

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)**
 $= -410 \text{ kJ mol}^{-1}$ **(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.*

$$\Delta H_{\text{latt}} = (-411) - (-364) - (+121) - (+494) - (+109) \text{ **(1)**}$$

$$= -771 \text{ **(1)** (kJ mol}^{-1}\text{)}$$

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 Mg²⁺ magnesium is smaller and double charged/
 Cl⁻ and O²⁻ 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

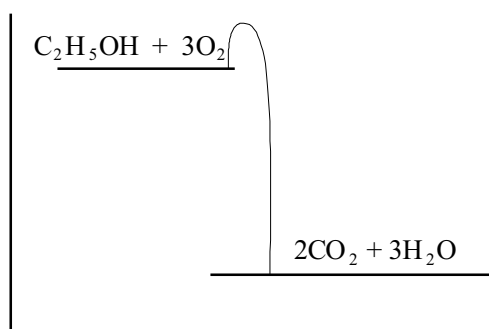
- (b) • Enthalpy or heat change **for complete combustion / complete reaction** with oxygen / burning in **excess air (1)**
- per **mole** of substance **(1)**
- 1 atm or standard states **(1)** 3

- (c) (i) $\text{C}-\text{C} + 5\text{C}-\text{H} + \text{C}-\text{O} + \text{O}-\text{H} + 3\text{O}=\text{O} \rightarrow +4719$ **(1)**
 $4\text{C}=\text{O} + 6\text{O}-\text{H} \rightarrow -5750$ **(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

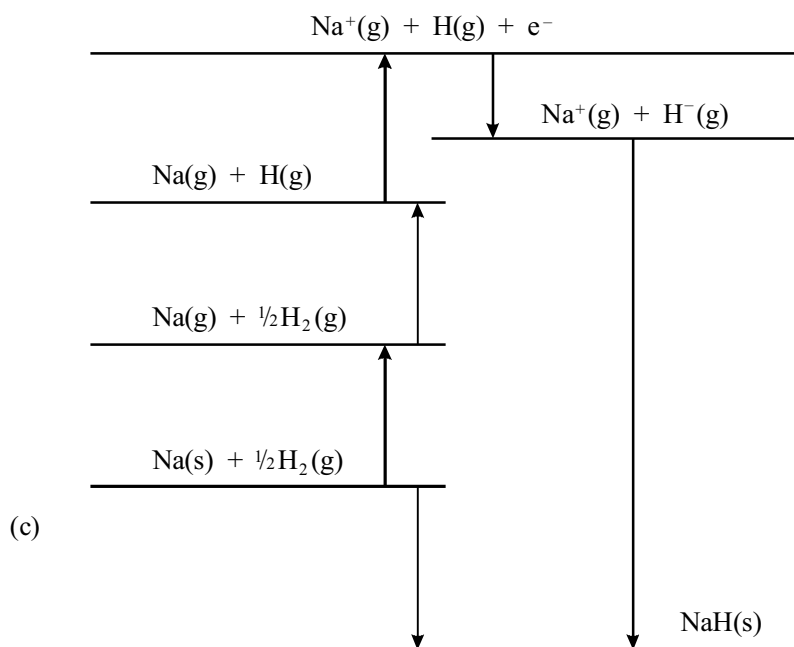
Reference to problem of how the experiment is carried out practically e.g. reaction slow / too much to do all at once **(1)**

Any 2

2

- (b) Extrapolation of lower and upper temperatures at 3.5 min **(1)**
 ΔT correct to $\pm 1.0^\circ\text{C}$ according to candidate's method **(1)**
 Consequential on sensible method of finding temp
 change between 3 and 4 minutes 2
- (c) $\Delta H = -4.18 \times \text{candidate's } \Delta T$
 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)**
 = $-76.5 \text{ (Kj mol}^{-1}\text{)}$ **(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 change* 1
- (ii) $+150 + 736 + 1450 + (2 \times 121) + 642 = 3220$
 $= 2493 + 2x$ (1)
 $2x = 727$
 $x = -363.5$ (1) **sign vital**
n. b. -727 scores 1, -303 scores 1, -606 scores 0 2



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**)
- $\frac{1}{2}\text{H}_2$ to H (**1 mark**)

n. b. the whole cycle could be doubled to give $2 \times$ 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

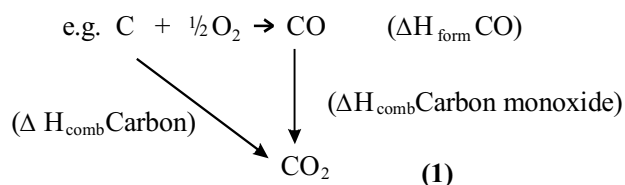
[11]

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 $\text{H}^+ + \text{OH}^- \rightarrow, \text{H}_2\text{O}$ (**1**) 1
- (b) $q = mc\Delta T$ (**1**) other unambiguous symbols/names
= $100 \times 4.18 \times 6.90$ (**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) $\div 0.05$ /allow answer from (b) $\times 20$
= $-57.7 \text{ kJ mol}^{-1}$ (**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]

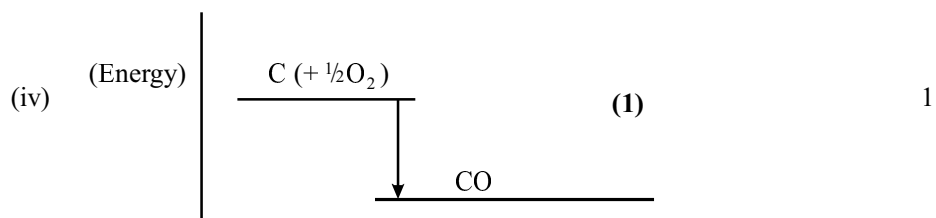
8. (a) (i) Enthalpy or heat change / released when 1 mol of substance **(1)**
 is burned in excess oxygen / completely **(1)**
 all substances in standard states (at a specified temp)/
 at a pressure of 1 atm. **(1)** 3

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



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

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

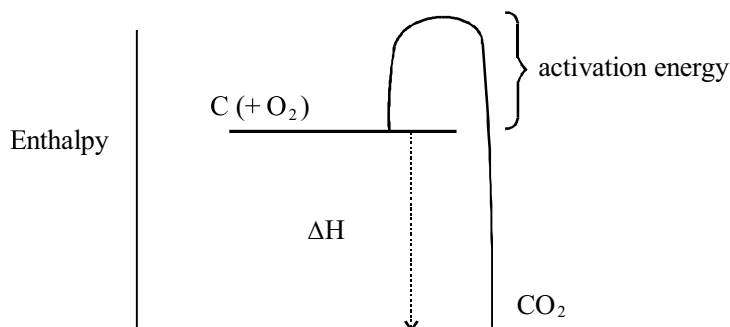
9. (a) **Note 1 mark for improvement 1 mark for related reason in each case to max 4 marks.**
Reason must relate to improvement. Max 2 for improvement. Max 2 for reason.

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

- (b) (i) Heat change = $50.0 \times 4.18 \times 15.2\text{J}$
 $= 50.0 \times 4.18 \times 15.2 / 1000\text{kJ}$
 $= 3.18\text{kJ}$ or 3180J **(1)**
Ignore sig. fig. Allow mark if units omitted
If units quoted but wrong eg 3.18 J score 0. 1
- (ii) No of mols of copper sulphate = $50.0 \times 0.500 / 1000$
 $= 0.025$ **(1)** 1
- (iii) Enthalpy change per mol = $3.18 / 0.025 = -127\text{kJ}$ **(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) $\text{Cu}(\text{OH})_2$ **(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) $q = 1210 \text{ J} / 1.21 \text{ kJ}$ **(1)** *Consequential on (b)(i)* 1
- (iii) • $\Delta H = 1210 \text{ J} / 0.020$ **(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 = $20 \times 4.18 \times 26.3 = (2198.68)$
 $\Delta H = (-) \frac{2198.68}{0.01}$ **(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)

$$\{(-333.0) + (-285.8)\} - \{(2 \times -46.2) + (-393.5)\}$$

$$= -618.8 + 485.9$$

$$= -132.9 \text{ kJ (3)}$$

Correct answer with some correct working (3)

Correct answer alone (1)

$$+ 132.9 \text{ kJ (2)}$$

Omitting the $\times 2$ gives -179.1 kJ (2)

$$+ 179.1 \text{ kJ (1)}$$

Incorrect application of Hess's Law gives -1104.7 kJ (2)

$$+ 1104.7 \text{ kJ (1)}$$

Incorrect Hess's Law and omit $\times 2$ gives -1058.5 kJ (1)

$$+ 1058.5 \text{ kJ (0)}$$

NOT AMENDED (ignore units)

$$\{(632.2) + (-285.8)\} - \{(2 \times -46.2) + (-393.5)\} \text{ (1)}$$

$$= -918.0 + 485.9$$

$$= -432.1 \text{ kJ (3)}$$

Correct answer with some correct working (3)

Correct answer alone (1)

$$+ 432.1 \text{ kJ (2)}$$

Omitting the $\times 2$ gives -478.3 kJ (2)

$$+ 478.3 \text{ kJ (1)}$$

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

$$+ 1403.9 \text{ kJ (1)}$$

Incorrect Hess's Law and omit $\times 2$ gives 1357.1 kJ (1)

$$+ 1357.1 \text{ kJ (0)}$$

[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 / E_a 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)**

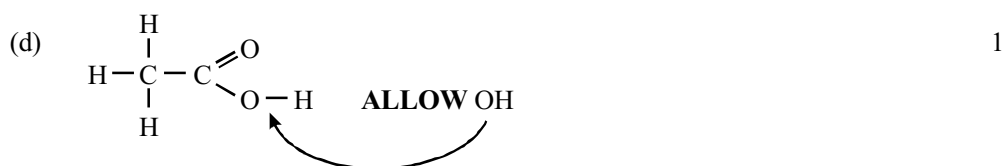
i.e. C-I = 228 kJ mol^{-1} **(1)**

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



[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) $2\text{N}_2(\text{g}) + 6\text{H}_2(\text{g}) + 5\text{O}_2(\text{g})$
Correct diatomic elements with state symbols (1)
Balanced cycle (1) 2
- (ii) ie $\Delta\text{H} = 4(90.2) + 6(-241.8) - 4(-46.1)$ (2)
 $= 360.8 - 1450.8 + 184.4$
 $= -905.6 \text{ kJ mol}^{-1}$
 $= -906 \text{ kJ mol}^{-1}$ (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) $(\Delta T = 38.1 - 19.5 =) 18.6$ ($^{\circ}\text{C}$) *calculated or correctly used* (1)
 $\frac{200 \times 4.18 \times 18.6}{1000} = 15.5/15.55$ (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) $\text{Mg(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{Cu(s)}$
entities (1)
state symbols (1) 2
- (ii)
- $$\begin{array}{c} \text{Mg(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{Cu(s)} \\ \swarrow \quad \searrow \\ \text{Mg(s)} + \text{Cu(s)} \end{array}$$
- $\Delta H_{(r)}^{\circ} = \Delta H_f^{\circ}[\text{Mg}^{2+}(\text{aq})] - \Delta H_f^{\circ}[\text{Cu}^{2+}(\text{aq})]$
entities including state symbols (1)
arrows (1)
Hess applied (1) 3
- (b) (i) $4.2 \times 150 \times 60$ (1)
 $= 37800 / 38000 \text{ J}$ (1)
OR $37.8 / 38 \text{ kJ}$ 2
- (ii) $37800 / 530000$
 $= 0.07(13) \text{ (mol)}$ 1
- (iii) $1000 \times 0.0713 / 8$
 $= 8.9(2) \text{ cm}^3$
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) $\begin{array}{c} ++ \\ +\text{Cl}+ \\ ++ \end{array}$ 1
- (iii) homolytic 1

- (b) B and C 1
- (c) (i) $\text{Cl}_2 + \text{CH}_4 \rightarrow \text{CH}_3\text{Cl} + \text{HCl}$ 1
- (ii) $+242 + 4 + -339 = -93 \text{ kJ mol}^{-1}$
 (A + B + F)
OR
 $+4 - 97 = -93 \text{ kJ mol}^{-1}$
 (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) $5.00 + 84.0 = 0.0595 \text{ mol}$ 1
- (ii) $50.0 \times 4.18 \times 6.5$ (1) ignore sign
 $\div 1000$ (1) = 1.36kJ mark consequentially
 (1.49.kJ if use 55.0 g (1)) 2
- (iii) Answer to (ii) \div 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
 Do not allow shc is $4.18 \text{ J g}^{-1}\text{C}^{-1}$ 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)
 $= 460\text{J} / 0.460 \text{kJ}/459.8\text{J}$ (1) 2
- (ii) $M_r \text{MgSO}_4 \cdot 7\text{H}_2\text{O} = 246$ (1)
 $12.3/246 = 0.05$ (1) Allow TE 2
- (iii) $460/0.05$
 $+9200 \text{J mol}^{-1} / +9.2 \text{kJ mol}^{-1}$ (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) $+9.2 - -85.2$
 $= +94 \text{kJ mol}^{-1}$ (1)
sign and units (1) 2

[15]

21. (a) (i)
-
- 1

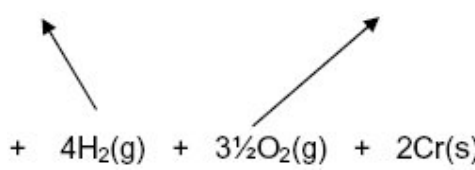
ACCEPT all dots/crosses

- (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) $\text{PH}_3(\text{g}) \rightarrow \text{P}(\text{g}) + 3\text{H}(\text{g})$ 1
- (ii) Hess applied (1)
Multiples (1)
Correct answer $+ 963(.2)/960 \text{ kJ mol}^{-1}$ (1) 3
- (iii) Answer to (ii) divided by 3
 $+ 321(.1)/320 \text{ kJ mol}^{-1}$ 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 $4 \times \text{C-H} = + 1740$
 $2 \times \text{O=O} \begin{array}{l} = +996 \\ = +2736 \end{array}$ (1)
- Bonds made $2 \times \text{C=O} = - 1610$
 $4 \times \text{H-O} \begin{array}{l} = -1856 \\ = -3466 \end{array}$ (1)
- $\Delta H = + 2736 + (-3466) = - 730$ (1) (kJ mol^{-1}) 3
- (c)
- $$\begin{array}{ccc} \text{CH}_4(\text{g}) + 2\text{H}_2\text{O}(\text{g}) & & \text{CO}_2(\text{g}) + 4\text{H}_2(\text{g}) \\ & \swarrow \quad \searrow & \uparrow \\ & 4\text{H}_2(\text{g}) + \text{C}(\text{s}) + \text{O}_2(\text{g}) & \end{array}$$
- Cycle (1)
do not allow the word "elements"
Arrows labelled ΔH_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 cm³ 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 $\Delta T = 7.0 \pm 0.1$ ($^{\circ}\text{C}$) 2sf for ΔT
 Reading V_N consequentially **(1)** expected $V_N = 22.5$ to 23.0 (cm³) 3sf for V_N
 $\Delta T = 6.9$ ($^{\circ}\text{C}$) $V_N = 25.0$ (cm³) scores **(1)** only 2
- (d) (i) Heat calculated using candidate's values in (c)
 ignore 3 or more SF at this stage 1
- (ii) $(-)\frac{\text{Answer to (d)(i)}}{0.025}$
 Method consequentially **(1)**
 Answer, sign and 2–4 SF **(1)** 2
- | ΔT | Vol | Heat/kJ | $\Delta H/\text{kJ mol}^{-1}$ |
|------------|------|---------|-------------------------------|
| 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)
- 

 $+ 4\text{H}_2(\text{g}) + 3\frac{1}{2}\text{O}_2(\text{g}) + 2\text{Cr}(\text{s})$
- 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) $4 \times -242 + -1140$ (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) $\text{Cl}_2(\text{g}) (+) \frac{1}{2} \text{O}_2(\text{g})$ 1
- (ii)
- $+ 80.3 \text{ (kJ mol}^{-1}\text{)}$

$2 \times (+121.7) + (+ 249.2)$
OR $+ 492.6 \text{ (kJ mol}^{-1}\text{)} + \text{sign required}$
- ALLOW T. E from (i)* 1
- (iii) $\Delta H^\ominus_{\text{at}} [\text{Cl}_2\text{O}(\text{g})] = -80.3 + 492.6 = + 412.3 \text{ (kJ mol}^{-1}\text{)}$
 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) $E[\text{Cl}-\text{O}] (= \frac{1}{2} \times (+ 412.3)) = (+)206.15 \text{ (kJ mol}^{-1}\text{)}$
ALLOW TE from (iii)
ALLOW (+)206.15
ALLOW missing sign 1
- [4]**
-
26. (a) (i) $\frac{1664}{4} = 416 \text{ (kJ mol}^{-1}\text{)}$ *IGNORE "+" signs* 1
- (ii) energy needed to break bonds:
 $2 \times 436 + 193 = (+)1065 \text{ (1)}$
 energy change in making bonds:
 $-348 + 4x -416 + 2x -276 = (-) 2564 \text{ (1)}$
 enthalpy change = $1065 - 2564 = - 1499 \text{ (kJ mol}^{-1}\text{)}$ **(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 = $50 \times 4.18 \times \Delta T$ (= 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 = 1 g cm^{-3} / total volume after reaction 50 cm^3 / total mass is 50 g.
 ACCEPT $1 \text{ g} = 1 \text{ cm}^3$
 ACCEPT Density is same as that for water
 ACCEPT Heat capacity of metal is irrelevant
 NOT density = 1 1
- (iii) $(1.0 \times 50 / 1000) = 0.05(0)$ (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 Γ) **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) $\text{Ca}^{2+}(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \rightarrow \text{Ca}^{(2+)}\text{CO}_3^{(2-)}(\text{s})$
 left-hand side **(1)**
 right-hand **(1)** 2
*BUT if all formulae correct (including charges) but missing/
 wrong state symbols 1 max*
- (b) (i) (Energy = $100 \times 4.2 \times 1.5$) (+) 630 (J)
 NOT – 630 (J) 1
- (ii) Quantity of $\text{CaCl}_2 = (50/1000) \times 1.00$
 = 0.05 mol 1
- (iii) $\Delta H = \frac{(630/0.05)}{1000} = +13 \text{ kJ mol}^{-1}$ [2 SF]
 answer (i) \div (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) / ΔH **(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) $\Delta H = \{(4x + 435) + (2x + 498)\}$ (1)
 $+ \{(2x - 805) + (4x - 464)\}$ (1)
IGNORE signs for first two marks, ie marks for total enthalpies of bonds broken and made.
 $= -730 \text{ (kJmol}^{-1}\text{)}$ (1)
3rd mark is consequential on their values for first two marks
 $+ 730 \text{ (kJmol}^{-1}\text{)}$ (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 H₂O(g) (rather than H₂O(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) *Consequential 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 cm³ ALLOW ± 1.0 cm³ 1
 (ii) 9.3 ± 0.5 °C 1

- (c) (i) $\frac{(b)(i) \times 2}{1000}$
ALLOW correct answer with no working 1
- (ii) (c)(i) 1
- (iii) (c)(ii) $\times \frac{1000}{50}$ **(1)**
Correct answer – see table below (1) 2
- (d) (i) $50 + (b)(i)$ **(1)**
 $\times 4.2 \times \frac{(b)(ii)}{(1000)} = \text{answer}$ **(1)**
Must use (b)(i) in calculation to score 2nd mark
If the units are given, they must be correct 2
- (ii) $\Delta H = -\frac{(d)(i)}{0.05 \times (c)(iii)} = \text{answer plus units}$
 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 / $\frac{3.5}{7} = 0.50 / \frac{1}{2}$ **(1)**

If candidate does first part only, working must be shown

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

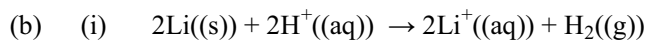
ACCEPT 3.0 OR 3 OR 3.010($\times 10^{23}$)

NOT 3.01²³

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

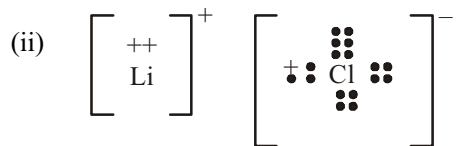
Correct answer with no working (2)

2



ALLOW multiples Ignore state symbols

1

**(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 / 10⁵ Pa / 1.01 × 10⁵ Pa / 10² k Pa /

101 k Pa / 10⁵ 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) $(\Delta H = -306 - (-399)) = (+) \underline{93} \text{ (kJ mol}^{-1}\text{)}$

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)

If (i) has a negative answer (exothermic)

equilibrium moves to left hand side **(1)**

Because (forward) reaction is exothermic **(1)**

If answer to (i) is +93 or 93 but state that this is exothermic

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) $4.2 \times 20 \times 2.5 = 210$ (J) OR 0.210 kJ
 IGNORE +/- signs
 Incorrect units **(0)** 1
- (iii) Number of moles of $\text{CaCO}_3 = 0.02$ **(1)**
 $\frac{210}{0.02} = 10\,500$ **(1)**
 $\Delta H_1 = -10500 \text{ J mol}^{-1}$ OR $-10.5 \text{ kJ mol}^{-1}$ **(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 $\Delta H_{\text{formation}}$ / $\Delta H^\circ_{\text{formation}}$ /formation
 NOT ΔH_f / ΔH°_f 1

[10]

35. (a) (i) $\text{H(g)} + \text{O(g)} + \text{Cl(g)}$ *in top RH box*
 $\frac{1}{2} \text{H}_2\text{(g)} + \frac{1}{2} \text{O}_2\text{(g)} + \frac{1}{2} \text{Cl}_2\text{(g)}$ *in lower box*
Brackets around the state symbols are not required 1
- (ii) $589 - 667 = -78 \text{ (kJ mol}^{-1}\text{)}$
ALLOW final answer on its own 1
- (iii) $667 - 464 = (+)203 \text{ (kJmol}^{-1}\text{)}$
ALLOW final answer on its own 1
- (b) (i)
- | | | | | |
|-------|--------|-------|--------|-------|
| (1) | (1) | | (1) | (1) |
| oo | ++ | | ++ | oo |
| H + O | + Cl + | ALLOW | H + Cl | + O o |
| o | o | | o | + |
| oo | ++ | | ++ | oo |
- 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) $100 - 106^\circ$ (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
 $\text{N}\equiv\text{N}$ (+)945 $6\text{N}-\text{H}$ (-)2346 **(1)**
 and

$$3\text{H}-\text{H} \begin{matrix} (+)1308 \\ (+)2253 \end{matrix} \text{ (1)}$$

$$\Delta H = 945 + 1308 - 2346 \\ = -93 \text{ sign and value (1)}$$

$$\Delta H^\ominus = -93 = -46.5 \text{ (kJ mol}^{-1}\text{)}$$

sign and value q on 3rd mark **(1)**

2

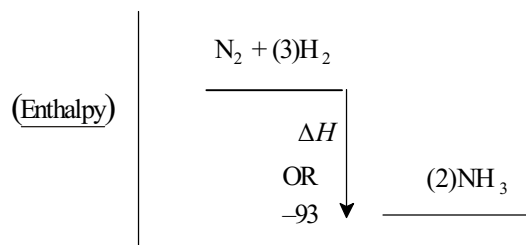
4

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) advantage
 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) $\Delta T = 26\text{ }^{\circ}\text{C}$ **(1) STAND ALONE**
 Heat change = $104 \times 26.0 \times 4.09 = 11060\text{ J}$ **(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

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

$$= -369 \text{ (kJ mol}^{-1}\text{) (1)}$$

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) $\frac{1}{2}\text{Br}_2 \rightarrow \text{Br}$ (1)
 state symbols (1)
 $\frac{1}{2}\text{Br}_2(\text{g}) \rightarrow \text{Br}(\text{g})$ scores only one
 e.g.
 $\frac{1}{2}\text{Br}_2(\text{l}) \rightarrow \text{Br}(\text{g})$ (2)
 $\text{Br}_2(\text{l}) \rightarrow 2\text{Br}(\text{g})$ (1) ie for state symbols
 $\text{Br}_2 \rightarrow \text{Br}$ (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. $\text{Na}^+(\text{g}) + \text{Cl}^-(\text{g}) \rightarrow \text{NaCl}(\text{s})$
 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 cations 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
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

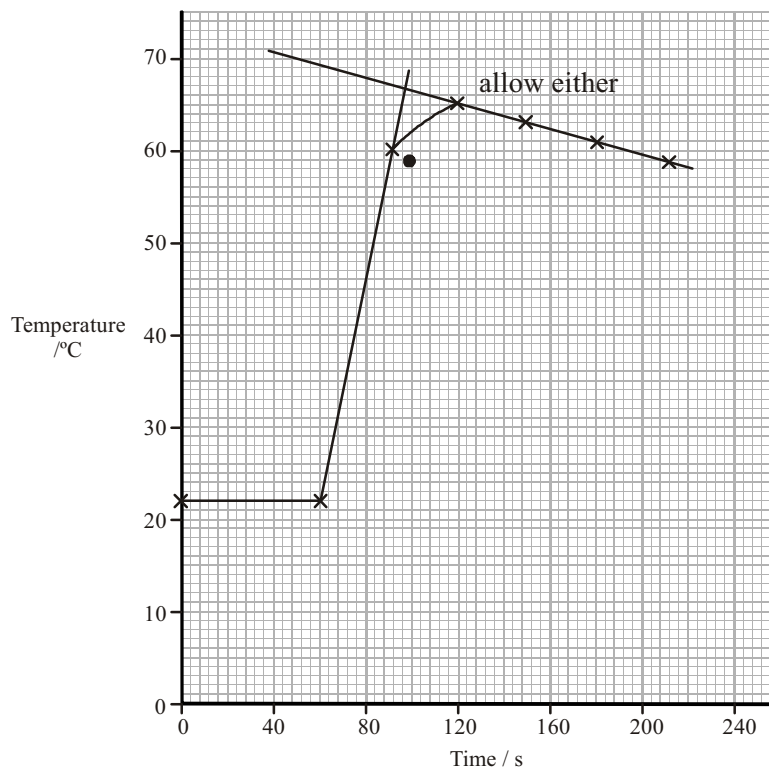
1

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 cm³ 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 CuSO₄) **(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 / Cu²⁺ / 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.

$66 = 44^\circ \text{ rise} = 9240$

$68 = 46^\circ \text{ rise} = 9660$

$69 = 47^\circ \text{ rise} = 9870$

$65 = 43^\circ \text{ rise} = 9030$

(Allow minus sign) ignore sign

$70 = 48^\circ \text{ rise} = 10080$

$65.5 = 43.5^\circ \text{ rise} = 9135$

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 $\div 0.08$ 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) C₄H₉ 1
- Accept C₈H₁₈ → C₄H₉*
- (iii) C₂H₄ 1
- Reject CH₂CH₂*
- (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) C₈H₁₈ + 17/2 O₂ → 8CO + 9H₂O
OR 2C₈H₁₈ + 17 O₂ → 16CO + 18H₂O
OR C₈H₁₈ + 9/2 O₂ → 8C + 9H₂O (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 CO₂*
- 17/2 can be written 8.5 or 8½*
- Allow balanced equations based on C₈H₁₈ with a smaller alkane in the products for 1 mark eg*
- C₈H₁₈ + O₂ → CO + C₇H₁₆ + H₂O (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) N₂ / nitrogen is (major) part of air/ N₂ 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
 $2\text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{l})$
 balance **and** state symbols (1)
- Left arrow label
 $2\Delta H_c C + 3\Delta H_c H_2$
 OR $(2x - 394) + (3x - 286)$ (kJ) units not essential
 OR $-788 - 858$
 OR -1646 kJ (1)
- right arrow label
 $\Delta H_c \text{C}_2\text{H}_5\text{OH}$
 OR -1371 (kJ) (1) 3
- (ii) $\Delta H_c \text{C}_2\text{H}_5\text{OH} = (2x - 394) + (3x - 286) - (-1371)$ (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 ≥ 2 SF
- (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) $\text{Mg}^{2+}(\text{g}) (+) \text{O}^{2-}(\text{g})$ 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_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) $E[\text{Ca}(\text{OH})_2] = 25.0 \times 4.2 \times 16.5 = 1730 \text{ (J)}$

$E[\text{CaO}] = 25.0 \times 4.2 \times 25.5 = 2680 \text{ (J)}$

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) $\frac{1.00}{74.0} = 0.0135 \text{ mol}$

Answer must be decimalised

1

Accept 0.014

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

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

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

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) $\Delta H_{\text{reaction}} = \Delta H_1 - \Delta H_2$ /relevant values being subtracted **(1)**
 $= -130 - (-200) = +70 \text{ kJ mol}^{-1}$ **(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 solids (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 $388 \times 6/ (= 2328)$ **(1)**
 $\Delta H = -76 \text{ (kJ mol}^{-1}\text{)}$ **(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 $N\equiv N$ **(1)**
 [confusion between thermodynamic and kinetic loses first 2 marks]. 3
Accept because $N\equiv N$ 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
 $47.75 \times 4.18 \times 10.5 = 2096$ (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) = $\frac{25 \times 1.5}{1000} = 0.0375$ (1)
 $\Delta H = (-) \frac{2096}{(1000 \times 0.0375)}$ (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)

$$\Delta H = (-) \frac{2100}{(1000 \times 0.0375)} \text{ (1)}$$

$$= -56.0 \text{ (kJ mol}^{-1}\text{)} \text{ (1)}$$

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
 $\Delta H_f = \Delta H_2 + \Delta H_3 + \Delta H_4 + \Delta H_5 + \Delta H_6$
 OR
 $\Delta H_f = (+178) + (1735) + 2 \times (+218) + 2 \times (-73) + (-2389)$
 $= -186 \text{ (kJ mol}^{-1}\text{)} \text{ (1)}$

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 MgH₂ smaller (than in CaH₂) (1)*Accept magnesium ion has greater charge density than calcium ion for first mark.**Reject reference to 'atoms' or 'molecules' or 'H₂' scores zero overall.***Second mark:**

but charges the same (1)

Third mark:(so) stronger (forces of) **attraction** between **ions** (in MgH₂) (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 MgH₂", 3rd mark cannot be awarded in either case***OR****First and second mark combined:**Mg²⁺ (ion) or Mg²⁺ (cation) smaller (radius) than Ca²⁺ (2)**Third mark:**(so) stronger (forces of) **attraction** between **ions** (in MgH₂) (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) + 1/2O₂(g) in both left hand boxes

Balancing (1)

state symbols for Mg/C/O₂ 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 CO₂ 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 = $4.2 \times 100 \times 4.5$
 = 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 $J \text{ mol}^{-1}$ kJ mol^{-1}

- (v) $\Delta H = \frac{-1.89}{0.00417}$
 $= -453 \text{ kJ mol}^{-1}$ **(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) $24 + 12 + 3 \times 16 = 84$ (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) $\Delta H = \frac{-1.05}{0.0262}$
 $= -40.1 \text{ kJ mol}^{-1}$ 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:
 $\Delta H_1 = (b)(v)$
 $\Delta H_2 = -680$
 $\Delta H_3 = (c)(ii)$
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. $455.6 + 4 \times 121.7 - (4 \times 407.4)$

Multiples (1)

Hess applied (1)

$= -687(.2) \text{ kJ mol}^{-1}$ (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) $q = 50 \times 63.5 \times 4.18 = 13271.5 \text{ J}$
 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 $\text{CuSO}_4 = 50 \times \frac{1.25}{1000} = 0.0625$ (1)
Correct answer with some working scores full marks
Accept Ecf from moles

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

$$= -212 \text{ (kJ mol}^{-1}\text{)}$$

 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 "F₂" or "I₂" 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**

Γ^- (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

$1.25 \times 10^{24} / 1.254 \times 10^{24} / 1.26 \times 10^{24}$

Allow TE from a 1

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

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

$= 90 / 90.3\text{g}$ (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) $(-4.41/0.015) = -294 \text{ kJ mol}^{-1}$
 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 $0.5 \text{ }^{\circ}\text{C}$ 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 H_f^{\ominus} / (standard) enthalpy (change) of formation (of CuBr_2) **(1)** 3
- (b) $\Delta H_f = \Delta H_{a(\text{Cu})} + E_{m1(\text{Cu})} + E_{m2(\text{Cu})} + 2 \times \Delta H_{a(1/2 \text{ Br}_2)} + 2 \times E_{\text{aff}(\text{Br})} + \Delta H_{\text{latt}}$
 OR
 Lattice energy = D – (other enthalpy changes) **(1)**
 Can be shown using the numbers
 $= -141.8 - (338.3 + 746 + 1958 + 2 \times 111.9 + 2 \times -342.6) = -141.8 - 2580.9$
 $= -2722.7 = -2723 \text{ (kJ mol}^{-1}\text{)} \text{ (2)}$
 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]**