Mark schemes

1

(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
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]

2 B

[1]

3 (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

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]

4

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

State symbols essential

1

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

1

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

1

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

1

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

1

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

1

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

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

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

Both required

1

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

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

1

F–F = 632 / 4 = 158 (kJ mol^{-1})

1

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

Relevant comment comparing to other bonds

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

1

[10]

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

1

(b) Temperature rise = 20.1

q = 50.0 × 4.18 × 20.1 = 4201 (J)

1

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

∴ 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]

6

(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

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**

Σ B **(reactants)** − Σ 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, <u>any two</u> from**

- <u>heat</u> loss or not all <u>heat</u> transferred to the apparatus or <u>heat</u> 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 <u>do not refer to specific compounds</u> OR MBE <u>values vary with different compounds / molecules</u> OR are average / mean values taken <u>from a range of compounds / molecules</u>

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]

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

M1 $\Delta H = \Sigma \Delta H_f$ **(products)** − $\Sigma \Delta H_f$ **(reactants)**

OR a correct cycle of balanced equations

M2 = 5(−635) − (−1560)

= − 3175 + 1560

(This also scores M1)

M3 = **− 1615** (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 score 2 marks (**M1** and **M2**)*
- *If no AE, check for a correct method; this requires either a correct cycle with V_2O_5 and 5CaO OR a clear statement of **M1** which could be in words and scores **only M1***

M4 Type of reaction is

- reduction
- redox
- (or accept) V_2O_5 / it / V(V) has been reduced

*In **M4** not "vanadium / V is reduced"*

M5 Major reason for expense of extraction − the answer must be about calcium

Calcium is produced / extracted by electrolysis
OR calcium is expensive to extract
OR calcium extraction uses electricity
OR calcium extraction uses large amount of energy
OR calcium is a (very) reactive metal / reacts with water or air
OR calcium needs to be extracted / does not occur native

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) **0** to (+)**3**

OR

(changed by) **+3**

*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

- HCl / hydrogen chloride / hydrochloric acid is acidic / corrosive / toxic / poisonous
- Explosion risk with hydrogen (gas) OR H_2 is flammable

*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 only*

M4

The only other product / the HCl is easily / readily removed / lost / separated because it is a gas *OR* will escape (or this idea strongly implied) as a gas
OR vanadium / it is the only solid product (and is easily separated)
OR vanadium / it is a solid and the other product / HCl is a gas

*In **M4** it is not enough to state simply that HCl is a gas, since this is in the question.*

4

[11]

8

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]

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

Allow heat energy

1

Averaged over a range of compounds / molecules

Penalise energy but mark on

ignore states

CE = 0 for ionic bonds

1

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

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

1

= 436 + 496 / 2 − 2 × 464

1

= −244 (kJ mol^{-1})

Allow 1 mark only for +244 and −488

Units not essential but penalise incorrect units

1

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

Do not allow similar

1

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

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

Allow reference to bond energy rather than bond enthalpy

Do not allow heat loss or experimental error

Do not allow mean bond enthalpies are not accurate

1

[7]