3.1.4.2 Period 3 elements

173 minutes

169 marks

M1. (a) Elements in the p block have their outer electron(s) in p orbital(s) or levels or sub-shells **(1)**
example of element **(1)**
correct electronic configuration **(1)**

3

(b) Pattern in the change in the properties of a row of elements **(1)**
OR Trend in the properties of elements across a period

Repeated in the next row **(1)**
OR element underneath (or in same group) has similar properties

atomic radius
decreases across the row **(1)**
CE if trend is wrong

number of protons increases **(1)** (or nuclear charge increases)
more attraction for electrons in the same shell **(1)**

electronegativity
increases across the row **(1)**
number of protons increases **(1)** (or nuclear charge)
atomic radius decreases **(1)** (or shielding remains the same or electrons in the same shell) more attraction for bonding or shared electrons **(1)**

conductivity
decreases row **(1)**
OR significant drop from Al to Si

Na–Al metals **(1)**
OR metallic bonding or description of metallic bonding

Two of Si - Ar non metals **(1)**
OR molecular or covalent

EITHER electrons free to move (or delocalised) in metals
OR electrons unable to move in non-metals **(1)**

13

[16]

M2. (a) Macromolecular **or** giant structure **(1)**

Accept diamond shaped lattice

Intermolecular forces / molecular lattice / comparison to graphite structure, = 'con'

Held together by covalent bonds **(1)**

'Giant covalent structure' earns both M1 and M2

(Much) energy needed to break bonds **Or** many bonds to be broken **(1)**
Mark tied to earning 'covalent' M2 If explanation is clearly of ionic bonding = CE

Vand der Waal / temporary induced dipole-dipole / London / disperse forces **(1)**

Forces increase with size **or** with number of electrons **or** with surface area etc. **(1)**

Description must be of the molecules of P and S

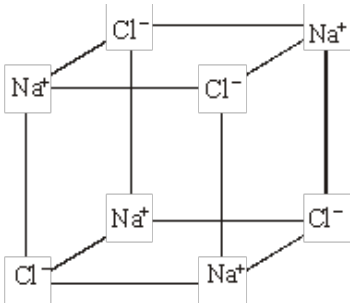
P_4 **or** M_r = 124 **(1)** S_8 **or** M_r = 256 **(1)**

If M6 (i.e. P_4) and M7 (i.e. S_8) are not attempted, allow S molecule bigger /more surface area than P molecule for 1 mark

7

(b) Diagram NaCl = cubic **(1)**

Allow if 3 full faces shown correctly



Ions identified and placed properly **(1)**

If diagram shows '+' and '–' signs rather than symbols for ions, identification of the ions could be from the text

(Bonding) identified in writing as being ionic **(1)**

Not ionic molecule

Due to strong electrostatic attractions **or** similar description about attraction between oppositely charged ions.**(1)** **QoL**

Not just: *'ionic bonds are strong' / 'need much energy to break bonding'*

4

(c) Be – no reaction with water or steam **(1)**

__Not__: Be does not dissolve

Mg reacts **with steam** **or** reacts slowly with cold/hot water **(1)**

White solid **(not precipitate)** formed Bubbles **(1)**

or Mg glows or burns (with bright white light) Not 'fizzes' or 'gas evolved'

$Mg + H_2O \rightarrow MgO + H_2$ $Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$ **(1)**

Condition, equation and observation marks are tied. Candidate can't mix-and-match but, when both conditions quoted, select the higher scoring option

4

[15]

M3. (a) (i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$ **(1)**

Allow subscripted electron numbers

(ii) p (block) **(1)**

Allow upper or lower case 's' and 'p' in (a)(i) and (a)(ii)

2

(b) Lattice of metal / +ve ions/ cations / atoms **(1)**

Not +ve nuclei/centres

Accept regular array/close packed/tightly packed/uniformly arranged

(Surrounded by) delocalised electrons **(1)**

Note: Description as a 'giant ionic lattice' = CE

2

(c) Greater nuclear or ionic charge or more protons **(1)**

Smaller atoms / ions **(1)**

Accept greater charge density for either M1 or M2

More delocalised electrons / e^- in sea of e^- / free e^- **(1)**

Stronger attraction between ions and delocalised / free electrons etc. **(1)**

Max 3

Note: 'intermolecular attraction/ forces' or covalent molecules = CE

Accept stronger 'electrostatic attraction' if phrase prescribed elsewhere

Ignore references to m/z values

*If Mg or Na compared to Al, rather than to each other, then: **Max 2***

*Treat description that is effectively one for Ionisation Energy as a '**contradiction**'*

3

(d) (Delocalised) electrons **(1)**

Move / flow in a given direction (idea of moving non-randomly)
or under the influence applied pd *QoL mark* **(1)**

Allow 'flow through metal'

Not: 'Carry the charge'; 'along the layers'; 'move through the metal'

2

[9]

M4. (a) $2Al + 3CuCl_2 \rightarrow 2AlCl_3 + 3Cu$;

(accept multiples/fractions)

OR

$2Al + 3Cu^{2+} \rightarrow 2Al^{3+} + 3Cu$;

1

(b) (i) increases;

1

(ii) lower than expected / lower than Mg /

1

less energy needed to ionise; e^- removed from (3)p sub-level;

1

('e^- removed' may be implied)

of higher energy / further away from nucleus / shielded by <u>3s</u> e^-s;

1

(c) $Al^+(g) \rightarrow Al^{2+}(g) + e^-$;

1

(d) trend: increases;

1

more protons / higher charge on cation / more delocalised e^- / smaller atomic/ionic radius;
stronger attraction between (cat)ions and delocalised/free/mobile e^-

1

OR

stronger metallic bonding;

1

[9]

M5. (a) enthalpy/energy change/required when an electron is removed/ knocked out / displaced/ to form a uni-positive ion

(ignore 'minimum' energy)

1

from a gaseous atom

(could get M2 from a correct equation here)
(accept 'Enthalpy/energy change for the process...' followed by an appropriate equation, for both marks)
(accept molar definitions)

1

(b) $1s^2\ 2s^2 2p^6$

(accept capitals and subscripts)

1

(c) 's' block

(not a specific 's' orbital – e.g. 2s)

1

(d) $Mg^+(g) \rightarrow Mg^{2+}(g) + e^-$ or

$Mg^+(g) + e^- \rightarrow Mg^{2+}(g) + 2e^-$ or

$Mg^+(g) - e^- \rightarrow Mg^{2+}(g)$

1

(e) Mg^{2+} ion smaller than Ne atom / Mg^{2+} e^- closer to nucleus

(Not 'atomic' radius fo Mg^{2+})

1

Mg^{2+} has more protons than Ne / higher nuclear charge or
e^- is removed from a charged Mg^{2+}ion / neutral neon atom

(accept converse arguments)

*(If used 'It' or Mg/magnesium/Mg^{3+} etc. & 2 correct reasons, allow **(1)**)*

1

(f) (i) trend: increases

(if 'decreases', CE = 0/3)

1

Expl^n: more protons / increased proton number / increased nuclear charge

(NOT increased atomic number)

1

same shell / same shielding / smaller size

1

(ii) QoL reference to the e^- pair in the 3p sub-level

(penalise if wrong shell, e.g. '2p', quoted)

1

repulsion between the e^- in this e^- pair

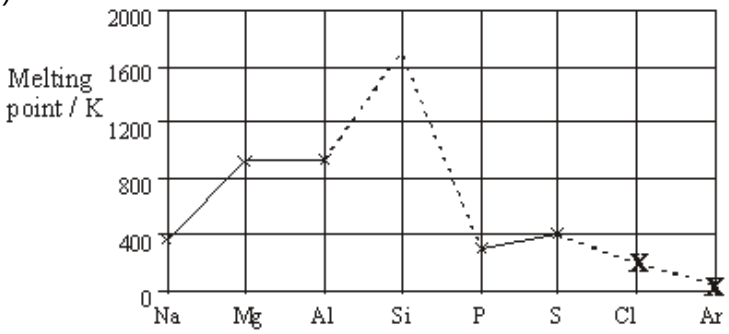
(if not stated, 'e^- pair' must be clearly implied)

(mark M4 and M5 separately)

1

[12]

M6. (a) (i)



M1 Si: cross ≥ 1200

1

M2 Cl: cross below S

1

M3 Ar: cross below Cl

[allow, even if M2 wrong)

[If Cl cross missing and Ar below S, allow M3]

1

(ii) Si is macromolecular/giant molecular/giant covalent/ giant atomic

1

Covalent bonds need to be <u>broken</u>/accept 'overcome'

[Not loosened/weakened]

1

Covalent bonds are strong / many covalent bonds involved/
requires much energy/hard to break

[Tied to 'break' or near miss in M2] [Not 'structure' is broken]

[Must mention 'covalent' somewhere in part (a)(ii) to earn M2/M3]

[If van der Waals'/IMF mentioned M2/M3 = CE = 0.

[If ions mentioned M1/M2/M3 = CE = 0]

1

(iii) Intermolecular force = van der Waals'/induced dipole–dipole/dispersion forces

1

QoL Sulphur has greater M_r / size / surface area/more electrons/more atoms **so** stronger intermolecular forces (comparison)

[Mark separately] [Not 'more shells']

1

(b) Trend: Decreases

[If trend wrong = CE = 0]

1

Increase in size of ion/atom / more shells / decrease in charge density / decrease in charge size ratio

1

Weaker attraction for delocalised/free/sea of electrons / weaker metallic bonding

[Ignore shielding]

[van der Waals' etc. = CE = 0 for M2 and M3]

1

[11]

M7. (a) (i) Energy/enthalpy (change)/ΔH/ needed to remove 1 mole of electrons;

Allow 1 electron
Not heat alone

1

From 1 mol of gaseous atoms;

From 1 gaseous atom
Not mix and match moles and one electron.
Allow 1 for balanced eq with ss

1

(ii) Increase;

If blank mark on
If incorrect CE = 0

1

Increasing nuclear charge/ increasing number of protons;

Not increasing atomic number

1

Same or similar shielding /same number of shells or energy levels/ (atomic) radius decreases/electron closer to nucleus;

Not same distance from nucleus.

1

(iii) Aluminium/Al;

If incorrect CE = 0

1

Electron in higher energy /p or 3p orbital;

Not 2p
Ignore shielding

1

Less energy needed to lose electron/ electron more easily lost/ ionisation energy less;

1

(b) Silicon/Si;

If incorrect CE = 0
If silicone, silica Si_8, Si_4 mark on.

1

Macromolecular/ Giant molecular or atomic or covalent;

If IMFor ionic or metallic in Silicon then CE = 0 for explanation

1

Many or strong covalent bonds need to be broken/ lots of energy needed to break the covalent bonds;

Not loosened bonds

1

[11]

M8. (a) $2s^2\ 2p^6$;

If ignored the $1s^2$ given and written $1s^2 2s^2 2p^6$ mark as correct
Allow capitals and subscripts

1

(b) (i) $Na^+(g) \rightarrow Na^{2+}(g) + e^{(-)}$;

One mark for equation and one mark for state symbols

$Na^+(g) + e^{(-)} \rightarrow Na^{2+}(g) + 2e^{(-)}$;

M2 dependent on M1
Allow $Na^+(g) - e^{(-)} \rightarrow Na(g)$
Allow $X^+(g) \rightarrow X^{2+}(g) + e$ = 1 mark

2

(ii) $Na^{(2+)}$ requires loss of e^- from a 2(p) orbital or 2nd energy level or 2nd shell <u>and</u> $Mg^{(2+)}$ requires loss of e^- from a 3(s) orbital or 3rd energy level or 3rd shell / $Na^{(2+)}$ loses e from a lower (energy) orbital/ or vice versa;

Not from 3p

1

Less shielding (in Na);

Or vice versa for Mg

1

$e^{(-)}$ closer to nucleus/ more attraction (of electron to nucleus) (in Na);

M3 needs to be comparative

1

(iii) Aluminium /Al;

1

(c) Decreases;

If not decreases CE = 0
If blank, mark on

1

Increasing nuclear charge/ increasing number of protons;

1

Electrons in same shell or level/ same shielding/ similar shielding;

1

(d) Answer refers to Na;

Allow converse answers relating to Mg.

Na few<u>er</u> protons/small<u>er</u> nuclear charge/ fewer delocalised electrons;

Allow Mg is 2+ and Na is +.
If vdw CE = 0.

1

Na is a bigg<u>er</u> ion/ atom;

1

Small<u>er</u> attraction between nucleus and delocalised electrons;

If mentioned that charge density of Mg^{2+} is great<u>er</u> then allow first 2 marks.
(ie charge / size / attraction).
M3 allow weak<u>er</u> metallic bonding.

1

(e) (Bent) shape showing 2 lone pairs + 2N−H bond pairs;

Atoms must be labelled.
Lone pairs can be with or without lobes.

1

Bent / v shape/ triangular;

Not tetrahedral.
Allow non-linear.
Bent-linear = contradiction.

1

(f) Ne has full sub-levels/ can't get any more electrons in the sub-levels/ Ne has full shells;

Not $2s^2 2p^6$ alone.
Not stable electron configuration.

1

[16]

M9. (a) $2s^2 2p^6 3s^1$

$1s^2$ can be rewritten
Allow $2s^2 2p_x^2 2p_y^2 2p_z^2 3s^1$
Allow subscripts and capitals

1

(b) (i) Energy/enthalpy (needed) to remove one mole of electrons from one mole of atoms/compounds/molecules/elements

1

OR

Energy to form one mole of positive ions from one mole of atoms

OR

Energy/enthalpy to remove one electron from one atom

In the gaseous state (to form 1 mol of gaseous ions)

Energy given out loses M1
M2 is dependent on a reasonable attempt at M1
Energy needed for this change
$X(g) \rightarrow X^+(g) + e^{(-)}$ = 2 marks
This equation alone scores one mark

1

(ii) $Mg^+(g) \rightarrow Mg^{2+}(g) + e^{(-)}$
$Mg^+(g) + e^{(-)} \rightarrow Mg^{2+}(g) + 2e^{(-)}$
$Mg^+(g) - e^{(-)} \rightarrow Mg^{2+}(g)$

Do not penalise MG
Not equation with X

1

(iii) Electron being removed from a positive ion (therefore need more energy)/electron being removed is closer to the nucleus/Mg^+ smaller (than Mg)/Mg^+ more positive than Mg

Allow from a + particle/species
Not electron from a higher energy level/or higher sub-level
More protons = 0

1

(iv) Range from 5000 to 9000 kJ mol^{-1}

1

(c) Increase

If decrease CE = 0/3
If blank mark on

1

Bigger nuclear charge (from Na to Cl)/more protons

QWC

1

electron (taken) from same (sub)shell/similar or same shielding/
electron closer to the nucleus/smaller atomic radius

If no shielding = 0
Smaller ionic radius = 0

1

(d) Lower

If not lower CE = 0/3
If blank mark on
Allow does not increase

1

Two/pair of electrons in (3)p orbital or implied

Not 2p

1

repel (each other)

M3 dependent upon a reasonable attempt at M2

1

(e) Boron/B or oxygen/O/O_2

1

[13]

M10. (a) Macromolecular/giant covalent/giant molecular/giant atomic

If IMF/H-bonds/Ionic/metallic CE = 0/3
covalent bond between molecules CE = 0/3
If giant unqualified M1 = 0 but mark on

1

Many/strong covalent bonds

M2 and M3 can only be scored if covalent mentioned in answer
Ignore metalloid and carbon
Ignore bp

1

Bonds must be broken/overcome

Ignore numbers of bonds and references to energy

1

(b) (Simple) molecular

QoL

Do not allow simple covalent for M1

Giant covalent/ionic/metallic, CE = 0

If breaking covalent bonds CE= 0/3

1

S bigger molecule (than P) or S_8 and P_4 references

QoL

Allow more electrons in sulfur molecule or S_8

Do not allow S is bigger then P

Allow S molecule has a bigger M_r

Do not allow contradictions

1

So more/stronger van der Waals' forces (to be broken or overcome)

Not just more energy to break

1

(c) Regular arrangement of minimum of 6 particles in minimum of 2 rows

Ignore e–

Do not allow ring arrangements OR structures bonded with electrons

1

+ charge in each one (of 6)

Allow +, (1+, 2+ or 3+) in ions/or in words

1

Rows/planes/sheets/layers (of atoms/ions) can slide (owtte) over one another

M3 independent

If ionic bonding/molecules/IMF/vdw/covalent, penalise M3

Ignore layers of electrons sliding

1

(d) Bigger charge (3+ compared to 1+)

CE = 0 if molecules, ionic, covalent, IMF

(Allow Al^{2+})

OR smaller atom/ion in Al/more protons/bigger nuclear charge

1

More free/<u>delocalised</u> electrons (in Al)/bigger sea of electrons in Al

Accept 2 or 3 delocalised electrons compared to 1 in Na

1

Stronger metallic bonding/stronger (electrostatic) attraction between the (+) ions or nuclei and the (delocalised) electrons (or implied)

Must be implied that the electrons are the delocalised ones not the electrons in the shells.

Accept converse arguments

1

[12]

M11. (a) $4d^{10}\ 5s^{2}\ 5p^{1}$ in any order

Allow subscripts for numbers

Allow capitals

1

(b) (i) Using an electron gun/(beam of) high energy/fast moving electrons

Ignore 'knocks out an electron'

1

(ii) $In(g) + e^- \rightarrow In^+(g) + 2e^-$

OR

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

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

The state symbols need not be present for the electron - but if they are they must be (g)

No need to show charge on electron

If I CE = 0

Ignore any equations using M

1

(iii) So no more than 1 electron is knocked out/so only one electron is knocked out/prevent further ionisation

Allow stop 2+ and 3+/other ions being formed

Not to get wrong m/z

1

(iv) Any two processes from

- Accelerate (owtte)
- Deflect (owtte)
- Detect (owtte)

Ignore wrong causes of process

2 max

(c) (i) <u>Average/mean mass of (1) atom(s) (of an element)</u>

1

1/12 mass of one atom of ^{12}C

1

OR

<u>(Average) mass of one mole of atoms</u>

1/12 mass of one mole of ^{12}C

OR

<u>(Weighted) average mass of all the isotopes</u>

1/12 mass of one atom of ^{12}C

OR

Average mass of an atom/isotope compared to C-12 on a scale in which an atom of C-12 has a mass of 12

Not average mass of 1 molecule

Allow the wording Average mass of 1 atom of an element compared to 1/12 mass atom of ^{12}C (or mass 1/12 atom of ^{12}C)

Allow if moles of atoms on both lines

Accept answer in words

Can have top line × 12 instead of bottom line ÷12

If atoms/moles mixed, max = 1

(ii) $\frac{113x + 115y}{x + y} = 114.5$

Allow idea that there are 4 × 0.5 divisions between 113 and 115

1

ratio (113:115) = 1:3 **OR** 25:75 **OR** 0.5:1.5 etc

Correct answer scores M1 and M2

If 1:3 for In(115):In(113), max = 1

1

(d) None

1

Same no of electrons (in the outer shell)/same electron configuration)

Ignore electrons determine chemical properties/ignore protons

M2 dependent on M1 being correct

1

(e) 29.0%/29% O

If no O calculated, allow M2 if In and H divided by the correct A_r

1

$$\frac{69.2}{114.8/114.5} \qquad \frac{1.8}{1} \qquad \frac{29.0}{16}$$

1

or

0.603 1.8 1.81

1 3 3

EF = In H_3O_3

Allow $In(OH)_3$

Do not allow last mark just for ratio 1:3:3

If InO_3H_3 given with no working then allow 3 marks

If I not In, lose M3

1

[15]

M12. (a) P = 100 000 (Pa) and V = 5.00 x 10^{-3} (m^3)

M1 is for correctly converting P and V in any expression or list

Allow 100 (kPa) and 5 (dm^3) for M1.

1

$$n = \frac{PV}{RT} = \frac{100\ 000 \times 5.00 \times 10^{-3}}{8.31 \times 298}$$

M2 is correct rearrangement of PV = nRT

1

= 0.202 moles (of gas produced)

This would score M1 and M2.

Therefore $\frac{0.202}{5}$ = 0.0404 moles B_2O_3

M3 is for their answer divided by 5

1

Mass of B_2O_3 = 0.0404 x 69.6

M4 is for their answer to M3 x 69.6

1

= 2.81 (g)

M5 is for their answer to 3 sig figures.
2.81 (g) gets 5 marks.

1

(b) $B + 1.5\ Cl_2 \rightarrow BCl_3$

Accept multiples.

1

3 bonds

1

Pairs repel equally/ by the same amount

Do not allow any lone pairs if a diagram is shown.

1

(c) (i) 43.2/117.3 (= 0.368 moles BCl_3)

1

0.368 x 3 (= 1.105 moles HCl)

Allow their BCl_3 moles x 3

1

Conc HCl = $\frac{1.105 \times 1000}{500}$

Allow moles of HCl × 1000 / 500

1

= 2.20 to 2.22 mol dm^{-3}

Allow 2.2
Allow 2 significant figures or more

1

(ii) $H_3BO_3 + 3NaOH \rightarrow Na_3BO_3 + 3H_2O$

Allow alternative balanced equations to form acid salts.
Allow $H_3BO_3 + NaOH \rightarrow NaBO_2 + 2H_2O$

1

(d) $\frac{10.8}{120.3}(\times 100)$

Mark is for both M_r values correctly as numerator and denominator.

1

8.98(%)

Allow 9(%).

1

Sell the HCl

1

(e) Alternative method

Cl = 86.8%

Cl = 142 g

1

B	Cl
$\frac{13.2}{10.8}$	$\frac{86.8}{35.5}$

B	*Cl*
$\frac{21.6}{10.8}$	$\frac{142}{35.5}$

1

1.22 2.45 or ratio 1:2 or BCl_2

2:4 ratio

1

BCl_2 has M_r of 81.8 so
81.8 x 2 = 163.6
Formula = B_2Cl_4

B_2Cl_4

Allow 4 marks for correct answer with working shown.

Do not allow $(BCl_2)_2$

1

[20]

M13. (a) Carbon / C

If M1 incorrect, CE = 0 / 3

1

Fewest protons / smallest nuclear charge / least attraction between protons (in the nucleus) and electrons / weakest nuclear attraction to electrons

Allow comparative answers.

Allow converse answers for M2

1

Similar shielding

Allow same shielding.

1

(b) <u>Increase</u>

1

Oxygen / O

If not oxygen, then cannot score M2, M3 and M4

1

Paired electrons in a (2)p orbital

If paired electrons in incorrect p orbital, lose M3 but can award M4

1

(Paired electrons in a p orbital) repel

1

(c) $C(g) \rightarrow C^{+}(g) + e^{(-)}$

OR

$C(g) + e^{(-)} \rightarrow C^{+}(g) + 2e^{(-)}$

OR

$C(g) - e^{(-)} \rightarrow C^{+}(g)$

Ignore state symbols for electron.

1

(d) (More energy to) remove an electron from a (more) positive ion / cation

Allow electron closer to the nucleus in the positive ion.

1

(e) Lithium / lithium / Li

If formula given, upper and lower case letters must be as shown.

1

[10]