1. (a)

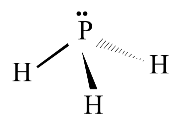
H	C
11.1 / 1	88.9 / 12 **(1)**
= 11.1	= 7.4
1.5	1 **(1)**

Empirical formula C_2H_3 **(1)** 3

(b) HI has more electrons **(1)**

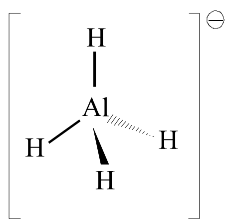
has greater induced–dipole–induced dipole / vdW forces **(1)** 2

(c) (i) *pyramidal*



Need to show evidence of three dimensional or state it is pyramidal with two dimensional diagram **(1)**
3 bond pairs and 1 lone pair to get as far apart as possible **(1)** 2

(ii) *tetrahedral*



Need to show evidence of three dimensional or state it is tetrahedral with two dimensional diagram **(1)**
4 bond pairs around aluminium as far apart as possible **(1)** 2

(d) Amount of phosphine = 8.0/24000 **(1)**

$= 3.33 \times 10^{-4}$ mol

Number of molecules of phosphine $= 6.0 \times 10^{23} \times 3.33 \times 10^{-4}$ **(1)** 2

$= 2.0 \times 10^{20}$

[11]

2. (a) (i) number of protons (in the nucleus)/ proton number **(1)**
not *'number of electrons' or 'number of protons in an element'* **(1)**

(ii) Electronic configuration differs from previous element by an electron in a *d* (sub) shell or orbital / *d*-shell is filling / *d* electron is last electron **(1)**

Allow outer electron is d / highest energy electron is d 1

(iii) Forms at least one ion/compound with partially full / incomplete *d* sub shell **(1)**

1

(b) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^5$ or $3d^5 4s^2$ **(1)** 1

(c) (i) The heat/energy/enthalpy change needed to remove one mole of electrons **(1)** from (1 mole) of gaseous (chlorine) atoms **(1)**

Correct equation i.e. $Cl(g) \rightarrow Cl^+(g) + e^-$ can score second mark. 2

(ii) Increasing slopes **(1)**

Jump after 7 **(1)**

Jump after 15 **(1)**

Ignore small jumps in the correct places. The points do not need to be joined.

3

(d) *There are several way of doing this calculation; the following is one way. All other valid ways score full marks*

43.7/55 = 0.795   56.3/35.5 = 1.59 **(1)**

0.795/0.795 = 1   1.59/0.795 = 2 **(1)**

$MnCl_2$ **(1)** This is a stand alone mark

or

$MnCl_2$ and some correct working **(3)**

Note:

If a candidate gets a formula $MnCl_x$ where × is between 2 and 7 because they have made a chemical error, they can score a maximum of 1 mark. If the error is mathematical they can score a maximum of 2 marks

3

[12]

3. (a) (i) fizzing/ effervescence

metal disappears /gets smaller

floats/ moves around on surface

melts/ turns into ball

any 2

do not allow ‘dissolves’ 2

(ii) $2Na + 2H_2O \rightarrow 2NaOH + H_2$

species **(1)** balance **(1)** 2

(b) amount Na = 3.0123 = 0.13 mol **(1)**

amount H_2 = 0.065 mol **(1)**

vol $H_2 = 0.065 \times 24\ dm^3 = 1.\ 6\ (dm^3)$ (allow 1.56, 1.57 or 1.565) **(1)**

answers consequential on equation in (a)(i)

If units quoted and are wrong final mark lost 3

[7]

4. (a) (i) Number of protons + number of neutrons **(1)** 1

(ii) (weighted) average / mean mass of **one atom (1)**

relative to one twelfth the mass of carbon-1 2 (atom) / on a scale in which $^{12}C = 12$ **(1)** 2

(iii) **atoms** with same atomic no/ same no of protons/ same element **(1)**
but different numbers of neutrons / mass number **(1)** 2

(b) $(24 \times 0.7860) + (25 \times 0.1011) + (26 \times 0.1129)$ **(1)**
24.33 **(1)** 2

[7]

5. (a)

Na	Cl 33.3 / 35.5	O	
21.6/23		45.1/16	**(1)**
= 0.939	= 0.938	= 2.82	
	÷ by smallest		**(1)**
1	1	3	

$NaClO_3$
Could argue from formula and calculate back to shown percentages for full marks. 2

(b) (i) $3OCl^- \rightarrow 2Cl^- + ClO_3$
species **(1)** balance **(1)**
Fully balanced molecular equation score / mark only 2
ignore spectator sodium ions in ionic equation if on both sides

(ii) Identification of oxidation states **(1)** +1 +5 −1
Identification of an oxidation reaction **(1)** +1 to +5
Identification of a reduction reaction **(1)** +1 to −1
Disproportionation because (Cl in) OCl^- both oxidised or reduced **(1)**
Final mark can be awarded for a simple definition of disproportionation related to chlorine.
n. b. reference to a single atom of chlorine not acceptable. 4

(c) (i) $Cl_2 + 2e^- \rightarrow 2Cl^-$ **(1)** (*) 1

(ii) $2Br^- \rightarrow Br_2 + 2e^-$ **(1)** (*) 1

(*) or multiples / negative charge on e not required

[10]

6. (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]

7. (a) (i) $\frac{0.25}{97}$ = 0.00258 / 2.58×10^{-3} / 0.0026 / 0.002577 **(1)** — 1

(ii) 0.00258 / *same number of moles as calculated in (i)* **(1)**
$0.00258 \times \frac{1000}{23.45}$ **(1)** = 0.110 (mol dm^{-3}) **(1)** *units not required*
consequential on (i) possible answers 0. 11, 0.110, 0.1111 — 3

(b) $\frac{2 \times 0.01 \times 100}{0.25}$ = 8% **(1)**

but allow $\frac{0.01}{0.25} \times 100 = 4\%$ — 1

(c)

W	Weighing	must be evidence of two weighings at some point in the process **(1)**
P	Preparation	Rinsing out one piece of relevant apparatus correctly **(1)** (*)
D	Dissolve	Dissolve in water in beaker / volumetric flask **(1)** (*)
R	Rinse	Rinse beaker and add washing to volumetric flask / rinse funnel (if solid straight to volumetric flask) **(1)** (*)
V	Volumetric flask	Volumetric / standard / graduated flask **(1)** DO NOT AWARD IF CANDIDATE USES VOLUMETRIC FLASK TO MEASURE OUT 250 cm^3 (*)
M	250 cm^3	Making up to mark / exactly 250 cm^3 of solution **(1)** (*)
S	Shake	Shake / invert / mix final solution **(1)** *n.b. this is at end* (*)

C concentration = $\dfrac{\text{mass of sulphamic acid}}{97 \text{ (or Mr)}} \times \dfrac{1000}{250}$ **(1)**

H Safety
(solution of) acid is corrosive and appropriate safety precaution
e.g. wear eye protection and/or gloves **(1)**

(*) Max 5 marks

[13]

8. (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)**

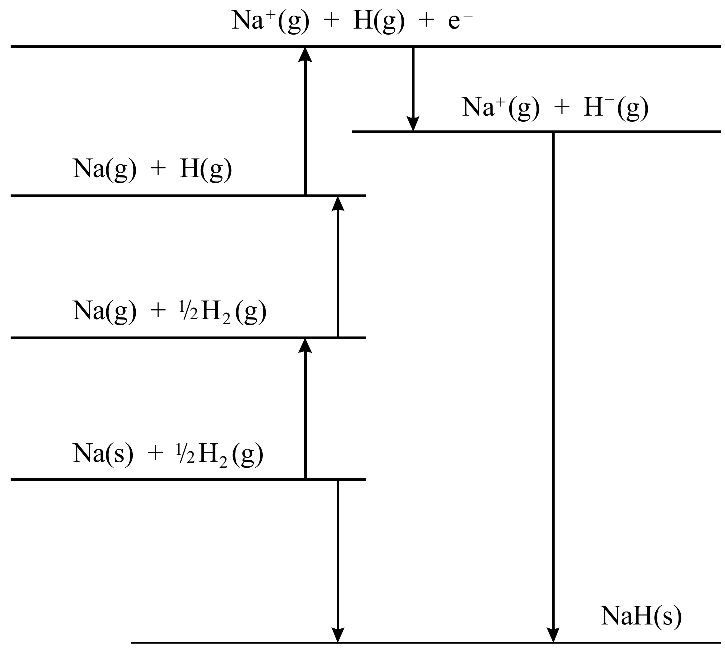
from an element in its standard state **(1)**

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)**
- $\frac{1}{2}H_2$ 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]

9. (a) (i) moles of KNO_3 = 10.1/101 = 0.100 **(1)** 1
Allow 0.1/0.10

(ii) moles of KOH = 0.100 **(1)**
or answer from (i)– could be shown in calculation *below*.
volume = 0.1 × 1000/2 = 50.0(cm^3) **(1)** 2
Consequential on (i); allow 50

(iii) moles of O_2 = 0.1/2 = 0.0500 **(1)** i.e. *divide by 2*
vol O_2 = 0.05 × 24 = 1.2 (dm^3) **(1)** i.e. × *by 24* 2

consequential on (ii) or (i)
*if use wrong unit eg mol dm^{-3} max **(1)***

(b) (i) Percentage of oxygen = 29.1 % **(1)** *stand alone*

K	O
70.9/39	29.1/16 **(1)** *i.e. divide by A_r*
1.82	1.82
1	1

KO **(1)** 3

If assume KO and prove it (Max 2)

(ii) M_r (= 22/0.2) = 110 **(1)**
(M_r of KO = 55 so) molecular formula = K_2O_2) **(1)** 2

[10]

10. (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]

11. (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]

12. (a) (i) • Energy / enthalpy change per mole **(1)**
• required to remove an electron **(1)**
from / mole of gaseous atoms **(1)** 3

(ii) • The nuclear charge on K is greater than on Na **(1)**
• the outer electron is further from the nucleus **(1)**
but there is more shielding around K than Na **(1)** 3

(b) (i) 4.56 / 71 **(1)** = 0.0642 **(1)**mol 2

(ii) Answer from (i) – 2 **(1)** = 0.0321 mol 1

(iii) Answer from (ii) × 24 **(1)** 0.771 dm^3 1

(iv) Answer from (iii) × 3/2 **(1)** 1.16 dm^3 1

[11]

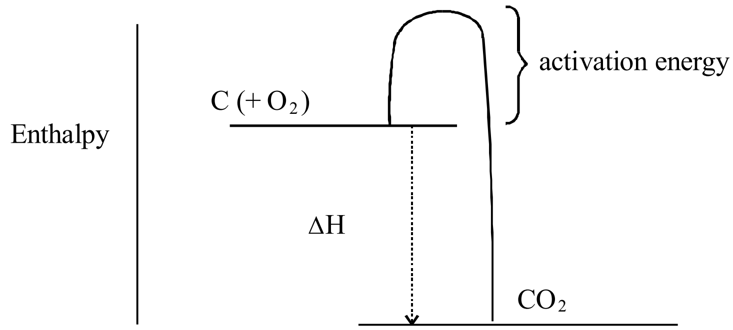
13. (a) • Enthalpy or heat change or heat energy / released when 1 mol of substance / element or compound (need to say both) **(1)**
• is burned in excess oxygen / completely / reacts completely **(1)**
at 1 atm pressure and specified temperature **(1)** 3

(b) $\Delta H = 2\Delta H_c(C) + 2\Delta H_c(H_2) - \Delta H_c(CH_3COOH)$ **(1)** for this or equivalent cycle drawn;

$\Delta H = (-394 \times 2) + (-286 \times 2) - (-874)$ **(1)**
$= -486$ 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]

14. (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]

15. (a) (i) NO_3^-

(ii) CrO_4^{2-} 2

(b) Ag^+, CrO_4^{2-} or names 1

(c) $2Ag^+(aq) + CrO_4^{2-}(aq) \rightarrow Ag_2CrO_4(s)$
Formulae and balancing **(1)**
State symbols **(1)** 2

[5]

16. (a) $^{20}/_{1000} \times 0.5 = 0.01$ 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]

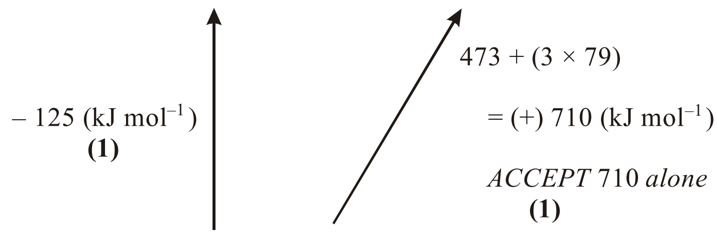
17.	(a)	(i)	(46 × 8 + 47 × 7.3 + 48 × 74 + 49 × 5.5 + 50 × 5.2) ÷ 100 = 47.926 = 47.9 Method **(1)** Correct answer to three significant figures **(1)**	2
		(ii)	mass spectrometer	1
	(b)	(i)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ **(1)** $4s^2\ 3d^2$ OR $3d^2\ 4s^2$ **(1)**	2
		(ii)	Transition metals /elements *OR* d block	1
	(c)	(i)	reduction or redox	1
		(ii)	940 – 2 × 110 = +720 kJ mol^{-1} Method **(1)** Value **(1)** Sign and units **(1)**	3
		(iii)	Hess / Law of Conservation of Energy First Law of Thermodynamics	1
		(iv)	Carbon monoxide / CO is produced **(1)** which is toxic / poisonous **(1)**	2

[13]

18.	(a)	(i)	Description of asymmetry of electron/charge cloud hence attractive forces between neighbouring induced dipoles	1
		(ii)	NCl_3 / chlorine because more electrons	1
		(iii)	NF_3 because F more electronegative (than Cl)	1
		(iv)	Van der Waals forces more significant/greater than permanent dipole-dipole interactions	1

(b) (i) N(g) + 3F(g) in top right-hand box
½ N_2(g) + 1 ½ F_2(g) in lower box. 1

(ii)



Arrows in correct directions and labelled with correct data 2

(iii) $\Delta H^{\ominus}_{at}$ for [NF_3(g)] → N (g) + 3F (g) = 710 – (– 125) = (+) 835 (kJ mol^{-1}) **(1)**

E (N – F) = $\frac{835}{3}$ = (+) 278 kJ mol^{-1} **(1)**

Penalise 4 or more SF
Penalise incorrect units 2

[9]

19. (a) (i) Weighted average (mass) of 1 atom **(1)**
on a scale in which 1 atom of ^{12}C = 12 units / compared to
1/12 atom of ^{12}C **(1)** 2

(ii) Number of protons plus / and neutrons or nucleons in a nucleus / an atom. 1

(iii) Atoms of same atomic number / same proton number **(1)**

which differ in the number of neutrons **(1)** (in the nucleus) 2

(b) (i) Concept of high energy electron collision:
Electron bombardment / gun / acceleration / fired **(1)**
knocks off electron / equation showing electron being knocked off **(1)** 2

(ii) Positive, +, S^+ 1

(iii) Voltage differential across plates / charged plates [plural] /
electrostatic field / electric field 1

(c) [95.0 × 32 + 0.76 × 33 + 4.24 × 34] / 100 **(1)**
= 32.0924 = 32.09 **(1)** **NOT** 32 or 32.10 2

(d) $1s^2 2s^2 2p^6 3s^2 3p^4$ 1

[12]

20. (a) % oxygen 100 – (31.84 + 28.98) = 39.18 **(1)**

K	Cl	O	
31.84/39	28.98/35.5	39.18/16	Divide by A_r **(1)**
0.8164	0.8163	2.448	Divide by smallest
1	1	3	

Must be 2 or more significant figures

Alternative multiply by A_r + SUM **(1)** Calc % **(1)** 39.18 for 0 **(1)** 3

(b) Ratio of moles or mass **(1)**
Moles of A or relative mass of A **(1)**
× 24 or volume of O_2 **(1)** (not stand alone)

E.g.

2 moles of A gives 3 mols of oxygen **(1)**
1.0g of A 1.00/122.5 moles of A
therefore 1.00 × 3/122.5 × 2 moles of oxygen
volume of oxygen = 1.00 × 3 × 24 / 122.5 × 2
= 0.294 dm^3

OR

1.00g of A gives 0.3918 g of oxygen **(1)**
0.3918 g of oxygen = 0.03918/32 moles of oxygen = 0.0122 moles **(1)**
0.0122 moles of oxygen = 0.0122 × 24 dm^3 of O^2 = 0.293 dm^3 **(1)**

2-4 significant figure in answer allowed 3

[6]

21. (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) **<u>AMENDED</u>** (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]

22. (a) 31e, 38n, 31p
All correct → **(2)**
2 correct → **(1)** 2

(b) $\frac{(69\times 60)+(71\times 40)}{100}$ **(1)**
= (4140 + 2840)/100
= 69.8 **(1)**
-1 *for more or less than 3 SF* 2

(c) Metallic/ metal 1

[5]

23. (a) (i) 4gS = 1/8 mol / 0.125 mol — 1

(ii) 1/8mol S $\rightarrow$ 1/8 mol SO_2 (stated or implied) **(1)**
Volume = 24/8 = 3 dm^3 / 3.0 dm^3/ 3.00 dm^3 / 3000 cm^3 **(1)**
–1 for incorrect/missing units — 2

(b) $SO_2 + 2OH^- \rightarrow SO_3^{2-} + H_2O$ — 2
(1) **(1)**

[5]

24. (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]

25. (a) Density = 1.0 g cm^{-3}
OR 1 cm^3 (of water) weighs 1 g — 1

(b) (ΔT = 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]

26. Number of molecules
= **12/24 (1)** × 6×10^{23}
= 3×10^{23} **(1)** 2

27. (a) $H_2SO_4(aq) + CuCO_3(s) \rightarrow CuSO_4(aq) + CO_2(g) + H_2O(l)$

Reactants **(1)**
Products **(1)**
No/wrong state symbols **1max**
If H_2CO_3 product **1 max** 2
$H_2SO_4(I)$ **1 max**

(b) (i) Measuring cylinder / pipette / burette
Volumetric flask **(0)** 1

(ii) 2.5×10^{-2} / 0.025 1

(c) (i) 2.5 × 10^{-2} × 123.5 **(1)** × 1.1 = 3.4 / 3.40 / 3.396 g **(1)**
ALLOW TE from (b)(ii) 2

(ii) To prevent the reaction mixture from frothing out of the beaker 1

(iii) Filter (to remove unreacted copper(II) carbonate) 1

(d) (i) 249.5 — 1

(ii) actual mass/ mol × 100 / = 3.98 / 249.5 × 100
method
theoretical mass / mol 2.5×10^{-2}

OR method using masses = 3.98 = 3.98 etc
(1)
0.025×249.5   6.2375 — 2

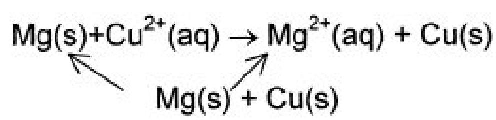
answer 63.8 / 64 % **(1)**
ALLOW TE from (a) / (c) (I) / (d)(i)

(e) Toxic/irritant/enzyme inhibitors — 1

[12]

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

(ii)



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

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

(b) (i) 4.2×150×60 **(1)**
= 37800 / 38000 J **(1)**
OR 37.8 / 38 **kJ** — 2

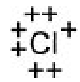
(ii) 37800 / 530000
= 0.07(13) (mol) — 1

(iii) 1000 × 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]

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

(ii)  — 1

(iii) homolytic — 1

(b) B and C — 1

(c) (i) $Cl_2 + CH_4 \rightarrow CH_3Cl + HCl$ — 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]

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

(ii) $50.0 \times 4.18 \times 6.5$ **(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]

31. (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

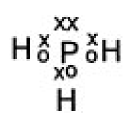
(iii) 460/0.05
+9200 J mol^{-1} /+9.2 kJ mol^{-1} **(1)**
sign and units **(1)**
–1 for incorrect SF.
ALLOW TE from b(i) and/or b(ii) 2

(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]

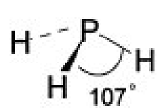
32. (a) (i)



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]

33. (a) Reduction is electron gain **(1)** *IGNORE* any reference to oxygen and hydrogen
ALLOW decrease in oxidation number/state 1

(b) In (i) and (ii) allow multiples

(i) $Fe^{3+} + e^- \rightarrow Fe^{2+}$ 1

(ii) $2I^- \rightarrow I_2 + 2e^-$ *Do NOT allow I for ½I_2* 1

(iii) $2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$

Stand alone
This equation must be correct for the mark and not just a combination of (i) and (ii) 1

(c) (i) Cl is (+) 1 in NaClO **(1)**,
(+) 5 in $NaClO_3$ **(1)**,
and –1 in NaCl **(1)**
ACCEPT as Roman numerals 3

(ii) Chlorine is both oxidised and reduced
OR
The chlorine's oxidation number goes from +1 to +5 and –1.
consequential on oxidation numbers in (i) provided that chlorine has gone both up and down 1

(d) (i) Amount of N_2 = 54 dm^3/20 dm^3 mol^{-1} = 2.7 (mol) 1

(ii) Amount of NaN_3 = 2.7 × 2/3 = 1.8 mol 1

(iii) 117 g **(2)**
Salvage marks:
M_r of NaN_3 = 65 g mol^{-1} **(1)**
Mark consequentially (i–iii)
2–4 SF
117 with no unit **(1)**
117 with wrong unit **(1)** 2

[12]

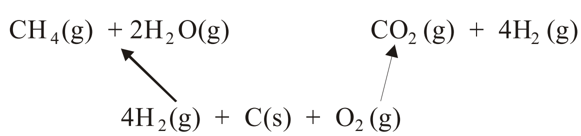
34. (a) Enthalpy / heat/energy change when 1 mol of a substance **(1)**
NOT "heat needed"
is burnt in excess / burnt completely in **air/oxygen (1)**
under standard conditions of 1 atm pressure & stated temperature / at 298 K **(1)** 3

(b) Bonds broken 4 × C-H = + 1740
2 × O=O = +996
= +2736 **(1)**

Bonds made 2 × C=O = – 1610
4 × H–O = –1856
= –3466 **(1)**

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

(c)



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

ΔH_r = – 394 – (– 75) – 2 × (–242) **(1)**
= + 165 **(1)** (kJ mol^{-1}) 4

[10]

35. (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) $(\pm)\ \dfrac{Answer\ to\ (d)(i)}{0.025}$

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]

36. *Only penalise wrong or missing units once in parts (a) & (b).*

(a) 24 dm^3 *OR* 24 000 cm^3 1

(b) 48 dm^3 OR 48 000 cm^3 1

[2]

37. (a) (ionic) precipitation 1

(b) (i) (2)NH_4^+ and $Cr_2O_7^{2-}$ 2

(ii) $Cr_2O_7^{2-}$((aq)) + 2NH_4^+((aq)) → $(NH_4)_2Cr_2O_7$((s))
State symbols not required 1

(iii) The orange colour would move towards the anode / + / left 1

(c) (i) 18 × 2 + 52 × 2 + 16 × 7 = 252 (g / g mol^{-1})
Penalise incorrect units eg 252 g^{-1} in (i) and (ii) only once. 1

(ii) 0.1 mol has a mass of 25.2 (g)
ALLOW TE 1

(iii) 100 cm^3 / 0.1 dm^3 must have units 1

(iv) Filter **(1)**
Wash with (small quantity) / (cold) water **(1)**
Dry between filter papers / in a warm oven (< 40° C) / in a dessicator **(1)** 3

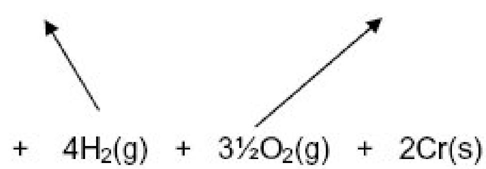
(v) Some remains in solution)
Some lost on washing) *Any two*
Transfer loss eg on glassware, filter paper) 2

[13]

38. (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)



Cr_2 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]

39. (a) (i) % of oxygen = 45.1% **(1)**
54.9/39 = 1.41 and 45.1/16 = 2.82 **(1)**
1.41/1.41 = 1 and 2.82/1.41 = 2 (hence KO_2) / 1.41 : 2.82 ≡ 1 : **(1)**
2
MUST have some working 3
*Correct inductive reasoning **(3)***

(ii) -0.5 / – ½ / -.5 1

(b) KNO_3 because K^+ / potassium ion has larger radius / is larger - *ion essential* **(1)**
but same charge - *stated or K^+ and Li^+ given*
[lower charge density scores 1 out of the first two marks]
"Charge density" *on its own* **(1)** *UNLESS term is explained* **(2)**
polarises/distorts nitrate/negative ion/anion less **(1)**
OR weakens bonds in nitrate less
NOT weakens ionic bond
If $LiNO_3$ more stable **(0)** 3

[4]

40. (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]

41. (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) $\dfrac{\text{answer to (b) (i)}}{\text{answer to (b) (ii)}}$ **(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]

42. (a) (i) Filter **(1)**

Evaporate some of the filtrate by **boiling / heating (1)**

Leave to crystallise / cool (collect crystals) **(1)**

Dry between sheets of filter paper / blotting / dessicator / **warm** oven **(1)**
NOT "dabbing" / "patting" on its own
NOT "hot oven"
NOT "oven"
If temperature quoted, must be < 70 °C

Stages must be in correct order.
Mark until procedure fails
Can score remaining 3 marks even if initial filtration has not been carried out 4

(ii) $BaCO_3(s) + 2HCl(aq) \rightarrow BaCl_2(aq) + H_2O(l) + CO_2(g)$

ALLOW $H_2CO_3(aq)$

balanced equation **(1)**
state symbols **(1)**

$BaCl_2.2H_2O(aq/s)$ *acceptable, providing extra* $H_2O(l)$ *on left*
ALLOW 2nd *mark provided a sensible but unbalanced equation is given.* 2

(iii) moles of HCl used =
$((25/1000) \times 1.0)$
$= 0.025 / 2.5 \times 10^{-2}$
IGNORE units 1

(iv) M_r [$BaCl_2.2H_2O(s)$] = 137 + 71 + 36
= 244 (g mol^{-1}) 1

(v) Moles of $BaCl_2.2H_2O$ = 0.5 × 0.025 = 0.0125
Mass of crystals = 0.0125 × 244 = 3.05 / 3.1 (g)
IGNORE units
ALLOW transferred error from (ii), (iii) and (iv) 1

(vi) Any one

$BaCl_2$ lost in the (saturated) filtrate when crystals collected / OWTTE **(1)**

Transfer loss/ OWTTE **(1)**

Loss when washing **(1)**

NOT incomplete reaction/ inaccurate measurement of materials / spillage *on its own BUT neutral otherwise* 1

(b) (i) (Apple) green / yellow-green *NOT* yellow 1

(ii) Pt/nichrome (wire)/ceramic rod / spatula
NOT nickel / chromium wire
NOT wire of indeterminate material 1

[12]

43. (a) $Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow Ca^{(2+)}CO_3^{(2-)}(s)$
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 × 4.2 × 1.5 =) (+) 630 (J)
NOT – 630 (J) 1

(ii) Quantity of $CaCl_2$ = (50/1000) × 1.00
= 0.05 mol 1

(iii) $\Delta H = \frac{(630/0.05)}{1000} = +\ 13\ \text{kJ mol}^{-1}$ [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]

44. (a) (i) moles Na = 92 / 23 = 4 = moles NaCl
mass NaCl = 4 × 58.5 = 234 (g)
Penalise use of atomic numbers once
Incorrect answer scores (1) only if moles (NaCl) mentioned

OR
23g Na ⇒ 58.5g NaCl **(1)**

Mass NaCl $= \frac{92 \times 58.5}{23} = 234$ (g) **(1)**

2

(ii) $\frac{4}{10} = 0.40$ **mol dm^{-3}** *OR* $\frac{234}{10} = 23.4$ **g dm^{-3}**

consequential on (a)(i)
units required 1

(iii) moles chlorine = 2
vol = 2 × 24 = 48 (dm^3)
Consequential on (a)(i)

Correct answer (some working) **(2)**
Correct answer (no working) **(1)**
Incorrect answer scores **(1)** *only if moles of Cl_2 mentioned* 2

(b) Regular pattern or lattice of (sodium) **ions**

in a sea of electrons / delocalised electrons
ALLOW "cloud of electrons"

electrons are mobile / free to move (under an applied potential and so conduct electricity)
NOT 'free' on its own or carry the charge 3

(c) (i) Energy (allow enthalpy) required per mole
to remove 1 electron (per atom)
from gaseous atoms
OR
$X(g) \rightarrow X^{+}(g) + e$
Species **(1)**
State symbols **(1)** – *only on correct equation*
Electron affinity defined ***(0)*** 3

(ii) chlorine has more protons / nucleus more positive

Same shielding / same number of inner electrons/atomic radius less *ALLOW* outer electron(s) in same shell
(so more energy required)

OR
effective nuclear charge increases (**1**) 2

[13]

45. (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.

$= – 730$ (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]

46. (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) $\frac{(b)(i) \times 2}{1000}$

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

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

(ii) $\Delta H = -\frac{(d)(i)}{0.05 \times (c)(iii)}$ = 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]

47. (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* $3.010(\times 10^{23})$

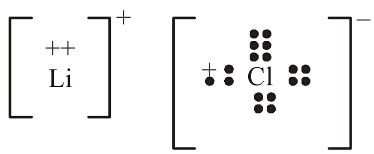
NOT 3.01^{23}

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]

48. (a) 2

Protons	18	} **(1)**
Electrons	18	
Neutrons	22	**(1)**

(b) Position depends on proton number/ atomic number (not mass) / Ar atom has 1 less proton than K atom.
IGNORE references to number of protons = number of electrons — 1

(c) Average = $\frac{36 \times 1.34 + 38 \times 0.16 + 40 \times 98.5}{100}$ **(1)**

= 39.9 **(1)**

–1 for more or less than 3 SF
IGNORE units — 2

(d) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
Numbers following letters can be subscript or superscript — 1
s and p can be upper or lower case

(e) (i) $Ar(g) \rightarrow Ar^+ (g) + e^{(-)} ((g))$
OR $Ar(g) - e^{(-)}((g)) \rightarrow Ar^+ (g)$
Symbol of Ar must be correct — 1

(ii) Potassium value well below sulphur in range 250-750 **(1)**
Low ionisation energy as electron which is removed is more shielded / further from the nucleus / in a higher energy level **(1)**
NOT just 'because electron is in fourth shell' — 2

(iii) Sulphur has 4 electrons in (3) p / phosphorus has 3 **(1)**

Plus any one from:
Electrons in shared p orbitals repel (so are lost more easily) **(1)**
half-filled sub-shells are (more) stable **(1)**
phosphorus has half-filled sub-shell **(1)** — 2

(iv) Chlorine has more protons/greater nuclear charge **(1)**
Shielding unchanged /electrons in same shell/ electrons same distance from nucleus **(1)**
Could be answered in terms of S having fewer protons — 2

(f) Argon inert / unreactive so filament can't react/ vaporises less easily/ lasts longer **(1)** — 1

[14]

49. (a) (i) –1/–l, 0 –1/–l, 0
minus can be either side, sub or superscript

iodine no's correct **(1)**
chlorine no's correct **(1)** 2

(ii) chlorine oxidation number goes down/goes from 0 to –1, so reduced **(1)**

iodine oxidation number goes up/goes from –1 to 0, so oxidised **(1)** 2
Mark consequentially on (a)(i)

(iii) moles NaI = $\frac{30.0}{150} = 0.2$ **(1)**

moles I_2 = 0.1 **(1)**

mass of I_2 = 0.1 × 254 = 25.4 (g) **(1)**

OR
300g NaI **(1)** → 254g I_2 **(1)**

$30.0 \times \frac{254}{300} = 25.4$(g) **(1)**

Correct answer with some working **(3)**
Use of atomic numbers **2 max**
Penalise wrong units 3

(iv) vol = 0.1 × 24 = 2.4 (dm^3) 1
If not 2.4, check for consequential on (a)(iii)

(b) (i) black/grey/grey-black **(1)**
NOT blue-black
NOT purple
IGNORE shiny/silvery
Solid **(1)** 2

(ii) $I(g) \rightarrow I^+(g) + e^{(-)}$ *OR* $I(g) - e^{(-)} \rightarrow I^+(g)$

species **(1)**
state symbols **(1)** - *award state symbols mark only if species correct and in correct place, or if wrong halogen used*
If I_2 *OR* ½I_2 **(0)** 2

[12]

50. (a) (i) 4 pairs of electrons /2 lone pairs and 2 bond pairs **(1)**

so electron pairs arranged tetrahedrally
OR
Arranged to give maximum separation/minimum repulsion **(1)** — 2

(ii) 103 – 105 $^{(°)}$ **(1)**

lone pair repulsion> bond pair repulsion **(1)** — 2

(b) (i) trigonal planar diagram **(1)**
e.g two opposite wedges gets **(1)**
three wedges of two types gets **(1)**
one wedge only gets **(0)**
IGNORE name

120 $^{(°)}$ marked on diagram **(1)** - *stand alone* — 2

(ii) B and Cl have different electronegativities / Cl more electronegative than B — 1
OR different electronegativities explained

(iii) Dipoles (or vectors) cancel/symmetrical molecule/centres of positive and negative charges coincide
IGNORE polarity cancels — 1

(iv) Induced-dipole(-induced dipole)/dispersion/London/v der Waals/vdw
Temporary or instantaneous can be used instead of induced

NOT "dipole" forces
NOT permanent dipole
NOT dipole-dipole — 1

(c) $\frac{14.9}{31} = (0.481)$ $\frac{85.1}{35.5} = (2.40)$ **(1)**

$\frac{0.481}{0.481} = 1$ $\frac{2.40}{0.481} = 5$, so **PCl_5** **(1)**

Use of atomic number **max 1** — 2

[11]

51. (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) (ΔH = – 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]

52. (a) To make sure the decomposition/ reaction is complete / all the carbon dioxide has been given off.
Reference to burning **(0)**
NOT "maximum CO_2" 1

IGNORE significant figures in (b) and (c)

(b) (i) 2.2(0) (g) 1

(ii) $\frac{2.20}{44}$ = 0.05(00) *mark is for ÷ 44* 1

(iii) 0.05(00) 1

(iv) $\frac{5.75}{0.0500}$ **(1)** = 115 (g mol^{-1}) 1

(v) 115 – (12 + 48) = 55 1
Consequential BUT answer must be sensible

(c) (i) Molar mass error = $\frac{115 \times 0.91}{100}$ = (±) 1(.05) **(1)** 1
Consequential on (b)(iv)
ALLOW a ***range*** *of 2 × error*

(ii) 114 to 116 1
Consequential on (i)

(iii) 54 to 56 1
Consequential on (ii)

(iv) "Could be Mn or Fe" 1
Consequential on (iii)
MUST be metals and must give <u>all</u> possible in range

[10]

53. (a) $L = \frac{79.0}{1.31 \times 10^{-22}}$ **(1)**
$= 6.03 \times 10^{23}$ **(1)**

–1 mark for SF error
Final answer must be 6.03×10^{23} for 2nd mark
Correct answer with no working (2)
6×10^{23}/ 6.02×10^{23} quoted with no working (0)
Error in method, max (1) 2

(b) 80 is the average mass of Br atoms / isotopes
OR
There must be another/at least one Br isotope of mass **greater than** 80/with **more than** 45 neutrons
NOT naturally occurring isotope has mass 80 — 1

[3]

54. (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 $\Delta H_{reaction}$ 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 $CaCO_3 = 0.02$ **(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]

55. (a)

	Neutrons	Electrons
$^{24}_{12}Mg$		12
$^{26}_{12}Mg$	14	
$^{24}_{12}Mg^{2+}$		10

1 mark each number 3

Accept words or numbers

(b)

	1s	2s	2p	2p	2p	3s	3p	3p	3p
Mg			↑↓	↑↓	↑↓	↑↓			
Cl			↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑

Arrows can be
↿ for ↑
⇂ for ↓ 2

Accept both arrows up or both down

Reject numbers

(c) $Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$

Formulae **(1)**
State symbols **(1) –** only if formulae correct or near miss for $MgCl_2$
(e.g. $MgCl/Mg_2Cl$) 2

Accept multiples
Accept $Mg^{2+}(Cl^-)_2(s)$

Reject "$Mg^{2+} + 2Cl^-$" for $MgCl_2$
(0 mark)

(d) $\frac{(56.25\times 70)+(37.50\times 72)+(6.25\times 74)}{100}$ **(1)**

= 71 **(1)**

Any unit **max 1**

2nd *mark consequential on fraction provided 70, 72 and 74 used* 2

Accept answer ≥ 2 SF

Reject use of Ar ***(0 mark)***

Reject just "71" with no working ***(0 mark)***

(e) $\frac{4.73}{71}$ moles **(1)**

X 30.6 = 2.04 **dm^3** **(1)**

Answer with no working **1 max** 2

Accept consequential if wrong answer to (d) used.

Accept 71 used when (d) incorrect

Accept answer ≥ 2 SF

*Reject no or incorrect unit of volume (**loses 1 mark**)*

(f) Type – Metallic**(1)**

Attraction between **Mg^{2+}** **(1)**

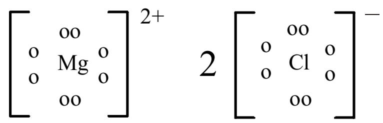
And (surrounding) sea of electrons/delocalised electrons **(1)**

Stand alone 3

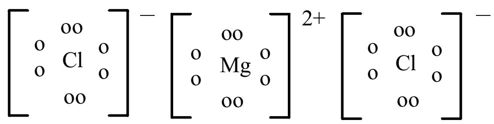
Accept cations/positive ions /magnesium ions

Reject atoms/nuclei/ions
"force between" if used instead of "attraction"

(g) Ionic **(1)**



OR



Correct charges and number of ions **(1)**
Correct electronic structures **(1)**
Stand alone 3

Accept diagram without brackets

Accept Mg with no electrons shown
ie $[Mg]^{2+}$

Reject any suggestion of electrons being shared

Reject $[Mg^{\bullet}]^{+}$

[17]

56. (a) (i) 23 + 3 × 14 = 65(g)
Ignore units e.g. g mol^{-1}, g/mol 1

(ii) 48 dm^3 = 2 moles **(1)**

allow TE from (a)(i)
allow 87 g/86.67 g

Reject 86 g
86.6 g
86.6666666 g

number of moles of NaN_3 = 2/3 × 2 = 4/3

mass = 4/3 × 65 = 86.7 g (1)
ALLOW 2,3 or 4 SF

*Accept correct answer with no working **(2)***

If 2 moles of N2 seen anywhere award 1st mark 2

(b) Formation of sodium which is reactive with water/air / oxygen **(1)**

Reject –1 if discuss poisonous flammability of N_2 as well as correct problems with sodium

to produce hydrogen which is flammable / NaOH which is corrosive **(1)**

Reject sodium is poisonous

Max 1 if only discuss sodium and air 2

[5]

57. (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)**

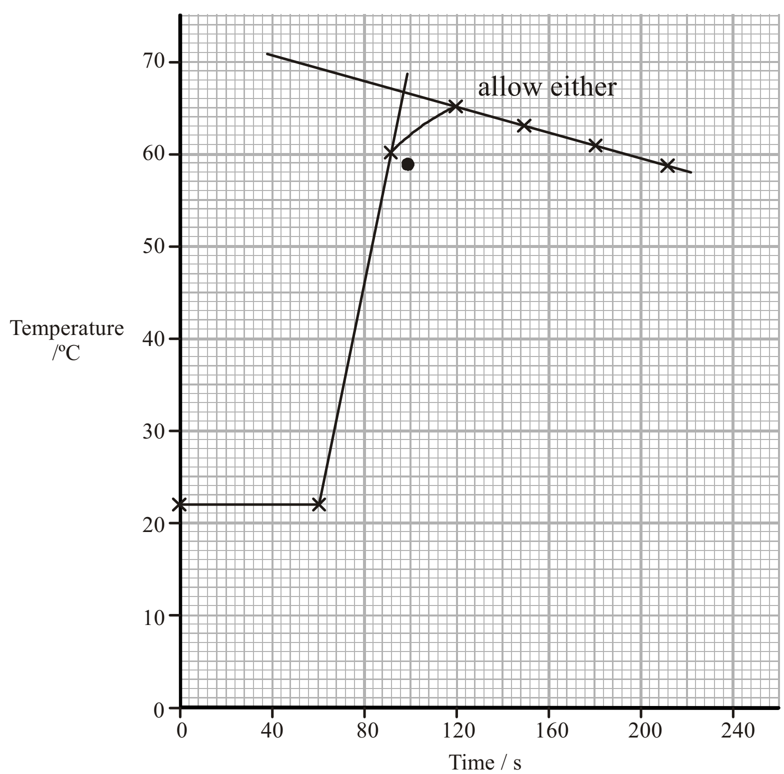
Copper sulphate / Cu^{2+} / CuSO4 **(1)**

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 × 4.2 × 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]

58. (a) $^{79}_{35}Br$: 44 neutrons **(1)**

$^{81}_{35}Br$: 35 protons **(1)**

$^{81}_{35}Br^-$: 36 electrons **(1)** 3

(b) Na $2s^2\ 2p^6\ 3s^1$ **(1)**

Br *$2s^2\ 2p^6$* $3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^5$ **(1)**

Ignore repeat of $1s^2$ 2

Allow subscripts and ignore capital letters

Allow $4s^2\ 3d^{10}\ 4p^5$

Allow p as pxpypz with 2 in each

(c) They have the same (number of protons and) electron(ic) configuration
Same (number of protons and)electronic structure
Same (number of protons and)electron arrangement
same (number of protons and)number of electrons
MUST MENTION ELECTRONS 1

Reject 'just' Same number of protons
Reject 'just' same number of electron shells
Reject same number of outer electrons
Reject same number of electrons in outer shell
Reject correct answer followed by reference to outer shell scores ***(0)***

(d) Mass spectrometer 1

Allow variations of spelling

Reject mass spec ***(1)***

(e) $\frac{(78.93\times 50.54)+(80.91\times 49.46)}{100}$ **(1)**
= 79.91**(1)**
2nd mark consequential on transcription error data used
Correct answer with no working scores 2
Answer to 4 S.F. with NO units but allow **g/mol** 2

(f) Between the atoms: Covalent **(1)**

*Between the molecules :*Induced dipole-(induced) dipole
OR dispersion OR London OR van der Waals OR
instantaneous OR Temp dipole – **(1) (forces)** 2

Accept variations on van der Waals such as de and walls, vdW

Reject dipole-dipole OR 'JUST' intermolecular forces

Reject ID–ID

[11]

59. (a) The number of atoms in 12g of ^{12}C **(2)**
The number of atoms in 1 mole of ^{12}C **(2)** 2

Accept number of atoms in 1 mole ***(1)*** *of atoms / stated monatomic substance* ***(1)***
OR Number of molecules in 1 mole ***(1)*** *of molecules / stated molecular substance* ***(1)***
OR Number of electrons in 1 mole ***(1)*** *of electrons* ***(1)***
OR Number of particles in 1 mole ***(1)*** *max*

If answer just quotes the number it does not score it is in the question.
Reject number of particles in 1 mole of a substance

(b) (i) 1.907 g of Z contains 2.87×10^{22}

Accept moles of Z = $2.87 \times 10^{22} / 6.02 \times 10^{23}$ = (0.04767) ***(1)***

$1.907 \times 6.02 \times 10^{23} / 2.87 \times 10^{22}$ is 1 mol **(1)**
= 40.(0) **(1)** No units but allow 40 g/mol
IGNORE s.f. in answer

Accept atomic mass = 1.907/moles = 40.(0) ***(1)***

Allow 39.7 for 2 marks this is rounding 0.04767 to 2 sig figs in calc
Allow 38.14 for 1 mark as this is rounding to 1 sig fig.
Correct answer with some working **(2)** 2

(ii) Ar / Argon
Consequential on (i) but must be nearest group 0 1

(c) (i) Amount hydrogen peroxide produced = $\frac{3.09}{34}$ = 0.09088 (moles) **(1)**
Amount of potassium superoxide = 0.09088×2 (moles) **(1)**

34g of H_2O_2 requires 2 × 71g of KO_2 ***(1)***

3.09g requires $\frac{2 \times 71 \times 3.09}{34}$ ***(1)*** *or* ***(2)*** *if this is start line*

= 12.9 g ***(1)***

If round 0.09088 to 0.09 can score ***2*** *for 12.78*

mass of potassium superoxide = $0.09088 \times 2 \times 71$
= 12.9g **(1)** / 13g
incl unit but ignore S.F. (note = 6.45 g scores 2 marks)

Correct answer with some working scores 3 marks 3

(ii) Volume of oxygen = $\frac{3.09 \times 24}{34}$ = 2.18 dm^3 **(1)** IGNORE s.f. &
do not penalise lack of units twice
Allow error carried forward. i.e if omit to ×2 in part (i)
only penalise it in part (i) not here 1

Accept 2.2

[9]

60. (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) $\frac{1.0}{21.5}$ × 100 = (±)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]

61. $[CH_3COOH] = \frac{1000}{25.0} \times 0.020 = 0.8(0)\ (mol\ dm^{-3})$

Accept correct answer with no working.

[1]

62. (a) $(1s^2)\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ ……….... **(1)**
……. $3d^8\ 4s^2$ / $4s^2\ 3d^8$ **(1)** 2

(b) Mr[Ni] = (58 × 0.6902) + (60 × 0.2732) + (62 × 0.0366)
Or correct fraction using percentages **(1)**

= 58.6928 (calculator value)
= 58.7 (3 s.f.) **(1)**
No 2nd mark if units given, e.g. g, % etc 2

Accept 58.6928 / 58.693 / 58.69
Mr[Ni] = 59, if working shown

Reject 60 /Incorrectly rounded answer, e.g. 58.692, 58.70, 58.6

(c) 5.9 g of nickel = $\frac{5.9}{59}$ = 0.10 (mol) **(1)**
From equation, 0.40 mol of CO required

Volume of CO = 0.40 × 24 = 9.6 dm^3 / 9600 cm^3 **(1)**
Correct units needed for 2nd mark, eg $dm^3\ mol^{-1}$/dm^{-3} **(0)**
Allow TE for 2nd mark, from wrong number of moles
(i.e. 4 × number of moles × 24 dm^3) 2

Allow full marks for answer based on A_r[Ni] calculated in (b)

(d) (i) $Ni + 2H^+ \rightarrow Ni^{2+} + H_2$
Ignore state symbols 1

Accept $Ni + 2H_3O^+ \rightarrow Ni^{2+} + 2H_2O + H_2$ **(1)**

(ii) **Stop marking when operation no longer "works", e.g. distil/add $CaSO_4$/boil solution to dryness**

Boil/heat (**NOT** warm) to drive off some of the water/to concentrate (not to dryness) **(1)**

leave/set aside for some time/overnight (to crystallise) / allow to cool (must be evident that some solution remains afterwards) **(1)**

Collect crystals by decantation/filtration/use of tweezers **(1)**

Dry crystals between (sheets of) filter paper (must imply an "active process" – leaving on filter paper isn't enough) / use of **warm** oven, not just "oven" **(1)**

4 key points → 3
3 key points → 2
2 key points → 1
1 or 0 key point → 0 3

(iv) Mr[$NiSO_4.7H_2O$]= 59 + 32 + 64 + (7 × 18)
= 281 (g mol^{-1}) **(1)**
2.95 g of Ni = $\frac{2.95}{59}$ = 0.050 mol
Mass of crystals formed = 0.050 × 281 = 14.1 **(g)** **(1)**
Ignore units, e.g. g mol^{-1}
Allow TE from incorrect M_r[$NiSO_4.7H_2O$], i.e. 0.05 × M_r
Allow full credit for answer based on accurate A_r[Ni], e.g. 58.7 2

Accept 14.05 g answer to between 2 and 4 sig. fig

[12]

63. (a) (i) $E[Ca(OH)_2] = 25.0 \times 4.2 \times 16.5 = 1730$ (J)
$E[CaO] = 25.0 \times 4.2 \times 25.5 = 2680$ (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]

64. (a) (i) Amount of $CO_2 = \frac{53}{24000}$
$= 0.0022$ (mol)

Accept 0.002 with working

Amount of $H_2O = \frac{0.020}{18}$
$= 0.0011$ (mol) — 3

Amount of C = 0.0022 mol = 0.0265(g)
Amount of H = 0.0022 mol = 0.0022(g)

Any one of above needed for 1st mark **(1)**

Mass of O in Z = 0.0714 (g)
OR amount of O in Z = 0.0045 (mol)
Some clear indication they have done it correctly **(1)**

Empirical formula CHO_2 **(1)**

(ii) $(CHO_2)_y = (12 + 1 + 2 \times 16)y = 90$
Y = 2
Molecular formula $C_2H_2O_4$
Allow TE from (i)
Allow $C_2H_2O_4$ with no working
Allow any indication they know how to do it
eg 'n × empirical mass = molar mass' — 1

Reject $C_4H_{10}O$ only (no connection with (i))

(iii) (0.01 mol **Z** contain $\frac{20.0 \times 1.00}{1000}$ =) 0.02 (mol) **(1)**

Accept formula alone for Z

CO_2H
|
CO_2H **(1)** — 2

Accept fully/partially displayed formula

(iv) **W** $CH_2{=}CH_2$ **(1)**
X CH_2BrCH_2Br **(1)**
Y CH_2OHCH_2OH **(1)**

Look out for TE and internal TE
Eg **W** CH_3CHCH_2
X $CH_3CHBrCH_3$
Y $CH_3CHOHCH_3$
is worth **1 max** 3

Accept full credit for consistent answers based on other gaseous alkenes eg $CH_3CHOHCH_2OH$ etc

(v) $C_{20}H_{42} \rightarrow C_{18}H_{38} + C_2H_4$ **(1)**
Allow $C_{17}H_{36} + C_3H_6$ OR $C_{16}H_{34} + C_4H_8$ 1

*Accept TE for **W***

Accept any balanced equation including ethane

(b) Potassium manganate((VII))/KMnO4 **(1)**
Sulphuric acid/H_2SO_4 consequential on potassium manganate **(1)**
ALLOW 'acidified potassium manganate((VII))' for both marks 2

Accept TE for W alkene and corresponding monohydric alcohol
1. H_2SO_4/sulphuric acid
2. H_2O/water

Reject other Roman numerals after managate

[12]

65. (a) (i) Copper
.......$3d^{10}4s^1$ 1

Accept subscripts/ignore capitals 4s inside 3d

Reject $3d^9 4s^2$

(ii) Bromide ion
.......$3d^{10}4s^24p^6$ 1

Accept subscript/ignore capitals 4s inside 3d

Reject 4p inside 3d

(b) The **average mass** (taking into account the abundance of each isotope) of the **atoms** (of that element) **(1)**

relative to 1/12th the (mass of a) carbon 12 atom
Or
relative to $^{12}C = 12$ (exactly) **(1)**
second mark stand alone 2

Accept weighted/mean in place of average

Atoms must be mentioned at least once to score ***(2)***

Accept average mass of a mole of atoms of an element relative to 1/12th mole of C^{12} / relative to one mole of $^{12}C = 12$ (exactly) ***(2)***

(c) $$\frac{[62.93 \times 69.17] + [64.93 \times 30.83]}{100}$$ **(1)**

= 63.55 **(1)**
must be to 2 decimal places

cq only on transcription error e.g. 69.71 provided answer to 2 d.p. 2

Accept 63.54 with some working scores ***(1)***

Correct answer alone scores ***(2***

Answer should have no unit, but allow unit of "g mol^{-1}" but ***not*** *"grams" or "g"*

(d) (i)

Cu	C	O	H
$\frac{57.5}{63.5}$	$\frac{5.40}{12}$	$\frac{36.2}{16}$	$\frac{0.900}{1}$
0.906	0.450	2.26	0.900
2.01	1	5.02	2.00

Use of atomic number scores ***0***

Empirical formula $Cu_2CO_5H_2$
(1) for dividing by atomic mass
(1) stating empirical formula 2

Correct answer without working scores ***(2)***

(ii) Empirical formula mass = 221 = M_r
Molecular formula $Cu_2CO_5H_2$

Must show use of 221 1

If use atomic number in (i) allow mark for Cu_2CO_5H and 220

Allow any formula that adds up to the correct molecular formula

(e) (Highest = $^{65}Cu + 2\ ^{37}Cl$) = 139 **(1)**
(Lowest = $^{63}Cu + 2\ ^{35}Cl$) = 133 **(1)**
Ignore units 2

[11]

66. (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 × 3 + 944/ (= 2252) **(1)**
Calculation of bonds made 388×6/ (= 2328) **(1)**
ΔH = –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]

67. (a) $Mg(s) + C(graphite) + 1\frac{1}{2}O_2(g)$ 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 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) $\Delta H = \dfrac{-1.05}{0.0262}$

$= -40.1\ kJ\ mol^{-1}$ 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)**
$= -453 - 680 + 40$
$= -1090\ kJ\ mol^{-1}$ **(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]

68. (i) Ignore sig figs unless they round to 1 sig.fig during calculation
Incorrect /absent units in final answer penalise only once in part (i)/(ii)

7.19 g of $PCl_5 = \dfrac{7.19}{208.5}$ mol **(1)**

*2 × 31 g of P produce 2 × 208.5 g of PCl_5 **(1)***

(= 0.03448)
(1 mol of PCl_5 from 1 mol of P)

Mass of P = 0.03448 × 31 = 1.07 g **(1)**

7.19 g of PCl_5 from $\dfrac{2\times 31\times 7.19}{2\times 208.5}$

*= 1.07g **(1)***

Penalise use of Atomic Number only once
Answer with no working scores 2 2

Allow 0.034 but NOT 0.035

(ii) Mark consequentially on part (i)

Moles of chlorine needed = 0.03448 × 2.5 **(1)**

Accept 2 × 208.5 g of PCl_5 produced from 5 × 24 dm^3 of Cl_2 ***(1)***

Volume = 24 × 0.03448 × 2.5 = 2.07 dm^3 **(1)**
Value **and** unit necessary

Value consequential on their calculated/stated moles of chorine × 24
Answer with no working scores 2 — 2

7.19 g PCl_5 produced from $\frac{5\times 24\times 7.19}{2\times 208.5}$ *= 2.07 dm^3* ***(1)***

Just 24 × 2.5 = 60 dm^3 scores zero

[4]

69. (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]

70. (i) 112 1

(ii) $$\frac{(188 \times 15.2) + (189 \times 17.4) + (190 \times 26.4) + (192 \times 41.0)}{100}$$ **(1)**

= 190.3 **(1)**

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

Accept 190.34/190.342 with no working = max 1

Reject 190
Reject 190.34
Reject 190.342

[3]

71. (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 × –285.8) – (–296.8 +(2 × –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]

72. (a) A 1

(b) B 1

[2]

73. (a) C 1

(b) D 1

(c) A 1

(d) D 1

[4]

74. (a) $CuCO_3(s) + H_2SO_4(aq) \rightarrow CO_2(g) + CuSO_4(aq) + H_2O(l)$ 1

(b) B 1

(c) (i) (0.025 × 123.5) × 1.1 = **(1)**

3.396/ 3.40 / 3.4g (g) **(1)**
OR
0.025 mol copper carbonate = 3.087/3.09 (g)**(1)**
3.087 +10% = 3.396/ 3.40/ 3.4 (g)

Full marks for correct answer with no working 2

(ii) No, as copper carbonate is in excess 1

Reject no, as molar mass is only to one decimal place

(d) Filter to remove excess copper carbonate 1

(e) (i) 249.6 1

(ii) Expected yield = 0.025 × 249.6 **(1)**
= 6.24g

% yield = (100 × 3.98/6.24)= 63.8/63.78% **(1)** 2

[9]

75. (a) QWC (i) **&** (iii)

(Lattice of) positively charged ions/ ions with 2+charge **(1)**

held together by (electrostatic) attraction to delocalised electrons **(1)**

Delocalised electrons /free electrons/ electrons in sea of electrons
are free to move and carry charge / current **(1)** 3

Reject incorrect use of the terms atom or molecule for ion.

Reject incorrect descriptions of delocalised electrons.

(b) (i) Mg^{2+} shown as 2,8 **(1)** 1

(ii) F^{-} shown as 2,8 **(1)** 1

(c) When molten/ when dissolved in water so that ions can move/
lattice breaks down **(1)** 1

Reject dissolved in other solvents.

Reject reference to atoms or molecules rather than ions.

(d) (i) 77% ^{24}Mg, 10% ^{25}Mg, 13% ^{26}Mg **(1)**

Average atomic mass

$$\frac{((77\times 24)+(10\times 25+13\times 26))}{100} = 24.36 = 24.4 \text{ g } \mathbf{(1)}$$ 2

(ii) Have same electron configuration 1

Reject same number of electrons in outer orbit

(e) (i) 1.20×10^{-9} mol of Mg per dm^3 **(1)**

$(1.20 \times 10^{-9} \times 24.3 \times 10^{-3}) =$

2.92×10^{-11} / 29.2×10^{-12} (g) **(1)**

max 1 for more/less than 3 significant figures eg 2.916 2

(ii) Hydrogen because it has the least number of electrons per atom 1

[12]

76. (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]

77. (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 °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]

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

$= -141.8 - (338.3 + 746 + 1958 + 2 \times 111.9 + 2 \times -342.6) = -141.8 - 2580.9$
$= -2722.7 = -2723\ (\text{kJ mol}^{-1})$ **(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]