1. (a) (i)

1st ionisation energy of sodium	**B**
1st electron affinity of chlorine	**F**
enthalpy of atomisation of sodium	**C**
enthalpy of atomisation of chlorine	**A**
lattice energy of sodium chloride	**E**
enthalpy of formation of sodium chloride	**D**

all six **(3)**; 5 – 4 **(2)**, 3 – 2 **(1)**, 1 – 0 **(0)** 3

(ii) D = A + B + C + E + F
= 121 + 494 + 109 – 770 – 364 **(1)**
= – 410 kJ mol^{-1} **(1)**

The answer might be filled in in the table; if so and there is no working then **(1)** only. Answer is consequential on the letters chosen in (i). 2

(b) calculations assume ions are point charges / separate / no distortion / uses the ionic model **(1)**
silver iodide has some / significant / degree of covalent character polarisation of the iodide by the silver **(1)** 2

(c) bigger atoms – electrons further from nucleus **(1)** i.e. size
more shielded **(1)**
ionisation energy decreases **(1)** 3

[10]

2. (a) *There are several routes to the answer; one possible route is given below. Alternative routes are acceptable.*

ΔH_{latt} = (– 411) – (-364) – (+121) – (+494) – (+109) **(1)**
= -771**(1)** (kJ mol^{-1})

Possible wrong answers:
–710.5 1 mark - wrong use of ΔH_{atom} *of Cl*
+771 (0) marks - lack of understanding of cycle 2

(b) Reference to fact that doubly charged ion(s) involved in the MgO **(1)**
Reference to fact that this leads to stronger forces of attraction (than in NaCl) **(1)**
or
Comparison of charge **(1)**
Comparison of radii **(1)**
or
Lattice enthalpy depends upon sizes of ions and charges or charge density **(1)**
Na^+ and Mg^{2+} magnesium is smaller and double charged/
Cl^- and O^{2-} oxygen is smaller and double charged **(1)** 2

(c) AgI is (partially) covalent **(1)**
Calculation assumes 100%/ fully ionic / point charges / perfect spheres **(1)** 2

[6]

3. (a) Enthalpy change / heat changes **(1)**

is independent of route **(1)** 2

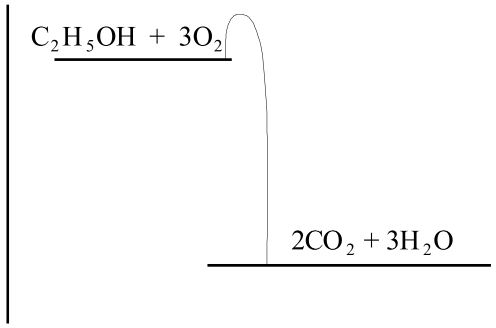
(b)
- Enthalpy or heat change **for complete combustion** / **complete reaction** with oxygen / burning in **excess** air **(1)**
- per **mole** of substance **(1)**
- 1 atm or standard states **(1)** 3

(c) (i) C–C + 5C–H + C–O + O–H + 3O=O →= +4719 **(1)**
4C=O + 6O–H = → –5750 **(1)**
$\Delta H = +4719 - 5750 = -1031 \text{ kJ mol}^{-1}$ **(1)** 3

(ii) Diagram showing an exothermic reaction and labelled 'products' and reactants' / equations **(1)**

Showing energy barrier **(1)**

Consequential marking on (i)



2

[10]

4. (a) *Three possible reasons*
Reason 1
Any fluctuations in temperature smoothed out / minimizes reading error / allows line of best fit to be drawn **(1)**
Reason 2
Able to allow for cooling effect / able to calculate more accurate **temperature** change / need to find highest temperature **(1)**
Reason 3
Reference to problem of how the experiment is carried out practically e.g. reaction slow / too much to do all at once **(1)**
Any 2 2

(b) Extrapolation of lower and upper temperatures at 3.5 min **(1)**
ΔT correct to ± 1.0°C according to candidate's method **(1)**
Consequential on sensible method of finding temp change between 3 and 4 minutes 2

(c) ΔH = - 4.18 × **candidate's** ΔT
ΔH correctly calculated **(1)**
with consequentially correct sign and to 3 or 4 SF **(1)**
This is consequential on part (b) 2

[6]

5. (a) (i) **Enthalpy/heat change** for formation of **1 mole** of a compound **(1)**
from its **elements (1)**
in their **standard states** / or stated temperature of 298K (25°C) and 1 atm (or suitable unit) **(1)** 3

(ii) = **-**60.4 – (52.3–36.2) **(1)**
= **-**76.5 (Kj mol^{-1}) **(1)** 2

(iii) negative sign means reaction exothermic/gives out heat **(1)**
if no answer given to part (ii) must give general explanation that negative means exothermic and positive means endothermic reaction 1

(b) Energy in = (612 + 366) = 978 **(1)**
Energy out = 348 + 412 + 276 = 1036 **(1)**
Energy change = 978 – 1036 = **-**58 **(1)** consequential
If candidates choose to include the four C-H bonds the above figures are 2626, 2684 and -58 3

(c) **Average** values from many compounds used in bond enthalpies **(1)**
Actual values for these compounds probably slightly different / or, calculation in (a) (ii) uses real / actual / experimental /standard/ values **(1)**
n.b. do not accept arguments based on error 2

[11]

6. (a) Lattice Energy:

- enthalpy or heat energy released (could mention the process is exothermic or value negative) **(1)**

a when gaseous ions **(1)**
(come together to) form / mole solid / crystal / lattice **(1)**
but not substance

if equation given could get state marks and energy change marks if ΔH shown 3

Enthalpy of Atomisation:

- heat energy change for the formation of one mole of gaseous atoms **(1)**

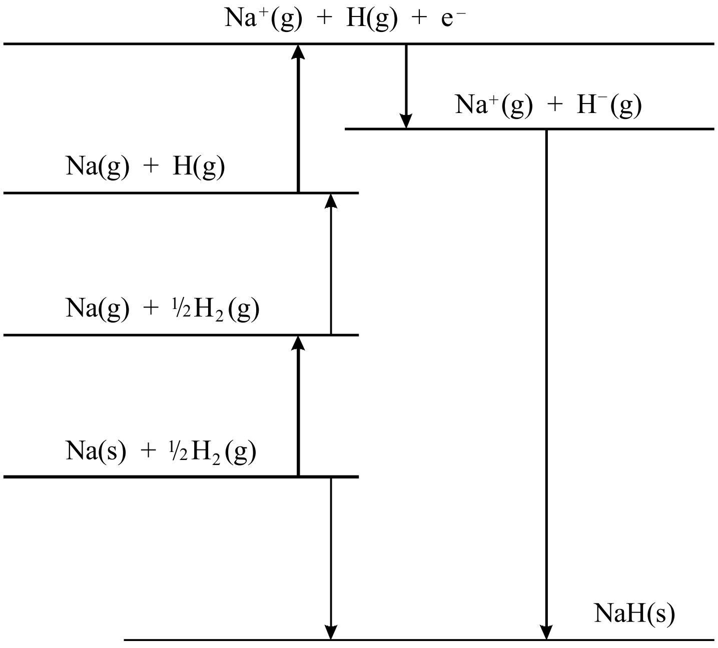
from an element in its standard state **(1)**

not standard conditions
if state or imply exothermic max 1 2

(b) (i) correct step shown **(1)** *must identify <u>change</u>* 1

(ii) $+150 + 736 + 1450 + (2 \times 121) + 642 = 3220$
$= 2493 + 2x$ **(1)**
$2x = 727$
$x = –363 – 1$ **(1) sign vital**
n. b. −727 scores 1, –303 scores 1, −606 scores 0 2

(c)



Marking points on cycle

- all correct species and steps plus state symbols where crucial **(1 mark)**

n. b. crucial steps Na (s) to Na (g) + gaseous ions to solid NaH

- complete cycle **(1 mark)**
- ½H_2 to H **(1 mark)**

n. b. the whole cycle could be doubled to give 2 × electron affinity
n. b. an energy diagram as above is not essential any correct cycle in any representation is equally acceptable 3
n. b. any cycle containing H^+ scores 0 marks

[11]

7. (a) Enthalpy / heat (energy) change on the neutralisation / reaction of one mole of a **monobasic** acid / hydrogen ions (by an alkali)
or
Enthalpy / heat (energy) change on the formation of one mole of water when an acid is neutralised
Or
Enthalpy change per mole for reaction $H^+ + OH^- \rightarrow$, H_2O **(1)** 1

(b) q = mcΔT **(1)** other unambiguous symbols/names
= 100 × 4.18 × 6.90 **(1)**
= 2884 J including units **(1)** 3
Consequential on sensible chemistry in line 2 i.e. use of 50 for mass or temp in K or data for temperature, transposed(max2). Ignore sign of answer
Allow 3 or 4 significant figures

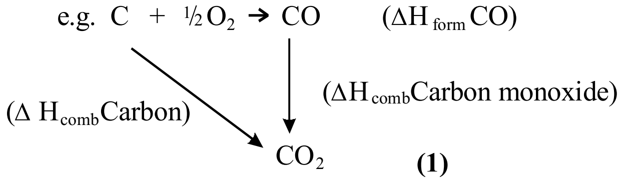
(c) 2884/0.05 **(1)**
answer from (b) ÷ 0.05/allow answer from (b) × 20
= – 57.7 kJ mol^{-1} **(1)** accept – 57.6 2
If wrong sign (max 1)
If wrong units (max 1)

(d) Ensures all acid reacts / neutralisation (of acid) completed / reaction (of acid) completed / all H^+ reacted **(1)** 1

[7]

8. (a) (i) Enthalpy or heat change / released when 1 mol of substance **(1)**
is burned in excess oxygen / completely **(1)**
all substances in standard states (at a specified temp)/ at a pressure of 1 atm. **(1)** 3

(ii) Suitable cycle (need not be labelled but if labelled, these must be correct) **(1)**
working **(1)**
answer **(1)**

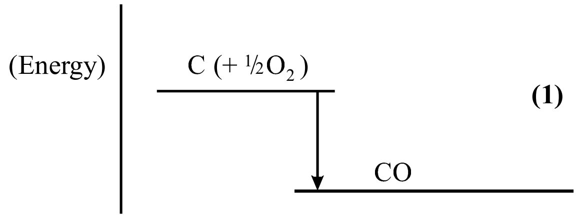


(1)

$= -394 - (-283)$ **(1)**
$= -111$ (kJ mol^{-1}) **(1)**
Penalise 1 mark if units incorrect 3

(iii) (some) CO_2 is always produced in the reaction **(1)** 1

(iv)



(1) 1

Consequential on (a) (ii)
n.b. if no answer in(a) (ii), correct diagram can still score

(b) Methane (and oxygen) / reactants thermodynamically unstable w.r.t. products **(1)**
Must be a comparison
Since reactants are at a higher energy level (than products) **(1)**
or reverse argument
Reactants / methane, oxygen kinetically stable **(1)**
Due to high activation energy **(1)** 4
If no reference to methane in the answer (max 3)

[12]

9. (a) ***Note 1 mark** for improvement **1 mark** for related reason in each case to **max 4 marks**.*
Reason must relate to improvement. Max 2 for improvement. Max 2 for reason.

Improvement	insulate beaker / polystyrene cup / plastic cup / use lid **(1)**	
Reason	Prevents / reduces heat loss or absorbs less heat **(1)**	
Improvement	Use pipette / burette **(1)**	
Reason	More accurate (than measuring cylinder) **(1)**	
Improvement	Measure temperature for several minutes before the addition **(1)**	
Reason	Allows more accurate value for the initial temperature **(1)**	
Improvement	Measure temperature more often **(1)**	
Reason	Allows for better extrapolation / more accurate temperature change from graph **(1)**	
Improvement	Read thermometer to 1 dp / use more precise thermometer/ digital thermometer **(1)**	
Reason	Gives more accurate temperature change **(1)**	
Improvement	Stir mixture **(1)**	
Reason	Ensure even temperature / reaction faster less heat loss with time **(1)**	
Improvement	Use finely divided iron / smaller pieces **(1)**	
Reason	Reaction faster less heat loss with time **(1)** Not speeds up alone	4

(b) (i) Heat change = 50.0 × 4.18 × 15.2J
= 50.0 × 4.18 × 15.2 / 1000kJ
= 3.18kJ or 3180J **(1)**
Ignore sig. fig. Allow mark if units omitted 1
If units quoted but wrong eg 3.18 J score 0.

(ii) No of mols of copper sulphate = 50.0 × 0.500 / 1000
= 0.025 **(1)** 1

(iii) Enthalpy change per mol = 3.18/.025 = –127kJ **(1)**
negative sign **(1)** *stand alone*
consequential on (i) and (ii)
max 4 sig fig and answer must be in kJ mol^{-1} *even if units omitted.* 2

[8]

10. (a)

- Enthalpy or heat change or heat energy / released when 1 mol of substance / element or compound (need to say both) **(1)**
- is burned in excess oxygen / completely / reacts completely **(1)**

at 1 atm pressure and specified temperature **(1)** 3

(b) $\Delta H = 2\Delta H_c(\text{C}) + 2\Delta H_c(\text{H}_2) - \Delta H_c(\text{CH}_3\text{COOH})$ **(1)** for this or equivalent cycle drawn;

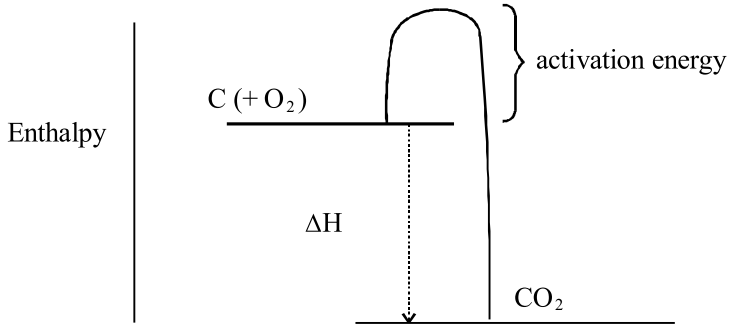
$\Delta H = (-394 \times 2) + (-286 \times 2) - (-874)$ **(1)**
$= -486\ \text{kJ mol}^{-1}$ **(1)** 3

(c) (Enthalpy of) formation / ΔH_f **(1)**

(d)

- correct orientation of energy levels / labelled (at least one) **(1)**
- ΔH shown - number allowed **(1)**

reaction profile showing E_a **(1)**
[if based on (b) max 2]



[10]

11. (a) (i)

- Reaction is complete **(1)**
- addition of **cooler** NaOH causes temp to fall **(1)** 2

(ii) 20.0 cm^3 **(1)** 1

(iii) $20.0 \times 2.00 / 1000$ **(1)**= 0.0400 mol 1

(iv) $20 \times 1.00 / 1000$ **(1)** =0.0200 mol 1

(v) 1 : 2 **(1)** *MUST be consequential on working in (iii) to (iv)* 1

(vi) $Cu(OH)_2$ **(1)** *Consequential provided that the ratio of Cu to OH is a whole number* 1

(b) (i) 7.2 °C (or K) **(1)** 1

(ii) q = 1210 J / 1.21 kJ **(1)** *Consequential on (b)(i)* 1

(iii)
- ΔH = 1210 J / 0.020 **(1)** *ie. method* Mark consequentially on (a)(iv) and (b)(ii).
- – sign **(1)**

Correct units **(1)** (*)
2 max if numerical error (*)
In final answer 3

(c)
- No stirring / poor mixing **(1)**
- Specified method of stirring or mixing e.g. magnetic stirrer / swirl cup between additions **(1)**

or

- Solutions at different initial temperatures **(1)**

Allow them to stabilise at room temperature **(1)**
Do not allow anything to do with heat loss. Do not allow 'more accurate thermometer` since the one specified is good enough. 2

[14]

12. (a) $\frac{20}{1000} \times 0.5 = 0.01$ 1

(b) Energy change = 20 × 4.18 × 26.3 = (2198.68)

$\Delta H = (-)\,\dfrac{2198.68}{0.01}$ **(1)**

–220, *ALLOW 4sf* –219.9*, no units needed*
OR – 220,000 J **(1)** 2

[3]

13. (a) (i)
- It is the enthalpy / heat (energy) change / evolved for the formation of **1 mol of urea (1)**
- from its **elements (1)**
- in their standard states / at 1 atm and stated temperature {298K} **(1)** 3

(b) **AMENDED** (ignore units)

{(-333.0) + (– 285-8)} – {(**2** × –46.2) + (–393.5)}

= - 618.8 + 485.9

= - 132.9 kJ **(3)**

Correct answer with some correct working **(3)**

Correct answer alone **(1)**
+ 132.9 kJ **(2)**
Omitting the ×2 gives –179.1 kJ **(2)**
+ 179.1 kJ **(1)**
Incorrect application of Hess's Law gives –1104.7 kJ **(2)**
+ 1 1 04.7 kJ **(1)**
Incorrect Hess's Law and omit ×2 gives –1058.5 kJ **(1)**
+ 1058.5 kJ **(0)**

NOT AMENDED (ignore units)

{(632.2) + (–285.8)) – **((2** × –46.2) + (–393.5)} **(1)**
= - 918.0 + 485.9
= - 432.1 kJ **(3)**

Correct answer with some correct working **(3)**

Correct answer alone **(1)**

+ 432.1 kJ **(2)**

Omitting the ×2 gives – 478.3 kJ **(2)**

+ 478.3 kJ **(1)**

Incorrect application of Hess's Law gives – 1403.9 kJ **(2)**

+ 1403.9 kJ **(1)**

Incorrect Hess's Law and omit x2 gives 1357.1 kJ **(1)**

+ 1357.1 kJ **(0)**

[6]

14. (a)

- A species with a lone pair / pair of electrons **(1)**
  NOT "negative ion" alone or as an alternative
- which it uses / donates to form a (dative) covalent bond **(1)** 2

(b) (i)

- Ammonia / NH_3 (in ethanol) **(1)**
- heat **(1)** **NOT** heat under reflux *UNLESS* in a sealed tube

  If a temperature is quoted it must be greater than 100°C
- in sealed tube / under pressure / concentrated **(1)**

  If a pressure is quoted it must be greater than 1 atm

Conditions are dependent on correct reagent.

If ammonia and an additional reagent **max (1)** for two correct conditions. 3

(ii) Carbon-bromine bond stronger / higher bond enthalpy than carbon – iodine / Ea for C-Br is higher than C-I

IGNORE any extra explanations involving the alkyl groups 1

(c) Identify bonds broken **and** made **(1)**

e.g. Energy in + 464 or + 3340

AND Energy out (-) 656 or (-) 3532 **(1)**

Energy needed to break bonds – energy released to make bonds = 36 **(1)**

e.g. C-I + 464 – 656 = + 36

or C-I + 3340 – 3532 = + 36 **(1)**

Correct evaluation dependent on use of 36 **(1)**

i.e. C-I = 228 kJ mol^{-1} **(1)**

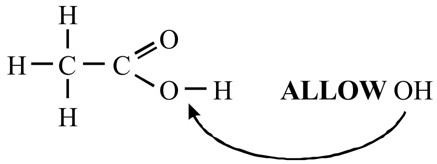
Correct answer with some correct working **(3)**

If final answer is negative max **(2)**

If 36 is on the wrong side, then 156 max 2 (-156 **(1)**)

If miss out 36, then ±192 **max 1** 3

(d) 1



[10]

15.	(a)	(i)	H_2O is proton / H^+ / hydrogen ion donor	1
		(ii)	Strong base ionises completely in water/solution or weak base does not ionise/ interact to any extent in water or strong base is a better proton acceptor than weak base Don't allow definitions based on rate	1
	(b)	(i)	$2N_2(g) + 6H_2(g) + 5O_2(g)$ Correct diatomic elements with state symbols **(1)** Balanced cycle **(1)**	2
		(ii)	ie $\Delta H = 4(90.2) + 6(–241.8) –4(–46.1)$ **(2)** $= 360.8 – 1450.8 + 184.4$ $= – 905.6$ kJ mol^{-1} $= – 906$ kJ mol^{-1} **(1)** –1 for incorrect significant figures correct use of Hess cycle **(1)** correct use of multiples **(1)** consequential answer with correct sign and units **(1)**	3

[7]

16. (a) Density = 1.0 g cm^{-3}

OR 1 cm^3 (of water) weighs 1 g — 1

(b) ($\Delta T = 38.1 – 19.5 =$) 18.6 (°C) *calculated or correctly used* **(1)**

$$\frac{200 \times 4.18 \times 18.6}{1000} = 15.5/15.55 \text{ (kJ)}$$ **(1)**

Correct answer with some working **(2)** — 2

(c) (Mass used = 198.76 – 197.68 =) 1.08 *calculated or correctly used* **(1)**

Moles = $\frac{1.08}{46.0} = 0.0235 / 0.02348$ **(1)** — 2

(d) $\frac{\text{Answer to(b)}}{\text{Answer to(c)}}$ **(1)**

e.g. $\frac{15.5}{0.0235}$

negative sign and kJ mol^{-1} **(1)**

answer correct to 3sf **(1)** — 3

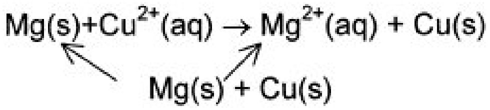
(e) (i) Ethanol vaporises/evaporates **(1)** 1

(ii) Carbon/soot **(1)**
Incomplete **combustion**/insufficient oxygen so reaction does not go to completion **(1)** 2

[11]

17. (a) (i) $Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$
entities **(1)**
state symbols **(1)** 2

(ii)



$\Delta H^{\circ}_{(r)} = \Delta H^{\circ}_{f}[Mg^{2+}(aq)] - \Delta H^{\circ}_{f}[Cu^{2+}(aq)]$

entities including state symbols **(1)**
arrows **(1)**
Hess applied **(1)** 3

(b) (i) $4.2 \times 150 \times 60$ **(1)**
= 37800 / 38000 J **(1)**
OR 37.8 / 38 **kJ** 2

(ii) 37800 / 530000
= 0.07(13) (mol) 1

(iii) $1000 \times 0.0713 / 8$
= 8.9(2) cm^3
ALLOW TE from (i) and (ii) 1

(c) Heat losses to **surroundings** /**container** / through container **(1)**
Heat capacity of chemicals not considered **(1)**
Incomplete reaction / mixing **(1)**
Any two reasonable points 2

[11]

18. (a) (i) a particle / species /group with an unpaired electron /OWTTE 1

(ii)

1

(iii) homolytic 1

(b) B and C 1

(c) (i) $C1_2 + CH_4 \rightarrow CH_3Cl + HCl$ 1

(ii) +242 + 4 + –339 = –93 kJ mol^{-1}
(A + B + F)
OR
+4 – 97 = –93 kJ mol^{-1}
(B + C)
Method **(1)**
answer with units **(1)** 2

(d) (i) -242 kJ mol^{-1} 1

(ii) Exothermic because a bond has been formed. 1

(e) Less endothermic **(1)**
the bond is weaker **(1)** 2

[11]

19. (a) (i) 5.00 + 84.0 = 0.0595 mol 1

(ii) 50.0 × 4.18 × 6.5 **(1)** ignore sign
÷ 1000 **(1)** = 1.36kJ mark consequentially
(1.49.kJ if use 55.0 g **(1)**) 2

(iii) Answer to (ii) ÷ answer to (i) **(1)** /correct method.
(expected answer +22.6 to + 22.9 for 50.0 g or +24.8 to +25.1 for 55.0g)
Answer with positive sign to 3 sfs **(1)** 2

(b) (i) Increase temperature for Na_2CO_3 and decrease for $NaHCO_3$ **(1)**
Larger ΔT with Na_2CO_3 (or consequential on (a)(iii) **(1)** 2

(ii) No heat lost/gained to/from surroundings/reaction is complete
shc of the solution is the same as water
Allow 1 cm^3 of solution has a mass of 1g 1
Do not allow shc is 4.18 J $g^{-10}C^{-1}$

[8]

20. (a) (i) Nichrome/platinum wire/ceramic rod **(1)**
cleaned in **concentrated** hydrochloric acid **(1)**
dipped in powdered sample and heated in flame **(1)**
both ideas needed for 3rd point. 3

(ii) Electrons promoted/excited to higher energy levels **(1)**
Fall back releasing energy as light of a particular frequency /wavelength/emr **(1)** 2

(iii) Sodium/Na^+ 1

(b) (i) $4.18 \times 100 \times 1.1$ **(1)**
= 460J / 0.460 kJ/459.8J **(1)** 2

(ii) M_r $MgSO_4.7H_2O$ = 246 **(1)**
12.3/246 = 0.05 **(1)** Allow TE 2

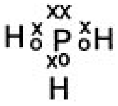
(iii) 460/0.05
+9200 J mol^{-1} /+9.2 kJ mol^{-1} **(1)**
sign and units **(1)**
–1 for incorrect SF.
ALLOW TE from b(i) and/or b(ii) 2

(c) (i) $\Delta H_r = \Delta H_1 - \Delta H_2$ 1

(ii) +9.2 – –85.2
= +94 kJ mol^{-1} **(1)**
sign and units **(1)** 2

[15]

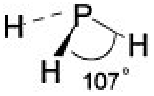
21. (a) (i)



1

ACCEPT all dots/crosses

(ii)



Trigonal pyramid/Tetrahedral/'Three leg stool' shape **(1)** – *must be some attempt at 3D or correct name*
107° *ALLOW* 92-108 **(1)** 2

(iii) repulsion between four pairs of electrons gives tetrahedral shape **(1)**)
Greater repulsion of non-bonding electrons/lone pair closes down tetrahedral bond angle **(1)** 2

(b) (i) $PH_3(g) \rightarrow P(g) + 3H(g)$ 1

(ii) Hess applied **(1)**
Multiples **(1)**
Correct answer + 963(.2)/960 **kJ mol^{-1}** **(1)** 3

(iii) Answer to (ii) divided by 3
+ 321(.1)/320 **kJ mol^{-1}** 1

[10]

22. (a) Enthalpy / heat/energy change when 1 mol of a substance **(1)**
NOT "heat needed"
is burnt in excess / burnt completely in **air/oxygen** **(1)**
under standard conditions of 1 atm pressure & stated temperature / at 298 K **(1)** 3

(b) Bonds broken 4 × C-H = + 1740

$$2 \times O{=}O \quad \frac{= +996}{= +2736} \quad \textbf{(1)}$$

Bonds made 2 × C=O = – 1610

$$4 \times H{-}O \quad \frac{= -1856}{= -3466} \quad \textbf{(1)}$$

ΔH = + 2736 + (–3466) = – 730 **(1)** (kJ mol^{-1}) 3

(c)

$$\begin{tikzcd} CH_4(g) + 2H_2O(g) & & CO_2(g) + 4H_2(g) \\ & 4H_2(g) + C(s) + O_2(g) \arrow[ul] \arrow[ur] & \end{tikzcd}$$

Cycle **(1)**
do not allow the word "elements"
Arrows labelled Δ H_f etc or numbers **(1)**

$\Delta H_r = -394 - (-75) - 2 \times (-242)$ **(1)**
$= +165$ **(1)** (kJ mol^{-1}) 4

[10]

23. (a) Step II Wait before reading temperature/ take a series of (temperature) readings **(1)**

NOTE Ignore any references to time or more accurate thermometer

Step III Stir after each addition / leave thermometer in solution throughout/do not rinse **(1)** 2

(b) Drawing two best fit lines (second line can be through first three points) **(1)**

Extending to a maximum **(1)** 2

Curve between 20 and 25 cm^3 scores first mark only
Note if use wrong last point for first line, no marks can be scored.

Hand sketched (without ruler) scores one mark only.

(c) Reading ΔT consequentially **(1)** expected $\Delta T = 7.0 \pm 0.1$ (°C) 2sf for ΔT
Reading V_N consequentially **(1)** expected $V_N = 22.5$ to 23.0 (cm^3) 3sf for V_N

$\Delta T = 6.9$ (°C) $V_N = 25.0$ (cm^3) scores **(1)** only 2

(d) (i) Heat calculated using candidate's values in (c)
ignore 3 or more SF at this stage 1

(ii) $(-)\ \dfrac{Answer\ to\ (d)(i)}{0.025}$

Method consequentially **(1)**
Answer, sign and 2–4 SF **(1)** 2

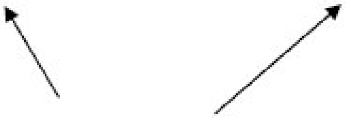
ΔT	**Vol**	**Heat/kJ**	**ΔH/kJ mol^{-1}**
7.0	22.5	1.39	-55.6
7.0	23.0	1.40	-56.0 / - 56.2
6.9	25.0	1.44	-57.7 / - 57.6

[9]

24. (a) thermal decomposition / redox
NOT reduction or oxidation *on their own* 1

(b) (i) Formation of 1 mole of the compound/substance **(1)**
from its elements **(1)**
in their standard states/ under standard conditions/ (temperature and pressure) at 298K and 1 atmosphere pressure **(1)** 3

(ii)



$+\ 4H_2(g)\ +\ 3\tfrac{1}{2}O_2(g)\ +\ 2Cr(s)$

Cr₂ loses formula mark 2 max

Mark independently formulae **(1)**
number of moles **(1)**
arrows and state symbols **(1)** – *depend on one mark being given for the above.* 3

(iii) 0 / zero (kJ mol^{-1}) 1

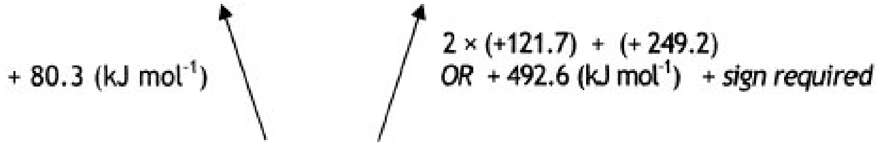
(iv) 4 × –242 + –1140 (*OR* – 2108) – –1810 **(1)**
–298 kJ mol^{-1}
value **(1)**
signs and units **(1)** *dependent on value being one of these given* 3

(c) Exothermic + attempt at explanation **(1)**
Bonds are formed when a gas turns to a liquid **(1)**
ACCEPT answers based on kinetic theory
Evaporation is endothermic (therefore by Hess's Law) the reverse must be exothermic 2

[13]

25. (i) $Cl_2(g)$ (+) ½ $O_2(g)$ 1

(ii)



ALLOW T. E from (i) 1

(iii) $\Delta H^{\ominus}_{at}$ [$Cl_2O(g)$] = –80.3 + 492.6 = + 412(.3) (kJ mol^{-1})
SIGN essential
PENALISE wrong units
Correct answer with no working **(1)** 1
ALLOW TE from(ii), provided Hess' Law applied correctly
for **their** cycle

(iv) E[Cl –O] (= ½ × (+ 412.3)) = (+)206(.2) (kJ mol^{-1})
ALLOW TE from (iii)
ALLOW (+)206.15
ALLOW missing sign 1

[4]

26. (a) (i) $\frac{1664}{4}$ = 416 (kJ mol^{-1}) *IGNORE "+" signs* 1

(ii) energy needed to break bonds:
2 × 436 + 193 = (+)1065 **(1)**

energy change in making bonds:
–348 + 4x –416 + 2x –276 = (–) 2564 **(1)**

enthalpy change = 1065 – 2564 = – 1499 (kJ mol^{-1}) **(1)**
[value and –ve sign needed for 3rd mark] 3
ALLOW T.E.
+ 1499 with working scores **(2)**

(b) C not in standard state / C not solid 1

[5]

27. (a) (i) Points accurately plotted **(1)**

Two straight lines of best fit. **(1)**
NOT dot-to-dot, IGNORE any other joining – up. 2

(ii) Suitable extrapolation to find maximum temperature rise at 3 ½ min **(1)**
Value from candidate's graph ±0.5 °C **(1)**
(43.5-44.5°C for accurate plot) 2

(iii) (The best fit line) allows for cooling effect
OR heat loss
OR calculation of more accurate temperature **change**
OR response time of the thermometer
OR slowness of reaction
NOT "more accurate" *on its own* 1

(b) (i) Heat change = 50 × 4.18 × ΔT (= 9196J or 9.196kJ)
Consequential on (a) (ii)
If no units given, assume J
If kJ must be correct value
Wrong units eg kJ mol^{-1} **(0)**
IGNORE SF or sign 1

(ii) Density = 1g cm^{-3} / total volume after reaction 50 cm^3 / total mass is 50 g.
ACCEPT 1g = 1 cm^3
ACCEPT Density is same as that for water
ACCEPT Heat capacity of metal is irrelevant
NOT density = 1 1

(iii) (1.0 × 50 / 1000) = 0.05(0) (mol) 1

(iv) $\frac{\text{answer to (b) (i)}}{\text{answer to (b) (ii)}}$ **(1)**
divide by 1000, value, negative sign (for units of kJ mol^{-1}). **(1)**
ALLOW answer in J mol^{-1} *if unit given.* 2
IGNORE SF.

(c) *Improvement is a stand alone mark, reason is not*
Any two from:

QWC Improvement: Place a lid on the polystyrene cup **(1)**
Reason: Reduces heat loss **(1)**

Improvement: Use a pipette or burette (to measure the volume of solution) **(1)**
Reason: More accurate (way of measuring volume) **(1)**

Improvement: Use more precise thermometer / digital thermometer **(1)**
Reason: Gives more accurate temperature **change (1)**

Improvement: Mechanical stirrer / magnetic stirrer **(1)**
Reason: to ensure complete / or faster reaction **(1)**
NOT 'spread heat…'

Improvement: Measure temperature more often
Reason: Allows for better extrapolation **(1)**
OR can obtain a more accurate value of maximum temperature / temperature change from graph 4

NOT repeating few times
NOT "cotton wool insulation" *alone*
NOT more accurate weighing.

[14]

28. (i) Potassium **ion** / K^+ larger than Ca^{2+} **(1)**
*Must **not** refer to atoms*

QWC* K^+ smaller charge than Ca^{2+} **(1)**
Must **not** refer to atoms, but CAN say "potassium" has a smaller charge *(than "calcium")*

Charge density of K^+ is less than charge density for Ca^{2+} without explanation is worth **(1)** *out of these 1st two marks*

Less **attraction** between (K^+ and I^-) **ions (1)**
NOT just "weaker bonds"

ACCEPT reverse argument
IGNORE references to extent of covalency 3

(ii) Potassium **ion** / K^+ **less** polarising (than Ca^{2+}) **(1)**
KI (close to) 100 % ionic / no covalent character **(1)**
CaI_2 partially/ significantly covalent
OR
Correct description of anion polarisation in CaI_2
NOT just 'distortion' of anion **(1)** 3

[6]

29.	(a)	$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow Ca^{(2+)}CO_3^{(2-)}(s)$ left-hand side **(1)** right-hand **(1)** *BUT if all formulae correct (including charges) but missing/ wrong state symbols* **1 max**	2
	(b)	(i) (Energy = 100 × 4.2 × 1.5 =) (+) 630 (J) *NOT* – 630 (J)	1
		(ii) Quantity of $CaCl_2$ = (50/1000) × 1.00 = 0.05 mol	1
		(iii) $\Delta H = \dfrac{(630/0.05)}{1000} = +\ 13\ \text{kJ mol}^{-1}$ [2 SF] answer (i) ÷ (ii) **(1)** sign, units and 2 SF **(1)** *2nd mark dependent on 1st unless clear method given* *Answer can be calculated in J* mol^{-1} + 13 kJ mol^{-1} *with no working* **(2)** + 13 000 J mol^{-1} *with no working* **(2)**	2
		(iv) Temperature, since ΔT is so small (and therefore leads to relatively large % error) / thermometer has limited accuracy *Heat loss / gain not sufficient*	1
		(v) Thermos flask / (expanded) polystyrene/plastic cup / a beaker contained in a larger one lagged with cotton wool *OR* Calorimeter (unqualified) **(0)** *BUT* "with cotton wool"/ insulated/lagged etc *gets* **(1)**	1
	(c)	1.5 °C / no change	1

[9]

30.	(a)	Heat / enthalpy / energy change (for a reaction) / Δ*H* **(1)** is independent of the pathway / route (between reactants and products) *OR* depends only on its initial and final state **(1)** *Both marks can score from a diagram and equation*	2

(b) (i) ΔH = {(4x + 435) + (2x + 498)} **(1)**

+ {(2x – 805) + (4x – 464)} **(1)**
IGNORE signs for first two marks, ie marks for total enthalpies of bonds broken and made.

= – 730 (kJmol^{-1}) **(1)**
3rd mark is consequential on their values for first two marks

+ 730 (kJmol^{-1}) **(max 2)** 3

(ii) (Enthalpy of) combustion
DO NOT penalise "standard" 1

(iii) At 1 atm pressure *OR* 101 / 100 kPa *OR* 1 bar **(1)**
stated temperature **(1)**
ACCEPT 298 K / 25 °C 2

(iv) Reaction has $H_2O(g)$ (rather than $H_2O(l)$) **(1)**
So not standard conditions **(1)** – *2nd mark is conditional on the 1st*
Average bond enthalpies used (so not specific) **(1 max)** 2

QWC (c) (Exothermic so) products are at lower energy than reactants **(1)**

Reactants are therefore thermodynamically unstable
(with respect to products) **(1)** C*onsequential on 1st mark*
NOT 'reaction' or 'system' is thermodynamically unstable
Can argue from point of view of products.

E_a is high (for noticeable reaction at room temperature) **(1)**
NOT 'E_a high' *on its own*

So **reactants** are kinetically stable (with respect to products) **(1)**
Consequential on 3rd mark

If "reaction" *instead of reactants is used* **(3 max)** 4

[14]

31. (a) Two intersecting straight lines through data 1

(b) (i) 27.0 cm^3 *ALLOW* ± 1.0 cm^3 1

(ii) 9.3 ± 0.5 °C 1

(c) (i) $\frac{\text{(b)(i)} \times 2}{1000}$

ALLOW correct answer with no working 1

(ii) (c)(i) 1

(iii) (c)(ii) × $\frac{1000}{50}$ **(1)**

Correct answer – see table below **(1)** 2

(d) (i) 50 + (b)(i) **(1)**

× 4.2 × $\frac{\text{(b)(ii)}}{(1000)}$ = answer **(1)**

Must use (b)(i) in calculation to score 2nd mark
If the units are given, they must be correct 2

(ii) $\Delta H = -\frac{\text{(d)(i)}}{0.05 \times \text{(c)(iii)}}$ = answer plus units

sign **(1)**
numerical answer, using candidate's figures, to 2 or 3 s.f. **(1)**
kJ mol^{-1} **(1)** *can be in J or KJ* 3

Table of answers

(b)(i)	(b)(ii)	(c)(i) & (ii)	(c)(iii)	(d)(i) / kJ	(d)(ii) / kJ mol^{-1}
26.0	9.4 9.6	0.052	1.04	3.00 3.06	– 57.7 – 58.8
26.5	9.4 9.6	0.053	1.06	3.02 3.08	– 57.0 – 58.1
27.0	9.4 9.6	0.054	1.08	3.04 3.10	– 56.3 – 57.4

(e) Insulate calorimeter / (polystyrene) cup
OR put (calorimeter) in a (glass) beaker
OR put a lid on 1

[13]

32. (a) Number of moles / $\frac{3.5}{7} = 0.50$ / ½ **(1)**

If candidate does first part only, working must be shown

Number of atoms = 3.01×10^{23} **(1)**

ACCEPT 3.0 *OR* 3 *OR* $3.010(\times 10^{23})$

NOT 3.01^{23}

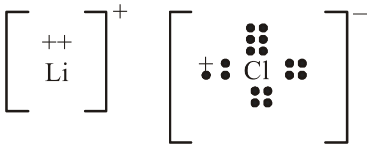
If all working shown, allow TE for 2nd mark Ignore units

Correct answer with no working (2) 2

(b) (i) $2Li((s)) + 2H^+((aq)) \rightarrow 2Li^+((aq)) + H_2((g))$

ALLOW multiples Ignore state symbols 1

(ii)



(1) **(1)**

Allow all dots or all crosses on Cl⁻

Max 1 if no/wrong charges

If covalent (0)

Do NOT penalise if electrons not shown in pairs

Maximum 1 if Li and Cl not labelled

Li and Cl symbols can go below diagram

Square brackets not essential

Allow number of protons/positive charges in nucleus as alternative to symbols for Li and Cl 2

(iii) Any two from:

Temp 298 K/ 25 °C *OR* "at a specified temperature"

Unit of temperature needed

NOT "room temperature"

(Acid/solution) concentration 1 mol dm^{-3} / 1 molar

Pressure 1 atm / 10^5 Pa / 1.01×10^5 Pa/10^2 k Pa /
101 k Pa/10^5 N m^{-2} / 76 cm Hg

NOT "pressure of hydrogen" OR "pressure of reactants"

NOT atmospheric pressure

Must be the most stable/usual/normal physical states

NOT "standard states"

If more than 2 conditions given, deduct 1 mark for each incorrect answer 2

[7]

33. (a) Heat/enthalpy/energy **change** per mole of substance/compound/product

OR

heat/enthalpy/energy **change** for the formation of 1 mol of substance/ compound/product **(1)**

"heat released" *and* "heat required" *not allowed unless both mentioned*

NOT molecule

from its **elements** in their standard states **(1)**

at 1 atm pressure and a stated temperature/298 K **(1)**
NOT "room temperature and pressure"
NOT "under standard conditions" 3

(b) (i) ($\Delta H = -306 - (-399)$) = (+) **<u>93</u>** (kJ mol^{-1}) 1

ALLOW kJ
Incorrect units lose mark otherwise

(ii) The equilibrium moves to right hand side
OR amount of dissociation increases **(1)**

Because the (forward) reaction is endothermic **(1)**

Needs to be consistent with (i)

<u>If (i) has a negative answer (exothermic)</u>
equilibrium moves to left hand side **(1)**
Because (forward) reaction is exothermic **(1)**

<u>If answer to (i) is +93 or 93 but state that this is exothermic</u>
If reaction moves to left hand side **(1)**
If reaction moves to right hand side **(0)** 2

(iii) add chlorine **(1)**
which drives equilibrium to the left **(1)**

OR
increase the (total) pressure **(1)**
because there are fewer (gas) molecules on left hand side **(1)**

OR
add PCl_3 **(1)**
Which drives equilibrium to the left **(1)** 2

[8]

34. (a) Difficult to decide when reaction complete/ reaction may be incomplete **(1)**

OR All $CaCO_3$ may not decompose **(1)**

OR Difficult to measure temperature changes in solids **(1)**

OR ΔT or $\Delta H_{\text{reaction}}$ cannot be determined because heat is supplied **(1)**

OR Necessary temperature cannot be reached **(1)**

OR No suitable thermometers (for measuring temperature change at high temperatures) **(1)**

ALLOW "heat is required so temperature change will not be accurate"

NOT "Heat is supplied so temperature cannot be measured/ will not be accurate" 1

(b) (i) Reaction occurs quickly / incomplete reaction (in reasonable time) with lumps **(1)**

Heat losses occur if reaction is **slow (1)** 2

(ii) 4.2 × 20 × 2.5 = 210 (J) *OR* 0.210 kJ
IGNORE +/- signs
Incorrect units **(0)** 1

(iii) Number of moles of $CaCO_3$ = 0.02 **(1)**

$\frac{210}{0.02} = 10\,500$ **(1)**

$\Delta H_1 = -10500 \text{ J mol}^{-1}$ *OR* –10.5 kJ mol⁻1 **(1)**

ALLOW TE from (ii)
–1 for incorrect/missing sign/units
Third mark depends on correct method for 2nd mark 3

(iv) $\Delta H_r = \Delta H_1 - \Delta H_2$ **(1)** $= -10.5 - (-181)$ *ie use of Hess*

= (+) 170.5/ (+) 171 (kJ mol^{-1}) **(1)**

ALLOW T.E. from (iii)
Watch for adding J to kJ 2

(c) (Standard) enthalpy (change) of formation (of calcium carbonate)
ACCEPT $\Delta H_{formation}$ / $\Delta H^{\circ}_{formation}$/*formation*
NOT ΔH_f / ΔH°_f 1

[10]

35. (a) (i) H(g) + O(g) + Cl(g) *in top RH box*

½ H_2(g) + ½ O_2(g) + ½ Cl_2(g) in lower box

Brackets around the state symbols are not required 1

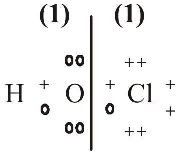
(ii) 589 – 667 = **–78** (kJ mol^{-1})

ALLOW final answer on its own 1

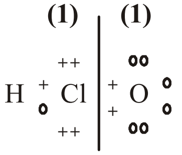
(iii) 667 – 464 = (+)**203** (kJmol^{-1})

ALLOW final answer on its own 1

(b) (i)



ALLOW



ALLOW all dots/crosses

*ALLOW **1 max** if electrons are correct but atoms are not identified*

*If ionic dot and cross diagram **(0)*** 2

(ii) 100 – 106° **(1)**

as lone / non-bonding pairs take up **more** space/
repel **more strongly** than bonded pairs **(1)**

NOT bonds being repelled/H and Cl being repelled 2

(c) No change **(1)**

as number of **gaseous** reactant molecules = number of **gaseous** product molecules **(1)**

*ALLOW **1 max** if candidates state or imply a very small change with correct justification*

eg “hardly changes”
“doesn’t change much”
“very little effect/change” 2

[9]

36. (a) Enthalpy/heat/energy change for **one mole** of a compound/substance/ a product **(1)**
NOT solid/molecule/species/element

Reject "heat released or heat required" unless both mentioned

to be formed from its **elements** in their **standard** states **(1)**
ALLOW normal physical state if linked to standard conditions

Reject "natural state" / "most stable state"

standard conditions of 1 atm pressure and a stated temperature (298 K) **(1)** 3

Reject "room temperature and pressure"

Reject "under standard conditions"

(b) (i)

Bonds broken	Bonds made
N≡N (+)945	6N–H (–)2346 **(1)**

and

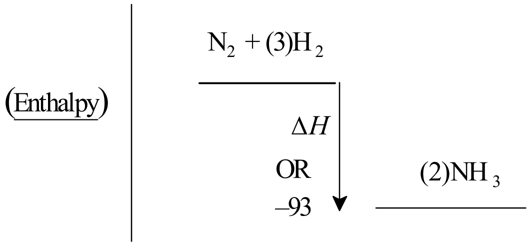
3H–H $\frac{(+)1308}{(+)2253}$ **(1)**

$\Delta H = 945 + 1308 - 2346$
$= -93$ sign and value **(1)**
$\Delta H^{\ominus} = \frac{-93}{2} = -46.5$ (kJ mol^{-1})
sign and value q on 3rd mark **(1)** 4

Accept –46.5 (kJ mol^{-1}) with working ***(4)***

Accept + 46.5 with working ***max (3)***
Accept +93 with working max ***(2)***

(ii)



Accept –46.5

Correct labelled levels **(1)**

Reject "Reactants" and "Products" as labels

ΔH labelled **(1)**
direction of arrow must agree with thermicity

Accept double headed arrow

Diagram marks cq on sign and value of ΔH in (b)(i)
IGNORE activation energy humps 2

(iii) 350–500 °C **(1)**

Accept any temperature or range within this range

higher temperature gives higher rate **(1)**
but a lower yield because reaction is exothermic **(1)**

Accept favours endothermic reaction ***more than*** *exothermic so lower yield*

OR
Lower temperature give higher yield because reaction is exothermic **(1)**
but rate is slower **(1)** 3

Accept cq on sign of ΔH_f in (b)(i) or levels in (ii)

Reject lower temp favours exothermic reaction

(iv) Iron / Fe **(1)** IGNORE any promoters
no effect on yield **(1)** 2

(v) temp would have to be much higher for a reasonable rate then yield would be too low
"lower activation energy" implies reasonable rate
OR
Allows reaction at a lower temp at a reasonable/fast rate giving a reasonable yield. 1

Accept rate too slow without catalyst at ***a*** *temp giving a reasonable yield*

Reject to lower activation energy of reaction

(c) (i) <u>advantage</u>
higher (equilibrium) yield/more NH3 in equilibrium mixture/equilibrium shifts to right **(1)**

because smaller number of (gaseous) moles/molecules on rhs **(1)**
IGNORE any reference to change in rate 2

Reject just "more ammonia"

(ii) disadvantage
(plant more) expensive because thicker pipes would be needed

OR
cost (of energy) for compressing the gases/cost of pump
OR
Cost of equipment/pressure not justified by higher yield 1

Accept stronger or withstand high pressure for thicker

Accept vessel/container/plant /equipment/reaction vessels for pipes

Reject "just more expensive"

Reject "just thicker pipes etc"

Reject apparatus

[18]

37. ***IGNORE sig figs provided 2 or better in (i) and (ii)***

(i) ΔT = 26 °C **(1) STAND ALONE**
Heat change = 104 × 26.0 × 4.09=11060 J **(1)** ignore sign at this point
The second mark may be appearing in part (ii) 2

If use 100g answer is 1063(4)
And gives ***355*** *as the final answer*

If use 4 g gives 425.2 and gives 14.2 kJ mol^{-1}

(ii) Moles = $\frac{4.00}{133.5}$ **(1)** = 0.02996

Accept 0.03

$\frac{\text{Answer in (i)}}{\text{moles}} \times \frac{1}{1000}$ **(1)**

= –369 (kJ mol^{-1}) **(1)**

Accept –369 (kJ mol^{-1}) with some working ***(3)***

Error carried forward if wrong Mr 3

Accept –369000 J mol^{-1} ***(max 2)***

Reject –369000 kJ mol^{-1} does not score 3rd marking point

[5]

38. (a) (i) ½Br_2 → Br **(1)**
state symbols **(1)**
½ $Br_2(g)$ → Br(g) scores only one

e.g.
½$Br_2(l)$→ Br(g) **(2)**
$Br_2(l)$→ 2Br(g) **(1)** ie for state symbols
Br_2→ Br **(0)** 2

Reject wrong halogen or use of "X" ***(0)***

(ii) Energy change when **1 mol (1)**

Accept heat or enthalpy for energy;
energy released instead of energy change

Reject "energy required"

of a solid/crystal/lattice **(1)**

is formed from its (isolated) gaseous ions **(1)**
IGNORE standard states 3

Just balanced equation
e.g. $Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$
can score only last two marks

(b) $MgCl_2$ has (a degree of) covalent character **(1)**

Mention of "atoms" or "molecules" scores ***(0)*** *for all of (b)(ii)*

due to polarisation of the anion **(1)**
(by Mg^{2+} cation) 2

Reject just "Mg^{2+} *(strongly) polarising"*

(c) As group descended, radius of M^{2+} (ion) increases
OR cation increases **(1)**

Accept reverse arguments

Accept "size" instead of "radius"

Reject mention ***specifically*** *of atoms (e.g. Mg atoms) or molecules ($MgCl_2$ molecules) scores* ***(0)*** *for all of part (c)*

Charge on ions remains the same/2+ **(1)**

*Accept correct formulae of cation****s*** *for charge mark*
Accept "charge density decreases" scores one of the first two marks

(down group) weaker forces of **attraction** between **ions (1)** 3

Reject "weaker bonds"
OR "weaker bonding"

[10]

39. (a) (i) An ion which is unchanged during the reaction owtte
An ion which does not take part in the reaction 1

Reject an ion which does not change its state

Reject use of word "element" instead of "ion"

(ii) SO_4^{2-} 1

(iii) $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$
IGNORE state symbols 1

Accept $Zn + Cu^{++} \rightarrow Zn^{++} + Cu$

Accept $Zn + Cu^{2+} = Zn^{2+} + Cu$

(b) measuring cylinder 1

Accept burette
Accept pipette
Accept volumetric pipette
Accept graduated pipette
Accept 50 cm^3 pipette
Accept pipette = pipette filter
Accept reasonable phonetic spelling e.g. pipet, biurette

Reject beaker
Reject biuret
Reject graduated flask
Reject volumetric flask
Reject beaker or a pipette
Reject pepite
Reject conical flask

(c) Any two

polystyrene conducts heat less well than metals/less heat lost to surroundings **(1)**

Accept discussion of either polystyrene or metal

has a lower (specific) heat capacity/absorbs less heat energy **(1)**

Plastic inert whereas metal container might react (with $CuSO_4$) **(1)** 2

(d) Zinc 5/65.4 = (0.0765/0.08/0.076/0.77) **(1)**

Copper sulphate 50/1000 = 0.05 **(1)**

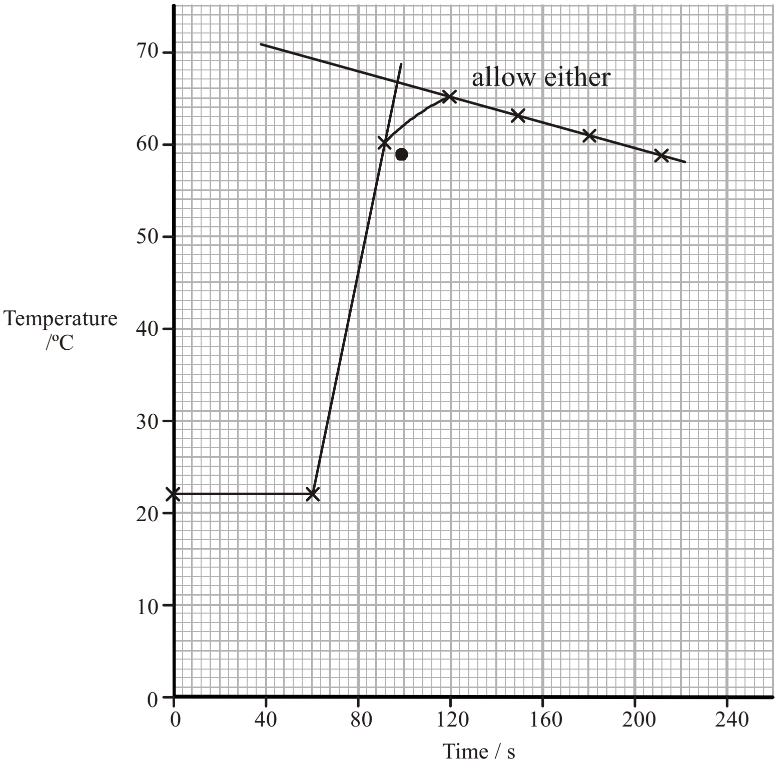
Copper sulphate / Cu^{2+} / CuSO4 **(1)**

Accept consequential on copper being less than zinc

Accept zinc is in excess

IGNORE sig figs 3

(e) (i)



correctly plotted points **(1)** – All 7 (including 0, 22) must be correctly plotted

points joined by suitable lines **(1)**

Accept curve/straight lines

[If you cannot see a line, check twice, if still not visible send to review as out of clip] 2

(ii) reaction not instant / so some time before all heat energy released/measured **(1)**

Accept energy lost

(temperature (slowly) declines) as heat energy given out (to the surroundings) **(1)** 2

Reject no temp change for first 60 s because zinc has not been added. Slow to start

Reject temp slowly declines because reaction is complete

Reject no marks for describing shape of graph without explanation

(iii) 66 – 69 °C 1

Reject 65.5 and less and 69.5 and more

(f) (i) $50 \times 4.2 \times 45 = 9450$ (J) for 67°C

Ignore units unless value and units are incompatible e.g.
9240 kJ (0)
9.24 J (0) 1

Accept TE from e(iii)
e.g.
66 = 44 ° rise = 9240
68 = 46 ° rise = 9660
69 = 47 ° rise = 9870
65 = 43 ° rise = 9030
(Allow minus sign) ignore sign
70 = 48 ° rise = 10080
65.5 = 43.5 ° rise = 9135
allow use of 65° even if different value in (iii)

Reject 55 for mass of solution + zinc

(ii)

	Max Temp
$\frac{9870}{0.05} \equiv -197{,}000 = -197\ \text{kJ mol}^{-1}$	69
$\frac{9660}{0.05} \equiv -193{,}000 = -193\ \text{kJ mol}^{-1}$	68
$\frac{9450}{0.05} \equiv -189{,}000 = -189\ \text{kJ mol}^{-1}$	67
$\frac{9240}{0.05} \equiv -185{,}000 = -185\ \text{kJ mol}^{-1}$	66
$\frac{9030}{0.50} \equiv -180{,}600 = -181\ \text{kJ mol}^{-1}$	65

This first mark is for dividing by 0.05 **(1)**

Value and sign **(1)**
units and 3 or 4sf **(1)** 3

Accept if ÷ 0.08 only 1st mark lost

[18]

40. (a) (i) 2,2,4-trimethylpentane
Ignore punctuation (Commas and hyphens may be interchanged) 1

Accept 2,4,4 - trimethylpentane

Reject pentan for pentane
2-dimethyl-4
methylpentane
2,2-dimethyl-4-methyl
pentane
2-methyl-4,4-dimethyl
pentane
2,4-trimethylpentane

(ii) C_4H_9 1

Accept $C_8H_{18} \rightarrow C_4H_9$

(iii) C_2H_4 1

Reject CH_2CH_2

(iv) Positive because energy is required to break (C–C) bonds
(and not completely replaced (from new bonds made))
OR Positive because cracking requires (continuous) supply of
heat so must be endothermic 1

Accept two C–C bonds are broken and one C=C made

Reject positive because it only occurs at high temperature

(v) $C_8H_{18} + 17/2\ O_2 \rightarrow 8CO + 9H_2O$

OR $2C_8H_{18} + 17\ O_2 \rightarrow 16CO + 18H_2O$

OR $C_8H_{18} + 9/2\ O_2 \rightarrow 8C + 9H_2O$ (or doubled)

Oxygen on left and correct formulae of products **(1)**
balancing **(1)**
Second mark depends on first and a sensible hydrocarbon
formula must be used. 2

Accept balanced equations including CO and/or C with CO_2
17/2 can be written 8.5 or 8½
Allow balanced equations based on C_8H_{18} *with a smaller alkane in the products for 1 mark eg*
$C_8H_{18} + O_2 \rightarrow CO + C_7H_{16} + H_2O$ ***(1)***

(b) (i) Increase in pressure: No effect as number of moles/molecules (of gas) doesn't change during reaction **(1)**

Increase in temperature: **more NO** as forward reaction endothermic OWTTE **(1)**

One mark for two correct predictions with incorrect explanations 2

Reject increase in temperature moves equilibrium to the right

(ii) Rate increases as converter gets hotter (as reaction is exothermic) 1

(iii) N_2 / nitrogen is (major) part of air/ N_2 unreactive/ not poisonous/ not a greenhouse gas / not acidic 1

Accept correct harmful properties of other 3 gases

(iv) Line from level of reactants to maximum labelled E_A **(1)**

Curve of similar shape above existing curve, starting and finishing at same levels, with maximum above original maximum **(1)** 2

[12]

41. (a) QWC

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

Accept heat / energy / enthalpy released
Accept both "element and compound" instead of substance

Reject energy etc required
Reject "reactant" instead of substance

is burnt in excess/burns completely in **air/oxygen (1)**

Accept complete combustion with air/oxygen
OR reacts completely with air/oxygen

Reject reacts with oxygen

conditions of 1 atm/ 100 kPa/101 kPa pressure and specified temperature/298 K **(1)** 3

Reject room temperature

(b) (i) Bottom box

$2CO_2(g) + 3H_2O(l)$

balance **and** state symbols **(1)**

Left arrow label

$2\Delta H_cC + 3\Delta H_cH_2$

OR (2x – 394) + (3x – 286) (kJ) units not essential

OR –788–858

OR –1646 kJ **(1)**

right arrow label

$\Delta H_cC_2H_5OH$

OR –1371 (kJ) **(1)** 3

(ii) $\Delta H_fC_2H_5OH = (2x - 394) + (3x - 286) - (-1371)$ **(1)**

$= -275$ (kJ mol^{-1}) **(1)**

OR

1 mark for **their** left hand arrow minus **their** right hand arrow

1 for correct consequential sign and answer 2

Wrong unit negates last mark (but allow kJ)

[8]

42. (a) In (a)(i), (ii) and (iii) penalise 1SF on the first occasion only.

ACCEPT ≥ 2SF

(i) Mass methanol burnt = 0.34 (g) **(1)**

$\frac{0.34}{32} = 0.0106$ **(1)** 2

Accept 0.011, 0.01063, 0.010625

CQ on incorrect calculation of mass

*Correct answer with some working **(2)***

(ii) Temperature rise = 43.5 – 22 (= 21.5) (°C) **(1)**

(Heat energy =) $\frac{21.5 \times 4.18 \times 50}{1000} = 4.49$ (kJ) **(1)**

The temperature rise mark can be scored from the heat energy expression 2

Accept CQ on incorrect calculation of temp.

*Correct answer with some working **(2)***

Reject answer in Joules

(iii) $\frac{\text{Answer (ii)}}{\text{Answer (i)}} = \frac{4.49}{0.0106}$ **(1)**

Accept CQ on (i) and ii)

= –422.9 (kJ mol^{-1}) [calculator stored value]

Accept answers in the range –420 to –424

OR
= –423.6 (kJ mol^{-1}) [using rounded values] **(1) minus sign and value both required**

*Correct answer with some working **(2)***

If the final answer is incorrect the 2nd mark is only accessible if energy is divided by moles in first part of calculation 2

(b) (i) $\frac{1.0}{21.5} \times 100 = (\pm)4.65$ %
IGNORE SF 1

(ii) (21.5 + 1.0 =) 22.5 (°C)
OR
(44 – 21.5)=22.5 (°C)
OR
$\left(21.5 \times \frac{104.65}{100}\right) = 22.5$ (°C)

CQ on % error in b(i) if this is used to calculate the temperature 1

Reject all other values

(c) (i) Evaporation (of methanol/alcohol) 1

Accept turns to vapour
OR methanol volatile

Reject balance faulty or spills or Methanol reacts

(ii) Carbon **(1)**

Lower/less exothermic **(1)** ignore references to incomplete combustion 2

Accept soot

Reject any other substance

[11]

43. (a) (i) $Mg^{2+}(g)$ (+) $O^{2-}(g)$ 1

Reject if state symbols missing

Reject if $2e^{-}$ *included in box*

(ii) ΔH_1 (Enthalpy of) formation (of MgO) **(1)**

ΔH_2 (Enthalpy of) atomisation (of Mg) **(1)**

ΔH_3 1st plus 2nd electron affinity (of O)
OR 1st and 2nd electron affinity (of O) **(1)** 3

Accept recognisable abbreviation such as "EA" for electron affinity.

(iii) $\Delta H_f = -602 = (+150) + (+2186) + (+249) + (+657) + LE$
OR
(LE =) –(+657)–(+249)–(+2186)–(+150)+(–602)**(1)**

Doubling electron affinity and/or atomisation values scores ***(0)***

(LE =) –3844 (kJ mol–1) **(1)**

Correct answer only with no working **(1 max)** 2

Reject any incorrect sign in algebraic expression ***(0)***

(b) (i) The electrons around the iodide ion are drawn
towards the magnesium ion 1

Accept (Mg^{2+}*) polarises (*I^{-} *ion)*
Accept "distortion" if clearly linked to the iodide ion

Accept "Mg ***ion****"*
Accept "I ***ion****" OR "iodine* ***ion****"*

Reject any reference to atoms or molecules
e.g. "Mg polarises….."
Reject "iodine/I/I_2 *is polarised"*

Reject wrong polarisation e.g.
"magnesium ion is polarised"
"I^{-} *polarises* Mg^{2+}*"*

(ii) Radius/size (of ions) **(1)**

Accept distance between ions
OR Sum of (ionic) radii
OR Type of crystal structure
OR Madelung constant

*Reject "****atomic*** *radius"*

charge (on ions) **(1)** 2

Accept "Charge density"

(iii) Less (exothermic) **(1)**

Accept Smaller
OR more endothermic
OR Less negative
OR Lower

Reject higher/greater

covalent character (strengthens lattice) **(1)**

Accept theoretical value based on purely/100 % ionic model

*Reject any implication of magnesium iodide being **totally** covalent*

Mark each aspect independently 2

[11]

44. (a) (i) E[$Ca(OH)_2$] = 25.0 × 4.2 × 16.5 = 1730 (J)
E[CaO] = 25.0 × 4.2 × 25.5 = 2680 (J)
Both correct for 1 mark
Ignore negative signs in front of values / missing/wrong units 1

Accept 1732.5 / 1733 / 1700 J
Accept 2677.5 / 2678 / 2700 J
Answers in kJ acceptable

Reject 1732 J
Reject 2677 J

(ii) $\frac{1.00}{74.0} = 0.0135$ mol
Answer must be decimalised 1

Accept 0.014

Reject $\frac{1}{74}$ */ 0.01*

(iii) $\Delta H_1 = -\frac{1732.5}{0.0135} = -130$ (kJ mol^{-1}) (2 s.f.)

$\Delta H_2 = -\frac{2677.5}{0.0135} = -200$ (kJ mol^{-1}) (2 s.f.)

1st mark for method (dividing energy by number of moles)
2nd mark for both answers given to 2 sig fig and including negative signs.
2nd mark is dependant on 1st 2

Allow TE from (a)(i) and (a)(ii)

(b) (i) $\Delta H_{reaction} = \Delta H_1 - \Delta H_2$ /relevant values being subtracted **(1)**

$= -130 - (-200) = +70$ kJ mol^{-1} **(1)**

Mark independently

For 2nd mark: correct arithmetic, sign and units needed 2

Allow TE from (a)(iii)

Ignore sig. figs.

(ii) Using a **glass beaker** / no lid is likely to lead to heat loss **(1)**
(glass) **beaker** has significant heat capacity **(1)**
No apparent check made to ensure that $Ca(OH)_2$ was heated long enough/difficult to know whether $Ca(OH)_2$ was fully decomposed **(1)**
The likely use of an insufficiently accurate **thermometer (1)**
Any TWO valid and agreed sources of error 2

(iii) Measuring temperatures of <u>solids</u> **(**with a lab thermometer**)** isn't accurate / is difficult **(1)**
Bunsen/high temperatures are involved (above bpt. of Hg/ethanol) so lab thermometers can't be used **(1)**
Difficult to know when $Ca(OH)_2$ has fully decomposed **(1)**
Given high temperatures involved, impossible to use thermometer to measure energy taken in by the $Ca(OH)_2$ **(1)**
Any ONE of these 1

[9]

45. (a) N/N_2 goes from 0 to –3 = reduction **(1)**
H/H_2 goes from 0 to (+)1 = oxidation **(1)** 2

If "the oxidation number of N goes down hence reduced and the oxidation number of H goes up and hence oxidised" ***(max 1)***

If all O.N. correct but fails to state which is oxidation and which is reduction scores 1.

If all O.N. correct but both reactions misclassified, scores zero. Any answer not referring to nitrogen or hydrogen scores zero.

(b) (i) Calculation of bonds broken $463 \times 3 + 944$/ (= 2252) **(1)**
Calculation of bonds made 388×6/ (= 2328) **(1)**
$\Delta H = -76$ (kJ mol^{-1}) **(1)**
mark consequential on numerical values calculated above 3

Correct answer with some working scores 3 marks

Correct answer alone scores 2 marks

(ii) Average / mean bond enthalpy used for **N–H bond / ammonia** 1

Reject just "average bond enthalpies used"

(iii) Thermodynamic:
energy level of products lower than that of reactants
OR
energy released in bond formation > energy used to break bonds **(1)**

Accept ΔH negative / reaction exothermic

kinetic:
high activation energy **(1)**

because strong N≡N **(1)**
[confusion between thermodynamic and kinetic loses first 2 marks]. 3

Accept because N≡N is 944/ total bond breaking energy is high/2252(kJ mol^{-1})

(c) (i) QWC
One way
temperature increase therefore molecules have greater (average kinetic) energy **(1)**

Accept moving faster

more molecules/collisions have $E \geq E_{act}$ **(1)**

Therefore a greater **proportion** of/ more **of the** collisions are successful **(1)**
Ignore greater frequency of collision

Accept $E > E_{act}$ particles for molecules
greater frequency of successful collisions/ more successful conditions per unit time

Reject just "more successful collisions"

Another way
addition of (iron) catalyst **(1)**

Accept platinum catalyst

Reject incorrect catalyst

provides alternative route of lower activation energy **(1)**

EITHER:
A greater proportion of /more of the molecules/collisions have $E \geq E_{cat}$/ a greater proportion of collisions are successful

Reject just "more successful collisions"

OR provides (active) sites (where reactant molecules can bond / be adsorbed) **(1)**

Ignore any answers referring to pressure or concentration.
Do not penalise just "more collisions are successful" more than once 6

(ii) **QWC**
Decrease temperature **(1)**

because (forward) reaction exothermic **(1)**
increase pressure **(1)**
because more moles (of gas) on left **(1)** 4

Accept low temperature ΔH is negative

Answer based on endothermic reaction scores 0

Accept high pressure
Accept molecules for moles

[19]

46. (a) (i) Mass = 25 + 22.75 = 47.75 **(1)** or in equation below
47.75 × 4.18 × 10.5 = 2096 (J) **(1)**
(=2100 (J))
consequential on calculated mass 2

*Accept correct answer with some working **(2)***
Use of incorrect mass (e.g. m = 1 g) can gain 2nd mark
Accept answer changed to kJ

(ii) Moles (water)= $\frac{25\times1.5}{1000}$ = 0.0375 **(1)**

$\Delta H = (-)\frac{2096}{(1000\times.0375)}$ **(1)**

= –55.9 (kJ mol^{-1}) **(1)**
both value, in kJ mol–1, and sign needed
[ignore SF] 3

Accept correct answer –55.9 or –56.0 kJ mol^{-1} with some working (3)

$\Delta H = (-)\frac{2100}{(1000\times.0375)}$ *(1)*

= –56.0 (kJ mol^{-1}) (1)
scores full marks
Conversion to kJ can be at final stage

(b) Any one of
No heat is lost (to the surroundings)
OR
Polystyrene cup or thermometer have negligible heat capacity
OR
All the acid was transferred (from the beaker) to the polystyrene cup 1

Accept takes up negligible heat

[6]

47. (a) (i) ΔH_6 1

(ii) $\frac{\Delta H_5}{2}$ OR $\frac{1}{2}\Delta H_5$ 1

Reject ΔH_5

(b) Either

$\Delta Hf = \Delta H_2 + \Delta H_3 + \Delta H_4 + \Delta H_5 + \Delta H_6$

OR

$\Delta Hf = (+178) + (1735) + 2 \times (+218) + 2 \times (-73) + (-2389)$

$= -186$ (kJ mol^{-1}) **(1)**

Correct answer with no working **(2)**

Ignore kJ 2

[First mark only if doubles both ΔH_{at} *and electron affinity for hydrogen]*

[2nd mark is only consequential on failure to multiply either ΔH_{at} *or electron affinity or both giving: —404 / —113 /—331 (kJ* mol^{-1}*)]*

+186 scores ***(0)***

+404 / +113 /+331 scores ***(0)***

(c) **EITHER**

First mark:

Magnesium/Mg **ion** smaller (radius) than calcium/Ca **ion**
Or
the sum of the ionic radii in MgH_2 smaller (than in CaH_2) **(1)**

Accept magnesium ion has greater charge density than calcium ion for first mark.

*Reject reference to 'atoms' or 'molecules' or 'H_2' scores zero **overall**.*

Second mark:

but charges the same **(1)**

Third mark:

(so) stronger (forces of) **attraction** between **ions** (in *MgH_2*) **(1)**

[Correct reverse arguments can score both marks]

*Accept "stronger **ionic** bonding" for 3rd mark in either case.*

If "H^+ ions" or "hydrogen ions" referred to, 3rd mark cannot be awarded in either case

If just "stronger bonding in MgH_2", 3rd mark cannot be awarded in either case

OR

First and second mark combined:

Mg^{2+} (ion) or Mg^{2+} (cation) smaller (radius) than Ca^{2+} **(2)**

Third mark:

(so) stronger (forces of) **attraction** between **ions** (in *MgH_2*) **(1)**

[Correct reverse arguments can score both marks]

Ignore references to polarisation of the hydride ion or "covalent character" in the hydrides.

Ignore references to "energy required to separate ions/break bonds" 3

[7]

48. (a) Mg(s) + C(graphite) + 1½O_2(g) in both left hand boxes
Balancing **(1)**
state symbols for Mg/C/O_2 must be present and correct at least once **(1)** 2

Accept C(s)

Accept everything in all boxes doubled (allow 2HCl rather than 4HCl)

Reject equation with CO or CO_2 in it

(b) (i) $0\ \frac{0.1}{24} = 4.17 \times 10^{-3}$ / 0.00417 1

Accept 0.00416 (recurring)
Accept 0.0042

Reject 0.004
Reject 0.00416

(ii) Moles of HCl at the start = 0.2 **(1)**
Moles of HCl reacted = 2 × 0.00417
= 0.00834 **(1)**

Moles of HCl left = 0.2 – 0.00834
= 0.19166 **(1)**
ignore sf 3

Accept transferred error from (b)(i)
Eg 0.192
0.1917

Reject 0.2

Accept 0.196
(forgetting to multiply by 2)
Worth max of 2

(ii) Axes labelled and suitable scale – must cover more than half the provided grid and time must be on the horizontal axis **(1)**
All points plotted accurately and suitable curve/straight lines **(1)**
From 0 to 1 minute, must be straight horizontal line.
From 1 to 2 minutes, vertical or sloping line to 25.3 or above. From 2 to 6 minutes, straight line or smooth curve. 2

Reject temperature scale starting at 0°C (1 max)

(iv) Energy change = 4.2 × 100 × 4.5
= 1.89 (kJ) 1

Accept 1890 (J)
Accept 1.9 (kJ)
Accept 1900 (J)
Accept with either + or – or no sign

Reject answers using mass = 100.1g
Giving 1891.89 (J)
Reject J mol^{-1} kJ mol^{-1}

(v) $\Delta H = \dfrac{-1.89}{0.00417}$

$= -453\ \text{kJ mol}^{-1}$ **(2)**

1 mark for number and 1 for sign and units 2

Accept TE from (b)(i) and (iv)

Second mark dependent on the first

(vi) Either lines drawn on graph to show maximum temperature rise should be 4.5
Or
Some heat loss (and so the reading of 4.3 was too small) 1

Accept max temperature between 1 and 2 minutes

Reject rounded up to nearest 0.5

(c) (i) 24 + 12 + 3 x 16 = 84 (g) **(1)**
Number of moles = 2.2/84 = 0.0262 / 0.02619 **(1)**
Ignore sf except if only 1 (i.e. 0.03) 2

Accept 0.026

Reject 0.0261
Reject 0.02

(ii) $\Delta H = \dfrac{-1.05}{0.0262}$

$= -\ 40.1\ \text{kJ mol}^{-1}$ 1

Accept correct sign and units needed for mark
Allow K instead of k –40.131
Allow TE from (c)(i)

Reject 40.1

(d) $\Delta H_f = \Delta H_1 + \Delta H_2 - \Delta H_3$ **(1)**
$= -\ 453 - 680 + 40$
$= -\ 1090\ \text{kJ mol}^{-1}$ **(1)** 2

Only penalise missing units once
Accept –1093
Accept transferred error:
ΔH_1 = (b)(v)
ΔH_2 = –680
ΔH_3 = (c)(ii)
correct answer with no working gets 2 marks

*Reject incorrect application of Hess's Law **(0)***

(e) Elements don’t react together to form magnesium carbonate 1

Reject hard to measure temperature of solid

[18]

49. 455.6 + 4 × 121.7 – (4 × 407.4)
Multiples **(1)**
Hess applied **(1)**
= –687(.2) kJ mol^{-1} **(1)**
ignore sig fig
In general deduct one mark for each mistake
One wrong or missing multiples (2max)
Hess the wrong way round (2max)
No sign with answer (2max)
Examples: +169.9 (no multiples at all is two errors) **(1)**
–1052.3/+535 (either multiple missing) **(2)**
–930.6 (2 × Cl atomisation) **(2)**
+687.2 (Hess misapplied) **(2)**
+1052.3/–535/+930.6 **(1)**
–169.9 **(0)**

[3]

50. (a) Initially $CuSO_4$ in excess so amount of reaction depends on amount of Zn
or
More $CuSO_4$ reacts (as more Zn added) **(1)**

Accept $CuSO_4$ in excess

Accept more Zn reacts

Reject reaction is exothermic

Graph levels off because all $CuSO_4$ used up **(1)** 2

Accept Zn now in excess

Reject just ‘Reaction is complete’

(b) (i) Heat capacity (of metal)
low (compared with that of solution) 1

Accept metal has negligible/low specific heat capacity
Accept metal absorbs (much) less heat (than solution/water)

(ii) q = 50 × 63.5 × 4.18 = 13271.5 J
Units, if given, must be correct
Ignore signs 1

Accept 13300/13270/13272
Accept answer in kJ only if units stated

Reject 13271

(iii) Moles $CuSO_4 = 50 \times \frac{1.25}{1000} = 0.0625$ **(1)**

Correct answer with some working scores full marks

Accept Ecf from moles

$\Delta H = (-)\frac{13271.5}{0.0625 \times 1000}$ **(1)**

= – 212 (kJ mol^{-1})
1 mark for negative sign
1 mark for answer to 3 SF
Units, if given, must be correct 4

Accept Ecf from (ii) gives –213/–212/–212

(c) (i) Extra precision negligible compared with approximations in calculations/heat loss 1

Accept measuring cylinder is least accurate measuring instrument

(ii) Use a lid on the cup (to reduce heat loss) 1

Accept extra insulation for cup
Accept weigh $CuSO_4$ solution
Accept use burette/pipette to measure volumes

Reject repeat experiments
OR
use more accurate balance
OR
Smaller mass intervals

[10]

51. (a) **BOX A**

Ag*(g)* **(1)**

BOX B

F*(g)* **(1)**

C: enthalpy (change) of formation (of *AgF*)/ΔH_f /$\Delta H_{\text{formation}}$ **(1)**

IGNORE reference to 'standard' 3

Accept 'heat of formation'

(b) (i) **EITHER**

*Reference to "atoms" or "molecules" or "F_2" or "I_2" scores **(0)** overall*

FIRST MARK:

EITHER

iodide (ion) larger than fluoride (ion)

*Accept **just** 'iodide has smaller charge density than fluoride' scores first mark*

OR

Sum of ionic radii in AgI larger (than in AgF)

*Ag—X scores **(0)** overall*

OR

halide ion or X^- or anion increases in size down group **(1)**

Accept "atomic radius of halide ion/X^- /anion increases (down group)"

SECOND MARK:

Charges (on anions) same **(1)**

THIRD MARK:

(so) weaker (forces of) **attraction** between **ions** (in AgI) **(1)**

*Accept "weaker ionic bonding" **(1)***

*Reject **just** "weaker bonding (in AgI)"*

CORRECT REVERSE ARGUMENTS CAN SCORE ALL THE MARKS

OR

First and second combined by stating

I^- (ion) larger than F^- **(2)**

Accept ***just*** *iodide has smaller charge density than fluoride scores only one mark*

THIRD MARK:

(so) weaker (forces of) **attraction** between **ions** (in AgI) **(1)** 3

Accept "weaker ionic bonding" ***(1)***

Reject ***just*** *"weaker bonding (in AgI)"*

IGNORE ANY REFERENCES TO POLARISATION OF IONS ANYWHERE IN (b)(i)

(ii) Theoretical value (assumes) 100% ionic OR no covalent character **(1)**

(Experimental value is different) due to covalency **OR** covalent character **OR** polarisation **of anion(1)** 2

Mention of "Ag—X" OR "molecules" scores ***(0)***

(iii) (as) **size of anion increases** (down group) **(1)**

Accept "atomic radius of halide ion/X^-/anion increases (down group)"

Mention of "Ag—X" OR "molecules" scores ***(0) unless already penalised in (b)(ii)***

(anions) **more easily polarised** (down group) **OR** more distortion **of anion** (down group) **(1)**

Accept "more covalent character"/ "more covalent" for second mark

Reject "more covalent ***bonding****"* ***(0)***

MARK THESE POINTS INDEPENDENTLY 2

[10]

52. (i) $3S(s) + O_2(g) + 2H_2(g)$

correct entities **(1)**
state symbols and balancing **(1)** 2

(ii) Energy change when 1 mole of a compound is formed **(1)**

from its elements (in their standard states) **(1)**

at 298K/quoted temperature and 1atm **(1)** 3

(iii) $(2 \times -285.8) - (-296.8 + (2 \times -20.6))$ **(1)**
$= -233.6/-234$ (kJ mol–1) **(1)**

Allow transferred error for one minor slip (e.g. 20.4 instead of 20.6)
but not for omission of multiples.
Ignore units 2

Reject –233
Reject –230

[7]

53. D

[1]

54. (a) $(6.02 \times 10^{23} \times \frac{50}{24}) =$ 1

1.25×10^{24} / 1.254×10^{24} / 1.26×10^{24}
Allow TE from a 1

(b) $M_r = (23 + 42) = 65$ **(1)**

Mass = $(2 \times 65 \times \frac{50}{72})$ **(1)**

= 90/ 90.3g **(1)** Allow TE from (c) 3

Reject wrong unit eg kg

(c) decrease 1

(d) QWC (i) **&** (iii)

Sodium is hazardous **(1)**

May go on fire with water/ produces flammable gas with water/ produces explosive gas with water/ produces strong alkali with water/ reacts with moisture on skin and becomes hot /corrosive **(1)**

2nd mark depends on reference to sodium 2

Reject unspecific comments about sodium being poisonous / toxic / flammable without reference to water.

[8]

55. (a) (i) 4410 1

(ii) 0.015 1

(iii) (–4.41/ 0.015) = – 294 kJ mol^{-1}
Value **(1)**
Negative sign and units **(1)**
TE for answer to (i)/ answer to (ii) 2

(iv) QWC

Any two of:

Use an insulated container/(expanded) polystyrene cup
Use a lid
Use a thermometer calibrated to at least 0.5 °C 2

(b) (i) QWC

No effect, as all copper nitrate reacts anyway. **(1)**

Enthalpy change is based on mass of solution heating up
/ SHC of the metal is very low. **(1)** 2

(ii) QWC

Yes, temperature rise is smaller than it should be**(1)**

So enthalpy change less negative **(1)** 2

(c) Use more concentrated solution (with correspondingly more magnesium). 1

[11]

56. (a) A Cu(g)
B Cu^{+} (g)
C 2Br(g)
2 marks for all correct but max 1 if state symbols wrong/ missing
1 mark for 2 correct

D $Hf^{(\ominus)}$ / (standard) enthalpy (change) of formation (of $CuBr_2$) **(1)** 3

(b) $\Delta H_f = \Delta H_{a(Cu)} + E_{m1(Cu)} + E_{m2(Cu)} + 2 \times \Delta H_{a(1/2\ Br2)} + 2 \times E_{aff(Br)} + \Delta H_{latt}$
OR
Lattice energy = D–(other enthalpy changes) **(1)**
Can be shown using the numbers

= –141.8 – (338.3 + 746 + 1958 + 2 × 111.9 + 2 × –342.6) = –141.8 – 2580.9
= –2722.7 = –2723 (kJ mol^{-1}) **(2)**

max 1 if no multiples of 2 for Br
max 2 (out of 3) if positive sign 3

(c) (i) QWC

Not 100 % ionic/ has some covalent character 1

Reject answers where it is not clear that bonding has some intermediate character, but not entirely ionic or covalent

(ii) Non-spherical bromide / negative ion with bulge towards copper / positive ion **(1)** 1

[8]