1. (a) (i) **Atomic number:** number of protons (in the nucleus) **(1)**

Mass number: [Total/sum of the)numbers of protons plus/and neutrons **(1)**

2

(ii) Na^+ or $_{11}{}^{23}Na^+$ or a sodium ion 1

(b) (i) $(\,{}^{79}Br^{81}Br\,)^+$ or $(\,{}_{79}Br_{81}Br\,)^+$ 1

(ii) Some working or justification **(1)**

50:50 or equivalent **(1)** 2

e.g. Because the two peaks at 158 and 162 are the same height **(1)**

the relative abundance of each must be 50% **(1)**

(c) The heat /energy/ enthalpy change/ released per mole of electrons **(1)**
for addition to 1mol of gaseous(bromine) atoms **(1)**
$Br(g) + e^- \rightarrow Br^-(g)$ **(1)** 3

The word gaseous may be omitted provided the state symbol is present on both sides of the equation / vice versa

(d) (i) The heat /energy/ enthalpy change/needed per mol of electrons **(1)**
for removal from 1mol of gaseous(neon) atoms **(1)**
The equation is not asked for but can be used to score the second mark above.

2

$Ne(g) - e^- \rightarrow Ne^+(g)$

(ii) (The first ionisation energy increases as) the nuclear charge increases **(1)**
(Inner shell) shielding remains the same (as nuclear charge increases)/ electrons removed from same energy level/shell **(1)** 2

(iii) there is less inner shell shielding in Ne **(1)**
Although there is an increase in the nuclear charge from Ne to Ar **(1)** **OR**
atomic radius for Ne is smaller than for Ar/ the outer (2p) electron in Ne is closer to the nucleus than the (3p) electron in Ar **(1)** 2

[15]

2. (a)

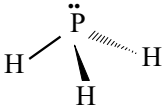
H	C
11.1 / 1	88.9 / 12 **(1)**
= 11.1	= 7.4
1.5	1 **(1)**

Empirical formula C_2H_3 **(1)** 3

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

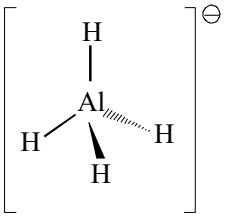
has greater induced–dipole–induced dipole / vdW forces **(1)** 2

(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

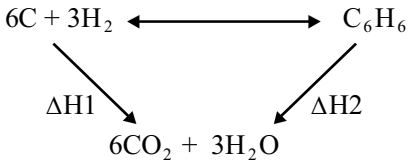
$= 2.0 \times 10^{20}$

[11]

3. (a) (i) The enthalpy / heat / heat energy change / released when 1 mol of benzene is formed **(1)** from its elements **(1)** under standard conditions 2

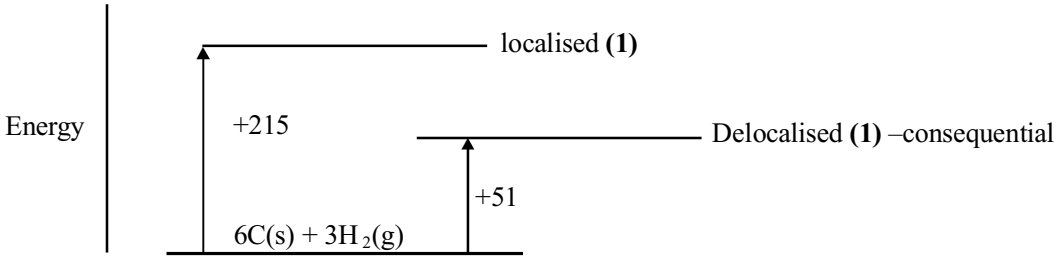
(ii) The enthalpy / heat / heat energy change when 1 mol of benzene burns **(1)** in excess oxygen / burns to form carbon dioxide plus water / is completely oxidized under standard conditions **(1)**
The second mark is not awarded if standard conditions are not mentioned in part (i) or (ii). 2

(b)



For correct cycle shown **(1)** or equivalent equations
$\Delta H1 = 6 \times (-394) + 3 \times (-286) = -3222$ kJ **(1)** for either showing calculation or answer
$\Delta Hf = -3222 - (-3273) = +51$ kJ mol^{-1} **(1)** 3

(c) Benzene has π electrons delocalised **(1)** Therefore bond energy NOT that of C–C or C=C



4

(d) (i) rate = k[benzene][bromine] 1

(ii) rate would be decreased **(1)**
E_a *of rate determining step* (or the idea of it) would be increased **(1)** 2

[14]

4. (a) (i) electron configuration or $3d^6 4s^2$ or $4s^2$
or number of outer electrons 1

(ii) 26 protons, 26 electrons, 30 neutrons
all 3 (2) any 2 **(1)** 2

(iii) atoms (of same element) with same number of
protons or same atomic number 1

different number of neutrons or mass number 1

(b) (i) A ionisation not vaporisation 1

B acceleration 1

C deflection 1

D detection 1

(ii) $\frac{(5.8 \times 54) + (91.6 \times 56) + (2.2 \times 57) + (0.33 \times 58)}{100}$ 1

= 55.87 1

[11]

5. (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]

6. (a) (i)
- Fast/high energy/fired/bombard/electrons (electron gun) strike sample atoms
- Knocking out/ remove electron from sample atom 2

(ii) Electric field/charged plates/negative plates 1

(b) (i) $^{65}Cu^{+}$ 1

(ii) (2)(different) isotopes 1

(iii) (63 × 69.1) + (65 × 30.9) divided by (69.1 + 30.9) **(1)**

= 63.6/63.62/63.618 **(1)** 2

[7]

7. (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 × 0.7860) + (25 × 0.1011) + (26 × 0. 1129) **(1)**
24.33 **(1)** 2

[7]

8. (a) (Heat) energy / enthalpy change needed/required per mole **(1)**
to remove an electron **(1)**
from an atom of magnesium in the gas phase **(1)**
For three marks to be awarded there must be some reference to magnesium in the written answer or in an equation. 3

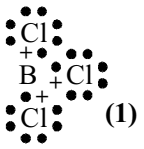
(b) (i) Two/big jumps show three/new/different shells present **(1)**
2 electrons with lowest I.E. in outer shell / first two electrons in outer shell / idea of order of removal **(1)**
then 8 then 2 / shows it is 2.8.2 **(1)**
Reference to s and p type electrons loses final mark because data does not show this.
The use of orbital/sub shell rather than shell should be penalised once only. 3

(c) (i) $1s^2 2s^2 2p^6 3s^2$ **(1)** 1

(ii) Same number of electrons (in all magnesium isotopes) **(1)**
outer electron structure determines chemical properties **(1)** 2

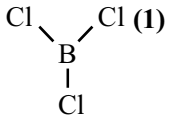
[9]

9. (a)



(1)

Must show all the outer electrons around the chlorine
Do not have to be • and + 1

(b) (i)  **(1)** 1

(ii) The (three) bonding (electron) pairs **(1)**
repel as far apart as possible / position of minimum repulsion **(1)** *not stand alone*
not just equal repulsion 2

(c) (i) Power (of an atom) to attract (the pair of) electrons **(1)**
in a covalent bond / bonding pair **(1)** 2

(ii) Bonds arranged symmetrically /molecule symmetrical /bond polarities directional/ are vectors **(1)**
Bond polarities cancel **(1)**
Could be shown as a diagram

Note:
The answer to (b) is consequential on the answer to (a) in the following situation
If the candidate puts a lone pair of electrons on the boron

- *the shape mark can be given for a clear, 3-D diagram of a molecule with the same shape as ammonia*
- *the explanation will need to refer to both bond and lone pairs of electrons* 2

[8]

10. (a) *Proton* + 1 **(1)**
Electron 1/1800 → 1/2000 or 'negligible' **(1)**
Neutron charge 0 / no charge **(1)** 3

Correct p n e in both C and H **(1)**
Notes there are 4 H **(1)**
Correct summation i.e 10p, 10e, 6n **(1)** 3
If no or inadequate working 1 mark for 10 p & 10 e
1 mark for 6 n.

(c) $(1s^2)\ 2s^2 2p^6 3s^2 3p^5$ **(1)** 1

(d) $^{37}Cl^+$
charge(stand alone) **(1)**
37 **(1)**
if incorrect number of protons / mass number
shown max 1 for charge 2

(e) (i) $S(g) + e^- \rightarrow S^-(g)$
species and charges **(1)**
state symbols in part (i) and (ii) equations **(1)** 2

(ii) $S(g) \rightarrow S^+(g) + e^-$
or
$S(g) - e^- \rightarrow S^+(g)$ **(1)**
Species and charge **(1)**
No need to show negative charge on electron.
If use 'X' in place of 'S' penalise once only 1

(f) Chlorine nucleus has greater charge / is more positive / has greater number of protons **(1)**
outer electron / electron being removed, is in same shell / has same shielding **(1)** 2

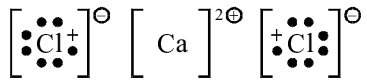
[14]

11. (a) (i) $(1s^2)2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^6$ **(1)** 1

(ii) 7 **(1)** 1

(b) (i) $Ca + Cl_2 \rightarrow CaCl_2$ **(1)** 1

(ii) Ionic **(1)** 1

(iii) 

- 1 mark for correct number of electrons on each ion **(1)**

1 mark for correct charges on each ion **(1)**
1 mark for correct ratio of ions **(1)** 3

[7]

12. (a) Protons 3 **(1)**
Neutrons 4 **(1)**
Electrons 2 **(1)** 3

(b) Relative atomic mass

$$= \frac{(6.02 \times 7.39) + (7.02 \times 92.61)}{100}$$ **(1)**

6.95 (must be three s.f.) **(1)** 2

(c)
- Dip Pt / nichrome wire in solid and place in hot/blue flame **(1)**
- Na salt gives yellow colour **(1)**

Li salt give deep / magenta red / crimson colour **(1)** 3

[8]

13. (a)
- Magnesium ions are arranged in a regular lattice **(1)**
- surrounded by a sea of / cloud of / delocalised electrons **(1)**

which can move through the solid when a potential is applied **(1)** 3

(b)
- At room temperature the ions are in a fixed position / in a lattice **(1)**
- as heat applied the ions vibrate more **(1)**

eventually ions have enough energy to overcome electrostatic attraction **(1)** 4
ions break free are able to move as solid melts **(1)**

(c)
- Solid has ions in fixed sites / cannot move **(1)**
- molten has ions free to move and carry current to electrodes **(1)** 2

[9]

14. (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]

15. (a) (i) $(46 \times 8 + 47 \times 7.3 + 48 \times 74 + 49 \times 5.5 + 50 \times 5.2) \div 100 = 47.926$

$= 47.9$

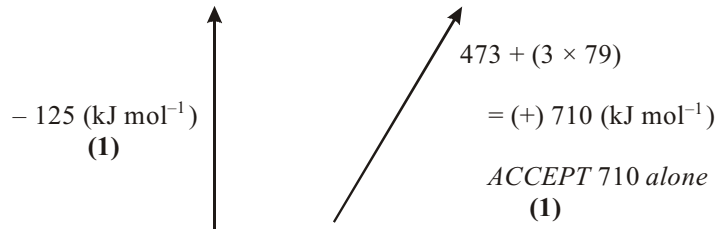
Method **(1)**
Correct answer to three significant figures **(1)** 2

	(ii)	mass spectrometer	1	
(b)	(i)	$1s^2\ 2s^2\ 2\ p^6\ 3s^2\ 3\ p^6$ **(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)	$940 - 2 \times 110 = +720$ 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]

16.	(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)**

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

Penalise 4 or more SF
Penalise incorrect units 2

[9]

17. (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]

18. (a) *Trend* - boiling point increases down the group / from He to Xe or Rn **(1)**
Reason – number of electrons (and protons) increases **(1)**
Increased strength of van der Waals'/ dispersion / London forces / temporary dipoles / induced dipoles / attraction between nucleus and electrons on other atom **(1)** 3

(b) (i) P or S or Cl / P_4, S_2, S_8, Cl_{12} / names 1

(ii)
- The atoms of silicon are held together by covalent bonds across the whole structure (1)
- High energy required (to break bonds) (1) consequential on indication of covalent. Mention of ionic or metallic or van der Waals' forces loses both marks. 2

(iii)
- 1. Magnesium ion has larger charge (density) than sodium / magnesium contributes two electrons per atom to the 'sea' of electrons. **(1)**
- 2. Hence magnesium (ions) have greater attraction for (sea of) electrons than sodium. **(1)**
- 3. Melting requires energy to overcome this attraction, hence greater attraction means higher melting temperature **(1)**
This mark is consequential upon the concept of metallic bonding. 3

[9]

19. (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]

20. (a) (i) $(1s^2)2s^22p^6$
OR $2s^22p_x{}^22p_y{}^22p_z{}^2$ 1

(ii) $2s^22p^63s^23p^63d^{10}4s^24p^6$ / $2s^22p^63s^23p^64s^23d^{10}4p^6$ 1

(b) Krypton because **greater/ stronger** (*NOT* **more**) van der Waals'/ London/ dispersion/ temporary or induced dipole forces / attractions **(1)**

Because of larger number of **electrons**/ extra shell(s) of electrons **(1)** 2

(c) (i) Sample bombarded/ fired at by electrons/ electron gun **(1)**

Knocks out/ loses/ removes electrons from the sample
Or equation **(1)** 2

(ii) Electric/electrostatic field/ (negatively) charged plates/ potential difference 1

(iii) Magnetic field/ (electro)magnet 1

[8]

21. (a) Weighted/ reference to abundance **average mass** of **atoms/ isotopes** (in sample) **(1)**

Relative to (mass of one atom of) ^{12}C **(1)** 2

(b) $^{19}_{9}F$
F and atomic no.9**(1)**
mass no.19 **(1)** 2

(c) Any (named) group 3 element **(1)** –

Big jump between 3rd and 4th I.E. /1st three electrons removed easily./
4th electron in lower energy level/ gained stable octet after $3e^-$ removed **(1)** 2

[6]

22. Si: giant molecular/ atomic/ structure
OR macro molecular/ atomic/ structure
OR Lattice
OR network
OR diagram with a minimum of 5 atoms shown with continuation **(1)**

P: **molecular** *OR* exists as P_4 **(1)**

Si: covalent bonds to break **(1)**

P: intermolecular forces/ van der Waals' forces between molecules to overcome **(1)**

Therefore more energy to separate silicon atoms **(1)** – *dependent on a reasonable explanation for Si and P* 5

[5]

23. (a) Diagram showing
Electrons 2,8 **(1)**
Charge 2+ **(1)** 2

(b) Energy/light/radiation
is emitted outside the visible spectrum/ in UV region
or frequency/wavelength/emission outside visible region. 1

24. (a) (i) Same numbers of protons/electrons **(1)**
Different numbers of neutrons **(1)** 2

(ii) $\mathbf{X} \times 69/100 + (100 - \mathbf{X}) \times 71/100$
$= 69.8$ Method **(1)**
$\therefore \mathbf{X} = 60\%$ Answer **(1)** 2

(b) (i) $Ga(g) - e^{(-)} \rightarrow Ga^{+}(g)$
Entities **(1)** 2
states **(1)**

(ii) As the ion becomes more positive it is harder to remove (negative) electrons / same nuclear charge attracting fewer electrons 1

(iii) An electron is removed from a lower/different quantum shell **(1)**
which is closer to the nucleus **(1)**
NOT shielding arguments 2

(c) (i) $GaCl_3$ / Ga_2Cl_6 1

(ii) Conductivity measurement / electrodes and simple circuit / electrolyse solution **(1)**
(High) reading for electrical conductivity / bulb lights/ high meter reading/ Cl_2 formed **(1)**
Microscope slide, filter paper etc / U-tube method – provided detailed **1 max**
ALLOW $AgNO_3(aq)$ **(1)** white ppt **(1)** 2

[12]

25. (a) (i) Idea of **impact** with **energy**
fast electrons strike sample/ high energy/accelerated electrons /electrons fired at sample/ sample bombarded with /blasted with electrons from electron gun **(1)**
Removes an electron/ knock out electrons/ eqn $X \rightarrow \mathbf{X}^{+} + e^{-}$ **(1)** 2

(ii) magnetic field /magnet / electromagnet *NOT* charged plates
ALLOW magnetic plates 1

(b) $(60.4 \times 69) + (39.6 \times 71) / 60.4 + 39.6$ **(1)**
$= 69.8$ **(1)**
69.792 scores **1 (out of 2)** 2

(c) (i) B **(1)**
mass no. 10 **(1)**
OR
^{10}B / B ^{10} **(2)**
If + is added max **(1)** ie *for mass number* 2

(ii) $..2s^2 2p^1$ 1

(iii) BCl_3
If an equation for formation of BCl_3 is given, look for BCl_3 and ignore rest 1

[9]

26. (a) (i) *ALLOW 3 or 4 sig figs – penalise once only*
MUST be some working

moles P = 93/31 = 3.0 **(1)**
moles PCl_3 also = 3.0 **(1)**
mass $PCl_3 = 137.5 \times 3.0 = 412.5 / 413$ (g) **(1)**
OR alternative route
Max 2 *if wrong units* 3

(ii) moles $Cl_2 = 3/2 \times 3 = 4.5$ **(1)**
volume of $Cl_2 = 4.5 \times 24 = 108$ (dm^3) **(1)** - *consequential on 1st mark* 2

(iii) Cl_2 *with* ***attempt*** *at reason* **(1)**
because gains electrons / ox. no. becomes more negative / oxidation number decreases / $0 \rightarrow -1$
OR
P loses electrons / oxidation number increases / $0 \rightarrow +3$ **(1)** 2

(b) (i) Outer shell of P in a molecule **(1)**
Cl lone pairs / six more electrons around each Cl **(1)**
Lone *pair must be in the same space.* 2

(ii) Trigonal pyramidal diag. **(1)**

Must be some attempt to show 3-D. A poor diagram can be rescued by a correct name.

100 – 108° **(1)** NOT consequential 2

(c) Tetrahedral 1

[12]

27. (a) bonding: (giant) **covalent (1)**
Diag. shows at least 5 carbon atoms correctly joined **(1)**
plus a hexagonal ring **(1)**
Must NOT be graphite 3

(b) **ions** mobile(in molten) / can move **(1)** *NOT* "free" *on its own*
fixed positions in solid / cannot move **(1)**
Max 1 if only one ion mentioned eg Na^+ 2

[5]

28. (a) (i) energy/enthalpy/heat energy change per mole **(1)** *Change ≡ required*
for removal of one electron / to form singly positive charged ion **(1)**
from **gas atoms (1)**
Could get **2 marks** for $X(g) \rightarrow X^+(g) + e^-$ 3

(ii) increases *plus some attempt at an explanation* **(1)**
nucleus more positive / more protons/increased charge **(1)**
outer electrons in same shell / same shielding/electrons being lost
from the same shell
OR atoms smaller so greater attraction/need more energy to be removed **(1)**
"Decreases" **0 (out of 3)** 3

(b) (i) $N^-(g) + e^{(-)} \rightarrow N^{2-}(g)$
species **(1)**
both state symbols **(1)** 2

(ii) (energy needed to overcome) repulsion **(1)** – *must relate to negatively charged species.*

between electron and negative ion **(1)**
ACCEPT "negative particles" if eqn in (i) correct
If "repulsion between electrons coming in and those already there"
ALLOW 1st mark 2

[10]

29. 160 1

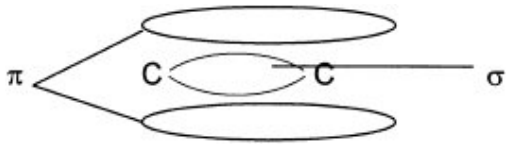
[1]

30. $1s^2 2s^2 2p^6 3s^2$ 1

31. (a) (i) $C_2H_6(g)/(I) \rightarrow C_2H_4(g) + H_2(g)$
If a state symbol is missing **(0)**
If (aq) **(0)** 1

(ii) At high pressure reaction goes in direction to reduce pressure/to oppose change by Le Chatelier's principle **(1)**
towards side with fewer molecules/moles **(1)** 2

(b) Shapes of orbitals between and above carbon



If p orbitals drawn msut show overlapping

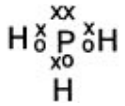
Shapes **(1)** ACCEPT crescents for π bonds NOT lines for σ bond 2
Labels **(1)**

(c) Addition of bromine **water/solution (1)**
from yellow/brown/orange to **colourless (1)**
OR
acidified potassium manganate(VII) **(1)**
from pink/purple to **colourless (1)** 2

(d) Addition **(1)**
Elecrophilic/electrophile *OR* appropriate *explanation* **(1)** 2

[9]

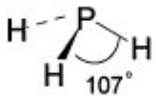
32. (a) (i)



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) (i) The mass of an atom (of the isotope) **(1)** – NOT average mass….
relative to 1/12th the mass of a ^{12}C atom
OR
relative to $^{12}C = 12$ **(1)** – *stand alone mark*
An answer all in moles can get 2 marks
Atom need only be mentioned once. If not mentioned **1 (out of 2)** 2

(ii) Both have 35 protons **(1)**
^{79}Br has 44 neutrons **(1)**
^{81}Br has 46 neutrons **(1)** 3

(b) (^{79}Br–$^{79}Br)^+$ **(1)**
(^{79}Br–$^{81}Br)^+$ **(1)**
(^{81}Br–$^{81}Br)^+$ **(1)**
–1 for no charge then check the rest
If give ^{79}Br + ^{79}Br etc with or without charge **1 (out of 3)**
79 + 79…all three must be given **1 (out of 3)** 3

[8]

34. (a) Al atom is ($1s^2$) $2s^2$ $2p^6$ $3s^2$ $3p^1$ **(1)**
Al^{3+} ion is ($1s^2$) $2s^2$ $2p^6$ **(1)** 2

(b) The structure is a regular array / lattice of positive ions **(1)** *NOT* nuclei surrounded by delocalised/ 'a sea of' electrons **(1)**
1st two marks can be on a diagram
(It conducts electricity) because the electrons are mobile. **(1)** 3

(c) (i) Energy/enthalpy change per mole **(1)**
For $E(g) \rightarrow E^{+}(g) + e^{(-)}$ **(2)**
OR equivalent in words 3

(ii) In aluminium the outer electron is in the (3)p orbital whereas in magnesium it is in the (3)s orbital **(1)** – *comparison between p and s required*

so aluminium's outer electron is in a higher energy (level)
OR
the (3)p electron is **more** shielded (and so less energy is needed to remove it.) **(1)** 2

[10]

35. (a) (i)  *OR all dots/crosses*

shared pair **(1)**
correct outer shell **(1)** – *consequential on 1st mark* 2

(ii) Because HI has more electrons **(1)** *NOT* iodine/iodide
NOT because atoms are bigger/heavier
it has stronger/larger **induced** dipole / vdW / London / dispersion forces **(1)**
more energy is required to separate the molecules/break/overcome vdW forces **(1)** 3

(b) (i) $HI + H_2O \rightarrow H_3O^+ + I^-$
IGNORE state symbols
NOT $HI \rightarrow H^+(aq) + I^-(aq)$ 1

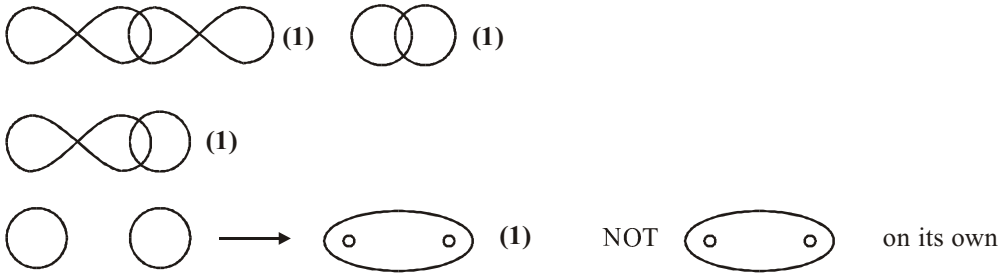
(ii) It forms (hydrated) hydrogen/hydroxonium ions
Any reference to H^+ will suffice
NOT proton donor 1

(c) (i) $CaO(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l)$
equation **(1)**
state symbols *consequential on correct equation* **(1)** 2

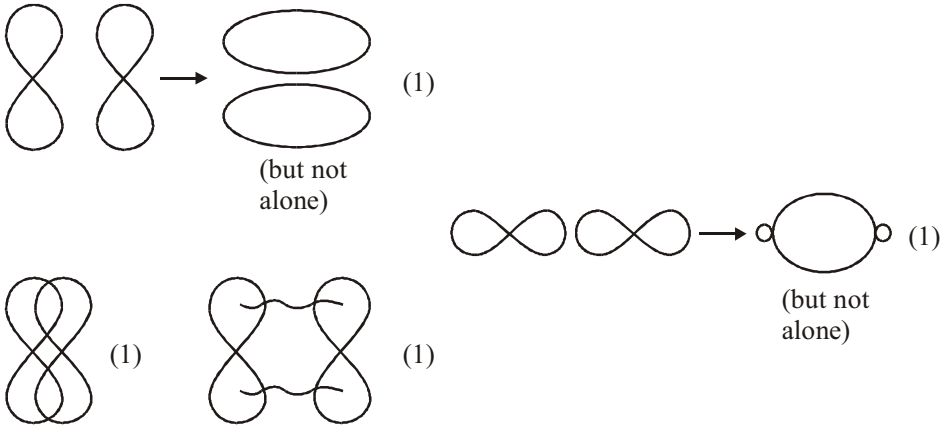
(ii) Because the surface of the calcium oxide gets coated with **insoluble**/sparingly soluble / impermeable calcium sulphate
"A protective layer of …. ≡ impermeable <u>and</u> coated 1

[10]

36. (a) <u>σ bond:</u>
diagram showing the head on overlap between two (s or p or s & p) orbitals **(1)**,



<u>π bond:</u>
diagram showing the side by side overlap of two (p) orbitals **(1)**



2

(b) (i) Methane is tetrahedral **(1)** – *stated or drawn 3D*
It has **4 pairs** of electrons **(1)**
Which repel to a position of maximum separation / minimum repulsion could be awarded from (ii) **(1)** – *can score even if first two are wrong*
Do not allow atoms or bonds repelling 3

(ii) Shape of CO_2 is linear **(1)** – *can be a diagram*
1st mark is stand alone

because there are 2 pairs of σ electrons / 2 sets of bonding electrons / 2 areas of negative charge/2 double bonds **(1)** 2

[7]

37. Too many electrons)
No electrons between the positive ions) *Any two*
Positive ions touching / should have gaps)

Check words like ion / molecule / atom / electron / are correctly used to award full marks 2

[2]

38. (a) $Mg + ½ O_2 \rightarrow MgO$ 1
IGNORE state symbols
ALLOW multiples

(b) Correct number of electrons on both ions (must include inner shell) **(1)**
Drawn or "2,8"

Correct charges on each ion **(1)**
Free standing marks

ACCEPT all dots/ crosses or combination 2

Max 1 if elements not identified

(c) (Electrostatic) **attraction** between **positive ions** and electrons **(1)**
Symbol with correct charge can be specified
NOT nuclei/ protons for positive ions
NOT held together for attraction

Electrons delocalised / sea of electrons free moving **(1)**

are mobile / can move / flow (under a potential difference) **(1)**
NOT "free" *on its own*
NOT carry the charge **(1)** 3

[6]

39. (a) (i) $(1s^2)2s^22p^63s^23p^64s^2$
OR
$(1s^2)2s^22p^63s^23p^63d^04s^2$
OR
$(1s^2)2s^22p^63s^23p^64s^23d^0$
ALLOW subscript numbers in place of superscripts

$2p^6 \equiv 2p_x^2 2p_y^2 2p_z^2$ numbers must be superscript
$3p^6 \equiv 3p_x^2 3p_y^2 3p_z^2$ *numbers must be superscript*
IGNORE caps 1

(b) (i) Energy/ enthalpy / heat energy change / required per **mole (1)**
NOT evolved
for the **removal of 1 electron (1)**
from **gaseous atoms** *NOT* molecules **(1)**
OR
$X(g) \rightarrow X^+(g) + e^-$ *states required for 2nd and 3rd marks* **(2)**
Can be actual symbol of an element
ACCEPT - $e^{(-)}$ 3

(ii) (Even though) there is a greater nuclear charge / number of protons
OR nuclear charge increases down the group **(1)**
outer / **valency** electron(s) further from nucleus *NOT* "shell" *on its own* **(1)**
and **more** shielded *OR* **more** (filled) inner shells/electrons **(1)** 3

(c) (i) Similarity: number of protons (proton number) **(1)**
IGNORE electrons
NOT atomic number

Difference: number of neutrons
[correct numbers can be given]
NOT atomic mass or number of nucleons **(1)** 2

(ii) $\frac{(24\times 78.6)+(25\times 10.1)+(26\times 11.3)}{100} = 24.3$

Method **(1)**

Answer must be to 3 SF **(1)**

Correct answer to 3 SF with some working **(2)**

IGNORE g or g mol^{-1} *other wrong units lose a mark* 2

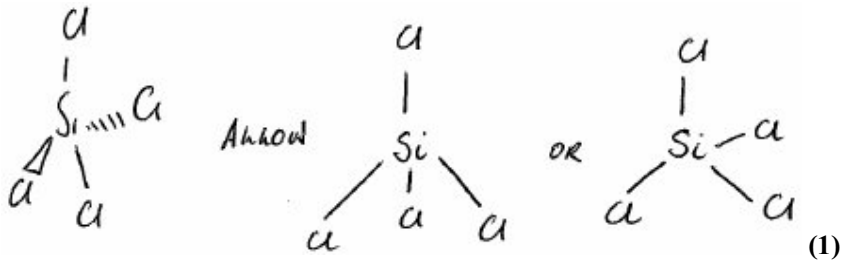
[11]

40. (a) (i) moles silicon = 10/28 = 0.357 **(1)**
moles $SiCl_4$ = 0.357 **(1)**
mass = 0.357 × 170 = 60.7 / 60.69 (g) *ALLOW 2- 4 SF* **(1)**
OR by mass ratio
Units not required but if given must be correct.
Correct answer with some recognisable working **(3)**
Correct answer with no working **(1)** 3

(ii) moles chlorine = 2 × 0.357 moles Si × 2 **(1)** **(1)**
∴ vol = 0.714 × 24.0 = 17.1 (dm^3) moles Cl_2 × 24 **(1)** **(1)**
ALLOW TE from (i)
ALLOW 2 – 4 SF
Units not required, but if given must be correct
Correct answer with some recognisable working **(2)**
Correct answer with no working **(1)**
Penalise SF once only across (i) and (ii) 2
Penalise units once across (i) and (ii)

ratio	10/28	10/28 = 0.357	10/28 = 0.36	10/28 = 0.4 loses SF mark
mass	60.69	60.71	61.2	68
vol	17.14	17.14	17.3	19.2

(b)



(1)

*Wedges **not** required e.g.*
Atoms can be represented by circles etc provided there are 4 of one type and 1 of another

tetrahedral **(1)**

Any angle in range 109 – 109.5 ° **(1)**
degree symbol can be shown on diagram **(1)**

4 (bond) pairs of electrons / 4 bonding pairs **(1)**
NOT bonds
NOT atoms
NOT groups of electrons

Repel to position of **minimum** repulsion / **potential energy** *NOT* "Equal repulsion" **(1)**
OR Repel to position of **maximum** separation 5

4th mark cannot be awarded if atoms referred to

(c) (i) Si and Cl have different electronegativities / Cl attracts the **bonding electrons** very / more strongly / Si less electronegative than Cl / Cl **very** electronegative 1

(ii) symmetrical molecule / chlorines equally spaced **(1)**
bond polarities / dipoles / vectors cancel
OR
Centres of positive and negative charge coincide / vectors cancel. **(1)** 2

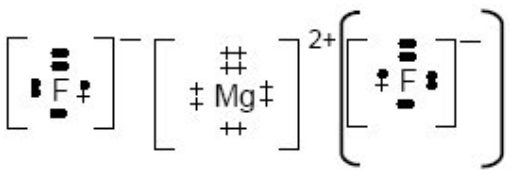
[13]

41. (a) (i) $Mg^{+}(g) \rightarrow Mg^{2+}(g) + e^{(-)}((g))$ / $Mg^{+}(g) - e^{(-)}((g)) \rightarrow Mg^{2+}(g)$

Equation **(1)**
State symbols **(1)**
2nd mark dependent on 1st except
– e on wrong side OR
– 1st or 3rd ionisation energy equation quoted OR
– cumulative 1st and 2nd ionisation energy quoted 2

(ii) B / b – *can be shown on graph* 1

(b)



Dots and crosses **(1)** – *all dots/ crosses acceptable*
Ensure that <u>all</u> electrons are being shown

Charges **(1)** – *2nd mark independent of 1st*

2nd F^- ion and square brackets <u>not</u> essential
ALLOW "Fl" for "F"
If one of the ions is completely correct (electrons & charge) **1 (out of 2)** 2

[5]

42. (a) (i) Protons = 19 **<u>and</u>** electrons = 19 **(1)**

neutrons = 20 **(1)**

ACCEPT as words or numbers 2

(ii) $1s^2 2s^2 2p^6 3s^2 3p^6 (3d^0) 4s^1$
ALLOW subscripts
MUST be in this order 1

(b) (i) $MnO_4^{(1)\ -}$ 1

(ii) **Purple /violet / mauve / lilac / pink** colour has moved towards/ is at the positive / left-hand electrode / anode
If purple colour associated with K^+ **(0)** 1

(iii) **Blue** colour moves towards the negative / right-hand electrode /cathode **(1)**
The Cu^{2+}/positive copper ion (is blue) (and is attracted to it) **(1)**
ALLOW:
Red/brown **deposit** forms on cathode **(1)**
$Cu^{2+} + 2e^{(-)}$ Cu or in words **(1)**
OR
Effervescence at anode **(1)**
$4OH^- - 4e^{(-)}\ 2H_2O + O_2$, *or in words* **(1)** 2

[7]

43. (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]

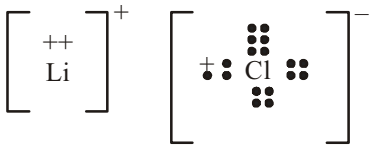
44. (a) Number of moles / $\frac{3.5}{7} = 0.50$ / ½ **(1)**

If candidate does first part only, working must be shown

Number of atoms = 3.01×10^{23} **(1)**
ACCEPT 3.0 *OR* 3 *OR* $3.010(\times 10^{23})$
NOT 3.01^{23}

If all working shown, allow TE for 2nd mark Ignore units
Correct answer with no working (2**)** 2

(b) (i) $2Li((s)) + 2H^{+}((aq)) \rightarrow 2Li^{+}((aq)) + H_2((g))$
ALLOW multiples Ignore state symbols 1

(ii) 

(1) **(1)**

Allow all dots or all crosses on Cl^-
Max 1 if no/wrong charges
If covalent (0)
Do NOT penalise if electrons not shown in pairs
Maximum 1 if Li and Cl not labelled
Li and Cl symbols can go below diagram
Square brackets not essential
Allow number of protons/positive charges in nucleus as alternative to symbols for Li and Cl 2

(iii) Any two from:

Temp 298 K/ 25 °C *OR* "at a specified temperature"
Unit of temperature needed
NOT "room temperature"

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

Pressure 1 atm / 10^5 Pa / 1.01×10^5 Pa/10^2 k Pa /
101 k Pa/10^5 N m^{-2} / 76 cm Hg
NOT "pressure of hydrogen" OR "pressure of reactants"
NOT atmospheric pressure

Must be the most stable/usual/normal physical states
NOT "standard states"
If more than 2 conditions given, deduct 1 mark for each incorrect answer 2

[7]

45. (a) 2

Protons	18
Electrons	18
Neutrons	22

(1)

(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

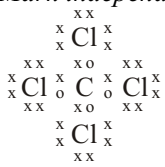
(f) Argon inert / unreactive so filament can't react/ vaporises less easily/ lasts longer **(1)** 1

[14]

46. (a) $..2s^2 2p^2$ *OR* $1s^2 2s^2 2p^2$ *OR* $(1s^2)2s^2 2p_x^{\ 1} 2p_y^{\ 1}$
ALLOW capitals and subscripts 1

(b) large gap/jump between 4^{th} and 5^{th} ionisation energies (so fifth in inner shell) 1

(c) 4 pairs of electrons around C atom **(1)**
all lone pairs shown **(1)**
Mark independently



ALLOW all dots/crosses 2
*Any attempt at an ionic diagram **(0)***

(d) (i) High energy/fast/gun electrons hit/strike
OR bombarded by electrons **(1)**

Removes/knocks out electron **(1)** 2
OR equation eg $X \rightarrow X^+ + e^{(-)}$ *IGNORE state symbols*
If knock out is mentioned, hit/strike is not required in 1st mark

(ii) magnetic field/magnet/electromagnet/magnetic plates 1

(e) (i) mass of one **atom** (of the isotope) **(1)**
relative to $1/12^{th}$ of the mass of **(1)**
a carbon -12 **atom (1)**

OR 2nd and 3rd marks can be awarded as follows:
On a scale where a ^{12}C atom **(1)**
has a mass of 12 (*NOT* grams) **(1)**

Word "atom" need only be mentioned once
Word "mass" need only be mentioned once
If define R.A.M……**max1** 3

(ii) 162 *IGNORE* units 1

(iii) (atoms with) same no. of protons **(1)**
NOT same atomic number

"different number of electrons" loses 1st mark but IGNORE "same number of electrons"

different number of neutrons **(1)**
NOT different mass number 2

Penalise incorrect reference to number of electrons

(iv) same number of electrons *IGNORE* "same number of protons"

OR same electronic configuration/pattern/structure
NOT same number in outer orbit 1

[14]

47. (a) (i) Covalent 1

(ii) 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

(iii) polymer has stronger/more vdw/intermolecular forces **(1)**
ALLOW dipole forces
because it has more electrons/larger electron cloud/more contact area **(1)**
NOT larger molecules/surface area

so more energy/heat needed to overcome/break these forces
OR so more energy/heat needed to separate these molecules **(1)**
NOT breaking **bonds** 3
3rd mark is NOT stand alone

(b) **strong** attraction between Mg **ions**/Mg^{2+}/cations/metal ions **(1)**
NOT electrostatic forces/metallic bonds

and **delocalised/sea** of electrons **(1)**
Mark independently 2

[7]

48. (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 $I_2 = 0.1 \times 254 = 25.4$ (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 = $0.1 \times 24 = 2.4$ (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* $\frac{1}{2}I_2$ **(0)** 2

[12]

49. (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 $^{(\circ)}$ **(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 $^{(\circ)}$ 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 $\mathbf{PCl_5}$ **(1)**

Use of atomic number **max 1** 2

[11]

50. (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]

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

½ H_2(g) + ½ O_2(g) + ½ Cl_2(g) in lower box
Brackets around the state symbols are not required 1

(ii) 589 – 667 = **–78** (kJ mol^{-1})
ALLOW final answer on its own 1

(iii) 667 – 464 = (+)**203** ($kJmol^{-1}$)
ALLOW final answer on its own 1

(b) (i)

ALLOW all dots/crosses
*ALLOW **1 max** if electrons are correct but atoms are not identified*
*If ionic dot and cross diagram **(0)*** 2

(ii) 100 – 106° **(1)**

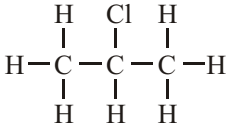
as lone / non-bonding pairs take up **more** space/
repel **more strongly** than bonded pairs **(1)**
NOT bonds being repelled/H and Cl being repelled 2

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

as number of **gaseous** reactant molecules = number of **gaseous** product molecules **(1)**
*ALLOW **1 max** if candidates state or imply a very small change with correct justification*
eg "hardly changes"
"doesn't change much"
"very little effect/change" 2

[9]

52. (a) (i) 2(-)chloropropane

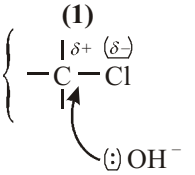


No internal TE from name to structure

MUST be fully displayed 2

(ii)

(1)

IGNORE rest of molecule 

(1)

Mark independently
Must attack the carbon
ALLOW attack by oxygen or negative charge or lone pair 2

NOT C^+

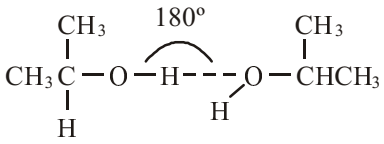
(b) (i) Elimination
NOT in conjunction with additional incorrect information
eg "nucleophile" 1

(ii) Sodium hydroxide / NaOH/potassium hydroxide / KOH **(1)**
Any additional incorrect reagent ***(0)***
NOT alkali on its own for 1st mark

Alcoholic solution / ethanolic solution **and** heat / warm / reflux **(1)**
2nd mark is dependent on mention of correct reagent or "alkali"
"aqueous" negates 2nd mark eg KOH(aq) + heat **(1)** – *ie reagent mark*
NaOH(alc) + heat **(2)** 2

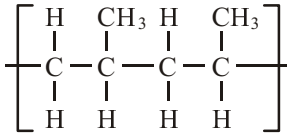
(c) (i) Hydrogen/H bonding 1

(ii)



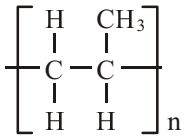
H-bond and rest of molecule ***(1)***
angle must be between 3 atoms for a correct H bond ***(1)***
ALLOW HOH 106-108° 2

(d) (i)



IGNORE any "n" in this diagram

Brackets optional but continuation must be shown
4 carbon chain with 6Cs overall in structure **(1)**
methyl groups can be on C_1 and C_3, C_1 and C_4, C_2 and C_4, C_2 and C_3 **(1)**



1 max 2

(ii) (big molecule) so large number of electrons **(1)**

Hence **large/strong van der Waals'** forces
(to be overcome to change state)**(1)** 2

[14]

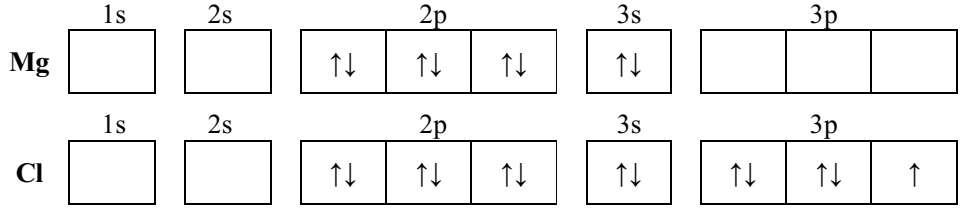
53. (a)

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

1 mark each number 3

Accept words or numbers

(b)



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)**

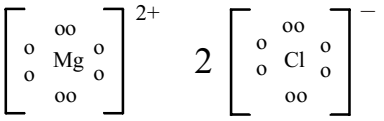
And (surrounding) sea of electrons/delocalised electrons **(1)**

Stand alone 3

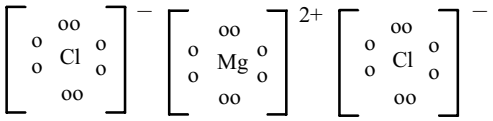
Accept cations/positive ions /magnesium ions

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]

54. (a) ***Penalise lack of nucleus/atom once only in (i) and (ii)***
Penalise use of element each time it occurs

(i) The number of protons in the nucleus of an atom (of an element)
OR
The number of protons in an atom/nucleus (of an element) 1

Reject the number of protons in an ***element***

Reject the number of protons

(ii) The number of protons plus the number of neutrons in the nucleus (of an atom)
OR
number of nucleons (in the nucleus of an atom) 1

Accept "and neutrons" instead of "plus the number of……"

Reject the number of protons plus neutrons in an ***element***

(b) (i) C **and** L **(1)**

(Group 0 elements) have the **highest** (first) ionisation energy (of each period) **(1)**

Accept implied e.g. ***immediately*** *precedes* ***large*** *drop*

Reject high first I.E.

Stand alone 2

Accept group 0 elements have the highest peaks on the graph

Accept highest (effective) nuclear charge/highest number of protons ***in period***

Reject filled shell

Reject smallest atom

Reject same shielding

(ii) F **(1)**

Third after noble gas/C **(1)**

Or
first element **in period** with p electron **(1)** 2

Accept first mini dip after big drop

Accept lowest after Group 1/D in ***same period (1)***

Accept (in F, e^- *removed from) p orbital is at a higher energy level than s orbital (in E)*

Reject just "electron in p orbital"

Reject just "s orbitals shield p"

(iii) Increase in (effective) nuclear charge **(1)**

Same shielding
OR same number of electrons in inner shell/orbitals **(1)**

Stand alone 2

Accept number of protons/atomic number

Reject same distance from nucleus

Reject increased ***size*** *of nucleus*

Reject same number of shells

Reject electrons in same shell

[8]

55. (a) (i) Minimum of one shaded blob **and** one clear blob labelled **(1)**
Labels are:
Na^+ or sodium ion **and** Cl^- or chlor**ide** ion 1

Reject Na and Cl
(ie no charge)

*Reject sodium / chlor**ine***

(ii) Strong (force of) **attraction** between (oppositely charged) ions **(1)**

Accept held together by strong ionic forces/bonds

Accept "attraction" may be implied by "breaking bonds"

a lot of energy needed to separate ions **(1)** 2

Accept a lot of energy implies "strong"

Accept break ionic bonds

Accept break lattice

Reject any reference to atoms
or molecules
Or covalent bonds
Or intermolecular forces
Or metallic bonds
(scores zero)

Reject all the bonds need to be broken

(b) Covalent between carbon atoms in plane **(1)**

Van der Waals' between planes of carbon atoms **(1)** 2

Accept induced dipole/ dispersion/ London forces/temporary dipoles

Names not linked to bonds **(max 1)**

Reject giant covalent delocalised e–

(c) Covalent

Label not needed 1

*Reject giant covalent BUT do **not** penalise twice*

(d) Covalent bonds in diamond are shorter than the distance between layers in graphite **(1)**

The atoms in diamond are packed closer together **(1)** 2

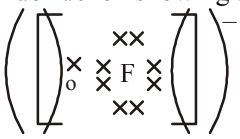
*Accept layers in graphite are far apart **(1)***

[8]

56. (a) SrF_2 **(1)** 1

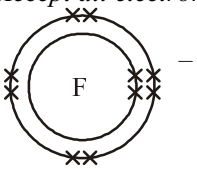
Reject SRF_2

(b) fluoride ion showing all 10 electrons and a single negative charge



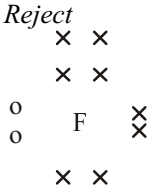
1

Accept all electrons can be the same



Can show rings
ALLOW Fl for F

Reject



[2]

57. (a) Isotope(s) 1

(b) 40 1

(c) (i) mass spectrometer 1

Accept mass spectrometry

(ii) $(60.2 \times 69 + 39.8 \times 71) \div 100$ **(1)**
$= 69.796 = 69.8$ **(1)**
must be 3sf 2

Accept correct answer with no working (2)
Allow g or g mol^{-1} or g/mol

Reject 1, 2, 4 or 5sf
Units of % (–1 mark)

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

Accept capitals/ subscripts/ any order

(ii) $Ga(g) \rightarrow Ga^{+}(g) + e^{(-)}$ ((g))
or $Ga(g) - e^{(-)}$ ((g)) $\rightarrow Ga^{+}(g)$

Mark independently
formulae **(1)**
state symbols **(1)** 2

Accept $Ga^{1+}(g) + e^{(-)}$

Reject (s) is wrong – take care to distinguish from (g)

(iii) B 1

Accept 579,1979,2963, 6200

[10]

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. Ionic / electrovalent **(1)**

$[Na]^+[:\underset{\cdot\cdot}{\overset{\cdot\cdot}{Br}}:]^-$ OR $[:\overset{\cdot\cdot}{Na}:]^+[:\underset{\cdot\cdot}{\overset{\cdot\cdot}{Br}}:]^-$

1 mark for correct charges

1 mark for electrons

Penalise wrong symbol only once

Allow dots or crosses

If choose to give inner shell electrons they must be correct

Accept charge could be on central atom e.g. Na^+

[ ] not necessary

If charges omitted can score electrons mark provided not covalent i.e. sig gap between Na & Br

Arrow to show transfer of an electron on its own does not score as this does not answer the question

*Anything that looks covalent **scores zero.***

[3]

60. (a) (i) Enthalpy/heat/ energy required/change to **remove** 1 electron **(1)**
from each of **one mole (1)**
of **gaseous atoms** (of an element) **(1)**
Ignore references to gaseous electrons 3

Accept $X(g) \rightarrow X^{+}(g) + e$

2 marks for the change and the state but not the mol

Accept isolated atoms in place of gaseous

If incorrect equation given after correct def – 1 mark

(ii) $O^{+}(g) \rightarrow O^{2+}(g) + e^{(-)}$
Or
$O^{+}(g) - e^{(-)} \rightarrow O^{2+}(g)$
State symbols required 1

Reject E (for element) in place of O

(b) (i) There is a **large** increase after the removal of 6 electrons **(1)**

*Accept **large** increase before removal of 7th electron*

Accept (big) jump between 6 and 7

(Group) 6 **(1)** Stand alone

(Need to look at diagram for annotation) 2

(ii) Sulphur / S / S_8

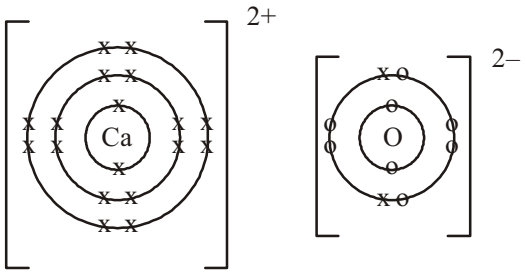
Not CQ 1

(c) S_8^{+}
1 mark 'S_8'
1 mark '$^{+}$' Stand alone 2

Accept $^{32}S_8^{+}$

[9]

61.



Brackets not essential
Electrons correct for both ions **(1)**
Charges (allow 2+ or +2 and 2– or –2) **(1)**

Accept electrons can all be dots and/or crosses

*Accept either ion completely correct (i.e. electrons and charge) **(1)***

Charges can be shown outside structure, or inside against symbol

[2]

62. (a)

	Protons	Electrons
H^-	1	2
Li^+	3	2

1 mark per row **(2)**
Allow **(1)** for correct electrons column 2

(b) H^- is larger **(0)**
Same number of electrons for each ion ……. **(1)**
H^- has only 1 proton to hold them in place, whereas Li^+ has 3 protons to pull them in more tightly **(1)**
"nuclear charge" can be used instead of "protons"

3 points to consider: –1 per error, or omission, from total of 2
H^- has a lower proton: electron ratio than Li^+ **(1 max)**
H^- has fewer protons than electrons, whereas Li^+ has more protons than electrons **(1 max)**
2 correct key points, but Li^+ larger **(1 max)**

Allow TE from (a) if, and only if protons for Li^+ > protons for H^- **and** number of electrons are the same for each ion 2

*Accept H^- is smaller, based on 0 for the electrons in table (i.e. misread as H^+) plus justification **(1 max)***

[4]

63. (a) Group 1 / alkali metals **(1)**
(Relatively) large "jump" / gap / difference between Em_1 and Em_2 **(1)**

2nd mark dependent on 1st 2

Accept substantial drop for 1st ionisation energy from Q to R

(b) 6915–9000 (kJ mol^{-1}) (actual value: 7733 kJ mol^{-1}) **(1)**

500–730 (kJ mol^{-1}) (actual value: 578 kJ mol^{-1}) **(1)** 2

(c) **Q** must be a noble gas /in group 8/0, since **Q** and **R** have consecutive atomic numbers (and **R** is in group 1) 1

*Accept **Q** as it has a **very** high / the highest **first** ionisation energy **NOT** "high ionisation energies" (generally)*

(d) $R^{2+}(g) \rightarrow R^{3+}(g) + e(^{-})((g))$
symbols and charges **(1)**
state symbols **(1)**
[Mark independently] 2

Accept $R^{2+}(g) - e^{-} \rightarrow R^{3+}(g)$

(e) Outermost electron(s) for an atom of **X** is /are in a shell further from the nucleus / shell of higher energy than that of **R**. 1

Accept answer based on "better shielding" from inner electrons

[8]

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

Accept subscripts/ignore capitals 4s inside 3d

Reject $3d^{9}4s^{2}$

(ii) Bromide ion
…….$3d^{10}4s^{2}4p^{6}$ 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]

65. (a) Energy/Enthalpy/heat change **per mole** for the **(1)**

Accept "required" instead of "change"

Removal of **one electron** (per atom) **(1)**

From 1 mole of **gaseous atoms (1)**

If wrong equation given with a correct definition **(max 2)** 3

$X(g) \rightarrow X^+(g) + e^-$ can score last 2 marks

(b) Increase in shielding/screening **(1)**

Increase in nuclear charge/more protons/atomic number **(1)**

Increase in distance (of outermost electron)/larger atomic radius
OR
(increase in) shielding outweighs nuclear charge (increase) **(1)**

Accept electron at higher energy level

Ignore references to: effective nuclear charge OR nuclear attraction 3

(c) (i) Na:Mg:Al
metallic (structure)

Si
giant atomic (structure)

P:S:Cl:Ar
simple molecular
All three correct 1 mark 1

(ii) strong covalent bonds **(1)**

(throughout the lattice and lots of energy) need to
break **many** bonds **(1)** 2

(iii) Aluminium supplies more electrons (per atom)/Al ion is more highly charged/Al ion is smaller/ Al ion has a higher charge density **(1)**

Accept reverse for Na

The (attractive) forces between the aluminium ions and the electrons are stronger/require more energy to break than in the case of sodium. **(1)** 2

*Reject any reference to bonding **other than** metallic bond/ sea of electrons/ delocalised system*

[11]

66. (i) Electrons have opposite spin 1

Reject a paired spin of the electrons
Reject to show they repel each other
Reject going in different directions
Reject due to reverse spin
Reject moving in opposite directions

(ii) Start from n = 3 energy level and going upwards at least to another energy level **(1)**
End at or just above n = ∞ energy level **(1)** 2

Reject arrow into writing

(iii) No because energy levels split into two **(1)**
(2)s and (2)p (with the 2p higher than the 2s) **(1)** 2

*Accept no because there are 2s and 2p **(1)***
*Accept sublevels **(1)** /Subshells*

Reject no because increasingly hard to remove successive electrons

(iv) 1 electron in the n = 4 energy level and
8 electrons in the n = 3 energy level 1

Accept 2,8,8,1 for potassium

Accept n = 3 full, n = 4 1 electron

Reject one more level of electrons
Reject an extra full energy level
Reject more electrons in n=3

[6]

67. (a) (i) High energy/fast/gun electrons **hit/strike**
OR bombarded by electrons **(1)**

Removes/knocks out /causes loss of electron *OR* equation e.g.
$X \rightarrow X^{+} + e^{(-)}$
OR
$X + e \rightarrow X^{+} + 2e$ **(1)**
IGNORE state symbols
If knock out is mentioned, hit/strike is not required in 1st mark 2

Any suggestion that a negative ion is produced score zero overall

Reject if just "forms a cation/positive ion", not sufficient for second mark

(ii) Mass **(1)**

Accept weight

Charge **(1)**

Accept Mass: charge ratio
OR m/e
OR m/z ***(1)***

Ignore the following:
speed
kinetic energy
size/volume
radius
charge density
density 2

(b) **1st mark** (stand alone)
The mass of an **atom** (of the isotope) **(1)**

2nd mark (stand alone)
Relative to 1/12th the mass of a ^{12}C (atom)
OR
Relative to ^{12}C =
12(exactly)
OR
On a scale where C^{12} has a mass of 12 **(1)**

If 'atom' missing from 1st mark it can score if mentioned in 2nd mark 2

Accept
1st mark
The mass of a mole of the ***isotope (1)***

2nd mark
Relative to 1/12th the mass of a ***mole*** *of ^{12}C*
OR
On a scale where a ***mole*** *of C^{12} has a mass of 12 g* ***(1)***

Must mention the word 'mole' at least once in these definitions

Answer must be either consistently atoms or moles in order to be awarded both

Reject average mass/weighted average/
Reject element instead of isotope

(c) [(49.95 × 4.345) + (51.94 × 83.79) + (52.94 × 9.501) + (53.94 × 2.364)]/100 **(1)**
= 51.9958
= 52.00 *must be to 4 SF* **(1)**

Correct answer to 4SF with no working **(2)**
Should not have units but allow g mol^{-1}
Allow error carried forward only on transcription error of mass or percentage 2

Accept 51.99 scores ***(1)*** *not* ***(2)***

Reject 52
Reject 52.0
Reject 52.00 g

(d)

1s	2s	2p			3s	3p			3d					4s
					↑↓	↑↓	↑↓	↑↓	↑↓	↑	↑	↑	↑	↑↓

2 marks for fully correct configuration
1 mark if 26 electrons with 2 in 4s but the 3d electrons shown as pairs

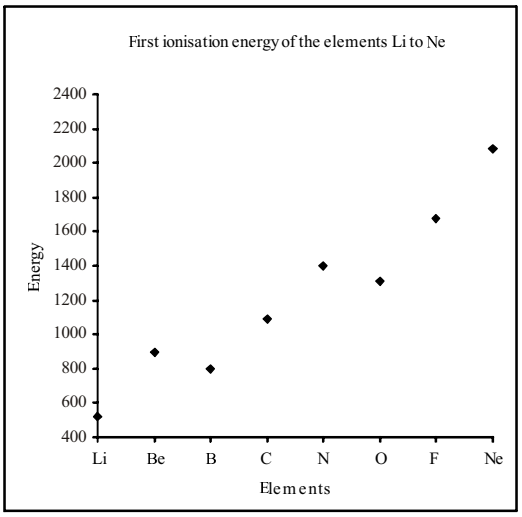
Ignore the way the arrow heads point in the singly occupied 3d boxes.

Allow half arrows ↿ or | or ↑ or any combination in any box 2

*Accept vertical lines in place of arrows **1 max***

[10]

68. (a)



General increase, starting with carbon above boron **(1)**

Dip from N to O only **(1)** 2

Accept lines joining points do not need to be drawn in.

Accept a very small drop from N to O

(b)
- The **nuclear** charge/proton number increases / becomes more positive **(1)**
- The (inner shell) shielding is the same/same number of inner shell electrons/ no or little increase in shielding **(1)**

Either

- **Outer** electron closer to nucleus /**atomic** radius decreases /size of atom decreases

Or

- electrons being removed are in same shell

Or

- **Outer** electrons are in same shell **(1)** 3

Reject Atomic Number increasing

(c) In boron the extra electron is in a p orbital /new sub-shell **(1)**

Either
Which has extra shielding (by the s orbital electrons)
OR
Which is at a higher energy (level than the s orbital in Be) **(1)** 2

Accept reverse argument for beryllium

Reject shell for sub-shell

Reject answers that refer to full shell being left do not score second mark

Further from the nucleus

[7]

69. (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]

70. (a) (i) metallic 1

Reject metal

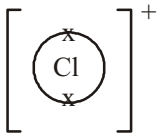
(ii) attraction between ions and delocalised electrons is stronger in lithium **(1)**

With reference to atoms 1 max

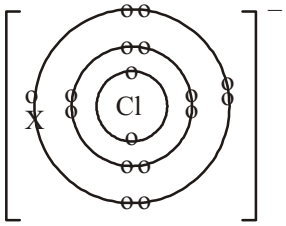
as lithium ion is smaller / lithium ion has greater charge density/ electrons closer to nucleus **(1)** 2

Accept reverse argument

(b) (i)



(1)



(1) 2

Accept all dots and crosses

Accept charges next to element symbols

Reject correct electronic structure but wrong or no charges max 1

Reject covalent structures = 0

(ii) **Electrons** are promoted (to higher energy level). **(1)**

Then they fall back to lower levels (they emit light of particular wavelength). **(1)** 2

(iii) strontium / calcium 1

Accept rubidium

[8]

71. B

[1]

72. C

[1]

73. D

[1]

74. B

[1]

75. (a) A 1

(b) B 1

(c) D 1

[3]

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

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

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

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

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

(c) (i) QWC

Not 100 % ionic/ has some covalent character 1

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

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

[8]