken − Sum of bonds formed = ΔH

OR

B(C-C) + B(C-O) + B(O-H) + 5B(C-H) + 3B(O=O)
– 4B(C=O) – 6B(O–H) = ΔH = −1279

Correct answer gains full marks.

*Credit **1 mark for − 496** (kJ mol^{-1})*

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 a correct method; this requires either a correct cycle with $2CO_2$ and $3H_2O$ OR a clear statement of **M1** which could be in words and scores **only M1**.*

M2 (also scores **M1**)
348+360+463+5(412)+ 3B(O=O)

(**3231**) (or **2768** if O–H cancelled)
− 4(805) − 6(463) = ΔH = − 1279

(**5998**) (or **5535** if O–H cancelled)

3B(O=O) = **1488** (kJ mol^{-1})

*Credit a maximum of one mark if the only scoring point is bonds formed adds up to **5998 (or 5535) OR** bonds broken includes the calculated value of **3231 (or 2768)**.*

M3

B(O=O) = **496** (kJ mol^{-1})

Award 1 mark for −496

Students may use a cycle and gain full marks

3

[15]

Q15.

(a) (Q = mcΔT)

= 50 × 4.18 × 27.3

*If incorrect (eg mass = 0.22 or 50.22 g) **CE = 0 / 2***

1

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= **5706 J** (accept 5700 and 5710)

Accept 5.7 kJ with correct unit. Ignore sign.

1

(b) M_r of 2-methylpropan-2-ol = 74(.0)

For incorrect M_r, lose M1 but mark on.

1

Moles = mass / M_r

= 0.22 / 74(.0)

= **0.00297 moles**

1

ΔH = –5706 / (0.002970 × 1000)

= **–1921 (kJ mol^{-1})**

If 0.22 is used in part (a), answer = –8.45 kJ mol^{-1} scores 3

(Allow –1920, –1919)

If uses the value given (5580 J), answer = –1879 kJ mol^{-1} scores 3

Answer without working scores M3 only.

Do not penalise precision.

Lack of negative sign loses M3

1

(c) ΔH = ΣΔH products – ΣΔH reactants
OR a correct cycle

Correct answer with no working scores 1 mark only.

1

ΔH = −(−360) + (4 × −393) + (5 × −286)

M2 also implies M1 scored.

1

ΔH = **–2642** (kJ mol^{-1}) This answer only.

Allow 1 mark out of 3 for correct value with incorrect sign.

1

(d) (–2422 – part (b)) × 100 / –2422

Ignore negative sign.

Expect answers in region of 20.7

If error carried forward, 0.22 allow 99.7

If 5580 J used earlier, then allow 22.4

1

(e) Reduce the distance between the flame and the beaker / put a sleeve around the flame to protect from drafts / add a lid / use a copper calorimeter rather than a pyrex beaker / use a food calorimeter

Any reference to insulating material around the beaker must be on top.

Accept calibrate the equipment using an alcohol of known enthalpy of combustion.

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1

(f) Incomplete combustion

1

[11]

Q16.

(a) Chloride (ions) are smaller (than bromide ions)

Must state or imply ions.

Allow chloride has greater charge density (than bromide).

Penalise chlorine ions once only (max 2 / 3).

1

So the force of attraction between chloride ions and water is stronger

This can be implied from M1 and M3 but do not allow intermolecular forces.

1

Chloride ions attract the δ+ on H of water / electron deficient H on water

Allow attraction between ions and polar / dipole water.

*Penalise H^+ (ions) and mention of hydrogen bonding for **M3***

Ignore any reference to electronegativity.

Note: If water not mentioned can score M1 only.

1

(b) $\Delta H_{solution} = \Delta H_L + \Delta H_{hyd}$ K^+ ions + ΔH_{hyd} Br^- ions / = 670 − 322 − 335

Allow $\Delta H_{solution} = \Delta H_L + \Sigma \Delta H_{hyd}$

1

= (+)13 (kJ mol^{-1})

Ignore units even if incorrect.

+13 scores M1 and M2

−13 scores 0

−16 scores M2 only (transcription error).

1

(c) (i) The entropy change is positive / entropy increases

ΔS is negative loses M1 and M3

1

Because 1 mol (solid) → 2 mol (aqueous ions) / no of particles increases

Allow the aqueous ions are more disordered (than the solid).

Mention of atoms / molecules loses M2

1

Therefore $\underline{T\Delta S > \Delta H}$

1

(ii) Amount of KCl = $5/M_r = 5/74.6 =$ 0.067(0) mol

If moles of KCl not worked out can score M3, M4 only (answer to M4 likely to be 205.7 K)

1

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Heat absorbed = 17.2 × 0.0670 = 1.153 kJ

Process mark for M1 × 17.2

1

Heat absorbed = mass × sp ht × Δ*T*

(1.153 × 1000) = 20 × 4.18 × Δ*T*

If calculation uses 25 g not 20, lose M3 only (M4 = 11.04, M5 = 287)

1

Δ*T* = 1.153 × 1000 / (20 × 4.18) = 13.8 K

If 1000 not used, can only score M1, M2, M3

M4 is for a correct ΔT

Note that 311.8 K scores 4 (M1, M2, M3, M4).

1

T = 298 − 13.8 = 284(.2) K

If final temperature is negative, M5 = 0

Allow no units for final temp, penalise wrong units.

1

[13]

Q17.

(a) The <u>enthalpy change / heat (energy) change</u> (at constant pressure) in a reaction is independent of the route / path taken (and depends only on the initial and final states)

Ignore the use of ΔH for enthalpy

1

(b) $\Delta H_{exp} + \Delta H_2 - \Delta H_1 = 0$

Any correct mathematical statement that uses <u>all three terms</u>

OR

$\Delta H_{exp} + \Delta H_2 = \Delta H_1$ ***OR*** $\Delta H_1 = \Delta H_{exp} + \Delta H_2$

OR

$\Delta H_{exp} = \Delta H_1 - \Delta H_2$ ***OR*** $\Delta H_{exp} = \Delta H_1 + (- \Delta H_2)$

1

(c) $\Delta H_{exp} = \Delta H_1 - \Delta H_2$

$\Delta H_{exp} = -156 - 12 =$ ***−168*** *(kJ mol^{-1})*

Ignore units

Award the mark for the correct answer without any working

1

(d) (i) M1 q = m c ΔT OR calculation (25.0 x 4.18 x 14.0)

Award full marks for correct answer

M2 = **1463**J OR **1.46** kJ (This also scores **M1**)

*In **M1**, do not penalise incorrect cases in the formula*

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M3 must have both the correct value within the range specified **and** the minus sign

*Penalise **M3** ONLY if correct numerical value but sign is incorrect; e.g. **+69.5 to +69.7 gains 2 marks** (ignore +70 after correct answer)*

For 0.0210 mol, therefore

ΔH_1 = **− 69.67** to **− 69.52** (kJ mol^{-1})

OR ΔH_1 = **− 69.7** to **− 69.5** (kJ mol^{-1})

*Penalise **M2** for arithmetic error but mark on*

Accept answers to 3sf or 4sf in the range − 69.7 to − 69.5

ΔT = 287, score q = m c ΔT only

Ignore -70 after correct answer

*If c = 4.81 (leads to 1684J) penalise **M2** ONLY and mark on for **M3** = − 80.17 (range − 80.0 to − 80.2)*

Ignore incorrect units

3

(ii) The idea of heat loss

NOT impurity

OR

Incomplete reaction (of the copper sulfate)

NOT incompetence

OR

Not all the copper sulfate has dissolved

NOT incomplete combustion

1

(e) Impossible to add / react the exact / precise amount of water

Not just "the reaction is incomplete"

OR

Very difficult to measure the temperature rise of a solid

OR

Difficult to prevent solid dissolving

OR

(Copper sulfate) solution will form

1

[8]

Q18.

(a) (i) **M1 (could be scored by a correct mathematical expression which must**

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have

all ΔH**symbols and the** $\sum$ or SUM)

M1 $\Delta H_r = \Sigma \Delta H_f$ **(products)** - $\Sigma \Delta H_f$ **(reactants)**

OR a correct cycle of balanced equations with 1C, $3H_2$ and $1O_2$

M2 $\Delta H_r = -201 + (-242) - (-394)$
$\Delta H_r = -201 - 242 + 394$
$\Delta H_r = -443 + 394$
(This also scores M1)

M3 = – **49** (kJ mol^{-1})
(Award 1 mark ONLY for + 49)
Correct answer gains full marks
Credit 1 mark ONLY for + 49 (kJ mol^{-1})
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 a correct method; this requires either*
  correct cycle of balanced equations with 1C, $3H_2$ and $1O_2$
  *OR a clear statement of **M1** which could be in words and*
  *scores only **M1***

3

(ii) It is an element / elemental
Ignore reference to "standard state"

OR

By definition

1

(b) **M1** (The yield) increases / goes up / gets more
*If M1 is given as "decreases" / "no effect" / "no change" then CE= 0 for clip, but mark on only **M2** and **M3** from a blank M1*

M2 There are more moles / molecules (of gas) on the left / of reactants
OR fewer moles / molecules (of gas) on the right / products
OR there are 4 moles /molecules (of gas) on the left and 2 moles / molecules on the right.
OR (equilibrium) shifts / moves to the side with less moles / molecules
*Ignore "volumes", "particles" "atoms" and "species" for **M2***

M3: Can only score M3 if M2 is correct

The (position of) equilibrium shifts / moves (from left to right) to oppose the increase in pressure
*For **M3**, not simply "to oppose the change"*

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*For **M3** credit the <u>equilibrium shifts / moves</u> (to right) to <u>lower / decrease the pressure</u>*

(There must be a <u>specific</u> reference to the change that is opposed)

3

(c) **M1** Yield increases goes up

M2 The (forward) reaction / to the right is <u>endothermic</u> OR <u>takes in/ absorbs heat</u>

OR

The reverse reaction / to the left is <u>exothermic</u> OR <u>gives out / releases heat</u>

*If M1 is given as "decrease" / "no effect" / "no change" then CE= 0 for clip, but mark on only **M2** and **M3** from a blank **M1***

Can only score M3 <u>if M2 is correct</u>

M3 The (position of) <u>equilibrium shifts / moves</u> (from left to right) <u>to oppose the increase in temperature</u> **(QoL)**

*For **M3**, <u>not</u> simply "to oppose the change"*

*For **M3**, credit the (position of) <u>equilibrium shifts / moves</u> **(QoL)***

*to <u>absorb the heat</u> **OR***

*to <u>cool the reaction</u> **OR***

to <u>lower the temperature</u>

(There must be a <u>specific</u> reference to the change that is opposed)

3

(d) (i) An activity which has no <u>net / overall</u> (annual) carbon emissions <u>to the atmosphere</u>

OR

An activity which has no <u>net / overall</u> (annual) greenhouse gas emissions <u>to the atmosphere</u>.

OR

There is no change in the <u>total amount / level</u> of carbon dioxide /CO_2 carbon /greenhouse gas present <u>in the atmosphere</u>.

The idea that the carbon /CO_2 given out equals the carbon /CO_2 that was taken in from <u>the atmosphere</u>

1

(ii) $CH_3OH + \mathbf{1}½\ O_2 \rightarrow CO_2 + \mathbf{2}H_2O$

Ignore state symbols

Accept multiples

1

(iii) $\mathbf{3}H_2 + \mathbf{1}½\ O_2 \rightarrow \mathbf{3}H_2O$

Ignore state symbols

OR

Accept multiples

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2H_2 + O_2 **2**H_2O

Extra species must be crossed through

1

(e) **M1** q = m c ∆T

Award full marks for correct answer

Ignore the case for each letter

OR q = 140 × 4.18 × 7.5

M2 = 4389 (J) OR 4.389 (kJ) OR 4.39 (kJ) OR 4.4 (kJ)(also scores M1)

M3 Using 0.0110 mol
therefore ∆H = **– 399** ($kJmol^{-1}$)
OR **– 400**

*Penalise **M3** ONLY if correct numerical answer but sign is incorrect; +399 **gains 2 marks***

*Penalise **M2** for arithmetic error and mark on*

*In **M1**, do not penalise incorrect cases in the formula*

If ∆T = 280.5; score q = m c ∆T only

*If c = 4.81 (leads to 5050.5) penalise **M2** ONLY and mark on for **M3** = – 459*

+399 or +400 gains 2 marks

Ignore incorrect units

3

[16]

Q19.

(a) Temperature on *y*-axis

*If axes unlabelled use data to decide that temperature is on *y*-axis.*

1

Uses sensible scales

*Lose this mark if the **plotted points** do not cover half of the paper.*

Lose this mark if the temperature axis starts at 0 °C.

1

Plots **all** of the points correctly ± one square

Lose this mark if the graph plot goes off the squared paper.

1

Draws two best-fit lines

*Candidate must draw **two** correct lines.*

Lose this mark if the candidate's line is doubled or kinked.

1

Both extrapolations are correct to the 4th minute

Award this mark if the candidate's extrapolations are within one square of your extrapolations of the candidate's best-fit lines at the 4th minute.

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1

(b) 19.5 (°C)

Accept this answer only.

1

(c) 26.5 ± 0.2 (°C)

Do not penalise precision.

1

(d) (c) – (b)

*Only award this mark if temperature rise is recorded to **1 d.p.***

1

(e) Uses $mc\Delta T$ equation

Allow use of this equation with symbols or values for M1 even if the mass is wrong.

1

Correct value using 25 × 4.18 × (d)

7.0 gives 732 J.

Correct answer with no working scores one mark only.

Do not penalise precision.

Allow answer in J or kJ.

Ignore sign of enthalpy change.

1

(f) $9.0(1) \times 10^{-3}$

Do not allow 0.01

Allow 9×10^{-3} or 0.009 in this case.

1

(g) If answer to (e) in J, then (e) / (1000 × (f))

or

If answer to (e) in kJ, then (e) / (f)

7.0 and 9.01×10^{-3} gives 81.2 kJ mol^{-1}

If answer to (e) is in J must convert to kJ mol^{-1} correctly to score mark.

1

Enthalpy change has negative sign

Award this mark independently, whatever the calculated value of the enthalpy change.

1

(h) The idea that this ensures that all of the solution is at the same temperature

Do not allow 'to get an accurate reading' without qualification.

1

(i) (i) Chlorine is <u>toxic / poisonous / corrosive</u>

Do not allow 'harmful'.

1

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(ii) Explosion risk / apparatus will fly apart / stopper will come out

Ignore 'gas can't escape' or 'gas can't enter the tube'.

1

[16]

Q20.

(a) q = 500 × 4.18 × 40

Do not penalise precision.

1

= 83600 J

Accept this answer only.
Ignore conversion to 83.6 kJ if 83600 J shown.
Unit not required but penalise if wrong unit given.
Ignore the sign of the heat change.
An answer of 83.6 with no working scores one mark only.
An answer of 83600 with no working scores both marks.

1

(b) Moles (= 83.6 / 51.2) = 1.63

Using 77400 alternative gives 1.51 mol
Allow (a) in kJ / 51.2
Do not penalise precision.

1

Mass = 1.63 × 40(.0) = 65.2 (g)

Allow 65.3 (g)
Using 77400 alternative gives 60.4 to 60.5
Allow consequential answer on M1.
1 mark for M_r (shown, not implied) and 1 for calculation.
Do not penalise precision.

2

(c) Molarity = 1.63 / 0.500 = 3.26 mol dm–3

Allow (b) M1 × 2
Using 1.51 gives 3.02

1

(d) Container splitting and releasing irritant / corrosive chemicals

*Must have reference to both aspects; splitting or leaking (can be implied such as contact with body / hands) **and** hazardous chemicals.*
Allow 'burns skin / hands' as covering both points
Ignore any reference to 'harmful'.
Do not allow 'toxic'.

1

(e) (i) $4Fe + 3O_2 \rightarrow 2Fe_2O_3$

Allow fractions / multiples in equation.
Ignore state symbols.

1

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(ii) Iron powder particle size could be increased / surface area lessened

Decrease in particle size, chemical error = 0 / 3

Change in oxygen, chemical error = 0 / 3

1

Not all the iron reacts / less reaction / not all energy released / slower release of energy / lower rate of reaction

Mark points M2 and M3 independently.

1

Correct consequence of M2

An appropriate consequence, for example

- *too slow to warm the pouch effectively*
- *lower temperature reached*
- *waste of materials*

1

(f) (i) Conserves resources / fewer disposal problems / less use of landfill / fewer waste products

Must give a specific point.

Do not allow 'does not need to be thrown away' without qualification.

Do not accept 'no waste'.

1

(ii) Heat to / or above 80 °C (to allow thiosulfate to redissolve)

Accept 'heat in boiling water'.

If steps are transposed, max 1 mark.

1

Allow to cool before using again

Reference to crystallisation here loses this mark.

1

[14]

Q21.

(a) **Three conditions <u>in any order</u> for M1 to M3**

M1 yeast or zymase

M2 30 °C ≥ T ≤ 42 °C

M3 anaerobic/no oxygen/no air OR neutral pH

M4 $C_6H_{12}O_6 \longrightarrow \mathbf{2}C_2H_5OH + \mathbf{2}CO_2$
OR
$\mathbf{2}C_6H_{12}O_6 \longrightarrow \mathbf{4}C_2H_5OH + \mathbf{4}CO_2$

Mark independently

Penalise "bacteria" and "phosphoric acid" using the list principle

Ignore reference to "aqueous" or "water" (i.e. not part of the list principle)

Or other multiples

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4

(b) **M**1 Carbon-neutral

Ignore "biofuel"

1

M2 6 (mol/molecules) CO_2/carbon dioxide taken in/used/used up (to form glucose or in photosynthesis)

1

M3 6 (mol/molecules) CO_2/carbon dioxide given out due to **2** (mol/molecules) CO_2/carbon dioxide from fermentation/ Process 2 and **4** (mol/molecules) CO_2/carbon dioxide from combustion/Process 3

It is NOT sufficient in M2 and M3 for equations alone without commentary or annotation or calculation

1

(c) **M1 (could be scored by a correct mathematical expression)**

(Sum of) bonds broken – (Sum of) bonds made/formed = Δ*H*

OR

(Σ) $B_{reactants}$ – (Σ) $B_{products}$ = Δ*H*

(where B = bond enthalpy/bond energy)

For M1 there must be a correct mathematical expression using ΔH or "enthalpy change"

M2 Reactants = (+) 4719
OR
Products = (–) 5750

M3 Overall + 4719 – 5750 = **–1031** (kJ mol^{-1}) **(This is worth 3 marks)**

Award full marks for correct answer.

Ignore units.

M2 is for either value underlined

M3 is NOT consequential on M2

3

Award 1 mark ONLY for +1031

Candidates may use a cycle and gain full marks.

M4 Mean bond enthalpies are not specific for this reaction *OR* they are average values from many different compounds/molecules

Do not forget to award this mark

1

(d) **M1** q = m c ΔT (this mark for correct mathematical formula)

M2 = 6688 (J) OR 6.688 (kJ) OR 6.69 (kJ) OR 6.7 (kJ)

M3 0.46g is 0.01 mol
therefore ΔH = **– 669** kJ mol^{-1} OR – **670** $kJmol^{-1}$

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OR **–668.8** kJ mol^{-1}

Award M1, M2 and M3 for correct answer to the calculation
Penalise M3 ONLY if correct answer but sign is incorrect
In M1, do not penalise incorrect cases in the formula
If m = 0.46 or m = 200.46 OR if ΔT = 281, CE and penalise M2 and M3
If c = 4.81 (leads to 7696) penalise M2 ONLY and mark on for M3 = –769.6 OR –770
Ignore incorrect units in M2

M4 Incomplete combustion

Do not forget to award this mark. Mark independently

4

[15]

Q22.

(a) (i) q = mc ΔT

Ignore case except T

1

(ii) 8.80 × 1.92 × 9.5 = **161** (J) to 160.5(12) (J)

Credit 0.161 provided it is clear that it is kJ.
Penalise wrong units

1

(iii) 11.95 × 0.96 × 9.5 = **109** (J) to 108.98(4) (J)

Credit 0.109 provided it is clear that it is kJ.
Penalise wrong units.

1

(iv) **M1** Addition of (a)(ii) and (a)(iii)

M2 Multiply by 10 and convert to kJ (divide by 1000) leading to an answer

Consequential on (a)(ii) and (a)(iii)
Penalise wrong units
Ignore the sign

Therefore ΔH = **(–) 2.69** ***OR*** **(–) 2.7(0)** (kJ mol^{-1})

Ignore greater numbers of significant figures (2.69496)
Subtraction in M1 is CE

2

(b) One from:

- No account has been taken of the intermolecular forces initially in the two liquids OR each liquid has its own intermolecular forces in operation before mixing.
- The liquids may react or reference to reaction or reference to bonds broken or formed

Any statement which shows that there are other intermolecular forces to consider.

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Ignore heat loss and ignore poor mixing.

1

[6]

Q23.

(a) Enthalpy change when 1 mol of compound (1)

Is formed from it's elements (1)

All substances in their standard state (1)

3

(b) $\Delta H = \Sigma \Delta H^{e}c$ (reactants) – $\Sigma \Delta H^{e}c$ (products) (1)

$= (7x - 394) + (4x - 286) - (-3909)$ (1)

$= +7$ kJmol^{-1} (1)

3

(c) Heat change = m c ΔT (1)

$= 250 \times 4.18 \times 60 = 62700\text{J} = 62.7\text{kJ}$ (1)

Moles $C_7H_8 = 2.5 / 92 = 0.0272$ (1)

$\Delta H = 62.7 / 0.0272 = -2307$ kJ mol^{-1} (1)

(allow –2300 to –2323)

4

(d) Mass of water heated = 25 + 50 = 75g
Temp rise = 26.5 – 18 = 8.5 °C

*both for **(1)** mark*

Heat change = $75 \times 4.18 \times 8.5 = 2665$ J = 2.665 kJ (1)

Moles HCl = 0.05 (1)

$\Delta H = -2.665 / 0.05 = -53.3$ kJmol^{-1} (1)

(allow –53 to –54)

4

(e) Less heat loss (1)

1

[15]

Q24.

(a) Particles are in maximum state of order

(or perfect order or completely ordered or perfect crystal or minimum disorder or no disorder)

(entropy is zero at 0 k by definition)

1

(b) (Ice) melts

(or freezes or changes from solid to liquid or from liquid to solid)

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1

(c) Increase in disorder

1

Bigger (at T_2)

1

Second mark only given if first mark has been awarded

(d) (i) Moles of water = 1.53/18 (= 0.085)

1

Heat change per mole = 3.49/0.085 = 41.1 (kJ mol^{-1})

(allow 41 to 41.1, two sig. figs.)

(penalise –41 (negative value), also penalise wrong units but allow kJ only)

1

(ii) $\Delta G = \Delta H - T\Delta S$

1

(iii) $\Delta H = T\Delta S$ or $\Delta S = \Delta H/T$

(penalise if contradiction)

1

ΔS = 41.1/373 = 0.110 kJ K^{-1} (mol^{-1}) (or 110 (J K^{-1} (mol^{-1}))

(allow 2 sig. figs.)

(if use value given of 45, answer is 0.12 (or 120 to 121)

(if ΔH is negative in (d) (i), allow negative answer)

(if ΔH is negative in (d) (i), allow positive answer)

(if ΔH is positive in (d) (i), penalise negative answer)

1

Correct units as above (mol^{-1} not essential)

1

[10]

Q25.

(a) (i) <u>enthalpy change</u> when 1 mol of a substance (or compound) (QL mark)

1

is (completely) burned in oxygen (or reacted in <u>excess</u> oxygen)

1

at 298 K and 100 kPa (or under standard conditions)

1

(ii) heat produced = mass of water × Sp heat capacity × ΔT (or $mc\Delta T$)

1

= 150 × 4.18 × 64 (note if mass = 2.12 lose first 2 marks then conseq) = 40100 J or = 40.1 kJ (allow 39.9 - 40.2 must have correct units)

1

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moles methanol = mass/M_r = 2.12/32 (1)
= 0.0663

1

ΔH = – 40.1/0.0663 = – 605 kJ (mol^{-1})

1

(allow –602 to –608 or answer in J)

(note allow conseq marking after all mistakes but note use of 2.12 g loses 2 marks

(b) (i) equilibrium shifts to left at high pressure

1

because position of equilibrium moves to favour fewer moles (of gas)

1

(ii) at high temperature reaction yield is low (or at low *T* yield is high)

1

at low temperature reaction is slow (or at high *T* reaction is fast)

1

therefore use a balance (or compromise) between rate and yield

1

(c) $\Delta H = \Sigma \Delta H_c^{\ominus}$(reactants) – $\Sigma \Delta H_c^{\ominus}$(products) (or correct cycle)

1

$\Delta H_c^{\ominus}(CH_3OH) = \Delta H_c^{\ominus}(CO) + 2 \times \Delta H_c^{\ominus}(H_2) - \Delta H$

1

= (–283) + (2 × –286) – (–91) (mark for previous equation or this)
= –764 (kJ mol^{-1}) (*units not essential but lose mark if units wrong)*
(note + 764 scores 1/3)

1

[15]

Q26.

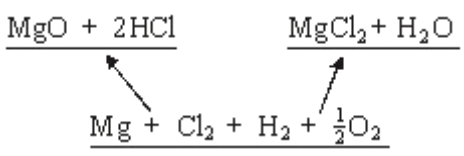
(a) (i) enthalpy (or heat or heat energy) change when
1 mol of a substance **(1)** (QL mark) is formed from its elements **(1)**
all substances in their standard states **(1) (**or normal states at 298K, 100 kPa or std condits)

not *STP, NTP*

3

(b) enthalpy change (or enthalpy of reaction) is independent of route **(1)**

$\Delta H = \Sigma \Delta H_f^{\ominus}$ prods - $\Sigma \Delta H_f^{\ominus}$ reactants (or cycle) **(1)**
minimum correct cycle is:



ΔH = -642 – 286 – (–602 + 2 × –92) **(1)**

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= –142 (kJ mol^{-1}) **(1)**

penalise this mark for wrong units

+142 scores 1 mark out of the last three

4

(c) $\Delta H = mcT$ **(1)** (or $mc\Delta T$)

$= 50 \times 4.2 \times 32 = 6720$ J $= 6.72$J **(1)**

mark is for 6720 J or 6.72 kJ

moles HCl $= \frac{\text{vol}}{1000} \times \text{conc} = \frac{50}{1000} \times 3$ **(1)**

$= 0.15$ **(1)**

if error here mark on conseq.

Therefore moles of MgO reacted = moles HCl/2 **(1)**
(mark is for/2, CE if not/2)
$= 0.15/2 = 0.075$

Therefore $\Delta H = 6.72/0.075$ **(1)**

= –90 kJ (mol^{-1})

kJ must be given, allow 89 to 91

*value **(1)***

*sign **(1)**; this mark can be given despite CE for /2*

8

Note various combinations of answers to part (c) score as follows:

–89 to –91 kJ **(8)** (or –89000 to 91000J)

*no units **(7)***

+89 to +91 kJ **(7)** (or + 89000 to +91000J)

*no units **(6)***

–44 to –46 kJ **(5)** (or -44000 to -46000J)

*no units **(4)** if units after 6.72 or 6720 (5)*

+44 to +46 kJ **(4)** (or +44000 to + 46000)

if no units and
*if no units after 6.72 or 6720 **(3)***
*otherwise check, could be **(4)***

[15]

Q27.

(a) $C_3H_6O + 4O_2 \rightarrow 3CO_2 + 3H_2O$ **(1)** (or multiple) 1

(b) (i) $\frac{1.45}{58}$ **(1)** = 0.0250 **(1)**

allow 0.025

allow conseq on wrong M_r

1.45/100, CE; $\frac{1.45}{58.1}$ *C.E.*

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(ii) heat released = mcΔT
= 100 × 4.18 × 58.1 **(1)**
if 1.45 used in place of 100 CE = 0

= 24300 J **(1)** (or 24.3kJ)
allow 24200 to 24300
ignore decimal places
units tied to answer
If use 0.1 × 4.18 × 51.8 allow ½ for 24.3 with no units

(iii) $\frac{24.3}{0.0250}$ = –972 (kJ mol^{-1}) **(1)**
allow –968 to –973
allow +972
allow conseq
allow no units
penalise wrong units

5

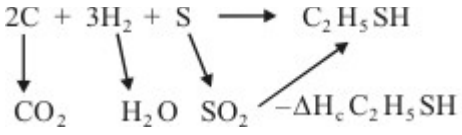
(c) (i) Heat loss **(1)** or energy loss
do not allow incomplete combustion

(ii) *Difference*: more negative **(1)** (or more exothermic)
QoL mark

Explanation: heat (*or energy*) released when water vapour condenses **(1)**
or heat/energy required to vaporise water
or water molecules have more energy in the gaseous state

3

(d) $\Delta H = \Sigma \Delta H_{reactants} - \Sigma \Delta H_{products}$ **(1)**

(or cycle 

)

= (2 × –394) + (3 × –286) + (–297) – (–1170) **(1)**
= –773 **(1)**
ignore units even if wrong
Allow 1/3 *for +773*

3

[12]

Q28.

(a) $2AgNO_3 + Zn \rightarrow Zn(NO_3)_2 + 2Ag$ **(1)**
Accept an ionic equation i.e. $2Ag^+ + Zn \rightarrow 2Ag + Zn^{2+}$

1

(b) Moles = mv / 1000 **(1) =** 0.20 × 50/1000 = 1.00 × 10^{-2}

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2

(c) Heat energy change = mCΔT **(1)** = 50 × 418 × 3.2 J

= 669 J (Ignore signs) **(1)**

Allow 668, 67.0 0.67kJ

Penalise wrong units if given

2

(d) $\frac{2 \times 669}{1 \times 10^{-2}}$ = 134 kJ mol^{-1}

Mark one : 2 × (answer to (c))

Mark two : Dividing by answers to (b)

Allow 133 – 134

Penalise incorrect units

Mark conseq to equation in (a) for full marks, also to that in (c)

If No working is shown and answer is incorrect zero

2

(e) Incomplete reaction or Heat loss **(1)**

1

[8]

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Q1.

(a) Many students struggled with this question, though it did discriminate well. The main problem stemmed from an inability to find the heat released using the enthalpy change (per mole) and the amount in moles of the acid or alkali reacting. Many believed that q was the same as the enthalpy change. Some students also incorrectly thought that amount in moles reacting' was the amount in moles of acid + moles of alkali.

(b) Very few students realised that the best-fit line was a curve and not a straight line. Some students also extrapolated to a time before the time of mixing. Only 3.8% of students gained both marks.

Q2.

(a) This question discriminated well: 28.3% of students correctly identified the types of intermolecular forces and noted that hydrogen bonding in the alcohol and the acid was stronger than dipole-dipole attractions between propanal molecules. Despite the request in the question to consider intermolecular forces, a few students still discussed the breaking of bonds in the molecules and so gained no marks, although fewer did this than is often the case in this type of question.

(b) Very few students (4%) scored both marks in this question and only 39.2% scored at least one mark, despite the question being based on one of the required practical activities.

(c) This part was answered well by nearly two-thirds of the students. The main error was to test for the aldehyde rather than the acid.

(d) This question discriminated well and there was a good spread of marks. Sadly, some students did not quote their answers to three significant figures and/or remember the negative sign for their exothermic enthalpy change of combustion.

(e) The major errors in the answers to this acid-catalysed elimination of water were where students confused this mechanism with the elimination of HX from a halogenoalkane using a base. However, just under a third of students scored full marks in a correct mechanism, either via the formation of a carbocation or by showing the simultaneous loss of water and H+ from a protonated alcohol.

(f) This part was challenging and a surprising proportion of students (8%) made no attempt. A large number scored no marks as they discussed the formation of different alkenes, rather than why pent-2-ene shows E-Z isomerism. Sadly, some of those who did gain the first mark failed to gain the second as this required two statements, not only that the C=C bond cannot rotate, but also that each carbon in the double bond has two different groups attached to it.

Q3.

(a) The usual advice is that a scale on a graph is 'suitable' if the plotted points take up more than half of the available space. In this case, the decision about the suitability of the scale was more 'relaxed' due to the need for students to allow space for the extrapolation to go higher than the highest plotted point. However, a significant number of students still managed to miss the mark by choosing scales that led to the plotted points being squeezed in to only a couple of squares on the vertical axis.

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There still seems to be a misconception amongst some students that all scales need to start at zero. Having plotted the points, most students recognised that their lines of best fit should ignore the point at 5 minutes. Although a lot of 'S-shaped' curves were seen (the reminder clue in the question was that candidates should draw suitable *lines* of best fit), some students failed to draw any line between 0 and 3 minutes, and the lines were sometimes not extrapolated to the 4th minute. A surprising number of students quoted the 'final' temperature at the 4th minute rather than giving ΔT. Pleasingly, 34.3% of students scored all five marks.

(b) Far more students than expected failed to double the uncertainty given in the question to reflect the fact that two temperature readings are taken with the thermometer. As a result, only 19.3% of students were awarded this mark.

(c) As expected, this was the easiest question on the paper with the vast majority of candidates (90.7%) able to suggest a way to reduce heat loss.

(d) This was another example of a question where some students were let down by not reading the question, which clearly asked for a change that would reduce the percentage uncertainty *in the use of the same thermometer*. Given that percentage uncertainty is calculated as apparatus uncertainty divided by measurement made, it was hoped that more students would recognise the need to increase the size of the measurement made, i.e. the temperature change. Many students who did recognise the need to generate a bigger temperature change suggested doing so by using smaller volumes; they thus failed to appreciate that this would reduce the amounts of reactants as well as the volume, so that less heat would be given out and the change in temperature would be the same as in the larger scale experiment. 58% of students scored zero.

(e) Despite the formula and name being given in the question, many students failed to recognise that ethanedioic acid is diprotic, which affected their equation and subsequent calculation. In the calculation, most were able to calculate the initial amounts of each reactant, but many then failed to recognise the idea that one is present in excess so that the other would be the limiting reagent and so determine the amount of water formed. Calculations involving adding 0.02 to 0.045, or subtracting 0.02 from 0.045, were frequently seen, although it was not always clear what students thought they were calculating when they did so, due to poor layout of calculations. There were also a lot of variations seen in the mass used for the mcΔT calculation. In any enthalpy change or calorimetry experiment of this type, it is the solution that is increasing in temperature, so it is the mass of solution that needs to be used (100 g here as 25 cm^3 of one solution was added to 75 cm^3 of another and all have a density of 1.00 g cm^{-3}). This calculation discriminated extremely well between students of different abilities; 21.2% scored maximum marks and only 6.4% failed to score anything.

(f) This was expected to be a high-level discriminator and that certainly proved to be the case for the second mark (achieved by only 3.3% of students). Although many gained a mark for referring to the fact that sulfuric acid is a stronger acid than ethanedioic acid, the second half of their answer often then incorrectly referred to ideas such as "it therefore reacts with more KOH", "more water is produced", and "bonds between K^+ and sulfate are stronger than between K^+ and ethanedioate". Only the best students recognised that the overall enthalpy change is the net result of the difference between 'energy supplied' and 'energy released'. In this case, the 'energy released' will be the same for both acids. Therefore, the difference in the enthalpies of neutralisation must be due to ethanedioic acid needing more energy to be supplied, in order to break O−H bonds during the neutralisation reaction (whereas the sulfuric acid is already fully dissociated).

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Q4.

(a) In this extended calculation the correct limiting reagent had to be used to gain full marks. This proved difficult for many students. The less able students were expected to be able to calculate the numbers of moles of the two reagents and/or state that q = mcΔT, but this was not always the case.

(b) 58.1% of students gained the mark for this question about a well-known practical issue.

(c) This practical question was marked using a levels of response mark scheme. There was a wide range of answers, showing that most had done this sort of practical during their course. Nearly all students were aware that insulation is the most obvious improvement to the technique but many students failed to read the question carefully. Many answers, even from the best students, described a technique but did not suggest clearly and then justify how the method given in the question could be improved.

Q5.

(a) This proved to be a much tougher starter question than had been anticipated, with only 12% of students earning the mark. Students did not recognise that enthalpy change could not be measured directly. In this case, the enthalpy change was for the formation of a hydrated salt from an anhydrous one, with the expected answer being that it would be impossible to prevent some salt dissolving during the addition of water to the anhydrous salt. An alternative answer, related to the difficulty in measuring the temperature of a solid, was also allowed.

Some students' answers revealed confusion between calorimetry and colorimetry, with suggested answers including the lack of colour change during the reaction. Some students also seemed to believe that calorimetry is only possible if something is being burned.

(b) This calculation was answered reasonably well, with less than 20% of students failing to score. There was confusion about the 'direction' around the Hess Cycle, and evidence of many students thinking that an equation of the form $\Delta H = \Sigma \Delta H_f$(products) - $\Sigma \Delta H_f$(reactants) can be used universally, when it only applies to the specific use of enthalpies of formation.

(c) Most students' encounter with this 'extended response' style of question produced a good spread of marks, although 37% of students failed to score. This was usually due to a completely inappropriate method being described, with incorrect answers such as: "making a solution of magnesium chloride", "using it to fill a spirit burner and lighting it under a beaker of water" and "putting a solution of magnesium chloride in a polystyrene cup and heating it over a Bunsen burner". Other incorrect answers included descriptions of the preparation of a standard solution followed by a titration and the addition of magnesium chloride to acid instead of to water.

This question was marked using a 'levels of response' mark scheme. The key to success was for students to concentrate first on the inclusion of as much correct chemistry as possible to ensure access to Level 3 (worth 5 or 6 marks). Within a level, the mark awarded depended on the clarity and coherence of an answer, together with a clear, logical progression through the description. Appropriate apparatus and quantities should have been mentioned as necessary. For example, rather than writing 'add water to a container', a good start to the answer would be to write 'A measuring cylinder was used to measure 50 cm^3 of water into a polystyrene cup'.

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Despite the fact that many students suggested in part (a), that it is difficult to measure the temperature of a solid, many then suggested putting the magnesium chloride into the polystyrene cup first and then recording its initial temperature, before adding the water.

(d) This was a challenging question, but one for which it proved relatively easy to score two marks; nearly 20% of students scored full marks here. Most students could successfully plot the points and draw a best fit line, although the negative scale on the y-axis confused some. Most students were also able to calculate the gradient of their line, although, as mentioned previously, it was not always clear what their suggested answer was. The calculation of ΔS proved trickier, with many trying to use the relationship $\Delta G = \Delta H - T\Delta S$, and either ignoring their calculated gradient or substituting it in for ΔH. Relatively few students recognised that this equation can be taken as $y = mx + c$ ($y = c - xm$ in this case) so that this graph of ΔG (y) vs T (x) gives a straight line with a gradient of $-\Delta S$.

Q10.

Part (a) - Only the best candidates were able to gain all five marks. Worryingly, many candidates seemed to attempt to measure the specific heat capacity of the alcohol by heating it in a water bath. Vague descriptions such as “burn some alcohol to heat some water” with a failure to state what variables need to be measured were also fairly common. Some wanted to use a polystyrene cup to hold the water. There were some very good answers too, though.

Part (b) - Generally well done.

Part (c) - Generally well answered. An incomplete reagent such as missing the condition “acidified” lost M1 but subsequent marks were available. Tollens’ reagent and Benedict’s reagent were favourite incorrect answers.

Part (d) - Only the best candidates were able to score full marks. There were many correct equations although some gave an unbalanced chemical equation forgetting the “O” in the alcohol and some gave only an equation for complete combustion. A common mistake was to give two environmental concerns or two economic concerns even though the question required one of each.

Q11.

Enthalpy of combustion & calorimetry

In the calculation of the enthalpy of combustion from the experimental data, many students used the mass of the fuel (rather than the water) when using $q = mc\Delta T$. Others incorrectly added 273 to the temperature rise. When finding the moles of methanol burned, some students rounded this to 1 significant figure which gave inaccurate answers. Some students failed to include the minus sign on their final answer to show that the reaction is exothermic. In (b) many students referred to the problems already stated in the question rather than an additional one. Many students suggested mistakes made during the experiment rather than design features. Many students scored the mark for (c) but many others did not know where to start. The calculation of apparatus percentage uncertainties should be an important and routine part of practical work. Few students realised that (d) related to the size of the uncertainty in the temperature rise compared to the actual temperature rise and/or heat loss in the experiment. Many students were uncertain how to start the calculation in (e), namely by using the density to find the mass of the ethanol. Others struggled to convert the volume in dm^3 to cm^3.

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Q12.

This question was answered well. Balancing the equation in part (a)i looks straightforward when you know the answer, but it is quite demanding if you have to work it out, and impressively half the students gave the correct answer. In part (b)i, it was necessary to draw unambiguous structures both for propan-2-ol (not given in the question) and propanone (given in part (a)i). The calculation in part (c) was well answered with the focus on correct chemistry rather than on the number of significant figures and the mathematics of rounding the final answer. The definition in part (d) was expected to be straightforward and yet still resulted in only 40% gaining all three marks. As many as 45% gained all three marks and 80% gained at least one mark from the very straightforward calculation in part (e), with errors occurring because some students did not know the bonding either in propanone or in carbon dioxide and used the unnecessary C−O that was given in the data set. It was decided that the very straightforward idea of “heat loss”, in whatever context, was worth only one mark in part (f) and that students needed to come up with other reasons why the values in part (c) and part (e) differed; many were able to do so and this led to 54% scoring both marks.

Q13.

In this question, the first mark (more water) was gained by many, although some suggested a volume larger than the calorimeter. Few managed to give a clear explanation, even though some seemed to have the right kind of idea but couldn’t express it sufficiently clearly.

Q14.

Part (a) discriminated almost as well as the earlier mechanism questions with well over half of the students scoring at least 3 of the 5 marks. Relatively few recognised that (fractional) distillation is a process used to produce a much more concentrated solution of ethanol and many referred to the hydration of ethene, having missed the requirement to start “from a dilute aqueous solution”. The concept of carbon-neutral “in the context of this biofuel” required reference both to carbon dioxide **and** the atmosphere. Part (b) was well answered with over half of all students scoring 4 out of 5 marks. By comparison, part (c) proved more demanding. The definition in part (c)(i) most often yielded only 1 of the 2 marks. Too often in part (c)(ii) it proved difficult to decipher the jumble of numbers that some students recorded on the page and only about one-third of students scored all 3 marks.

Q15.

(a) This part was mostly well answered, with the exception of those who chose to use the wrong mass.

(b) In this part, failure to give the negative sign was the most common error where students did not score full marks.

(c) This part was usually done very well.

(d) In contrast, this part was very poorly answered, almost always because –2642 was used from (c) rather than their answer to (b).

(e) Many vague answers were seen in response to this part. Simply adding insulation was insufficient and use of a polystyrene cup was wrong in this situation.

(f) The idea of incomplete combustion seemed to be poorly understood in this part, with quite a few students stating that ’not all the alcohol had burned’. Comments about

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heat loss etc were disqualified by the question.

Q16.

This question proved to be difficult. In part (a), most students scored one mark for mentioning that the ionic radius of the chloride ion is less than that for the bromide ion. However, many weaker students lost this mark because they did not make reference to a chloride ion; often, just chlorine was mentioned. Only the best students went on to discuss how a chloride ion is attracted to the partially positive hydrogen atom in a water molecule. Others referred incorrectly to intermolecular forces or to hydrogen bonding. About 60% of students gained both marks for the calculation in part (b). In part (c)(i), most students stated that the entropy would increase but many did not clearly explain why and also that the TΔS term would outweigh the positive enthalpy change. Although about a quarter of all students scored at least 4 marks in part (c)(ii), less than 10% went on to score full marks by subtracting the temperature change from 298 K. Marks were generally low because many students did not recognise that the heat absorbed could be calculated by multiplying the enthalpy of solution by the amount in moles of potassium chloride. Weak students also used a wrong value for the mass of water heated – usually 25 g or 5.00 g.

Q17.

Almost 85% of students were able to give a correct statement for Hess's Law and then attempted to apply it in parts (b) and (c), with over 70% success. No credit was given for a value calculated in part (c), consequent on an incorrect expression in part (b), since that is a chemical error.

Part (d) was generally well-answered although the negative sign was often missed in the answer leading to only 35% gaining all three marks. Only 7% were able to deduce a correct answer to part (e).

Q18.

The standard enthalpy change calculation in part (a) was straightforward and high scoring. In parts (b) and (c), good discrimination occurred and a great many well–articulated responses were seen. It is worth noting that no marks were scored in either of parts (b) or (c), if the effect on the yield was assigned incorrectly. The meaning of *carbon–neutral* in part (d) is spelled out in the specification and needs to refer to <u>net</u> emissions of carbon dioxide to the atmosphere. Parts (d)(ii) and (d)(iii) were challenging and only the best students were able to arrive at the equation for the overall reaction between hydrogen and oxygen to make water. Most students scored at least one mark in part (e); the commonest error was a failure to give the final answer a negative sign for this exothermic process.

Q19.

(a) In this part, most students completed the graph successfully. The usual problem was a mark being wrongly awarded for plotted points which did not cover half the grid because the student started the y-axis at zero. Some schools and colleges were very generous when awarding the mark for drawing a line of best fit. In graph questions where the points contain one or more anomalies, the line of best fit must ignore these anomalies to score the mark. The line of best fit mark cannot be awarded when the line itself is poorly drawn or doubled in places. A few schools and colleges did not allow the mark for extrapolation when the line of best fit was poor. As long as the line is extended correctly the mark for extrapolation can be awarded. If the line becomes kinked when extrapolated the mark for extrapolation cannot be awarded.

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(b) A few teachers failed to realise that the marks for part (b) and (c) were essentially for drawing the graph correctly rather than for reading from a poorly drawn graph.

(c) A few teachers failed to realise that the marks for part (b) and (c) were essentially for drawing the graph correctly rather than for reading from a poorly drawn graph.

(d) Few students lost the mark in this part for incorrect precision.

(e) In this part proved straightforward but a fair number of students used an incorrect mass in the equation.

(f) In this part, a good number of students were incorrectly allowed the second mark for the answer 0.01. This answer, being to one significant figure only, was disallowed in the Marking Guidelines.

(g) In this part was well answered, although a surprising number of students omitted the negative sign in their final answer.

(h) Answers to this part were generally good; the common error was to suggest that stirring ensured that the mixture was homogeneous.

(i) In this part (ii) a number of students thought that heat was the danger to the equipment and lost the mark.

The above notes are intended for that minority of schools and colleges experiencing difficulty in meeting the criteria. They must not be allowed to unduly detract from the very healthy overall picture. Given the pressures on teachers to deliver the teaching programme, this was once again a very positive and encouraging session. Schools and colleges are again warmly commended for the trouble taken to assemble a sample which proved to be easy to moderate. Their efforts continue to be much appreciated by the moderator team.

Q20.

Section B proved more demanding. In part (a), the calculation had similar faults to Question 5 but some students failed to read that the answer was to be in Joules - an answer in kJ was penalized unless there was a clear correct answer in the working. Part (b) and part (c) were well done though the alternative answer to part (a) was frequently used in these. In part (d), only a few students failed to highlight the need for the bag to split or the chemicals to come into contact with skin / hands. Part (e)(i) indicated that a considerable number of students found difficulties with the equation; common errors were the wrong formula for iron (III) oxide, the inclusion of ions on the reagent side of the equation and using Fe2 for the metal. Part (e)(ii) contained many good partial answers but there was a significant failure to focus finally on why longer times might not be an advantage. In part (f)(i), the main errors were to re-state the question about being reusable or to indicate that there would be no waste following use of these handwarmers. There were some vague answers to part (f)(ii) which referred to 'heating' the bag or 'keeping it in a warm place' and, for some, the contents were removed before further treatment. Nevertheless, sensible answers were frequently seen.

Q21.

Most candidates seem to know something about fermentation and part (a) discriminated extremely well.

In part (b), only the best candidates were able both to state that such a fuel is carbon-neutral and also to demonstrate that the six moles of CO_2 taken in during photosynthesis

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are later released in the fermentation process followed by the combustion of ethanol. Failure to recognise that two moles of ethanol were burning resulted in only four moles of CO_2 and left candidates confused. A few candidates seemed to think that a balanced equation with six carbon atoms on each side is carbon-neutral.

The calculation in part (c) proved demanding as candidates failed to count up accurately how many of each bond were broken and how many were formed. They were able quite often to get only one of these correct. The idea that mean bond enthalpies are average values obtained from many different compounds was not well known.

In part (d) the equation used to calculate the heat change was well known but conversion to enthalpy change proved difficult for all but the best. The idea of incomplete combustion was often missed.

Q22.

This was generally a well-answered question suggesting that the students were able to apply their knowledge in a novel context provided they had sufficient information. More than 70% of candidates scored full marks in all three parts (a)(i), (a)(ii) and (a)(iii) and almost half the candidates were able to use the calculated data for each liquid to arrive at some credit in part (a)(iv). Almost a third of the candidates gave plausible reasons for why the students may have made an incorrect deduction.

Q23.

Part (a) was generally well done by most candidates. The most common error was not referring to standard states. The calculation in part (b) proved more demanding for students than some previous enthalpy calculations with many candidates giving the incorrect answer of –7kJmor\ A large number of candidates did not give the correct mass or correct temperature rise in part (c) and therefore only scored the mark for the $Q = mc\Delta t$ equation. Many of the candidates who did calculate the heat evolved then failed to calculate molar quantities. The calculation in part (d) proved very difficult for candidates with very few scoring full marks. Common errors were incorrect mass, incorrect temperature rise and lack of conversion to molar quantities. Candidates should know that exothermic reactions are shown by a negative sign e.g. $–53.3kJmol^{-1}$. In part (e) many candidates failed to make the comparison regarding heat loss between the two experiments.

Q24.

This question also produced a wide range of marks. A major misconception was to relate entropy directly to the energy of particles rather than to their disorder. Most candidates gave a correct answer to part (b). In part (c) weak candidates often discussed the breaking of bonds rather than referring to disorder. Others just reiterated the question by stating that the entropy would increase. Good candidates usually gained one mark by stating that the disorder of particles increases when a liquid changes to a gas but only the best candidates answered the question fully by referring also to the smaller change in order on melting. It was pleasing to note that part (d) was answered correctly by many candidates. Marks were sometimes lost when giving units in part (d)(iii) that did not tally with the numerical answer. For example, when the numerical answer should have corresponded to $J\ K^{-1}\ mol^{-1}$ the units were frequently given as $kJ\ K^{-1}\ mol^{-1}$.

Q25.

In this question, good candidates were able to score full marks. Weaker candidates were less successful though they were usually able to pick up at least five or six marks.

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Answers to part (a) usually gained all three marks. Answers to part (b) by weaker candidates were less successful. One common error in the expression $mc\Delta T$ was to use the mass of methanol (2.12 g) instead of the mass of water (100 g). Another common error was to give an incorrect sign for the final value of the enthalpy of combustion. Candidates were expected to recognise that this exothermic process should lead to a negative value for the enthalpy of combustion of methanol. Weaker candidates also lost marks for incorrect units or for giving no units. It is important for candidates to give correct units for intermediate values in the calculation as well as for the answer. In this case, if a candidate gave a wrong final answer, it was still possible to gain an intermediate mark for the heat released to the 100 g of water. However, if the candidate did not make it clear whether the intermediate value was expressed in Joules or in kJ, it was not possible to give any credit.

Answers to part (b) were of a good standard and in part (b) (i) almost all candidates were awarded the two marks. Answers to part (b) (ii) were not quite so accurate and, in particular, only the best candidates stated that 500 K achieves the best balance between rate of reaction and yield.

Good candidates found part (c) straightforward but weaker candidates often omitted to allow for two moles of hydrogen and also used the wrong sign for the enthalpy of reaction (-91 kJ mol^{-1}) relative to the enthalpies of combustion of carbon monoxide and hydrogen.

Q26.

Most candidates answered this question well though it proved to be difficult to score maximum marks. The definition of standard enthalpy of formation in part (a) was usually correct though some candidates lost one mark because they did not make it clear that reactants and products should be in their standard states. In part (b) good candidates were able to score maximum marks but weaker candidates sometimes referred to energy rather than enthalpy when stating Hess's Law and such candidates often predicted an endothermic enthalpy change (+142 kJ mol^{-1}) rather than an exothermic one. Part (c) proved to be the most difficult part of this question. The major error was in the number of moles of magnesium oxide. Most candidates assumed that the number of moles of MgO would be the same as that of hydrochloric acid whereas it should have been half of that. This error led to a value for the enthalpy change that was too small by a factor of two. Such an answer resulted in the loss of three marks.

Q27.

This question proved accessible to most candidates; even the weaker candidates were able to score marks approaching half of those available. Answers to part (a) were usually correct.

Most candidates also gave a correct answer to part (b)(i) though there were a significant number of errors in the calculation of the relative molecular mass of propanone. Parts (b)(ii) and (b)(iii) were also answered well although there were some problems with units. The correct answer to part (c)(i) was known by most candidates but part (c)(ii) proved to be much more discriminating and only the best candidates were able to explain why the enthalpy of combustion is more negative when water is formed in the liquid state. A fair majority of candidates was able to give a correct answer to part (d) but as usual in this type of question, weaker candidates made an error in signs leading to an answer of +773 kJ mol^{-1} or made an error by omitting to multiply the relevant enthalpy of combustion by the number of moles of the substance involved.

Q28.

It was disappointing to find many wrong equations for the reaction between silver nitrate

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and zinc in part (a) especially as the use of silver nitrate solution to distinguish between halides ions forms part of this module and the formula of zinc nitrate was given.

Parts (b) and (c) were well answered and, as part (d) was marked consequentially to answers given in parts (a), (b) and (c), most candidates were also able to score full marks in part (d). Almost all candidates stated correctly in part (e) that loss of heat energy was the reason why the experimental value obtained was less than the correct value.

Q1.

(a) $2Fe(s) + \frac{3}{2}O_2(g) \rightarrow Fe_2O_3(s)$ 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]

Q2.

(a) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

allow fractions / multiples

allow any correct structural representation of molecules

ignore state symbols

1

(b) **M1** working that leads to n = 13

e.g. $-6650 = -(496\mathbf{n} + 202)$

and/or $496\mathbf{n} = 6650 - 202$

and/or $496\mathbf{n} = 6448$

$(\mathbf{n} = 13)$

1

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M2 $C_{13}H_{28}$

*$C_{13}H_{28}$ scores **M1** and **M2** if some correct working shown*

*$C_{13}H_{28}$ with no working scores **M2** only*

*allow error carried forward for **M2** for a correct formula of an alkane from the value of **n** worked out for **M1** (but there must be some working shown leading to this incorrect value of **n**); for example, allow $C_{14}H_{30}$ if error in **M1** stemming from error in rearranging equation*

1

(c) Idea that

- alkane is not gaseous or
- equation relates to gaseous alkanes or
- it takes energy to convert it into a gas or
- that water / alkane / substances are gaseous in calculations using bond enthalpies

ignore references to heat loss, incomplete combustion, loss of evaporation, not being in standard conditions or that it is not standard state

1

(d) **M1** plotting the four values correctly (allow one error where point is ±1 square out)

*If plotted points for wrong number of C atoms for two or more compounds, cannot score **M1** or **M2**, but could score **M3** if read value off for 3C atoms*

1

M2 smooth best fit curve

M2 *best fit curve for their four points for the correct number of C atoms*

1

M3 value from their best fit line for 3 C atoms (allow ± 1 square)

M3 *need – sign (but ignore units);*

*cannot score **M3** unless there is a line on the graph*

1

(e) **M1** mass of isooctane = 692 (g)

*correct answer scores **M1** and **M2***

1

M2 3.31×10^4 or 33100 (kJ) (**3sf only**)

M2 *correct value to incorrect number of sig figs is 1 mark;*

ignore sign ;

*no error carried forward for **M2***

1

[9]

Q3.

(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

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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]

Q4.

C

[1]

Q5.

(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

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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]

Q6.

(a) Bonds broken = 2(C=O) + 3(H–H) = 2 × 743 + 3 × H–H

Bonds formed = 3(C–H) +(C–O) + 3(O–H) = 3 × 412 + 360 + 3 × 463

Both required

1

–49 = [2 × 743 + 3 × (H–H)] – [3 × 412 + 360 + 3 × 463]

3(H–H) = –49 – 2 × 743 + [3 × 412 + 360 + 3 × 463] = 1450

Both required

1

H–H = 483 (kJ mol^{-1})

Allow 483.3(3)

1

(b) Mean bond enthalpies are not the same as the actual bond enthalpies in CO_2 (and / or methanol and / or water)

1

(c) The carbon dioxide (produced on burning methanol) is used up in this reaction

1

(d) 4 mol of gas form 2 mol

1

At high pressure the position of equilibrium moves to the right to lower the pressure / oppose the high pressure

1

This increases the yield of methanol

1

(e) Impurities (or sulfur compounds) block the active sites

Allow catalyst poisoned

1

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(f) Stage 1: moles of components in the equilibrium mixture

Extended response question

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

Initial moles	1.0	3.0	0	0
Eqm moles	(1–0.86) = 0.14	(3–3×0.86) = 0.42	0.86	0.86

1

Stage 2: Partial pressure calculations

Total moles of gas = 2.28

Partial pressures = mol fraction × p_{total}

1

p_{CO2} = mol fraction × p_{total} = 0.14 × 500 / 2.28 = 30.7 kPa

p_{H2} = mol fraction × p_{total} = 0.42 × 500 / 2.28 = 92.1 kPa

M3 is for partial pressures of both reactants

Alternative M3 =

pp_{CO2} = 0.0614 × 500

pp_{H2} = 0.1842 × 500

1

p_{CH3OH} = mol fraction × p_{total} = 0.86 × 500 / 2.28 = 188.6 kPa

p_{H2O} = mol fraction × p_{total} = 0.86 × 500 / 2.28 = 188.6 kPa

M4 is for partial pressures of both products

Alternative M4 =

pp_{CH3OH} = 0.3772 × 500

pp_{H2O} = 0.3772 × 500

1

Stage 3: Equilibrium constant calculation

$K_p = p_{CH3OH} \times p_{H2O} / p_{CO2} \times (p_{H2})^3$

1

Hence $K_p = 188.6 \times 188.6 / 30.7 \times (92.1)^3 = 1.483 \times 10^{-3} = 1.5 \times 10^{-3}$

Answer must be to 2 significant figures

1

Units = $\underline{kPa}^{-2}$

1

[16]

Q7.

B

[1]

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Q8.

(a) The <u>enthalpy / heat energy change</u> when <u>1 mol</u> (of a substance)

If enthalpy of formation definition given CE=O

***NOT** just 'energy'*

***ALLOW** alternatives for substance e.g. molecule/compound/element*

1

Is <u>burned/reacts completely in oxygen</u>

***ALLOW** reacts in excess oxygen*

1

With all reactants and products in their <u>standard states</u>

OR

With all reactants and products in their normal states at 298K/given temp & 100kPa

***ALLOW** 'everything' for 'reactants and products'*

Penalise incorrect conditions if given

***ALLOW** 'normal states under standard conditions'*

1

(b) $\Delta H = \Sigma \Delta H_c$(reactants) - $\Sigma \Delta H_c$ (products)

OR

Correctly and fully balanced cycle

Correct answer scores 3

1

$\Delta H = [3(-394) + 4(-286)] – (-2010)$

OR

$\Delta H = -2326 + 2010$

M2 also scores M1

1

$\Delta H = -316$ (kJ mol^{-1})

+316 scores 1 mark only

***IGNORE** units*

Check for AE in working – can award M3 as ecf (error carried forward) from M2 if M2 not given due to AE

1

(c) $\Delta H/-1893 = \Sigma B$(reactants) - ΣB(products)

OR

$\Delta H/-1893 = \Sigma$Bonds broken - ΣBonds formed

OR

$\Delta H/-1893 = 2B(C-C) + 7B(C-H) + B(C-O) + B(O-H) + 4½\ B(O=O) – 6B(C=O) – 8B(O-H)$

Correct answer scores 3

1

$-1893= 2B(C-C) + 7(412) + 360 + 463 + 4½(496) – 6(805) – 8(463)$

OR

$-1893= 2B(C-C) +5939 – 8534$

OR

$-1893= 2B(C-C) -2595$

OR

$2B(C-C) = 702$

M2 also scores M1

May see no 463 in bonds broken and 7x463 in made (gives 5476 – 8071)

1

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B(C-C) = (+)351(kJ mol^{-1})

*If **NOT** 351 check for AE. This would lose M2, but could gain M1 and M3*

(+)234 scores 1 (due to 3(C-C))

***NOT** M3 from incorrect M2 unless incorrect M2 is due to AE*

***IGNORE** units*

If no other mark awarded then

***ALLOW** 1 if 5939 or 5476 or 8534 or 8071 seen*

1

[9]

Q9.

(a) (i) $\mathbf{2}C_6H_{12}O_6 \longrightarrow \mathbf{3}CH_3COCH_3 + \mathbf{3}CO_2 + \mathbf{3}H_2O$

Or multiples

1

(ii) to speed up the reaction
OR
(provide a) catalyst or catalyses the reaction or biological catalyst
OR
release / contain / provides an enzyme

Ignore "fermentation"

Ignore "to break down the glucose"

Not simply "enzyme" on its own

1

(b) (i) $CH_3CH(OH)CH_3 + [O] \longrightarrow CH_3COCH_3 + H_2O$

Any correct representation for the two organic structures. Brackets not essential.

Not "sticks" for the structures in this case

1

(ii) Secondary (alcohol) OR 2° (alcohol)

1

(c) **M1** $q = m\ c\ \Delta T$

OR $q = 150 \times 4.18 \times 8.0$

Award full marks for correct answer

*In **M1**, do not penalise incorrect cases in the formula*

M2 = (±) 5016 (J) ***OR*** 5.016 (kJ) ***OR*** 5.02 (kJ)
(also scores M1)

M3 This mark is for dividing correctly the number of kJ by the number of moles and arriving at a final answer in the range shown.
Using 0.00450 mol

therefore ΔH = **− 1115** (kJ mol^{-1})

***OR* − 1114.6 to − 1120** (kJ mol^{-1})

Range (+)1114.6 to (+)1120 gains 2 marks

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BUT − 1110 gains 3 marks and +1110 gains 2 marks

AND − 1100 gains 3 marks and +1100 gains 2 marks

Award full marks for correct answer

*In **M1**, do not penalise incorrect cases in the formula*

*Penalise **M3** ONLY if correct numerical answer but sign is incorrect; **(+)1114.6 to (+)1120 gains 2 marks***

*Penalise **M2** for arithmetic error and mark on*

If ΔT = 281; score q = m c ΔT only

*If c = 4.81 (leads to 5772) penalise **M2** ONLY and mark on for **M3** = − 1283*

*Ignore incorrect units in **M2***

*If units are given in **M3** they must be either kJ or kJ mol^{-1} in this case*

3

(d) **M1** The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / element

M2 is burned / combusts / reacts completely in oxygen
OR
burned / combusted / reacted in excess oxygen

M3 with (all) reactants and products / (all) substances in standard / specified states

OR
(all) reactants and products / (all) *substances in normal states under standard conditions* / 100 kPa / 1 bar and specified T / 298 K

*For **M3***

Ignore reference to 1 atmosphere

3

(e) **M1**
$\sum$ B **(reactants)** − $\sum$ B **(products)** = Δ*H*
OR
Sum of bonds broken − Sum of bonds formed = Δ*H*
OR
2B(C−C) + B(C=O) + 6B(C−H) + 4B(O=O) (LHS)

− 6B(C=O) − 6B(O−H) (RHS) = Δ*H*

M2 (also scores **M1**)
2(348)+805+6(412)+4(496) [LHS = **5957**]

(696) (2472) (1984)

− 6(805) − 6(463) [RHS = (−) **7608**] = Δ*H*

(4830) (2778)

OR using only bonds broken and formed (**5152 − 6803**)

M3
Δ*H*= **− 1651** (kJ mol^{-1})

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Candidates may use a cycle and gain full marks.

Correct answer gains full marks

Credit 1 mark for (+) 1651 (kJ mol^{-1})

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 / addition error; this would score 2 marks (**M1** and **M2**)*
- *If no AE, check for a correct method; this requires either a correct cycle with $4O_2$, $3CO_2$ and $3H_2O$ OR a clear statement of **M1** which could be in words and scores **only M1***

Allow a maximum of one mark if the only scoring point is LHS = 5957 (or 5152) OR RHS = 7608 (or 6803)

Award 1 mark for + 1651

3

(f) **For the two marks M1 and M2, any two from**

- heat loss or not all heat transferred to the apparatus or heat absorbed by the apparatus or (specific) heat capacity of the apparatus not considered
- incomplete combustion / not completely burned / reaction is not complete
- The idea that the water may end up in the gaseous state (rather than liquid)
- reactants and / or products may not be in standard states.
- MBE data refers to gaseous species but the enthalpy of combustion refers to liquids in their standard states / liquid propanone and liquid water in standard states
- MBE do not refer to specific compounds OR MBE values vary with different compounds / molecules OR are average / mean values taken from a range of compounds / molecules

Apply the list principle but ignore incomplete reasons that contain correct chemistry

Ignore "evaporation"

Ignore "faulty equipment"

Ignore "human error"

Not enough simply to state that "MBE are mean / average values"

2

[15]

Q10.

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

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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]

Q11.

(a)

M1 $C_6H_{12}O_6 \longrightarrow$ **2**CH_3CH_2OH ($2C_2H_5OH$) + **2**CO_2

*Penalise C_2H_6O for ethanol in **M1**.*

M2 and **M3**

*Mark **M2** and **M3** independently.*

Any **two** conditions **in any order** for **M2** and **M3** from

- (enzymes from) yeast or zymase
- 25 °C ≤ T ≤ 42 °C OR 298 K ≤ T ≤ 315 K
- anaerobic / no oxygen / no air OR neutral pH

  A lack of oxygen can mean either without oxygen or not having enough oxygen and does not ensure no oxygen, therefore only credit "lack of oxygen" if it is qualified.

  Penalise 'bacteria', 'phosphoric acid', 'high pressure' using the list principle.

M4 (fractional) distillation or GLC

Ignore reference to 'aqueous' or 'water' (ie not part of the list principle).

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M5 Carbon-neutral **in this context** means

There is no net / overall (annual) carbon dioxide / CO_2 emission to the atmosphere

OR

There is no change in the total amount / level of carbon dioxide / CO_2 present in the atmosphere

*For **M5** – must be about CO_2 and the atmosphere.*

The idea that the carbon dioxide / CO_2 given out equals the carbon dioxide / CO_2 that was taken in from the atmosphere.

5

(b) **M1** q = m c ∆T (this mark for correct mathematical formula)

*Full marks for **M1**, **M2** and **M3** for the correct answer.*

*In **M1**, do not penalise incorrect cases in the formula.*

M2 = (75 × 4.18 × 5.5)

1724 (J) **OR** 1.724 (kJ) **OR** 1.72 (kJ) **OR** 1.7 (kJ)

(also scores **M1**)

*Ignore incorrect units in **M2**.*

M3 Using 0.0024 mol

therefore ∆H = **− 718** (kJ mol^{-1})

(Accept a range from −708 to −719 but do not penalise more than 3 significant figures)

*Penalise **M3** ONLY if correct numerical answer but sign is incorrect. Therefore **+718 gains two marks**.*

*If units are quoted in **M3** they must be correct.*

*If ∆T = 278.5, CE for the calculation and penalise **M2** and **M3**.*

M4 and **M5** in any order

Any **two** from

- incomplete combustion
- heat loss
- heat capacity of Cu not included
- some ethanol lost by evaporation
- not all of the (2.40 × 10^{-3} mol) ethanol is burned / reaction is incomplete

*If c = 4.81 (leads to 1984) penalise **M2** ONLY and mark on for **M3** = − 827*

5

(c) (i) **M1** enthalpy / heat / energy change (at constant pressure) or enthalpy / heat / energy needed in breaking / dissociating (a) covalent bond(s)

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Ignore bond making.

M2 averaged for that type of bond over different / a range of molecules / compounds

Ignore reference to moles.

2

(ii) **M1**

∑ B(**reactants**) − ∑ B(**products**) = ΔH

OR

Sum of bonds broken − Sum of bonds formed = ΔH

OR

B(C-C) + B(C-O) + B(O-H) + 5B(C-H) + 3B(O=O)
– 4B(C=O) – 6B(O–H) = ΔH = −1279

Correct answer gains full marks.

*Credit **1 mark for − 496** (kJ mol^{-1})*

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 a correct method; this requires either a correct cycle with $2CO_2$ and $3H_2O$ OR a clear statement of **M1** which could be in words and scores **only M1**.*

M2 (also scores **M1**)
348+360+463+5(412)+ 3B(O=O)

(**3231**) (or **2768** if O–H cancelled)
− 4(805) − 6(463) = ΔH = − 1279

(**5998**) (or **5535** if O–H cancelled)

3B(O=O) = **1488** (kJ mol^{-1})

*Credit a maximum of one mark if the only scoring point is bonds formed adds up to **5998 (or 5535) OR** bonds broken includes the calculated value of **3231 (or 2768)**.*

M3

B(O=O) = **496** (kJ mol^{-1})

Award 1 mark for −496

Students may use a cycle and gain full marks

3

[15]

Q12.

(a) (i) M1 c(oncentrated) phosphoric acid / c(onc.) H_3PO_4

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OR c(oncentrated) sulfuric acid / c(onc.) H_2SO_4

*In **M1**, the acid must be concentrated.*
Ignore an incorrect attempt at the correct formula that is written in addition to the correct name.

M2 Re-circulate / re-cycle the (unreacted) ethene (and steam) / the reactants
OR pass the gases over the catalyst several / many times

*In **M2**, ignore "remove the ethanol".*
Credit "re-use".

2

(ii) M1
(By Le Chatelier's principle) the equilibrium is driven / shifts / moves to the right / L to R / forwards / in the forward direction

M2 depends on a correct statement of M1
The equilibrium moves / shifts to

- oppose the addition of / increased concentration of / increased moles / increased amount of water / steam
- to decrease the amount of steam / water

Mark M3 independently
M3 Yield of product / conversion increase ***OR*** ethanol increases / goes up / gets more

3

(iii) M1 Poly(ethene) / polyethene / polythene / HDPE / LDPE

M2 At higher pressures
More / higher cost of electrical energy to pump / pumping cost
OR
Cost of higher pressure equipment / valves / gaskets / piping etc.
OR expensive equipment

*Credit all converse arguments for **M2***

2

(b) M1 for balanced equation

M2 for state symbols in a correctly balanced equation

$2C(s / graphite) + 3H_2(g) + ½O_2(g) \longrightarrow CH_3CH_2OH(l)$ (C_2H_5OH)

Not multiples but credit correct state symbols in a correctly balanced equation.

Penalise C_2H_6O but credit correct state symbols in a correctly balanced equation.

2

(c) (i) M1 The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / element

*If standard enthalpy of formation **CE=0***

M2 is burned / combusts / reacts completely in oxygen
OR burned / combusted / reacted in excess oxygen

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M3 with (all) reactants and products / (all) substances in standard / specified states
OR (all) reactants and products / (all) substances in normal states under standard conditions / 100 kPa / 1 bar and specified T / 298 K

*For **M3***
Ignore reference to 1 atmosphere

3

(ii) M1

Correct answer gains full marks

ΣB(**reactants**) − ΣB(**products**) = *ΔH*

Credit 1 mark for (+) 1279 (kJ mol^{-1})

OR
Sum of bonds broken − Sum of bonds formed = ΔH
OR
B(C-C) + B(C-O) + B(O-H) + 5B(C-H) + 3B(O=O) (LHS)
− 4B(C=O) − 6B(O−H) (RHS) = *ΔH*

M2 (also scores **M1**)
348+360+463+5(412)+3(496) [LHS = **4719**]
(2060) (1488)
− 4(805) − 6(463) [RHS = − **5998**] = *ΔH*
(3220) (2778)
OR using only bonds broken and formed (**4256 − 5535**)

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 a correct method; this requires either a correct cycle with 2C and 6H and 7O OR a clear statement of **M1** which could be in words and scores **only M1***

M3
ΔH= **− 1279** (kJ mol^{-1})

*Allow a maximum of one mark if the only scoring point is LHS = 4719 **OR** RHS = 5998*

Award 1 mark for +1279

Candidates may use a cycle and gain full marks

3

(d) (i) Reducing agent ***OR*** reductant ***OR*** electron donor
OR to reduce the copper oxide

Not "reduction".
Not "oxidation".
Not "electron pair donor".

1

(ii) CH_3COOH

1

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[17]

Q13.

(a) $3N_2H_4 \longrightarrow 4NH_3 + N_2$

Or multiples

Ignore state symbols

1

(b) M1 enthalpy / heat (energy) change / required / needed to break / dissociate a covalent bond (or a specified covalent bond)

Ignore bond making

Ignore standard conditions

M2** requires an attempt at **M1

M2 average / mean over different molecules / compounds / substances

2

(c) M1

Σ (bonds broken) − Σ (bonds formed) = ΔH

***M1** could stand alone*

OR

Sum of bonds broken − Sum of bonds formed = ΔH

Award full marks for correct answer

M2 (also scores **M1**)

Ignore units

4(+388) + 163 + 2(146) + 4(463) − 944 − 8(463) = ΔH
OR broken +3859 (2007) formed − 4648 (2796)

M3

ΔH = **− 789** (kJ mol^{-1})

Two marks can score with an arithmetic error in the working

Award 1 mark for + 789

*Credit **one mark only** for calculating either the sum of the bonds broken or the sum of the bonds formed provided this is the only mark that is to be awarded*

Students may use a cycle and gain full marks

3

[6]

Q14.

(a) (Enthalpy change to) break the bond in 1 mol of chlorine (molecules)

Allow (enthalpy change to) convert 1 mol of chlorine molecules into atoms
Do not allow energy or heat instead of enthalpy, allow heat energy

1

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To form (2 mol of) gaseous chlorine atoms / free radicals

Can score 2 marks for 'Enthalpy change for the reaction': $Cl_2(g) \rightarrow 2Cl(g)$

Equation alone gains M2 only

Can only score M2 if 1 mol of chorine molecules used in M1 (otherwise it would be confused with atomisation enthalpy)

Any mention of ions, CE = 0

1

(b) (For atomisation) only 1 mol of chlorine atoms, not 2 mol (as in bond enthalpy) is formed / equation showing ½ mol chlorine giving 1 mol of atoms

Allow breaking of one bond gives two atoms

Allow the idea that atomisation involves formation of 1 mol of atoms not 2 mol

Allow the idea that atomisation of chlorine involves half the amount of molecules of chlorine as does dissociation

Any mention of ions, CE = 0

1

(c) (i) $\frac{1}{2}F_2(g) + \frac{1}{2}Cl_2(g) \rightarrow ClF(g)$

1

(ii) $\Delta H = \frac{1}{2}E(F–F) + \frac{1}{2}E(Cl–Cl) – E(Cl–F)$

Allow correct cycle

1

$E(Cl–F) = \frac{1}{2}E(F–F) + \frac{1}{2}E(Cl–Cl) - \Delta H$

$= 79 + 121 - (-56)$

$= 256$ (kJ mol^{-1})

−256 scores zero

Ignore units even if wrong

1

(iii) $\frac{1}{2}Cl_2 + 3/2\ F_2 \rightarrow ClF_3$

If equation is doubled CE=0 unless correcr answer gained by / 2 at end
This would score M1

1

$\Delta H = \frac{1}{2}E(Cl–Cl) + 3/2\ E(F–F) - 3E(Cl–F)$

$= 121 + 237 - 768$ / (or 3 × value from (c)(ii))

This also scores M1 (note = 358 − 768)

1

$= -410$ (kJ mol^{-1})

If given value of 223 used ans = −311
Allow 1 / 3 for +410 and +311

1

(iv) (Bond enthalpy of) Cl−F bond in ClF is different from that in ClF_3

Allow Cl-F bond (enthalpy) is different in different compounds (QoL)

1

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(d) NaCl is ionic / not covalent

1

[11]

Q15.

(a) (i) $\Delta H = \Sigma$ bonds broken $-\Sigma$ 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 × 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 × 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)*

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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]

Q16.

(a) **Three conditions <u>in any order</u> for M1 to M3**

M1 yeast or zymase

M2 30 °C ≥ T ≤ 42 °C

M3 anaerobic/no oxygen/no air OR neutral pH

M4 $C_6H_{12}O_6 \longrightarrow \mathbf{2}C_2H_5OH + \mathbf{2}CO_2$
OR
$\mathbf{2}C_6H_{12}O_6 \longrightarrow \mathbf{4}C_2H_5OH + \mathbf{4}CO_2$

Mark independently

Penalise "bacteria" and "phosphoric acid" using the list principle

Ignore reference to "aqueous" or "water" (i.e. not part of the list principle)

Or other multiples

4

(b) **M**1 Carbon-neutral

Ignore "biofuel"

1

M2 <u>6 (mol/molecules) CO_2/carbon dioxide taken in/used/used up</u> (to form glucose or in photosynthesis)

1

M3 <u>6 (mol/molecules) CO_2/carbon dioxide</u> given out <u>due to **2** (mol/molecules) CO_2/carbon dioxide from fermentation/ Process 2 and **4** (mol/molecules) CO_2/carbon dioxide from combustion/Process 3</u>

It is NOT sufficient in M2 and M3 for equations alone without commentary or annotation or calculation

1

(c) **M1 (could be scored by a correct mathematical expression)**

(Sum of) <u>bonds broken</u> – (Sum of) <u>bonds made/formed = Δ*H*</u>

OR

(Σ) $\underline{B_{reactants} - (\Sigma)\ B_{products} = \Delta H}$

(where B = <u>bond</u> enthalpy/<u>bond</u> energy)

For M1 there must be a <u>correct</u> mathematical expression using ΔH or "enthalpy change"

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M2 Reactants = (+) 4719
OR
Products = (–) 5750

M3 Overall + 4719 – 5750 = **–1031** (kJ mol^{-1}) **(This is worth 3 marks)**

Award full marks for correct answer.
Ignore units.
M2 is for either value underlined
M3 is NOT consequential on M2

3

Award 1 mark ONLY for +1031

Candidates may use a cycle and gain full marks.

M4 Mean bond enthalpies are not specific for this reaction
OR they are average values from many different compounds/molecules

Do not forget to award this mark

1

(d) **M1** q = m c ΔT (this mark for correct mathematical formula)

M2 = 6688 (J) OR 6.688 (kJ) OR 6.69 (kJ) OR 6.7 (kJ)

M3 0.46g is 0.01 mol
therefore ΔH = **– 669** kJ mol^{-1} OR – **670** kJmol^{-1}
OR **–668.8** kJ mol^{-1}

Award M1, M2 and M3 for correct answer to the calculation
Penalise M3 ONLY if correct answer but sign is incorrect
In M1, do not penalise incorrect cases in the formula
If m = 0.46 or m = 200.46 OR if ΔT = 281, CE and penalise M2 and M3
If c = 4.81 (leads to 7696) penalise M2 ONLY and mark on for M3 = –769.6 OR –770
Ignore incorrect units in M2

M4 Incomplete combustion

Do not forget to award this mark. Mark independently

4

[15]

Q17.

(a) (i) Reducing agent

OR

Reduce(s) (WO_3/tungsten oxide)

OR

electron donor

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OR

to remove <u>oxygen</u> (from WO_3/tungsten oxide or to form water);

1

(ii) $WO_3 + \mathbf{3}H_2 \rightarrow W + \mathbf{3}H_2O$

Or multiples

1

(iii) *One from*

H_2 is

- explosive
- flammable or inflammable
- easily ignited

Ignore reference to pressure or temperature

1

(b) (i) Addition

Ignore "electrophilic"

Penalise "nucleophilic addition"

OR

(catalytic) hydrogenation

OR

Reduction

1

(ii) Geometric(al)

OR

cis/trans OR E Z OR E/Z

1

(c) (i) (If any factor is changed which affects an equilibrium), the position of <u>equilibrium</u> will <u>shift/move/change/respond/act</u> so as <u>to oppose the change</u>.

OR

(When a system/reaction in equilibrium is disturbed), the <u>equilibrium shifts/moves</u> in a direction which tends <u>to reduce the disturbance</u>

A variety of wording will be seen here and the key part is the last phrase and must refer to <u>movement of the equilibrium</u>.

QoL

1

(ii) **M1 – Statement of number of moles/molecules**

There are <u>more moles/molecules</u> (of gas) on the left/of reactants

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OR

fewer moles/molecules (of gas) on the right./products

OR

there are 4 moles/molecules (of gas) on the left and 2 moles/ molecules on the right.

Ignore "volumes" for M1

Mark independently

M2 – Explanation of response/movement in terms of pressure
Increase in pressure is opposed (or words to that effect)

OR

pressure is lowered by a shift in the equilibrium (from left) to right/favours forward reaction.

2

(d) ΣB(reactants) – ΣB(products) = Δ*H* (**M1**)

OR

Sum of bonds broken – Sum of bonds formed = ΔH (**M1**)

B(H–H) + ½B(O=O) – 2B(O–H) = – 242 (**M1**)

B(H–H) = – 242 – ½(+496) + 2(+463) (this scores **M1** and **M2**)

B(H–H) = (+)436 (kJ mol^{-1}) (**M3**)

Award 1 mark for – 436

Candidates may use a cycle and gain full marks.

M1 could stand alone

Award full marks for correct answer.

Ignore units.

Two marks can score with an arithmetic error in the working.

3

[11]

Q18.

(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

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	(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**

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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]

Q19.

(a) enthalpy change/ heat energy change when 1 mol of a substance

1

is completely burned in oxygen

1

at 298K and 100 kPa or standard conditions

1

(not 1atm)

(b) $\Delta H = \sum$ bonds broken – $\sum$ bonds formed

1

= (6 × 412) + 612 +348 + (4.5 × 496) – ((6 × 743) + (6 × 463))

1

= – 1572 kJ mol^{-1}

1

(c) by definition ΔH_f is formation from an element

1

(d) $\Delta H_c = \sum \Delta H_f$ products -$\sum \Delta H_f$ reactants or cycle

1

= (3 × – 394) + (3 × –242) – (+20)

1

= − 1928 kJ mol^{-1}

1

(e) bond enthalpies are mean/average values

1

from a range of compounds

1

[12]

Q20.

(a) enthalpy (or energy) to break (or dissociate) a bond;

1

averaged over different molecules (environments);

1

enthalpy (or heat energy) change when one mole of a compound;

1

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is formed from its elements;

1

in their standard states;

1

(b) enthalpy change = Σ(bonds broken) – Σ(bonds formed) or cycle;

1

= 4 × 388 +163 + 2 × 146 + 4 × 463 – (944 + 8 × 463);
(or similar)

1

= –789;
(+ 789 scores 1 only)

1

(c) (i) zero;

1

(ii) ΔH = Σ (enthalpies of formation of products)
–Σ (enthalpies of formation of reactants)

1

= 4 × –242-(75 + 2 × –133);

1

= –777;
(+ 777 scores one only)

1

(d) mean bond enthalpies are not exact
(or indication that actual values are different from real values)

1

[13]

Q21.

(a) ΔH = Σ(bonds broken) – Σ(bonds formed) (or cycle)

1

= +146 – 496/2 (or 2 × 463 + 146 –(2 × 463 + 496/2)

1

= – 102 (kJ mol^{-1}) **(1)**
*(accept no units, wrong units loses a mark; +102 scores **(1)** only)*

1

(b) $C(s) + 2H_2(g) \rightarrow CH_4(g)$ equation **(1)** Correct state symbols **(1)**

2

(c) (i) Macromolecular
(accept giant molecule or carbon has many (4) bonds)

1

(ii) $\Delta H = \Sigma \Delta H_f$(products) – $\Sigma \Delta H_f$(reactants) (or cycle)

1

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= 715 + 4 × 218 – (–74.9)

1

= 1662 (kJ mol^{-1})

(accept no units, wrong units loses one mark, allow 1660 to 1663, –1662 scores one mark only)

1

(iii) 1662/4 = 415.5

(mark is for divide by four, allow if answer to (c)(ii) is wrong)

1

[10]

Q22.

(a) Enthalpy (Energy) to break a (covalent) bond **(1) OR dissociation energy**
Varies between compounds so average value used **(1) QL mark**

OR average of dissociation energies in a single molecule / e.g. CH_4

Do not allow mention of energy to form bonds but with this case can allow second mark otherwise 2nd mark consequential on first

2

(b) (i) 1/2 N_2 + 3/2 H_2 → NH_3 **(1)**

Ignore s s

(ii) ΔH = (Σ)bonds broken – (Σ)bonds formed **(1)**
= 1/2 × 944 + 3/2 × 436 – 3 × 388 **(1)**
= –38 kJ mol^{-1} **(1)**

Ignore no units, penalise wrong units
Score 2/3 for -76
1/3 for +38
Allow 1/3 for +76

4

(c) 4 (C–H) + (C=C) + (H–H) – (6 (C–H) + (C–C)) = –136 **(1)**
OR (C=C) + (H–H) – ((C–C) + 2 (C–H)) = –136
2 (C–H) = 836 **(1)**
(C–H) = 418 (kJ mol^{-1}) **(1)**

Note: allow (1) for –836
another (1) for –418

3

[9]

Q23.

(a) (Energy required) to break a given <u>covalent</u> bond **(1)**
averaged over a range of compounds **(1)**

Penalise first mark if 'energy' / 'enthalpy' evolved

2

(b) (i) 4 × C−H = 4 × 413 = +1652
1 × C−C = 1 × 347 = 347
1 × C=O = 1 × 736 = 736
2½ × O=O = 2.5 × 498 = 1245 **(1)**

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= 2735 + 1245 = +3980 **(1)**

first mark for 4 : 1: 1 or 2735 ignore sign

(ii) 4 × H−O = -4 × 464 = –1856
4 × C−O = -4 × 736 = –2944 **(1)**
= –4800 **(1)**

First mark for 4 : 4

(iii) ΔH_R = ΣBonds broken − ΣBonds made
= +3980 − 4800 = −820 **(1)**

Conseq Mark for incorrect answers in (i) and (ii) as (i) Answer + (ii) Answer =

5

[7]

Q24.

D

[1]

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Q1.

(a) This was poorly answered, with many students missing state symbols and balancing the equation incorrectly. Only the best students (24.6%) gained the mark here.

(b) This proved challenging compared to questions set in the previous specification from this topic area. 34.3% of students failed to pick up even one mark.

(c) Again challenging for all but the best students, only 26.3% scored more than one mark.

(d) This was not as well answered as might have been expected. The fact that mean bond enthalpies are calculated using a range of compounds was not well understood.

Q2.

(a) Most students could write the equation for the complete combustion of propane.

(b) This question required students to rearrange a mathematical expression, but many could not do this because they made errors with minus signs on rearrangement.

(c) Very few students appreciated that bond enthalpies are measured in the gaseous state and so the expression would not give an accurate value for a liquid alkane.

(d) Most students plotted the points on the graph correctly, but a very significant proportion of them drew a best fit line that was straight rather than a curve. Most students read the value for propane off the graph, but some did not include the negative sign to show it was exothermic. Worryingly, some students did not know how many C atoms the alkanes contained and failed to score.

(e) Many students failed to find the mass of 1 dm^3 of isooctane, not appreciating that the density value given was in g cm^{-3} rather than g dm^{-3}. Some students lost the second mark because they did not appreciate that the answer should be given to three significant figures.

Q7.

This question involved several steps and many went wrong as they effectively used ΔH = [Sum bond enthalpies products] – [Sum bond enthalpies reactants] instead of ΔH = [Sum bond enthalpies reactants] – [Sum bond enthalpies products].

Q8.

Two-thirds of the marks in this enthalpy-based question involved students being able to carry out calculations based on Hess' Law and, as always, there was a divide between those who could cope with such questions and those who couldn't.

In part (a) the importance of learning definitions was illustrated. Many students failed to make clear that <u>all</u> reactants and products need to be in their standard states.

In questions such as part (b) students are strongly advised to start with a clear and complete indication of the expression relating the enthalpy change of the reaction to the data given or to draw out a clearly labelled cycle. Students who relied on the use of a

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learned expression often got this wrong way round, possibly due to confusion with the use of enthalpies of formation whereas, in this case, the data provided were enthalpies of combustion.

In a question like part (c) students are strongly advised to sketch out the displayed formulae of all reactants and products when working with bond energies. Failing to do so in many cases meant that bonds were omitted or miscounted (3 × C-C in propan-1-ol was often seen) by students.

Q9.

This question was answered well. Balancing the equation in part (a)i looks straightforward when you know the answer, but it is quite demanding if you have to work it out, and impressively half the students gave the correct answer. In part (b)i, it was necessary to draw unambiguous structures both for propan-2-ol (not given in the question) and propanone (given in part (a)i). The calculation in part (c) was well answered with the focus on correct chemistry rather than on the number of significant figures and the mathematics of rounding the final answer. The definition in part (d) was expected to be straightforward and yet still resulted in only 40% gaining all three marks. As many as 45% gained all three marks and 80% gained at least one mark from the very straightforward calculation in part (e), with errors occurring because some students did not know the bonding either in propanone or in carbon dioxide and used the unnecessary C−O that was given in the data set. It was decided that the very straightforward idea of “heat loss”, in whatever context, was worth only one mark in part (f) and that students needed to come up with other reasons why the values in part (c) and part (e) differed; many were able to do so and this led to 54% scoring both marks.

Q10.

Answers to part (a) were often incomplete; many students lost a mark because only one bond was broken rather than 1 mol of bonds. Answers to part (b) were usually correct but a fairly common mistake was to omit to halve the O=O bond enthalpy or to calculate a value for the formation of 2 mol of water. Answers to part (c)(i) were usually correct but in part (c)(ii) most students did not score because they did not refer to the O-H bond and some inadvisably thought that experimental error was a sufficient answer.

Q11.

Part (a) discriminated almost as well as the earlier mechanism questions with well over half of the students scoring at least 3 of the 5 marks. Relatively few recognised that (fractional) distillation is a process used to produce a much more concentrated solution of ethanol and many referred to the hydration of ethene, having missed the requirement to start “from a dilute aqueous solution”. The concept of carbon-neutral “in the context of this biofuel” required reference both to carbon dioxide **and** the atmosphere. Part (b) was well answered with over half of all students scoring 4 out of 5 marks. By comparison, part (c) proved more demanding. The definition in part (c)(i) most often yielded only 1 of the 2 marks. Too often in part (c)(ii) it proved difficult to decipher the jumble of numbers that some students recorded on the page and only about one-third of students scored all 3 marks.

Q12.

In part (a)(i), some students missed either the fact that the catalyst has to be a concentrated strong acid or that the unreacted ethene is re-circulated to achieve an overall yield of 95% and this meant that only a small number of students scored both marks. Considerable latitude was allowed in the responses for part (a)(ii), since it was

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clear that many students did not really understand what was happening in this process and this approach to the marking enabled the majority of students to gain at least two marks out of three. In part (a)(iii), some students recognised the possibility of poly(ethene) being formed and approximately 17% of students gained both marks.

It has been a while since a question like part (b) has been asked and it was not well answered with few students gaining full marks and over half scoring zero. Balancing the correct equation and then including the correct state symbols were both needed for full marks. Parts (c) and (d) proved straightforward for many and full marks were seen from over a third of students in each of parts (c)(i) and (c)(ii), respectively.

Q13.

The formula for ammonia and that for nitrogen caused the most problems in part (a) and only 60% scored the mark. The definition of mean bond enthalpy has not been examined for some time and the idea that it is a measure of the enthalpy change when a **covalent** bond is broken was missed by most, although many knew that the mean value comes from an average of the values obtained for the same bond in a range of different compounds. In part (c), 51% of students scored full marks, however, many students made transposition and arithmetic errors.

Q14.

Answers to this question were disappointingly poor. In part (a), there was not much evidence that the precise meaning of the term **bond dissociation enthalpy** was understood or had been learned. Only 20% of students scored both marks and over 50% scored zero. This enthalpy change refers to the conversion of one mole of chlorine gas into two moles of chlorine atoms but this was not usually stated. Answers to part (b) did not usually convey the understanding that this process is exactly the same as bond dissociation but that it involves only half a mole of chlorine gas. There was also confusion between chlorine molecules, chlorine atoms and chloride ions. Part (c)(i) was answered better but many answers were incorrect because they did not show chlorine and fluorine molecules. In part (c)(iii), many students used incorrect cycles or formulae and obtained an exothermic rather than an endothermic answer. In part (c)(iv), most students did not read or did not understand the question. A statement that bond enthalpies are obtained by averaging values from different compounds may be a correct statement but it is not an answer to the question.

Q15.

Only 28% of candidates gained all three marks in part (a)(i). The usual error was a failure to follow the instruction in the question that required an enthalpy change for only one mole of ammonia. In part (a)(ii) many candidates were unable to explain clearly that individual bond enthalpies in a specific compound will differ from data book values of mean bond enthalpies that are an average of bond enthalpy values from a range of different compounds. The remainder of this question was well answered by most candidates.

Q16.

Most candidates seem to know something about fermentation and part (a) discriminated extremely well.

In part (b), only the best candidates were able both to state that such a fuel is carbon-neutral and also to demonstrate that the six moles of CO_2 taken in during photosynthesis are later released in the fermentation process followed by the combustion of ethanol. Failure to recognise that two moles of ethanol were burning resulted in only four moles of

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CO_2 and left candidates confused. A few candidates seemed to think that a balanced equation with six carbon atoms on each side is carbon-neutral.

The calculation in part (c) proved demanding as candidates failed to count up accurately how many of each bond were broken and how many were formed. They were able quite often to get only one of these correct. The idea that mean bond enthalpies are average values obtained from many different compounds was not well known.

In part (d) the equation used to calculate the heat change was well known but conversion to enthalpy change proved difficult for all but the best. The idea of incomplete combustion was often missed.

Q17.

This question took hydrogen as its theme and asked questions across the subject. Overall it was a high scoring question. The application of Le Chatelier's principle was done well with only 10% of candidates failing to score any marks. By contrast, the calculation of a value for the H-H bond enthalpy proved very demanding and half the candidates scored no marks.

Q19.

More able candidates were able to obtain high marks in this question but the weaker candidates found the calculations difficult. The definition in (a) was usually attempted well with the majority of candidates scoring 3 marks. Answers to (b) discriminated between candidates. There were several arithmetic errors in the calculation, and a few candidates who did not know to subtract the sum of the bonds made from the sum of the bonds broken leading to an incorrect sign in the final answer. Most candidates realised that oxygen was an element in (c). Again the calculation in (d) discriminated well. A common incorrect answer was 1888 $kJmol^{-1}$ which was usually due to doing the calculation the wrong way round. Weaker candidates also failed to take account of the 3 moles of water and carbon dioxide in their calculation. The explanation of why answers to (b) were less accurate than (a) was not done as well as expected with many candidates scoring one out of the 2 marks. Candidates should know that mean bond enthalpies are averaged over a range of compounds which contain the same bond, or from the same compound which contains several of the same type of bond. A common incorrect answer here was 'heat loss'.

Q20.

More able candidates were able to obtain high marks for this question but less able candidates found the calculations hard. In part (a) candidates lost a mark if they referred to bond-formation instead of bond-breaking. Less able candidates were unable to explain that mean bond enthalpy refers to an average of bonds where the environment is different, usually due to existence in different molecules. In part (b) many candidates provided incorrect answers because they did not work out the correct number of bonds being broken or formed. For example, only the best candidates recognised that two O—O bonds were broken. It was disappointing in part (c) (i) that many candidates did not understand the question. It was quite common to find candidates attempting a calculation using the equation, the enthalpy of formation values given in the table and an assumption that the enthalpy change for the equation was zero. Answers to part (c) (ii) were more usually correct though weaker candidates failed to take account of the two moles of hydrogen peroxide and the four moles of water. Answers to part (d) were usually incorrect. A common wrong answer was the statement 'Heat loss'.

Q21.

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Good candidates were able to obtain high marks for this question but weak candidates found it very difficult and marks of zero out of ten were not unusual. In part (a), a common mistake was to use the O—O single bond enthalpy rather than the correct value for the O=O double bond and also to use one mole of oxygen rather than half a mole. In part (b) the balanced equation was usually correct but the state symbol for carbon was frequently shown as gaseous rather than solid (or graphite). In Part (c) (i) only the best candidates appeared to notice the wording in the question which required a reference to the structure of solid carbon. Part (c) (ii) also proved to be a difficult question for weaker candidates who rarely multiplied the enthalpy of formation of hydrogen atoms by the factor four. Also, the enthalpy of formation of methane (–74.9 kJ mol^{-1}) was usually added rather than subtracted. Incorrect cycles and equations involving combustion of methane were also common errors. Part (c) (iii) was answered well; the mark was awarded for dividing the answer to part (c) (ii) by four.

Q22.

This question proved to be very difficult and good answers were extremely rare. Part (a) of the question was used to assess candidates' quality of language. Explanations were usually rather vague or imprecise and whereas one mark out of two was common, answers that were awarded two marks were very infrequent. In part (b)(i), despite a specific statement in the question referring to one mole of ammonia, most candidates wrote an equation giving two moles of ammonia. In part (b) (ii), only the best candidates gave the correct answer of –38 kJ mol^{-1}. Some credit was given for a method of calculation that was partly correct but which lead to an incorrect nswer as a result of using the wrong signs or the wrong number of moles of ammonia. The incorrect answers that gained some credit were –76, +76 and +38 kJ mol^{-1}. Correct answers to part (c) were seen rarely. Common errors were confusion over signs when breaking bonds then forming bonds and a failure to include the enthalpy change value of –136 kJ mol^{-1} in any equation that was set up.

Q23.

The meaning of the term mean bond enthalpy was not well understood and, as in the June 2001 paper, few candidates scored two marks in part (a). Part (b)(i), in which candidates were required to use mean bond enthalpy data, was generally well answered and only candidates who failed to deduce the correct number and type of bond lost marks. In part (b)(ii) many candidates lost one mark when they failed to recognise that bond formation is an exothermic process. Part(c)(iii) was marked consequentially to answers given in parts (i) and (ii).

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Q1.

A

[1]

Q2.

(a) $C_3H_6O + 4O_2 \rightarrow 3CO_2 + 3H_2O$ **(1)** (or multiple) 1

(b) (i) $\frac{1.45}{58}$ **(1)** = 0.0250 **(1)**

allow 0.025
allow conseq on wrong M_r

1.45/100, CE; $\frac{1.45}{58.1}$ *C.E.*

(ii) heat released = mcΔT
= 100 × 4.18 × 58.1 **(1)**

if 1.45 used in place of 100 CE = 0

= 24300 J **(1)** (or 24.3kJ)

allow 24200 to 24300
ignore decimal places
units tied to answer
If use 0.1 × 4.18 × 51.8 allow ½ for 24.3 with no units

(iii) $\frac{24.3}{0.0250}$ = –972 (kJ mol^{-1}) **(1)**

allow –968 to –973
allow +972
allow conseq
allow no units
penalise wrong units

5

(c) (i) Heat loss **(1)** or energy loss

do not allow incomplete combustion

(ii) *Difference*: more negative **(1)** (or more exothermic)

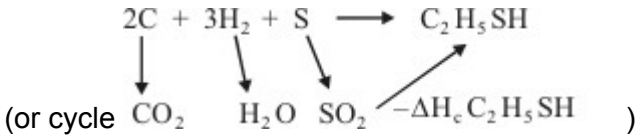
QoL mark

Explanation: heat (*or energy*) released when water vapour condenses **(1)**
or heat/energy required to vaporise water
or water molecules have more energy in the gaseous state

3

(d) $\Delta H = \Sigma\Delta H_{reactants} - \Sigma\Delta H_{products}$ **(1)**

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(or cycle)

= (2 × –394) + (3 × –286) + (–297) – (–1170) **(1)**
= –773 **(1)**

ignore units even if wrong

Allow 1/3 *for +773*

3

[12]

Q3.

C

[1]

Q4.

(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) $\Delta H = \Sigma \Delta H_f^{\ominus}$(products) - $\Sigma \Delta H_f^{\ominus}$(reactants) **(1) (Or a cycle)**
= 2 × –242 + ½ × –394 – (–365) **(1) (also implies first mark)**
= -316 kJ mol^{-1} **(1)**

3

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

[6]

Q5.

(a) Heat energy change **(1)**

Not energy on its own

measured at constant pressure **(1)**

Mark separately, ignore constant temperature statements

2

(b) (i) Enthalpy change when 1 mol of a substance (or compound / product) **(1)** is formed from its constituent elements **(1)** in their standard states **(1)**

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under standard conditions **(1)**

Mark separately

(ii) $2Na(s) + S(s) + 2O_2(g) \rightarrow Na_2SO_4(s)$

Balanced (1) State symbols (1), but only if all species are correct

Allow $\frac{1}{8} S_8(s)$

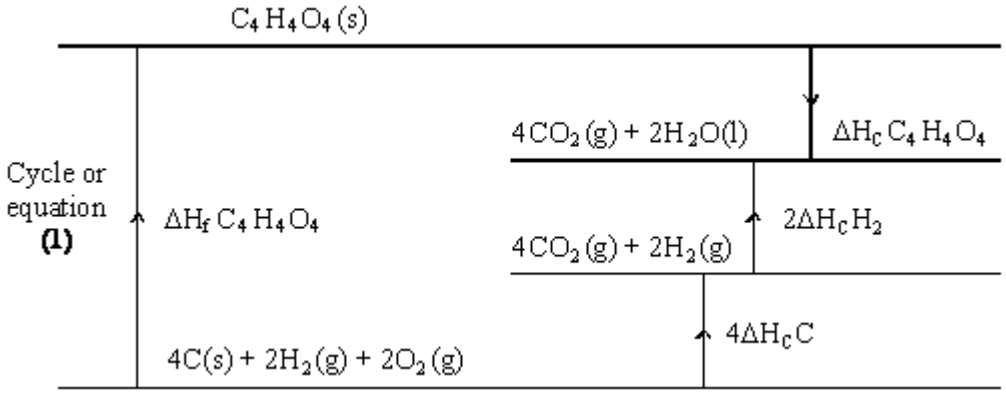
5

(c) Enthalpy change is independent of reaction route **(1)**

Penalise incorrect additional statements

1

(d)



$-1356 + (2 \times 285.8) + (4 \times 393.5) + \Delta H_f C_4H_4O_4 = 0$

$\Delta H_f = -789.6$ kJ mol^{-1}

If answer is incorrect:

Score +789.6 two marks

Score (× 1); (× 2) and (× 4) for species - one mark

If an incorrect negative answer given check for AE for loss of one mark

3

[11]

Q6.

(a) (Enthalpy change) when 1 mol **(1)** of a compound is formed from its constituent elements **(1)** in their standard states **(1)**

3

Allow energy or heat, Ignore evolved or absorbed

Mark each point independently

(b) (The enthalpy change for a reaction is) independent of the route **(1)**

1

(c) $\Delta H_R = \Sigma\Delta H_f$ products - $\Sigma\Delta H_f$ reactants **(1)**

= [(3 × -286) + (3 × -394)] - (-248) **(1)**

= -1792 **(1)** (kJ mol^{-1})

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Deduct one mark for each error to zero

3

[7]

Q7.

C

[1]

Q8.

B

[1]

Q9.

A

[1]

Q10.

D

[1]

Q11.

D

[1]

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Q2.

This question proved accessible to most candidates; even the weaker candidates were able to score marks approaching half of those available. Answers to part (a) were usually correct.

Most candidates also gave a correct answer to part (b)(i) though there were a significant number of errors in the calculation of the relative molecular mass of propanone. Parts (b)(ii) and (b)(iii) were also answered well although there were some problems with units. The correct answer to part (c)(i) was known by most candidates but part (c)(ii) proved to be much more discriminating and only the best candidates were able to explain why the enthalpy of combustion is more negative when water is formed in the liquid state. A fair majority of candidates was able to give a correct answer to part (d) but as usual in this type of question, weaker candidates made an error in signs leading to an answer of +773 kJ mol^{-1} or made an error by omitting to multiply the relevant enthalpy of combustion by the number of moles of the substance involved.

Q4.

This question was answered well by many candidates. Answers to part (a) were usually correct. Most candidates provided good answers to part (b) but some lost marks because they referred to energy or to enthalpy alone rather than to enthalpy change. In part (c) the most common error was to invert signs leading to an answer of 316 kJ mol-1 rather than to –316 kJ mol^{-1}.

Q5.

The meaning of the term enthalpy change, required in part (a), was not well stated and whilst many correctly referred to the heat energy change, most failed to state that this was measured at constant pressure. Part (b) was well answered with many correct definitions of the term standard enthalpy of formation of a compound though slightly fewer candidates gave a correct equation with state symbols in section (ii). Hess's Law was correctly stated by many candidates and it is particularly pleasing to report that the calculation required in part (d) was very well done.

Q6.

This question was very well answered and many candidates were able to score full marks. Happily, as candidates showed working in part (c), part marks could be awarded when incorrect answers were given.

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Q1.

(a) Two correct Cl ox states: HClO = +1 HCl = -1

1

(b) Oxidation:
$Cl_2 + 2H_2O \rightarrow 2HClO + 2H^+ + 2e^-$

Accept - $2e^-$ on the other side

Allow $Cl_2 + 2H_2O \rightarrow 2ClO^- + 2e^-$

1

Reduction:
$Cl_2 + 2H^+ + 2e^- \rightarrow 2HCl$

Allow $Cl_2 + 2e^- \rightarrow 2Cl^-$

If both equations correct but incorrect order, allow 1

Ignore state symbols

1

(c) $2NaOH + Cl_2 \rightarrow NaCl + NaClO + H_2O$

Allow

$2OH^- + Cl_2 \rightarrow Cl^- + ClO^- + H_2O$

Allow NaOCl

Ignore state symbols

1

(d) mol ClO^- = conc × vol = 0.0109 × 0.02
= <u>0.000218 / 2.18×10^{-4}</u> mol

1

mol KI = 0.000218 × 2 = 0.000436 mol

M2 = M1 x2

If incorrect ratio, M2 & M3 = 0

1

mass KI = Mr ×mol = 166.0 × 0.000436
= 0.072376 g
= 72.4 (mg)

M3 = M1 × 2 × 166.0 × 1000

Must be to <u>3 sig figs</u>

1

<u>black solid/ppt</u> appears/forms (in a colourless solution)
or (colourless solution) turns brown (solution)

Not purple. Not red. Not brown ppt/solid

Ignore grey.

1

(e) $KClO_4 \rightarrow KCl + 2O_2$

Ignore state symbols

Allow multiples

1

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ΔH = – 436 – – 434 = – 2 kJ mol^{-1}

Must be negative
Mark independently
Allow consequential for multiples

1

[10]

Q2.

A

[1]

Q3.

(a) $2Fe(s) + \frac{3}{2}O_2(g) \rightarrow Fe_2O_3(s)$ 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]

Q4.

(a) Not possible to prevent some dissolving

ALLOW It is soluble / dissolves / other hydrates may form / suggestions related to difficulty of measuring T (change) of a

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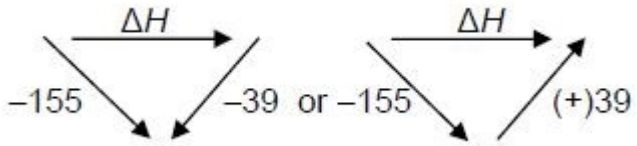
solid

1

(b) ($\Delta_{hyd}H$ =) –155 – (–39)

OR labelled cycle

Minimum needed for 'labelled cycle'



1

–116 (kJ mol^{-1})

1/2 for (+)116 or for –29 or for seeing –116 that has then be processed further

1

(c) This question is marked using levels of response. Refer to the Mark Scheme Instructions for examiners for guidance on how to mark this question

Level 3 (5 – 6 marks)

All stages are covered and the explanation of each stage is correct and virtually complete.
Stage 2 must include use of a graphical method for Level 3 (i.e. 'highest T reached' method is max Level 2)

Answer communicates the whole explanation, including reference to enthalpy, coherently and shows a logical progression through all three stages.Answer is full and detailed and is supported by an appropriate range of relevant points such as those given below:
For the answer to be coherent there must be some indication of **how** the graph is used to find ΔT

Level 2 (3 – 4 marks)

All stages are covered (NB 'covered' means min 2 from each of stage 1 and 3) but the explanation of each stage may be incomplete or may contain inaccuracies
OR two stages covered and the explanations are generally correct and virtually complete

Answer is coherent and shows some progression through all three stages. Some steps in each stage may be out of order and incomplete

Level 1 (1 – 2 marks)

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies
OR only one stage is covered but the explanation is generally correct and virtually complete

Answer shows some progression between two stages

Level 0 (0 marks)

Insufficient correct Chemistry to warrant a mark

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Indicative Chemistry Content

Stage 1 Method

(1a) Measures water with named appropriate apparatus
(1b) Suitable volume/mass / volume/mass in range 10 – 200 cm^3/g
(1c) Into insulated container / polystyrene cup (NOT just 'lid')
(1d) Add known mass of $MgCl_2(s)$
(1e) Use of 'before and after' weighing method. NOT 'added with washings'

Stage 2 Measurements (could mark from diagram)

(2a) Record initial temperature (min 2 measurements)
(2b) Record T at regular timed intervals for 5+ mins / until trend seen
(2c) Plot T vs time

Stage 3 Use of Results (3a and 3b could come from diagram)

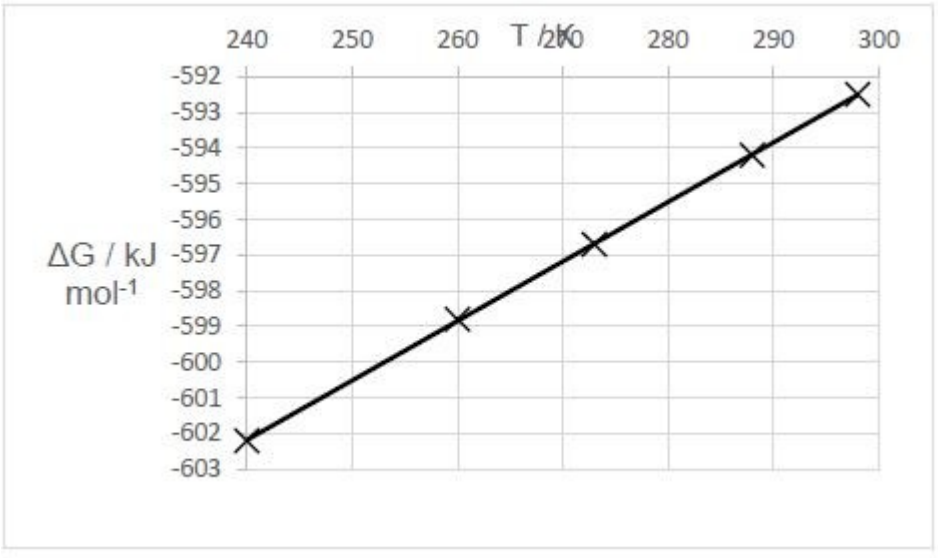
(3a) Extrapolate lines to when solid added (to find initial and final T)
(3b) $T_{final} - T_{initial} = \Delta T$ / idea of finding ΔT from graph at point of addition
(3c) $q = mc\Delta T$
(3d) amount = mass/Mr ($0.80/95.3 = 8.39 \times 10^{-3}$ mol)
(3e) $\Delta H_{soln} = -q/8.39 \times 10^{-3}$ or in words

This could all be described in words without showing actual calculations but describing stages

If method based on 'combustion' Max Level 1

6

(d)



***M1** = 5 points correctly plotted*
***M2** = line drawn correctly (NOT if curved, doubled or kinked)*
(Check line of best fit –
*if through 250, -600.5 and 280, -595.5 +/- one small square then award **M2**, if all crosses on line award **M1** as well)*

2

Gradient = $\Delta(\Delta G)/\Delta T$ = 0.167 ($kJ\ K^{-1}\ mol^{-1}$)

1

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($\Delta G = \Delta H - T\Delta S$ so gradient = $-\Delta S$)

ΔS = –167 (J K^{-1} mol^{-1})

M4 *= unit conversion i.e.* ***M3*** *× 1000; M5 = –sign (process marks)*

Correct answer with sign gets ***M3****,* ***M4*** *and M5*

ALLOW –163 to –171

1+1

[14]

Q5.

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

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 ΔH = −393−(−283)

ΔH = −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]

Q6.

(a) Decrease

1

Increasing pressure moves equilibrium to the side of least moles i.e. backward reaction

1

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To oppose the increase in pressure or to decrease the pressure

1

(b) A catalyst speeds up the rate of the forward and backward reaction

1

By the same amount

1

(c) ΔH = −111 − (−75 − 242)

1

206 (kJ mol^{-1})

1

(d) $\Delta S = 3 \times 131 + 198 - (186 + 189) = 216$ J K^{-1} mol^{-1}

1

$\Delta G = \Delta H - T\Delta S$

1

$0 = 206 - T\frac{216}{1000}$

1

T = 953.7 or 954 K

1

T = 681 (°C)

If the value given in the question is used then the answer is 283 (°C)

1

[12]

Q7.

B

[1]

Q8.

(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})

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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]

Q9.

(a) The <u>enthalpy / heat energy change</u> when <u>1 mol</u> (of a substance)

If enthalpy of formation definition given CE=O

***NOT** just 'energy'*

***ALLOW** alternatives for substance e.g. molecule/compound/element*

1

Is <u>burned/reacts completely in oxygen</u>

***ALLOW** reacts in excess oxygen*

1

With all reactants and products in their <u>standard states</u>

OR

With all reactants and products in their normal states at 298K/given temp & 100kPa

***ALLOW** 'everything' for 'reactants and products'*

Penalise incorrect conditions if given

***ALLOW** 'normal states under standard conditions'*

1

(b) $\Delta H = \Sigma\Delta H_c$(reactants) - $\Sigma\Delta H_c$ (products)

OR

Correctly and fully balanced cycle

Correct answer scores 3

1

ΔH = [3(-394) + 4(-286)] – (-2010)

OR

ΔH = -2326 + 2010

M2 also scores M1

1

ΔH = -316 (kJ mol^{-1})

+316 scores 1 mark only

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IGNORE *units*

Check for AE in working – can award M3 as ecf (error carried forward) from M2 if M2 not given due to AE

1

(c) ΔH/-1893 = ΣB(reactants) - ΣB(products)
OR
ΔH/-1893 = ΣBonds broken - ΣBonds formed
OR
ΔH/-1893 = 2B(C-C) + 7B(C-H) + B(C-O) + B(O-H) + 4½ B(O=O) – 6B(C=O) – 8B(O-H)

Correct answer scores 3

1

-1893= 2B(C-C) + 7(412) + 360 + 463 + 4½(496) – 6(805) – 8(463)
OR
-1893= 2B(C-C) +5939 – 8534
OR
-1893= 2B(C-C) -2595
OR
2B(C-C) = 702

M2 also scores M1

May see no 463 in bonds broken and 7x463 in made (gives 5476 – 8071)

1

B(C-C) = (+)351(kJ mol^{-1})

*If **NOT** 351 check for AE. This would lose M2, but could gain M1 and M3*

(+)234 scores 1 (due to 3(C-C))

***NOT** M3 from incorrect M2 unless incorrect M2 is due to AE*

***IGNORE** units*

If no other mark awarded then

***ALLOW** 1 if 5939 or 5476 or 8534 or 8071 seen*

1

[9]

Q10.

(a) **M1 (could be scored by a correct mathematical expression)**

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 = 5(−635) − (−1560)

= − 3175 + 1560

(This also scores M1)

M3 = **<u>− 1615</u>** (kJ mol^{-1})
Award 1 mark ONLY for (+) 1615

*Correct answer to the calculation gains all of **M1**, **M2** and **M3***

Credit 1 mark for(+) 1615 (kJ mol^{-1})

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*

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*score 2 marks (**M1** and **M2**)*

- *If no AE, check for a correct method; this requires either a correct cycle with V_2O_5 <u>and</u> 5CaO OR a clear statement of **M1** which could be in words and scores **<u>only M1</u>***

M4 Type of reaction is

- reduction
- redox
- (or accept) <u>V_2O_5 / it / V(V)</u> has been <u>reduced</u>

*In **M4** not "vanadium / V is reduced"*

M5 Major reason for expense of extraction − the answer must be about calcium

<u>Calcium is produced / extracted by electrolysis</u>
OR <u>calcium</u> is <u>expensive to extract</u>
OR <u>calcium extraction uses electricity</u>
OR <u>calcium extraction uses large amount of energy</u>
OR <u>calcium</u> is a (very) <u>reactive metal</u> / <u>reacts with water or air</u>
OR <u>calcium needs to be extracted / does not occur native</u>

QoL

Accept calcium is expensive "to produce" but not "to source, to get, to obtain, to buy" etc.

*In **M5** it is neither enough to say that calcium is "expensive" nor that calcium "must be purified"*

5

(b) **M1**

$2Al + Fe_2O_3 \longrightarrow 2Fe + Al_2O_3$

Ignore state symbols

Credit multiples of the equation

M2

(Change in oxidation state) <u>**0** to (+)**3**</u>
OR
(changed by) <u>**+3**</u>

*In **M2** if an explanation is given it must be correct and unambiguous*

2

(c) **M1**

$VCl_2 + H_2 \longrightarrow V + 2HCl$

*In **M1** credit multiples of the equation*

M2 and **M3**

Two hazards in either order

- <u>HCl / hydrogen chloride / hydrochloric acid is acidic / corrosive / toxic / poisonous</u>
- Explosion risk <u>with hydrogen</u> (gas) OR <u>H_2 is flammable</u>

*For **M2 / M3** there must be reference to hydrogen; it is not enough to refer simply to an explosion risk*

*For **M2 / M3** with HCl hazard, require reference to acid(ic) / corrosive / toxic <u>only</u>*

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M4
The only other product / the HCl is easily / readily <u>removed / lost / separated because it is a gas</u> *OR* <u>will escape</u> (or this idea strongly implied) <u>as a gas</u>
OR vanadium / it is the <u>only solid product</u> (and is easily separated)
OR vanadium / it is a <u>solid and the other product / HCl is a gas</u>

*In **M4** it is not enough to state simply that HCl is a gas, since this is in the question.*

4

[11]

Q11.

(a) (i) **3**Fe + Sb_2S_3 ⟶ **3**FeS + **2**Sb

Or multiples.
Ignore state symbols.

1

(ii) Fe ⟶ Fe^{2+} + $2e^-$

Ignore charge on the electron unless incorrect.
Or multiples.
Credit the electrons being subtracted on the LHS.
Ignore state symbols.

1

(b) (i) Sb_2S_3 + **4.5**O_2 ⟶ Sb_2O_3 + **3**SO_2

Or multiples.
Ignore state symbols.

1

(ii) SO_3 or sulfur trioxide / sulfur (VI) oxide

Credit also the following ONLY.
H_2SO_4 or sulfuric acid.
OR
Gypsum / $CaSO_4$ or plaster of Paris.

1

(c) (i) **M1 (could be scored by a correct mathematical expression)**

Correct answer gains full marks.

M1 <u>$\Delta H_r = \Sigma\Delta H_f$(**products**) − $\Sigma\Delta H_f$(**reactants**)</u>

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

Credit 1 mark for +104 (kJ mol^{-1}).

M2 = 2(+20) + 3(−394) − (−705) − 3(−111)

= 40 −1182 + 705 + 333

= −1142 − (−1038)

(This also scores M1)

M3 = **<u>−104</u>** (kJ mol^{-1})

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(Award 1 mark ONLY for + 104)

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.*
- *If no AE, check for a correct method; this requires either a correct cycle with 3CO, 2Sb and $3CO_2$ OR a clear statement of **M1** which could be in words and scores **only M1**.*

3

(ii) It / Sb is <u>not in its standard state</u>

OR

<u>Standard state</u> (for Sb) <u>is solid / (s)</u>

OR

<u>(Sb) liquid is not its standard state</u>

Credit a correct definition of standard state as an alternative to the words 'standard state'.

QoL

1

(iii) Reduction **OR** reduced **OR** redox

1

(d) Low-grade ore extraction / it

- uses (cheap) <u>scrap / waste</u> <u>iron / steel</u>
- is a single-step process

uses / requires <u>less / low(er) energy</u>

Ignore references to temperature / heat or labour or technology.

1

[10]

Q12.

(a) ($Q = mc\Delta T$)

$= 50 \times 4.18 \times 27.3$

If incorrect (eg mass = 0.22 or 50.22 g) ***CE = 0 / 2***

1

= **5706 J** (accept 5700 and 5710)

Accept 5.7 kJ with correct unit. Ignore sign.

1

(b) M_r of 2-methylpropan-2-ol = 74(.0)

For incorrect M_r, lose M1 but mark on.

1

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Moles = mass / M_r

= 0.22 / 74(.0)

= **0.00297 moles**

1

ΔH = –5706 / (0.002970 × 1000)

= **–1921 (kJ mol^{-1})**

If 0.22 is used in part (a), answer = –8.45 kJ mol^{-1} scores 3

(Allow –1920, –1919)

If uses the value given (5580 J), answer = –1879 kJ mol^{-1} scores 3

Answer without working scores M3 only.

Do not penalise precision.

Lack of negative sign loses M3

1

(c) ΔH = ΣΔH products – ΣΔH reactants
OR a correct cycle

Correct answer with no working scores 1 mark only.

1

ΔH = −(−360) + (4 × −393) + (5 × −286)

M2 also implies M1 scored.

1

ΔH = **–2642** (kJ mol^{-1}) This answer only.

Allow 1 mark out of 3 for correct value with incorrect sign.

1

(d) (–2422 – part (b)) × 100 / –2422

Ignore negative sign.

Expect answers in region of 20.7

If error carried forward, 0.22 allow 99.7

If 5580 J used earlier, then allow 22.4

1

(e) Reduce the distance between the flame and the beaker / put a sleeve around the flame to protect from drafts / add a lid / use a copper calorimeter rather than a pyrex beaker / use a food calorimeter

Any reference to insulating material around the beaker must be on top.

Accept calibrate the equipment using an alcohol of known enthalpy of combustion.

1

(f) Incomplete combustion

1

[11]

Q13.

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(a) **M1 (could be scored by a correct mathematical expression**

*Correct answer to the calculation gains all of **M1**, **M2** and **M3***

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

Credit 1 mark for − 101 (kJ mol^{-1})

OR a correct cycle of balanced equations

M2 = − 1669 − 3(− 590)
= − 1669 + 1770
(This also scores M1)

M3 = **+ 101** (kJ mol^{-1})

Award 1 mark ONLY for − 101

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 a correct method; this requires either a correct cycle with 3Sr and 2Al OR a clear statement of **M1** which could be in words and scores **only M1***

M4 - Using powders
Any **one** from

- To increase collision frequency / collisions in a given time / rate of collisions
- To increase the surface contact / contact between the solids / contact between (exposed) particles

Ignore dividing final answer by 3

*Penalise **M4** for reference to molecules.*

5

M5 Major reason for expense of extraction
Any **one** from

- Aluminium is extracted by electrolysis ***OR*** aluminium extraction uses (large amounts of) electricity
- Reaction / process / It / the mixture requires heat
- It is endothermic

(b) Calcium has a higher melting point than strontium, because

Ignore general Group 2 statements.

Correct reference to size of cations / proximity of electrons
M1 (For Ca) delocalised electrons closer to cations / positive ions / atoms / nucleus
OR cations / positive ions / atoms are smaller
OR cation / positive ion / atom or it has fewer (electron) shells / levels

*Penalise **M1** if either of Ca or Sr is said to have more or less delocalised electrons OR the same nuclear charge.*

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Ignore reference to shielding.

Relative strength of metallic bonding
M2 (Ca) has stronger attraction between the cations / positive ions / atoms / nucleus and the delocalised electrons
OR
stronger metallic bonding

(assume argument refers to Ca but credit converse argument for Sr)

CE= 0 *for reference to molecules or Van der Waals forces or intermolecular forces or covalent bonds.*

2

(c) **M1** **2**Mg + O_2 ⟶ **2**MgO

M2 Mg + **2**H_2O ⟶ $Mg(OH)_2$ + H_2

Credit multiples of the equations.

M3 Magnesium hydroxide is used as an antacid / relieve indigestion (heartburn) / neutralise (stomach) acidity / laxative

Not simply "milk of magnesia" in ***M3***

3

[10]

Q14.

(a) (i) **M1 (could be scored by a correct mathematical expression which must have all Δ*H* symbols and the Σ or SUM)**

Correct answer gains full marks

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

M1 $\Delta H = \Sigma\Delta H_f$ (**products**) - $\Sigma\Delta H_f$ (**reactants**)

OR a correct cycle of balanced equations

M2 $\Delta H = 3(-394) - 3(-111) - (-971)$
(This also scores M1)

M3 = **(+) 122**(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* ***M1 only***

3

(ii) By definition

Ignore reference to "standard state"

OR

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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 and 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]

Q15.

(a) The enthalpy change / heat (energy) change (at constant pressure) in a reaction is independent of the route / path taken (and depends only on the initial and final states)

Ignore the use of ΔH for enthalpy

1

(b) $\Delta H_{exp} + \Delta H_2 - \Delta H_1 = 0$

Any correct mathematical statement that uses all three terms

OR

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$\Delta H_{exp} + \Delta H_2 = \Delta H_1$ ***OR*** $\Delta H_1 = \Delta H_{exp} + \Delta H_2$

OR

$\Delta H_{exp} = \Delta H_1 - \Delta H_2$ ***OR*** $\Delta H_{exp} = \Delta H_1 + (- \Delta H_2)$

1

(c) $\Delta H_{exp} = \Delta H_1 - \Delta H_2$

$\Delta H_{exp} = -156 - 12 =$ ***−168*** *(kJ mol^{-1})*

Ignore units

Award the mark for the correct answer without any working

1

(d) (i) M1 q = m c ΔT OR calculation (25.0 x 4.18 x 14.0)

Award full marks for correct answer

M2 = **1463**J OR **1.46** kJ (This also scores **M1**)

*In **M1**, do not penalise incorrect cases in the formula*

M3 must have both the correct value within the range specified **<u>and</u>** the minus sign

*Penalise **M3** ONLY if correct numerical value but sign is incorrect; e.g. **+69.5 to +69.7 gains 2 marks** (ignore +70 after correct answer)*

For 0.0210 mol, therefore

$\Delta H_1 =$ **− 69.67** to **− 69.52** (kJ mol^{-1})

OR $\Delta H_1 =$ **− 69.7** to **− 69.5** (kJ mol^{-1})

*Penalise **M2** for arithmetic error but mark on*

Accept answers to 3sf or 4sf in the range − 69.7 to − 69.5

ΔT = 287, score q = m c ΔT only

Ignore -70 after correct answer

*If c = 4.81 (leads to 1684J) penalise **M2** ONLY and mark on for **M3** = <u>− 80.17</u> (range − 80.0 to − 80.2)*

Ignore incorrect units

3

(ii) The idea of <u>heat</u> loss

NOT impurity

OR

Incomplete reaction (of the copper sulfate)

NOT incompetence

OR

Not all the copper sulfate has dissolved

NOT incomplete combustion

1

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(e) Impossible to add / react the exact / precise amount of water

Not just "the reaction is incomplete"

OR

Very difficult to measure the temperature rise of a solid

OR

Difficult to prevent solid dissolving

OR

(Copper sulfate) solution will form

1

[8]

Q16.

(a) (Enthalpy change to) break the bond in 1 mol of chlorine (molecules)

Allow (enthalpy change to) convert 1 mol of chlorine molecules into atoms
Do not allow energy or heat instead of enthalpy, allow heat energy

1

To form (2 mol of) gaseous chlorine atoms / free radicals

Can score 2 marks for 'Enthalpy change for the reaction':
$Cl_2(g) \rightarrow 2Cl(g)$
Equation alone gains M2 only
Can only score M2 if 1 mol of chorine molecules used in M1 (otherwise it would be confused with atomisation enthalpy)
Any mention of ions, CE = 0

1

(b) (For atomisation) only 1 mol of chlorine atoms, not 2 mol (as in bond enthalpy) is formed / equation showing ½ mol chlorine giving 1 mol of atoms

Allow breaking of one bond gives two atoms
Allow the idea that atomisation involves formation of 1 mol of atoms not 2 mol
Allow the idea that atomisation of chlorine involves half the amount of molecules of chlorine as does dissociation
Any mention of ions, CE = 0

1

(c) (i) $\frac{1}{2}F_2(g) + \frac{1}{2}Cl_2(g) \rightarrow ClF(g)$

1

(ii) $\Delta H = \frac{1}{2}E(F–F) + \frac{1}{2}E(Cl–Cl) – E(Cl–F)$

Allow correct cycle

1

$E(Cl–F) = \frac{1}{2}E(F–F) + \frac{1}{2}E(Cl–Cl) - \Delta H$

$= 79 + 121 - (-56)$

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= 256 (kJ mol^{-1})

−256 scores zero

Ignore units even if wrong

1

(iii) ½Cl_2 + 3/2 F_2 → ClF_3

If equation is doubled CE=0 unless correcr answer gained by / 2 at end
This would score M1

1

ΔH = ½ E(Cl−Cl) + 3/2 E(F–F) − 3E(Cl−F)

= 121 + 237 − 768 / (or 3 × value from (c)(ii))

This also scores M1 (note = 358 − 768)

1

= −410 (kJ mol^{-1})

If given value of 223 used ans = −311
Allow 1 / 3 for +410 and +311

1

(iv) (Bond enthalpy of) Cl−F bond in ClF is different from that in ClF_3

Allow Cl-F bond (enthalpy) is different in different compounds (QoL)

1

(d) NaCl is ionic / not covalent

1

[11]

Q17.

(a) (i) **M1 (could be scored by a correct mathematical expression which must have**
all ΔH**symbols and the** $\sum$ or SUM)

M1 $\Delta H_r = \Sigma\Delta H_f$ **(products)** - $\Sigma\Delta H_f$ **(reactants)**

OR a correct cycle of balanced equations with 1C, $3H_2$ and $1O_2$

M2 ΔH_r = – 201 + (– 242) – (– 394)
ΔH_r = – 201 – 242 + 394
ΔH_r = – 443 + 394
(This also scores M1)

M3 = – **49** (kJ mol^{-1})
(Award 1 mark ONLY for + 49)
Correct answer gains full marks
Credit 1 mark ONLY for + 49 (kJ mol^{-1})
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 a correct method; this requires*

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either

correct cycle of balanced equations with 1C, $3H_2$ and $1O_2$

*OR a clear statement of **M1** which could be in words*

and

*scores only **M1***

3

(ii) It is an element / elemental

Ignore reference to "standard state"

OR

By definition

1

(b) **M1** (The yield) increases / goes up / gets more

*If M1 is given as "decreases" / "no effect" / "no change" then CE= 0 for clip, but mark on only **M2** and **M3** from a blank M1*

M2 There are more moles / molecules (of gas) on the left / of reactants
OR fewer moles / molecules (of gas) on the right
/ products
OR there are 4 moles /molecules (of gas) on the left and 2 moles / molecules on the right.
OR (equilibrium) shifts / moves to the side with less moles / molecules

*Ignore "volumes", "particles" "atoms" and "species" for **M2***

M3: Can only score M3 if M2 is correct

The (position of) equilibrium shifts / moves (from left to right) to oppose the increase in pressure

*For **M3**, not simply "to oppose the change"*

*For **M3** credit the equilibrium shifts / moves (to right) to lower / decrease the pressure*

(There must be a specific reference to the change that is opposed)

3

(c) **M1** Yield increases goes up

M2 The (forward) reaction / to the right is endothermic OR takes in/ absorbs heat

OR

The reverse reaction / to the left is exothermic OR gives out / releases heat

*If M1 is given as "decrease" / "no effect" / "no change" then CE= 0 for clip, but mark on only **M2** and **M3** from a blank **M1***

Can only score M3 if M2 is correct

M3 The (position of) equilibrium shifts / moves (from left to right) to oppose the increase
in temperature **(QoL)**

*For **M3**, not simply "to oppose the change"*

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*For **M3**, credit the (position of) equilibrium shifts / moves **(QoL)***

*to absorb the heat **OR***

*to cool the reaction **OR***

to lower the temperature

(There must be a specific reference to the change that is opposed)

3

(d) (i) An activity which has no net / overall (annual) carbon emissions to the atmosphere

OR

An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere.

OR

There is no change in the total amount / level of carbon dioxide /CO_2 carbon /greenhouse gas present in the atmosphere.

The idea that the carbon /CO_2 given out equals the carbon /CO_2 that was taken in from the atmosphere

1

(ii) CH_3OH + **1**½ O_2 CO_2 + **2**H_2O

Ignore state symbols

Accept multiples

1

(iii) **3**H_2 + **1**½ O_2 **3**H_2O

Ignore state symbols

OR

Accept multiples

2H_2 + O_2 **2**H_2O

Extra species must be crossed through

1

(e) **M1** $q = m\ c\ \Delta T$

Award full marks for correct answer

Ignore the case for each letter

OR $q = 140 \times 4.18 \times 7.5$

M2 = 4389 (J) OR 4.389 (kJ) OR 4.39 (kJ) OR 4.4 (kJ)(also scores M1)

M3 Using 0.0110 mol
therefore ΔH = **– 399** ($kJmol^{-1}$)
OR **– 400**

*Penalise **M3** ONLY if correct numerical answer but sign is incorrect; +399 **gains 2 marks***

*Penalise **M2** for arithmetic error and mark on*

*In **M1**, do not penalise incorrect cases in the formula*

If $\Delta T = 280.5$; score $q = m\ c\ \Delta T$ only

*If c = 4.81 (leads to 5050.5) penalise **M2** ONLY and mark on for **M3** = – 459*

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+399 or +400 gains 2 marks

Ignore incorrect units

3

[16]

Q18.

(a) (i) reduction **OR** reduced **OR** redox ***OR*** reduction–oxidation

Not "oxidation" alone

1

(ii) Fe^{3+} + **3**e^- ⟶ Fe

Ignore state symbols

Do not penalise absence of charge on electron

Credit Fe^{3+} ⟶ *Fe – **3**e^-*

Credit multiples

1

(b) (i) **Because (one of the following)**

CO is not the only product ***OR***

Reference to "incomplete combustion to form CO" does not answer the question

(Some) complete combustion (also)occurs ***OR***

CO_2 is (also) formed

Further oxidation occurs

1

(ii) The <u>enthalpy change</u> / <u>heat (energy) change at constant pressure</u> in a reaction is <u>independent of the route / path taken</u> (and depends only on the initial and final states)

1

(iii) **M1** The <u>enthalpy change</u> / <u>heat change at constant pressure</u> when <u>1 mol</u> of a compound / substance / element

For M1, credit correct reference to molecule/s or atom/s

M2 is <u>burned completely</u> / <u>undergoes complete combustion</u> in (excess) <u>oxygen</u>

M3 with <u>all reactants and products / all substances in standard states</u>

For M3

Ignore reference to 1 atmosphere

OR <u>all reactants and products / all substances in normal / specified states under standard conditions</u> / 100 kPa / 1 bar <u>and</u> specified T / 298 K

3

(c) **M1 (could be scored by a correct mathematical expression which <u>must</u> have <u>all</u> ΔH symbols and the $\sum$)**

Correct answer gains full marks

Credit 1 mark ONLY for –1 (kJ mol^{-1})

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M1 $\Delta H_r = \sum \Delta H_f$ (**products**) – $\sum \Delta H_f$ (**reactants**)

Credit 1 mark ONLY for – 27 (kJ mol^{-1}) i.e. assuming value for Fe(l) = 0

OR correct cycle of balanced equations with 2Fe, 3C and $3O_2$

M2 ΔH_r = 2(+14) + 3(– 394) – (– 822) – 3(–111)

= 28 –1182 + 822 + 333

(This also scores M1)

M3 = **(+) 1** (kJ mol^{-1})

(Award 1 mark ONLY for – 1)

(Award 1 mark ONLY for – 27)

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 a correct method; this requires either a correct cycle with 2Fe, 3C and $3O_2$ OR a clear statement of M1 which could be in words and scores only M1*

3

(d) (i) C(s) + O_2(g) CO_2(g)

State symbols essential

Possible to include C(s, graphite)

1

(ii) These two enthalpy changes are for the same reaction / same equation / same reactants and products

Penalise reference to CO_2 being produced by a different route

OR

They both make one mole of carbon dioxide only from carbon and oxygen (or this idea clearly implied)

"both form CO_2" is not sufficient (since other products might occur e.g.CO)

OR

The same number and same type of bonds are broken and formed

1

[12]

Q19.

(a) One from

- Ti is not produced

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- TiC / carbide is produced OR titanium reacts with carbon
- Product is brittle
- Product is a poor engineering material

Penalise ''titanium carbonate''

Ignore ''impure titanium''

Credit ''titanium is brittle''

1

(b) Heat (energy) change at constant pressure

QoL

1

(c) The enthalpy change in a reaction is independent of the route taken (and depends only on the initial and final states)

Credit ''heat change at constant pressure'' as an alternative to ''enthalpy change''

1

(d) **M1** The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / product

For M1, credit correct reference to molecule/s or atom/s

M2 is formed from its (constituent) elements

M3 with all reactants and products / all substances in standard states

OR all reactants and products / all substances in normal states under standard conditions / 100 kPa / 1 bar and any specified T (usually 298 K)

Ignore reference to 1 atmosphere

3

(e) (i) Na / it is not in its standard state / normal state under standard conditions

OR

Standard state / normal state under standard conditions for Na is solid / (s)

QoL

Ignore ''sodium is a liquid or sodium is not a solid''

1

(ii) **M1** $\Delta H_r = \sum \Delta H_f$ **(products)** $- \sum \Delta H_f$ **(reactants)**

M2 $\Delta H_r = 4(-411) - (-720) - 4(+3)$
$= -1644 + 720 - 12$
(This also scores M1)

M3 $= \mathbf{-936}$ (kJ mol^{-1})

Correct answer gains full marks

Credit 1 mark for + 936 *(kJ mol^{-1})*

Credit 1 mark for – 924 *(kJ mol^{-1})*

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i.e. assuming value for Na(l) = 0

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 a correct method; this requires* ***either*** *a correct cycle with $2Cl_2$ and 4Na OR a* ***clear complete statement*** *of M1 which could be in words and scores only M1*

3

(iii) Reducing agent

Ignore "reduces titanium"

OR reductant OR reduces $TiCl_4$

OR electron donor

1

[7]

Q20.

(a) Heat (energy) change at constant pressure

Ignore references to standard conditions, but credit specified pressure.

1

(b) The enthalpy change/heat (energy) change (at constant pressure) in a reaction is independent of the route/path taken (and depends only on the initial and final states)

1

(c) $\Delta H + 963 = -75 - 432$ OR $\Delta H + 963 = -507$ (**M1**)

$\Delta H = -75 - 432 - 963$ (**M1** and **M2**)

$\Delta H =$ **-1470** ($kJ\ mol^{-1}$)

Award 1 mark for + 1470

Award full marks for correct answer

Ignore units.

Ignore numbers on the cycle

M1 *and* ***M2*** *can score for an arithmetic error*

3

[5]

Q21.

(a) (i) **M1** The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / product

1

M2 Is formed from its (constituent) elements

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1

M3 With all reactants and products / all substances in standard states
OR
All reactants and products / all substances in normal states under standard conditions / 100 kPa / 1 bar and specified T / 298 K
Ignore reference to 1 atmosphere

1

(ii) By definition
OR
Because they are elements

1

(iii) **M1** $\Delta H_f = \Sigma \Delta H_f$ **(products)** – $\Sigma \Delta H_f$ **(reactants)**

1

M2 = –1669 – 3(–558)
(This also scores M1)

1

M3 = **(+) 5** (kJ mol^{-1})
Correct answer gains full marks.
Assume the value is positive unless specifically stated as negative.
Credit 1 mark if – 5 (kJ mol^{-1}).
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 a correct method; this requires either a correct cycle with 3BaO OR a clear statement of M1 which could be in words and scores <u>only M1</u>*

1

(b) (i) *One from*

- <u>Aluminium is expensive</u> (to extract *OR* due to electrolysis)
- <u>High energy cost</u>
- The <u>cost of heating strongly</u>
  This requires a clear statement about <u>cost</u>

1

(ii) *One from*

- <u>increase collision frequency</u>
- OR <u>more collisions</u>
- OR <u>more chance of colliding</u>
  The answer MUST refer to <u>more collisions</u>.
  Ignore "more available to collide"

1

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(c) (i) $Ba + \mathbf{2}H_2O \rightarrow Ba(OH)_2 + H_2$

Ignore state symbols
Allow multiples and correct ionic equations

1

(ii) **M1** $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$
(or the ions together)

Allow crossed out Na^+ ions, but penalise if not crossed out

1

M2 White precipitate / white solid

Ignore state symbols
Ignore "milky"

1

(iii) **M1** Barium meal or (internal) X-ray or to block X-rays

1

M2 $BaSO_4$ / barium sulfate is insoluble (and therefore not toxic)

Accept a correct reference to M1 written in the explanation in M2, unless contradictory.

For M2 NOT barium ions
NOT barium
NOT barium meal and NOT "It".

Ignore radio-tracing.

1

[14]

Q22.

(a) The enthalpy change when 1 mol of a compound

1

is completely burnt in oxygen

1

under standard conditions, or 298K and 100kPA

1

(b) (i) $C_2H_6 + 3½O_2 \rightarrow 2CO_2 + 3H_2O$

1

(ii) $\Delta H = 2 \times \Delta H_f^{\ominus} (CO_2) + 3 \times \Delta H_f^{\ominus} (H_2O) - \Delta H_f^{\ominus} (C_2H_6)$

1

$= -788 - 858 - (-85)$

1

$= -1561$ kJ mol^{-1}

1

(c) moles methane = $\frac{0.10}{16} = 6.25 \times 10^{-3}$

1

kJ evolved = $6.25 \times 10^{-3} \times 890 = 5.56$

1

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5.56×10^3 joules = (mc)ΔT

1

$\Delta T = \frac{5.56 \times 10^3}{120}$ = 46.4 K

1

[11]

Q23.

(a) Enthalpy change when 1 mol of compound (1)

Is formed from it's elements (1)

All substances in their standard state (1)

3

(b) $\Delta H = \Sigma \Delta H^{\ominus}c$ (reactants) – $\Sigma \Delta H^{\ominus}c$ (products) (1)

= (7*x* – 394) + (4 *x* – 286) – (– 3909) (1)

= + 7 kJmol^{-1} (1)

3

(c) Heat change = m c Δ*T* (1)

= 250 × 4.18 × 60 = 62700J = 62.7kJ (1)

Moles C_7H_8 = 2.5 /92 = 0.0272 (1)

ΔH = 62.7 / 0.0272 = – 2307 kJ mol^{-1} (1)
(allow –2300 to –2323)

4

(d) Mass of water heated = 25 + 50 = 75g
Temp rise = 26.5 – 18 = 8.5 °C
*both for **(1)** mark*

Heat change = 75 × 4.18 × 8.5 = 2665 J = 2.665 kJ (1)

Moles HCl = 0.05 (1)

Δ*H* = – 2.665 / 0.05 = –53.3 kJmol^{-1} (1)
(allow –53 to –54)

4

(e) Less heat loss (1)

1

[15]

Q24.

(a) enthalpy change/ heat energy change when 1 mol of a substance

1

is completely burned in oxygen

1

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at 298K and 100 kPa or standard conditions

1

(not 1atm)

(b) $\Delta H = \sum$ bonds broken – $\sum$ bonds formed

1

= (6 × 412) + 612 +348 + (4.5 × 496) – ((6 × 743) + (6 × 463))

1

= – 1572 kJ mol^{-1}

1

(c) by definition ΔH_f is formation from an element

1

(d) $\Delta H_c = \sum \Delta H_f$ products -$\sum \Delta H_f$ reactants or cycle

1

= (3 × – 394) + (3 × –242) – (+20)

1

= − 1928 kJ mol^{-1}

1

(e) bond enthalpies are mean/average values

1

from a range of compounds

1

[12]

Q25.

(a) enthalpy (or energy) to break (or dissociate) a bond;

1

averaged over different molecules (environments);

1

enthalpy (or heat energy) change when one mole of a compound;

1

is formed from its elements;

1

in their standard states;

1

(b) enthalpy change = Σ(bonds broken) – Σ(bonds formed) or cycle;

1

= 4 × 388 +163 + 2 × 146 + 4 × 463 – (944 + 8 × 463);
(or similar)

1

= –789;

(+ 789 scores 1 only)

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1

(c) (i) zero;

1

(ii) $\Delta H = \Sigma$ (enthalpies of formation of products) $-\Sigma$ (enthalpies of formation of reactants)

1

= 4 × –242-(75 + 2 × –133);

1

= –777;

(+ 777 scores one only)

1

(d) mean bond enthalpies are not exact

(or indication that actual values are different from real values)

1

[13]

Q26.

(a) (i) <u>enthalpy change</u> when 1 mol of a substance (or compound) (QL mark)

1

is (completely) burned in oxygen (or reacted in <u>excess</u> oxygen)

1

at 298 K and 100 kPa (or under standard conditions)

1

(ii) heat produced = mass of water × Sp heat capacity $x\Delta T$ (or $mc\Delta T$)

1

= 150 × 4.18 × 64 (note if mass = 2.12 lose first 2 marks then conseq) = 40100 J or = 40.1 kJ (allow 39.9 - 40.2 must have correct units)

1

moles methanol = mass/M_r = 2.12/32 (1)
= 0.0663

1

ΔH = – 40.1/0.0663 = – 605 kJ (mol^{-1})

1

(allow –602 to –608 or answer in J)

(note allow conseq marking after all mistakes but note use of 2.12 g loses 2 marks

(b) (i) equilibrium shifts to left at high pressure

1

because position of equilibrium moves to favour fewer moles (of gas)

1

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(ii) at high <u>temperature</u> reaction yield is low (or at low *T* yield is high)

1

at low <u>temperature</u> reaction is slow (or at high *T* reaction is fast)

1

therefore use a balance (or compromise) between <u>rate</u> and <u>yield</u>

1

(c) $\Delta H = \Sigma \Delta H_c^{\ominus}$(reactants) – $\Sigma \Delta H_c^{\ominus}$(products) (or correct cycle)

1

$\Delta H_c^{\ominus}(CH_3OH) = \Delta H_c^{\ominus}(CO) + 2 \times \Delta H_c^{\ominus}(H_2) - \Delta H$

1

= (–283) + (2 × –286) – (–91) (mark for previous equation or this)
= –764 (kJ mol^{-1}) (*units not essential but lose mark if units wrong)*
(note + 764 scores 1/3)

1

[15]

Q27.

B

[1]

Q28.

A

[1]

Q29.

(a) $\Delta H = \Sigma$(bonds broken) – Σ(bonds formed) (or cycle)

1

= +146 – 496/2 (or 2 × 463 + 146 –(2 × 463 + 496/2)

1

= – 102 (kJ mol^{-1}) **(1)**
*(accept no units, wrong units loses a mark; +102 scores **(1)** only)*

1

(b) $C(s) + 2H_2(g) \rightarrow CH_4(g)$ equation **(1)** Correct state symbols **(1)**

2

(c) (i) Macromolecular
(accept giant molecule or carbon has many (4) bonds)

1

(ii) $\Delta H = \Sigma \Delta H_f$(products) – $\Sigma \Delta H_f$(reactants) (or cycle)

1

= 715 + 4 × 218 – (–74.9)

1

= 1662 (kJ mol^{-1})

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(accept no units, wrong units loses one mark, allow 1660 to 1663, –1662 scores one mark only)

1

(iii) 1662/4 = 415.5

(mark is for divide by four, allow if answer to (c)(ii) is wrong)

1

[10]

Q30.

(a) (i) Δ*H* atomisation/sublimation of magnesium

1

(ii) Bond/dissociation enthalpy of Cl-Cl

OR 2 × *H* atomisation of chlorine

1

(iii) Second ionisation enthalpy of magnesium

1

(iv) 2 × electron affinity of chlorine

1

(v) Lattice formation enthalpy of $MgCl_2$

1

(b) Equation $2MgCl(s) \rightarrow MgCl_2(s) + Mg(s)$

State symbols not required but penalise if incorrect

1

Calculation ΔH reaction = $\Sigma\Delta H_f$ products – $\Sigma\Delta H_f$ reactants

1

= – 653 – (2 × –133)

1

= – 427 ($kJmol^{-1}$)

Allow +427 to score (1) mark

Other answers; award (1) for a correct Δ H reaction expression

1

(c) ΔH soln $MgCl_2$ = – ΔH Lat.form. + ΔH hyd.Mg^{2+} + 2ΔH hyd.Cl^-

1

or cycle
= 2502 – 1920 – (2 × 364)

1

= – 146 ($kJmol^{-1}$)

Allow + 146 to score (1) mark

Other answers; award (1) for a correct ΔH soln $MgCl_2$ expression/cycle

1

[12]

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Q31.

(a) *M1* $K_p = (_PY)^3 . (_PZ)^2 / (_PW)^2 . (_PX)$ *NB [ ] wrong* **1**

M2 temperature **1**

M3 increase **1**

M4 particles have more energy or greater velocity/speed **1**

M5 more collisions with $E > E_a$ or more successful collisions **1**

M6 Reaction exothermic or converse **1**

M7 Equilibrium moves in the left **1**

Marks for other answers

Increase in pressure or concentration	*allow M1, M5, M6*	*Max 3*
Addition of a catalyst;	*allow M1, M5, M6*	*Max 3*
Decrease in temperature;	*allow M1, M2, M6*	*Max 3*
Two or more changes made;	*allow M1, M6*	*Max 2*

(b) (i) Advantage; reaction goes to completion, not reversible or faster **1**

Disadvantage; reaction vigorous/dangerous

(exothermic must be qualified)

or HCl(g) evolved/toxic
or CH_3COCl expensive

NB Allow converse answers
Do not allow reactions with other reagents e.g. water or ease of separation **1**

(ii) $\Delta S = \Sigma S$ products $- \Sigma S$ reactants **1**

$\Delta S = (259 + 187) - (201 + 161)$ **1**

$\Delta S = 84$ (JK^{-1} mol^{-1}) *(Ignore units)*
*Allow – 84 to score **(1)** mark* **1**

$\Delta G = \Delta H - T\Delta S$ **1**

$= -21.6 - 298 \times 84/1000$
$= -46.6$ kJ mol^{-1} or $-46\,600$ J mol^{-1} **1**

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*Allow **(2)** for – 46.6 without units*
(Mark ΔG consequentially to incorrect ΔS)
(e.g. ΔS = –84 gives ΔG = +3.4 kJ mol^{-1})

1

[15]

Q32.

D

[1]

Q33.

C

[1]

Q34.

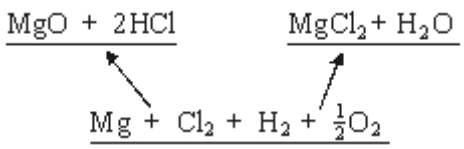
(a) (i) enthalpy (or heat or heat energy) change when
1 mol of a substance **(1)** (QL mark) is formed from its elements **(1)**
all substances in their standard states **(1) (**or normal states at 298K, 100 kPa or std condits)

***not** STP, NTP*

3

(b) enthalpy change (or enthalpy of reaction) is independent of route **(1)**

$\Delta H = \Sigma\Delta H_f^{\ominus}$ prods - $\Sigma\Delta H_f^{\ominus}$ reactants (or cycle) **(1)**
minimum correct cycle is:



ΔH = -642 – 286 – (–602 + 2 × –92) **(1)**
= –142 (kJ mol^{-1}) **(1)**

penalise this mark for wrong units
+142 scores 1 mark out of the last three

4

(c) $\Delta H = mcT$ **(1)** (or $mc\Delta T$)
= 50 × 4.2 × 32 = 6720 J = 6.72J **(1)**

mark is for 6720 J or 6.72 kJ

$$\text{moles HCl} = \frac{\text{vol}}{1000} \times \text{conc} = \frac{50}{1000} \times 3$$ **(1)**

= 0.15 **(1)**

if error here mark on conseq.

Therefore moles of MgO reacted = moles HCl/2 **(1)**

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(mark is for/2, CE if not/2)
= 0.15/2 = 0.075

Therefore ΔH = 6.72/0.075 **(1)**
= –90 kJ (mol^{-1})
kJ must be given, allow 89 to 91
*value **(1)***
*sign **(1)**; this mark can be given despite CE for /2*

8

Note various combinations of answers to part (c) score as follows:

–89 to –91 kJ **(8)** (or –89000 to 91000J)
*no units **(7)***

+89 to +91 kJ **(7)** (or + 89000 to +91000J)
*no units **(6)***

–44 to –46 kJ **(5)** (or -44000 to -46000J)
*no units **(4)** if units after 6.72 or 6720 (5)*

+44 to +46 kJ **(4)** (or +44000 to + 46000)
if no units and
*if no units after 6.72 or 6720 **(3)***
*otherwise check, could be **(4)***

[15]

Q35.

(a) *Standard enthalpy change, $\Delta H^{\ominus}$*: $\Delta H_R = \Sigma\Delta H_{f\text{products}} - \Sigma\Delta H_{f\text{reactants}}$ **(1)**
or cycle

ΔH_R = (0 + [2 × –242]) – (4 × –92) **(1)**
= -484 + 368
= –116 (kJ mol^{-1})
Allow max 1 for +116

Standard entropy change, $\Delta S^{\ominus}$: $\Delta S = \Sigma\Delta H_{f\ products} - \Sigma\Delta H_{f\ reactants}$

ΔS = ([2 × 223] + [2 × 189]) - (205 + [4 × 187]) **(1)**

= 824 – 953

= –129 (J K^{-1} mol^{-1})
allow max one for +129

6

(b) (i) *Effect*: Equilibrium displaced to right / to products **(1)**
Explanation: Reaction is endothermic **(1)**
Constraint reduced **(1)**
mark separately

(ii) Feasible when $\Delta G \leq 0$ **(1)**

$\Delta G = \Delta H - T\Delta S$ **(1)**

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T = $\Delta H/\Delta S$ = 208 × 1000 **(1)** / 253

= 822 K **(1)**

7

[13]

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Q1.

(a) This was answered well – nearly all students (83.8%) were able to state two correct oxidation states.

(b) Very few students were able give the first half-equation for the oxidation of chlorine whereas the second half-equation was more regularly correct.

(c) Only some students (23.1%) were able to recall this equation from the specification.

(d) Some students successfully calculated the mass of potassium iodide. However, many did not appreciate that this reaction was not 1:1 and so used the incorrect reacting ratio in their calculations. Many students stated incorrectly that the iodine formed would be observed as purple fumes or as a purple solution. This question discriminated particularly well.

(e) Most students were able both to write the correct equation and calculate the enthalpy change. Only 8.4% of students were unable to score at least one mark.

Q2.

Just over a third of students calculated the correct answer of +112 kJ mol^{-1}, but almost as many students gave –112 kJ mol^{-1}. A possible reason for this wrong answer is that students may use summary equations in calculations such as these and may be uncertain whether these involve (products – reactants) or (reactants – products).

Q3.

(a) This was poorly answered, with many students missing state symbols and balancing the equation incorrectly. Only the best students (24.6%) gained the mark here.

(b) This proved challenging compared to questions set in the previous specification from this topic area. 34.3% of students failed to pick up even one mark.

(c) Again challenging for all but the best students, only 26.3% scored more than one mark.

(d) This was not as well answered as might have been expected. The fact that mean bond enthalpies are calculated using a range of compounds was not well understood.

Q4.

(a) This proved to be a much tougher starter question than had been anticipated, with only 12% of students earning the mark. Students did not recognise that enthalpy change could not be measured directly. In this case, the enthalpy change was for the formation of a hydrated salt from an anhydrous one, with the expected answer being that it would be impossible to prevent some salt dissolving during the addition of water to the anhydrous salt. An alternative answer, related to the difficulty in measuring the temperature of a solid, was also allowed.

Some students' answers revealed confusion between calorimetry and colorimetry, with suggested answers including the lack of colour change during the reaction. Some students also seemed to believe that calorimetry is only possible if something

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is being burned.

(b) This calculation was answered reasonably well, with less than 20% of students failing to score. There was confusion about the 'direction' around the Hess Cycle, and evidence of many students thinking that an equation of the form $\Delta H = \Sigma \Delta H_f$(products) - $\Sigma \Delta H_f$(reactants) can be used universally, when it only applies to the specific use of enthalpies of formation.

(c) Most students' encounter with this 'extended response' style of question produced a good spread of marks, although 37% of students failed to score. This was usually due to a completely inappropriate method being described, with incorrect answers such as: "making a solution of magnesium chloride", "using it to fill a spirit burner and lighting it under a beaker of water" and "putting a solution of magnesium chloride in a polystyrene cup and heating it over a Bunsen burner". Other incorrect answers included descriptions of the preparation of a standard solution followed by a titration and the addition of magnesium chloride to acid instead of to water.

This question was marked using a 'levels of response' mark scheme. The key to success was for students to concentrate first on the inclusion of as much correct chemistry as possible to ensure access to Level 3 (worth 5 or 6 marks). Within a level, the mark awarded depended on the clarity and coherence of an answer, together with a clear, logical progression through the description. Appropriate apparatus and quantities should have been mentioned as necessary. For example, rather than writing 'add water to a container', a good start to the answer would be to write 'A measuring cylinder was used to measure 50 cm^3 of water into a polystyrene cup'.

Despite the fact that many students suggested in part (a), that it is difficult to measure the temperature of a solid, many then suggested putting the magnesium chloride into the polystyrene cup first and then recording its initial temperature, before adding the water.

(d) This was a challenging question, but one for which it proved relatively easy to score two marks; nearly 20% of students scored full marks here. Most students could successfully plot the points and draw a best fit line, although the negative scale on the y-axis confused some. Most students were also able to calculate the gradient of their line, although, as mentioned previously, it was not always clear what their suggested answer was. The calculation of ΔS proved trickier, with many trying to use the relationship $\Delta G = \Delta H - T\Delta S$, and either ignoring their calculated gradient or substituting it in for ΔH. Relatively few students recognised that this equation can be taken as $y = mx + c$ ($y = c - xm$ in this case) so that this graph of ΔG (y) vs T (x) gives a straight line with a gradient of $-\Delta S$.

Q9.

Two-thirds of the marks in this enthalpy-based question involved students being able to carry out calculations based on Hess' Law and, as always, there was a divide between those who could cope with such questions and those who couldn't.

In part (a) the importance of learning definitions was illustrated. Many students failed to make clear that <u>all</u> reactants and products need to be in their standard states.

In questions such as part (b) students are strongly advised to start with a clear and complete indication of the expression relating the enthalpy change of the reaction to the data given or to draw out a clearly labelled cycle. Students who relied on the use of a learned expression often got this wrong way round, possibly due to confusion with the use of enthalpies of formation whereas, in this case, the data provided were enthalpies of

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combustion.

In a question like part (c) students are strongly advised to sketch out the displayed formulae of all reactants and products when working with bond energies. Failing to do so in many cases meant that bonds were omitted or miscounted (3 × C-C in propan-1-ol was often seen) by students.

Q10.

This question provided a range of challenges. The calculation in part (a) was answered well and the necessity to focus on either the extraction or the reactivity of calcium was understood by many. In part (b), many students were unable to write a correct formula either for iron(III) oxide or for aluminium oxide and there was often a lack of clarity when stating the change in oxidation state of aluminium in this reaction. The equation in part (c) was generally done well and many students correctly linked an appropriate hazard to each of hydrogen and hydrogen chloride. The idea that the HCl could escape as a gas and the only other product was vanadium, was necessary to gain the final mark.

Q11.

Too many students had problems writing and balancing the equations in each of parts (a)(i), (a)(ii) and (b)(i). The calculation in part (c)(i) was straightforward and most students scored all 3 marks although errors were seen in simple mathematical operations. The remainder of the question was also relatively high scoring.

Q12.

(a) This part was mostly well answered, with the exception of those who chose to use the wrong mass.

(b) In this part, failure to give the negative sign was the most common error where students did not score full marks.

(c) This part was usually done very well.

(d) In contrast, this part was very poorly answered, almost always because –2642 was used from (c) rather than their answer to (b).

(e) Many vague answers were seen in response to this part. Simply adding insulation was insufficient and use of a polystyrene cup was wrong in this situation.

(f) The idea of incomplete combustion seemed to be poorly understood in this part, with quite a few students stating that 'not all the alcohol had burned'. Comments about heat loss etc were disqualified by the question.

Q13.

The whole of this question was relatively straightforward and it was pleasing to see the majority of students gain at least 3 marks in part (a) and over 40% gain both marks in part (b).

In part (c), too many students failed to balance their equations or could not write the correct formula for magnesium hydroxide. Fewer than half of all students gained all three marks.

Q14.

The calculation in part (a)(i) was high scoring with 72% gaining full marks and incorrect answers from the remainder due either to simple arithmetic errors or to chemical errors. In parts (b) and (c), incorrect chemical formulae were relatively common.

Q15.

Almost 85% of students were able to give a correct statement for Hess's Law and then attempted to apply it in parts (b) and (c), with over 70% success. No credit was given for a value calculated in part (c), consequent on an incorrect expression in part (b), since that is a chemical error.

Part (d) was generally well-answered although the negative sign was often missed in the answer leading to only 35% gaining all three marks. Only 7% were able to deduce a correct answer to part (e).

Q16.

Answers to this question were disappointingly poor. In part (a), there was not much evidence that the precise meaning of the term **bond dissociation enthalpy** was understood or had been learned. Only 20% of students scored both marks and over 50% scored zero. This enthalpy change refers to the conversion of one mole of chlorine gas into two moles of chlorine atoms but this was not usually stated. Answers to part (b) did not usually convey the understanding that this process is exactly the same as bond dissociation but that it involves only half a mole of chlorine gas. There was also confusion between chlorine molecules, chlorine atoms and chloride ions. Part (c)(i) was answered better but many answers were incorrect because they did not show chlorine and fluorine molecules. In part (c)(iii), many students used incorrect cycles or formulae and obtained an exothermic rather than an endothermic answer. In part (c)(iv), most students did not read or did not understand the question. A statement that bond enthalpies are obtained by averaging values from different compounds may be a correct statement but it is not an answer to the question.

Q17.

The standard enthalpy change calculation in part (a) was straightforward and high scoring. In parts (b) and (c), good discrimination occurred and a great many well–articulated responses were seen. It is worth noting that no marks were scored in either of parts (b) or (c), if the effect on the yield was assigned incorrectly. The meaning of *carbon–neutral* in part (d) is spelled out in the specification and needs to refer to <u>net</u> emissions of carbon dioxide to the atmosphere. Parts (d)(ii) and (d)(iii) were challenging and only the best students were able to arrive at the equation for the overall reaction between hydrogen and oxygen to make water. Most students scored at least one mark in part (e); the commonest error was a failure to give the final answer a negative sign for this exothermic process.

Q18.

The thinking required in part (b)(i) proved too much for many and only a few were able to state that, in practice, CO is not the only product and that some complete combustion to form CO_2 would occur. The answer of +1 kJ mol^{-1} was seen frequently in part (c), but some were disconcerted by this value and sought to find an alternative. State symbols were often missed in part (d)(i) and a clear statement in part (d)(ii) that the same reaction occurs for the two specified standard enthalpies was not well understood.

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Q19.

Overall, this was a relatively high-scoring question although only 26% of the candidates stated that enthalpy change is the heat change at constant pressure in part (b). Definitions continue to be learned poorly by a proportion of candidates and 15% of candidates failed to score any marks in part (d).

Q20.

Only 20% of the candidates stated that enthalpy change is the heat change at constant pressure, even though this is stated clearly in the specification. It was pleasing to see that more than half the candidates could correctly apply Hess's Law to an unfamiliar cycle and arrive at the right answer for the specified enthalpy change.

Q21.

The range of answers given to the meaning of the term *standard enthalpy of formation* in part (a)(i) indicated the variation in the ability of the candidates to learn basic information. Application of that information in the remainder of part (a) was generally well done, although too many candidates had their data the wrong way around in part (a)(iii).

Part (b) was answered correctly by approximately half of the candidates and there were some good answers in each section of part (c). The ability to construct and balance equations, including the simplest ionic equation in part (c)(ii), was made impossible for those candidates who did not know that Ba^{2+} is the formula of the barium ion.

Q23.

Part (a) was generally well done by most candidates. The most common error was not referring to standard states. The calculation in part (b) proved more demanding for students than some previous enthalpy calculations with many candidates giving the incorrect answer of –7kJmor\ A large number of candidates did not give the correct mass or correct temperature rise in part (c) and therefore only scored the mark for the $Q = mc\Delta t$ equation. Many of the candidates who did calculate the heat evolved then failed to calculate molar quantities. The calculation in part (d) proved very difficult for candidates with very few scoring full marks. Common errors were incorrect mass, incorrect temperature rise and lack of conversion to molar quantities. Candidates should know that exothermic reactions are shown by a negative sign e.g. $–53.3kJmol^{-1}$. In part (e) many candidates failed to make the comparison regarding heat loss between the two experiments.

Q24.

More able candidates were able to obtain high marks in this question but the weaker candidates found the calculations difficult. The definition in (a) was usually attempted well with the majority of candidates scoring 3 marks. Answers to (b) discriminated between candidates. There were several arithmetic errors in the calculation, and a few candidates who did not know to subtract the sum of the bonds made from the sum of the bonds broken leading to an incorrect sign in the final answer. Most candidates realised that oxygen was an element in (c). Again the calculation in (d) discriminated well. A common incorrect answer was 1888 $kJmol^{-1}$ which was usually due to doing the calculation the wrong way round. Weaker candidates also failed to take account of the 3 moles of water and carbon dioxide in their calculation. The explanation of why answers to (b) were less accurate than (a) was not done as well as expected with many candidates scoring one out of the 2 marks. Candidates should know that mean bond enthalpies are averaged over a range of compounds which contain the same bond, or from the same compound which contains several of the same type of bond. A common incorrect answer here was 'heat

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loss'.

Q25.

More able candidates were able to obtain high marks for this question but less able candidates found the calculations hard. In part (a) candidates lost a mark if they referred to bond-formation instead of bond-breaking. Less able candidates were unable to explain that mean bond enthalpy refers to an average of bonds where the environment is different, usually due to existence in different molecules. In part (b) many candidates provided incorrect answers because they did not work out the correct number of bonds being broken or formed. For example, only the best candidates recognised that two O—O bonds were broken. It was disappointing in part (c) (i) that many candidates did not understand the question. It was quite common to find candidates attempting a calculation using the equation, the enthalpy of formation values given in the table and an assumption that the enthalpy change for the equation was zero. Answers to part (c) (ii) were more usually correct though weaker candidates failed to take account of the two moles of hydrogen peroxide and the four moles of water. Answers to part (d) were usually incorrect. A common wrong answer was the statement 'Heat loss'.

Q26.

In this question, good candidates were able to score full marks. Weaker candidates were less successful though they were usually able to pick up at least five or six marks.

Answers to part (a) usually gained all three marks. Answers to part (b) by weaker candidates were less successful. One common error in the expression $mc\Delta T$ was to use the mass of methanol (2.12 g) instead of the mass of water (100 g). Another common error was to give an incorrect sign for the final value of the enthalpy of combustion. Candidates were expected to recognise that this exothermic process should lead to a negative value for the enthalpy of combustion of methanol. Weaker candidates also lost marks for incorrect units or for giving no units. It is important for candidates to give correct units for intermediate values in the calculation as well as for the answer. In this case, if a candidate gave a wrong final answer, it was still possible to gain an intermediate mark for the heat released to the 100 g of water. However, if the candidate did not make it clear whether the intermediate value was expressed in Joules or in kJ, it was not possible to give any credit.

Answers to part (b) were of a good standard and in part (b) (i) almost all candidates were awarded the two marks. Answers to part (b) (ii) were not quite so accurate and, in particular, only the best candidates stated that 500 K achieves the best balance between rate of reaction and yield.

Good candidates found part (c) straightforward but weaker candidates often omitted to allow for two moles of hydrogen and also used the wrong sign for the enthalpy of reaction (-91 kJ mol^{-1}) relative to the enthalpies of combustion of carbon monoxide and hydrogen.

Q29.

Good candidates were able to obtain high marks for this question but weak candidates found it very difficult and marks of zero out of ten were not unusual. In part (a), a common mistake was to use the O—O single bond enthalpy rather than the correct value for the O=O double bond and also to use one mole of oxygen rather than half a mole. In part (b) the balanced equation was usually correct but the state symbol for carbon was frequently shown as gaseous rather than solid (or graphite). In Part (c) (i) only the best candidates appeared to notice the wording in the question which required a reference to the structure of solid carbon. Part (c) (ii) also proved to be a difficult question for weaker candidates who rarely multiplied the enthalpy of formation of hydrogen atoms by the factor four. Also,

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the enthalpy of formation of methane (–74.9 kJ mol^{-1}) was usually added rather than subtracted. Incorrect cycles and equations involving combustion of methane were also common errors. Part (c) (iii) was answered well; the mark was awarded for dividing the answer to part (c) (ii) by four.

Q30.

Although candidates were specifically told in part (a) to note the direction of the indicated enthalpy change and the number of moles of species involved in the Born-Haber cycle, a significant number of candidates lost marks by failing to take this advice. Almost all candidates gave a correct equation for the disproportionation of MgCl in part (b) and many candidates scored full marks for the calculations required in parts (b) and (c). Sadly it was often impossible to award part scores to candidates who did not complete these calculations correctly as they did not give the necessary steps. Candidates must be encouraged to always show their working.

Q31.

Many candidates gave a correct expression for the equilibrium constant, K_p, for the reaction given in part (a). Some, who gave correct indices, lost a mark as they included square brackets, which are specific used to indicate concentration, in their expression. Identifying the one change which would increase the rate of reaction and decrease the value of K_p proved challenging but part marks were awarded for answers which addressed either of the two required changes. Candidates who gave more than one change of condition were able to score one mark for a correct K_p expression. There were many vague answers to part (b)(i), some of which assumed there were other reactants present with the most common example being water in Reaction 2. By contrast, (b)(ii) was very well answered with many candidates scoring full marks. Most candidates now remember to use either kJ mol^{-1} or J mol^{-1} throughout these calculations but a small number still failed to do this. Consequential marks were awarded in each part of the calculation.

Q34.

Most candidates answered this question well though it proved to be difficult to score maximum marks. The definition of standard enthalpy of formation in part (a) was usually correct though some candidates lost one mark because they did not make it clear that reactants and products should be in their standard states. In part (b) good candidates were able to score maximum marks but weaker candidates sometimes referred to energy rather than enthalpy when stating Hess's Law and such candidates often predicted an endothermic enthalpy change (+142 kJ mol^{-1}) rather than an exothermic one. Part (c) proved to be the most difficult part of this question. The major error was in the number of moles of magnesium oxide. Most candidates assumed that the number of moles of MgO would be the same as that of hydrochloric acid whereas it should have been half of that. This error led to a value for the enthalpy change that was too small by a factor of two. Such an answer resulted in the loss of three marks.

Q35.

This question was very well answered with many candidates scoring full, or nearly full marks. Just a few of the weaker candidates made errors when calculating the standard enthalpy change, $\Delta H^{\ominus}$, and the standard entropy change, $\Delta S^{\ominus}$, and marks were awarded consequentially to an arithmetic error. In part (b), most deduced correctly the effect of an increase in temperature on the equilibrium reaction but not all gave a full explanation of their answer. The calculation of the minimum temperature for the reaction to be feasible was also well done with few failing to use the same units for the enthalpy and the entropy changes.

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