Mark schemes

Q1.

(a) Enthalpy change when one mole of a substance burns completely in oxygen

Allow heat energy change / allow fully combust

1

With all substances in their standard states (at stated temperature and 100kPa)

1

(b) $q = m\ c\ \Delta T = 150 \times 4.18 \times 13.9 = 8715.3$ J

1

$n(\text{propan-1-ol}) = \frac{0.497}{60.0} = 0.00828$ mol

1

$\Delta H = -\frac{8.7153}{0.00828} = -1050$ kJ mol^{-1}

M3 = – M1×10^{-3}/M2

Minimum of 2 sf needed

Must be negative

1

(c) Incomplete combustion

Evaporation of fuel

Experiment not completed under standard conditions

1

[6]

Q2.

(a) Heat (energy) change at constant pressure

allow transfer for change

1

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

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

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

(made) 6(C=O) + 8(O–H) *(8162)*

1

M2 including 4(41) for vaporisation of water

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

1

M3 2(C–C)
= 6(C=O) + 8(O–H) + 4(41) – 2046 – 8(C–H) – 5(O=O)
= 6(743) + 8(463) + 4(41) – 2046 – 8(412) – 5(496)
= 504

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

1

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

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

252 scores 4

170 scores 3 (omits vaporisation of water)

168 scores 3 (3 C-C bonds)

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

88 scores 3 (vaporisation of water on wrong side)

Ignore units

1

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

1

[6]

Q3.

(a)

	Temp/ ^{o}C		Mass /g
Initial		Burner before	
Final		Burner after	
(ΔT)		(Mass heptane burned)	

M1 for Temperature data including units

M2 for Burner mass data including units If either unit

missing MAX 1

M1
M2

(b) Any two from:

Glass is a poorer conductor than copper

M1

Tripod and gauze would reduce heat transfer

Tripod and gauze would have a fixed height above the flame

Heat capacity of metal is less than glass or vice versa

M2

(c) Heat loss to surroundings or to copper/calorimeter

M1

Incomplete combustion

M2

(d) Use a wind shield (to reduce heat loss)

Allow use a lid

Insulate the sides of the calorimeter

1

[7]

Q4.

(a) Heat energy change at constant pressure

1

(b)

This question is marked using Levels of Response.	
Level 3: All stages are covered and the explanation of each stage is generally correct and virtually complete. Answer is well structured with no repetition or irrelevant points. Accurate and clear expression of ideas with no errors in use of technical terms.	5-6 marks
Level 2: All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete. Answer shows some attempt at structure. Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points. Some minor errors in use of technical terms.	3-4 marks
Level 1: 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 includes isolated statements but these are not presented in a logical order or show some confusion. Answer may contain valid points which are not clearly linked to an argument structure. Errors in the use of technical terms.	1-2 marks

Level 0: Insufficient correct chemistry to gain a mark.	0 marks

Indicative Chemistry

Stage 1: Apparatus
1a. Use a burette/pipette (instead of a measuring cylinder)
1b. Use a polystyrene cup (instead of a beaker) / insulate beaker
1c. Reweigh the watchglass after adding the solid 1d: Use powdered solid

Stage 2: Temperature Measurements
2a. Measure and record the initial temperature of the solution for a few minutes before addition
2b. Measure and record the temperature after the addition at regular intervals (eg each minute) for 8+ minutes/until a trend is observed

Stage 3: Temperature Determination
3a. Plot a graph of temperature against time
3b. Extrapolate to the point of addition
3c. Determine ΔT at the point of addition

6

(c) n(HCl) or n(NaOH) = 50 x 0.500 / 1000 = 0.025 moles

1

q = –ΔH x n = 57.1 x 0.025 = 1.4275 kJ

M2 *= 57.1 ×* ***M1***

1

ΔT = q/mc

1

ΔT = (1.4275 x 1000) / (100 x 4.18) = 3.4(2) °C

M4 *= (****M2*** *× 1000) / (100 × 4.18)*

1

Final Temperature = 18.5 + 3.4 = 21.9 °C

M5 *=* ***M4*** *+ 18.5 (but final temperature must be higher than 18.5 °C)*

1

(d) Increase the concentration of the solutions

1

[13]

Q5.

D

$Li(s) + ½ F_2(g) \rightarrow LiF(s)$

[1]

Q6.

B

–278

[1]

Q7.

D

+947

[1]

Q8.

D

7.7%

[1]

Q9.

A

$$-\frac{c\,w\,\Delta T\,M_r}{b}$$

[1]

Q10.

(a) Amount of hexane = $\frac{2}{86}$ = 0.0233 mol

1

q = 4154 x 0.0233 (= 96.6 - 96.8 kJ)

ecf = M1 x 4154

1

C_{cal} = $\frac{96.6}{12.4}$ = 7.79 - 7.81 (kJ K^{-1})

ecf = M2/12.4
If no other marks awarded, allow one mark for 4154/12.4 = 335

1

(b) $q = C_{cal}\Delta T$ = 7.79 x 12.2 = 95.0 kJ

Ecf for (a) x 12.2
If candidate converted 12.4 into kelvin in (a), ignore conversion to kelvin in (b)

1

(amount of octane = $\frac{2}{114}$ = 0.0175 mol)

heat change per mole = $\frac{95.0}{0.0175}$ = 5417 kJ mol^{-1}

Allow 5420 kJ mol^{-1}

Using the value given:
6.52 x 12.2 = 79.54(4)
79.54/0.0175 = 4545

1

(c) pressure not constant in bomb calorimeter

Allow enthalpy change requires constant pressure

1

(d) $100 \times \frac{0.2}{12.2} = 1.64\%$

Allow 1.6%
Allow 2% if working shown
NOT 2.0%

1

use bigger mass of fuel (so ΔT greater)

Allow octane or hexane as the fuel
Allow more / greater volume of fuel

1

[8]

Q11.

(a)

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

Correct answer scores 4 marks

1

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

*0.0075 scores **M1** with or without working*
*9120 or 9.12 scores **M1** and **M2** with or without working*

1

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

Allow ECF at each stage
*correct **M3** scores **M1** and **M2***

1

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

1

Alternative **M3/4**

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

M4 Final T = 62.7 or 63 (°C)

*Ignore negative sign for q in **M2** and/or ΔT in **M3**, but penalise if used as a temperature fall in **M4** (if alternative*

*method used for **M3/4** and negative value for q is used, allow **M3** for expression with negative q value but do not allow **M4**)*

(temperatures to at least 2sf)

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

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

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

(b) thermal energy / heat loss or

or idea of heat being transferred to calorimeter

incomplete combustion or

allow idea that it is not under standard conditions

evaporation

allow no lid / poor/no insulation

1

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

1

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

1

M3 = –160 (kJ mol–1)

1

–160 scores 3 marks; +160 scores 2 marks

–8000 scores 2 marks; +8000 scores 1 mark

–1876 scores 2 marks; +1876 scores 1 mark

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

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

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

Ignore any cycle

[8]

Q12.

(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 cm³ 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)*

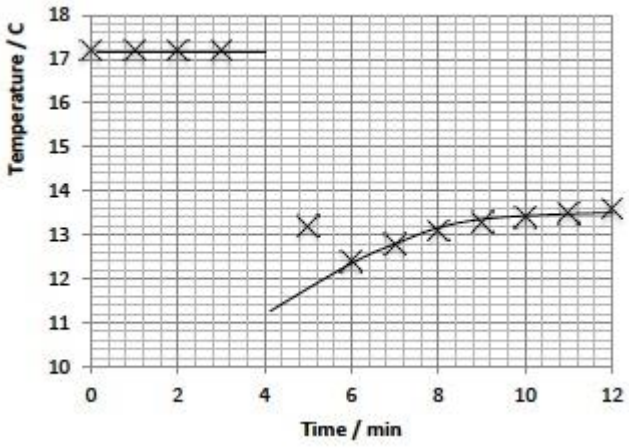
*Correct **M4** scores **M3**. If error made in **M4**, **M3** could score from substituted values in this expression in **M4***

***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

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]

Q13.

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

Don't allow multiples. States must be shown

1

(b) M1 Correct cycle or equation

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

1

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

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

1

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

−317 for 1 mark

+391 for 1 mark

1

Allow 2 sig fig or more

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

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

1

M2 $(6(N-H)) = 944 + 3(+436) + 92$

$(6(N-H)) = 2344$

−391 for 1 mark

1

M3 N−H = (+)391 kJ mol^{-1}

1

Allow 2 sig fig or more

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

1

[8]

Q14.

(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

(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 4th 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]

Q15.

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

1 mark for correct formulae and balancing

1

1 mark for all correct state symbols

1

(b) (Standard) enthalpy of formation

1

Difficult to prevent C reacting with O_2 to form some CO_2

1

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

1

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

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

1

(d) Correctly drawn Hess's law cycle

1

4 (Xe–F) = 252 + (2 × 158) = 568

Xe–F = 568 / 4

1

Xe–F = 142 (kJ mol$^{-1)}$)

1

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

1

[10]

Q16.

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)

$Q = mc\Delta T$

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

$\Delta H = 710.6 / 0.00988 = 71923.07$ J mol^{-1}

1

$\Delta H = -72$ (kJ mol^{-1})

Must be negative to score M6

1

Answer to 2 significant figures

1

[7]

Q17.

B

[1]

Q18.

B

[1]

Q19.

C

[1]

Q20.

(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

∴ 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]