AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



MARK SCHEME

3.1.1 ATOMIC STRUCTURE

SCORE	PERCENTAGE
/749	%

STEMUP

These questions belong to AQA, not to us.

The examination questions, mark schemes and examiner reports in this pack were written and published by AQA. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with AQA and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. AQA has not endorsed, approved or been involved in the production of it. AQA and the qualification titles used here belong to their respective owners and appear for identification only.

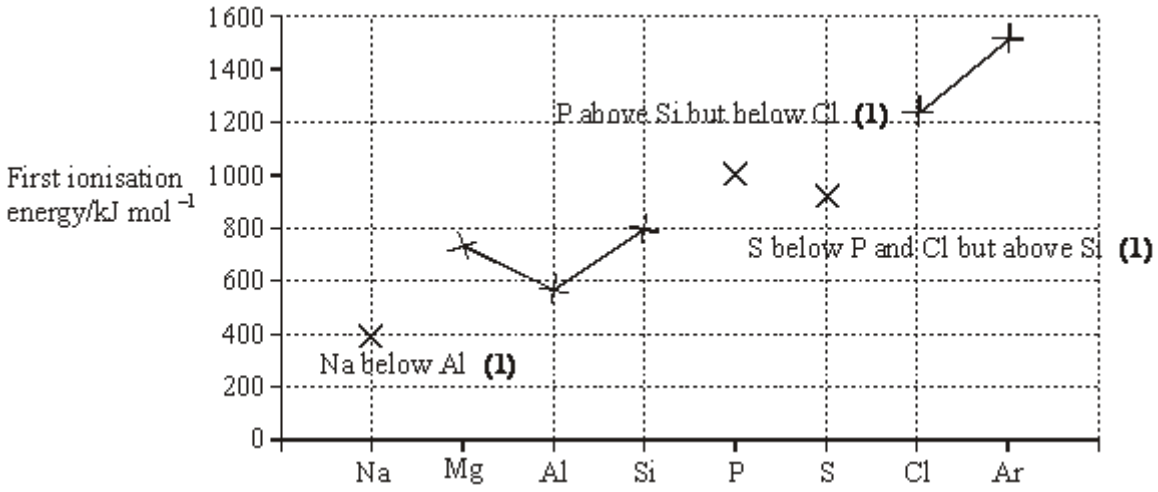
Where to find the originals

AQA publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at aqa.org.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

Q1.

(a)



1

(b) Increased nuclear charge / proton number **(1)**
NOT increased atomic number

Electrons enter same shell / energy level OR atoms get smaller OR same shielding **(1)**

Stronger attraction between nucleus and (outer) electrons **(1)**
Q of L

3

(c) *Explanation for aluminium*: (third) electron in (3)p sub-shell **(1)**
Sub-shell further away from nucleus OR of higher energy **(1)**
OR extra shielding from (3)s

Explanation for sulphur: Pair of electrons in (3)p orbital **(1)**
Repulsion between electrons **(1)**
tied to reference to e^- pair in M3
Penalise '2p' once only

4

[10]

Q2.

(a) $Na(g) \rightarrow Na^+(g) + e^-$
OR $Na(g) + e^- \rightarrow Na^+(g) + 2e^-$
(-) on electron not essential
equation (1)
state symbols (1)
Ignore state symbols on electrons

2

(b) *Trend* : Increases **(1)**

STEMUP.CO.UK

Explanation : Increased nuclear charge or proton number **(1)**
Stronger attraction (between nucleus and (outer) e^-) **(1)**

Trend <u>wrong</u>

Allow M2 only if M3 correct (con)

3

(c) *How values deviate from trend*: (both values) too low **(1)**
Explanation for Al: e^- removed from (3) p **(1)**
e^- or orbital is higher in energy or better shielded than (3)**s**
or p electron is shielded by <u>3s</u> electrons **(1)**

Allow e^- is further away

Mark independently

Explanation for S: e^- removed from (3)p electron <u>pair</u> **(1)**
repulsion between paired e^- (reduces energy required) **(1)**

Mark separately
If deviation <u>wrong</u> allow M2 and M4
If M3 and / or M5 right (con)
If used 'd' rather than 'p' orbital - lose M2 + M4 but may get M3, M5 (explanation marks)

5

[10]

Q3.

D

[1]

Q4.

(a) Ability (or power) of an atom to attract electron density (or electrons or -ve charge) **(1)**
in a covalent bond **(1)**

or shared pair
If remove an electron lose first mark

2

(b) *Trend:* increases **(1)**
Explanation: nuclear charge (number of protons) increases **(1)**
electrons in same shell **(1)**

OR similar shielding
OR atoms similar size or smaller
OR 1 mol of e^-

3

(c) Heat / enthalpy / energy for removal of one electron **(1)**
from a gaseous atom **(1)**
can score in an equation

must have first mark to score the second

2

(d) (i) 2 **(1)**

(ii) <u>Two elements</u> (or Na / Mg) before the drop (in energy) to Al **(1)**

STEMUP.CO.UK

(iii) ionisation energy of Al < that for Mg **(1)**

(iv) fall in energy from P to S **(1)**
or discontinuity in trend

From Al to P there are 3 additional electrons **(1)**
or three elements
For second mark idea of block of 3 elements

5

[12]

Q5.

D

[1]

Q6.

D

[1]

Q7.

D

[1]

Q8.

A

[1]

Q9.

C

[1]

Q10.

A

[1]

Q11.

B

[1]

Q12.

C

[1]

STEMUP.CO.UK

Q1.

Many candidates correctly positioned the crosses in the diagram, but errors were not uncommon. In some cases, the cross for sodium was omitted. Other common errors were to position the cross for sodium at the same level as that for aluminium, to place the cross for phosphorus below that for silicon and to place the cross for sulphur level either level with that for phosphorus, or level with that of silicon. Given that the questions in parts (b) and (c) are frequently asked, and so should be an essential part of a revision programme, the answers offered by many candidates were disappointing. The better candidates were well prepared and so scored well on this question; others lacked much of the basic knowledge required in this section of the specification. In part (b), many candidates attempted to explain the *deviations* from the general increase in ionisation energy across the period, rather than explaining the *general increase* itself, as required by the question, and so failed to earn the marks allocated to part (b). Where the explanation offered in part (b) helped to clarify an answer to part (c), which did require an explanation of the deviations from the general trend, credit for the marks allocated to part (c) was given. While some clear, concise and accurate explanations were seen in part (b), many attempts were vague. All that was required was for a link to be established between the increased nuclear charge of smaller atoms having no change in shielding and an increase in the attraction between the nucleus and the outer electrons. Many explanations lacked precision and failed to establish such a link. The phrase *effective nuclear charge* was incorrectly used as an explanation by some candidates. Many explanations in part (c) similarly were incomplete and lacked precision. Many candidates correctly identified the outermost electron in an aluminium atom as being in the 3p sub-level. The second mark, for explaining why this electron is more easily lost was less frequently earned. Some candidates successfully explained the second point, but omitted to state the location of the outermost electron. Some candidates referred to an increase in the shielding of the outer electron but omitted to identify the electrons responsible for this increase. In some cases, candidates simply stated that aluminium was in the 3s with no reference at all being made to electrons. While some candidates clearly explained the drop in ionisation energy between phosphorus and sulphur, many others vaguely attributed this deviation from the general trend to *mutual* repulsion, or to *repulsion between electrons*, without identifying the location, or the paired nature, of the electrons involved. Some vague references to the *increased stability* of the electron arrangement present were also seen.

Q2.

Although many candidates gave a correct equation for this process, errors were not uncommon. Some candidates lost the mark for the state symbols as examiners, who strove to differentiate between (*g*) and (*s*), were unable to clearly identify the squiggles used in the equation. Other candidates omitted the state symbols completely. Other errors seen in this equation included the use of *X*, *Z* or *M* to represent the metal, the use of positrons, single electrons being shown on both sides of the equation, or the equation being reversed. Part (b) was quite well done although unacceptable phrases such as *an increase in the nuclear force* or *core charge* were not uncommon. Many candidates struggled with part (c). Many knew that the first ionisation energy of both aluminium and sulphur are lower than the trend would suggest but the explanations offered were frequently vague, and the specific identification of the $3p^1$ electron, in aluminium, and the $3p^4$ electron pair, in sulphur, were often omitted.
Many candidates were aware that the outer electron in aluminium is of higher energy, better shielded or further removed from the nucleus but it was often not clear that a reference to *mutual repulsion* referred to the 3p paired electrons in sulphur. More often, explanations referred to repulsion between electron pairs, or simply to repulsion between electrons. Some candidates attempted to explain the deviation using vague references to

STEMUP.CO.UK

full or half-full shells/sub-shells having more stability.

Q4.

This question also discriminated very effectively. Answers to parts (a) and (b) were often correct but answers to part (c) lacked precision and in many cases did not refer to removal of an electron from a gaseous atom. Parts (d)(ii), (iii) and (iv) were not answered well. Many candidates did not appear to have read or perhaps understood the question. They were expected to compose their answers by showing how the statements were supported by evidence from the diagram. Most candidates just explained the variations in ionisation energies across the period.

STEMUP.CO.UK

Q1.

(a) Assume current model unless otherwise stated.

Statement about the nucleus:
(Central) nucleus contains protons and neutrons.

Allow "protons and neutrons are in the centre of the atom"

1

Statement about electrons
Electrons are now arranged in energy levels/shells/orbitals

Ignore "mostly empty space"

Ignore electrons surround / orbit nucleus

Allow additional statement about neutrons but must be separate from statement about nucleus to score

e.g.

no neutrons in plum pudding / neutrons now recognised

1

(b) $1s^2 2s^2 2p^3$

Ignore commas, capitals and subscripts

Allow $1s^2 2s^2 2px^1 2py^1 2pz^1$

1

(c) (R is N (nitrogen))

Formula Be_3N_2

Accept Be_3R_2 only if stated R = nitrogen

Accept N_2Be_3

1

[4]

Q2.

(a) M_r NaF = 42(.0)

Incorrect M_r loses M1 & M4

1

Mass NaF in 1 g = $2.88 \times 10^{-5} \times 42.0$ (= 1.210 (1.2096) $\times 10^{-3}$ g)

1

Mass NaF in 1 kg = 1.210 (1.2096) g

M3 = M2 × 1000 (g)

Units, if given, must match answer

1

(Mass in mg = 1210 (1209.6) mg)

Concentration of NaF = 1210 (ppm)

Allow 1.21×10^3 ppm

1

STEMUP.CO.UK

(b) Toxic mass = $3.19 \times 10^{-2} \times 75 \times 1000$
= 2390 mg
Allow 2393

1

(c) Mass of toothpaste needed = $\frac{2390}{2800}$
= 0.854 kg
Mark consequential to (b)
(b) ÷ 2800 (to at least 2 sig fig)
Allow 0.85 - 0.86 kg

1

(d) B
If not B, allow M2 only
If blank, read on.

1

Both Na^+ and F^- same electron arrangement ($1s^2 2s^2 2p^6$) or isoelectronic
Electronegativity, molecules or IMF = CE, M1 only

1

Sodium (ion) has more protons so attracts (outer) electrons closer / Sodium (ion) has more protons so stronger attractions for (outer) electrons
Ignore shielding, higher charge density, atomic radius
If reference to fluorine rather than fluoride, then penalise 1 mark only

1

[9]

Q3.

(a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ (4s^0)$

1

(b) **M1** In $Ca^{(+)}$ (outer) electron(s) is further from nucleus

Or $Ca^{(+)}$ loses electron from a higher (energy) orbital

Or $Ca^{(+)}$ loses electron from a 4(s) orbital or 4th energy level or 4th energy shell and $K^{(+)}$ loses electron from a 3(p) orbital or 3rd energy level or 3rd energy shell
Must be comparative
Allow converse arguments

1

M2 More shielding (in Ca^+)

1

(c) Be /Beryllium

1

(d) $Mg(OH)_2$

1

(e) $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$
Ignore state symbols

STEMUP.CO.UK

1

n $BaCl_2$ (6/1000 × 0.25) = 1.5×10^{-3} and n Na_2SO_4 = (8/1000 × 0.15) = 1.2×10^{-3}

and $BaCl_2$ /barium chloride in excess

Working required or 3×10^{-4} of $BaCl_2$

1

10 cm^3 (of 0.15 mol dm^{-3} sodium sulfate)

or 0.01dm^3

1

(f) **M1** Same electronic configuration / same number of electrons (in outer shell) / all have 37 electrons (1)

Ignore protons and neutrons unless incorrect numbers

Not just electrons determine chemical properties

1

M2 $\frac{86x + 87x + 88(100-2x)}{100} = 87.7$ = 87.7

Alternative M2:

$\frac{86 + 87 + 88y}{1 + 1 + y} = 87.7$

1

M3 x = 10% (or × = 0.1)

M3 y = 8

1

M4 (% abundance of 88 isotope is 100 – 2x10) = 80(.0)%

M4 % of 88 isotope is 100 – 10y = 80(.0) %

Allow other alternative methods

1

(g) $^{138}Ba^+$

1

(h) **M1** $\text{mass} = \frac{137 \times 10^{-3}}{6.022 \times 10^{23}}$ = 2.275×10^{-25} (kg)

Calculation of m in kg

If not converted to kg, max 4

If not divided by L lose M1 and M5, max 3

1

M2 $v^2 = \frac{2KE}{m} = \frac{2 \times 3.65 \times 10^{-16}}{2.275 \times 10^{-25}}$ = 3.2088×10^9

For re-arrangement

1

M3 $v = \sqrt{2KE/m}$ ($v = 5.6646 \times 10^4$)

For expression with square root

STEMUP.CO.UK

1

M4 v = d/t or d = vt or with numbers

1

M5 d = (5.6646 × 10^4 × 2.71 × 10^{-5}) = 1.53 - 1.54 (m)

M5 must be to 3sf

If not converted to kg, answer = 0.0485-0.0486 (3sf). This scores 4 marks

1

Alternative method

M1 $m = \frac{137 \times 10^{-3}}{6.022 \times 10^{23}} = 2.275 \times 10^{-25}$

M1 Calculation of m in kg

1

M2 v = d/t

M2, M3 and M4 are for algebraic expressions or correct expressions with numbers

1

M3 $d^2 = \frac{KE \times 2t^2}{m}$

1

M4 $d = \sqrt{\frac{KE \times 2t^2}{m}}$ (= √ (3.65 × 10^{-16} × 2 × (2.71 × 10^{-5})^2 / 2.275 × 10^{-25}))

1

M5 d = 1.53 – 1.54 (m)

M5 must be to 3sf

1

[18]

Q4.

(a) Cl^- $1s^2 2s^2 2p^6 3s^2 3p^6$

1

Fe^{2+} $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$

1

If [Ne] or [Ar] used then Max 1if both correct

Ignore $4s^0$

Allow subscripts

(b) $Mn^{2+}(g) \longrightarrow Mn^{3+}(g) + e^-$

1

States symbols are required

Allow $Mn^{2+}(g) - e^- \longrightarrow Mn^{3+}(g)$

Negative charge needed on electron

(c) Al

STEMUP.CO.UK

Mg then CE = 0

1

(Outer) electron in (3)p sublevel / orbital

Not just level or shell

1

Higher in energy / further from the nucleus
so easier to remove OWTTE

Both required for M3

1

Ignore shielding

(d) $^{58}Ni^{+}$

M1 needs mass and charge – allow subscripts

1

A_r= [(58 × 61.0) + (60 × 29.1) + (61 × 9.9)] / 100

1

A_r= 58.9 must be to 1dp

1

[9]

Q5.

D

[1]

Q6.

(a) $$\frac{(46 \times 9.1) + (47 \times 7.8) + (48 \times 74.6) + (49 \times 8.5)}{100} = \frac{4782.5}{100}$$

1

= 47.8

Correct answer scores 2 marks.
Allow alternative methods.
Allow 1dp or more.
Ignore units

1

(b) $Ti(g) \longrightarrow Ti^{+}(g) + e^{-}$

or $Ti(g) + e^{-} \longrightarrow Ti^{+}(g) + 2e^{-}$

or $Ti(g) - e^{-} \longrightarrow Ti^{+}(g)$

State symbols essential
Allow electrons without $^{-}$ charge shown.

1

46

1

(c) $8.1(37) \times 10^{-26}$

1

(d) M1 is for re-arranging the equation

STEMUP.CO.UK

$d = t\sqrt{\frac{2E}{m}}$ or $d = \frac{t}{\sqrt{\frac{m}{2E}}}$ or $d^2 = t^2 \times \frac{2E}{m}$

Allow t α square root of m

1

$d = t_{47}\sqrt{\frac{2E}{47 \times 10^{-3} / L}} = t_{49}\sqrt{\frac{2E}{49 \times 10^{-3} / L}}$

Or

d = 1.5(47)

This scores 2 marks

Allow this expression for M2

$\frac{t_{47}}{\sqrt{47}} = \frac{t_{49}}{\sqrt{49}}$

1

= 9.6(14) × 10^{-7}

Correct answer scores 3 marks.

1

[8]

Q7.

B

[1]

Q8.

C

[1]

Q9.

(a) [Kr] $5s^2$ $4d^{10}5p^5$

1

(b) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3
All stages are covered and the explanation of each stage is correct and complete.

Answer communicates the whole explanation coherently and shows a logical progression from stage 1 to stage 2 and then stage 3.

5-6 marks

Level 2
All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies **OR** two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows a progression through the stages. Some

STEMUP.CO.UK

steps in each stage may be out of order and incomplete.

3-4 marks

Level 1
Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, **OR** only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

1-2 marks

Level 0
Insufficient correct chemistry to warrant a mark.

0 marks

Indicative Chemistry content

Stage 1

I_2 is molecular.

HI is molecular.

Stage 2

IMF hold the molecules together.

There are weak IMF forces hence the melting point is low in both substances.

I_2 bigger molecule than HI so I_2 has more electrons.

Stage 3

Therefore stronger van der Waals between molecules in I_2 that need more energy to break causing the melting point to be higher.

HI also shows permanent dipole-dipole attraction between molecules but these forces are less than the vdW forces in iodine.

6

(c) No delocalised electrons or ions

1

(d) $\frac{1}{2}H_2 + \frac{1}{2}I_2 \longrightarrow HI$

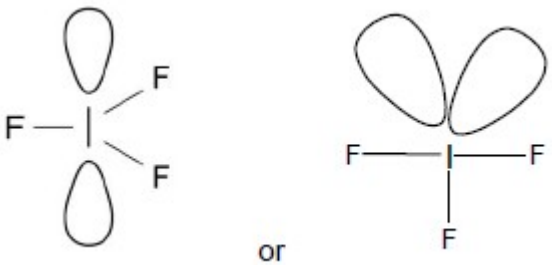
Allow multiples

1

(e) NH_4I_3

1

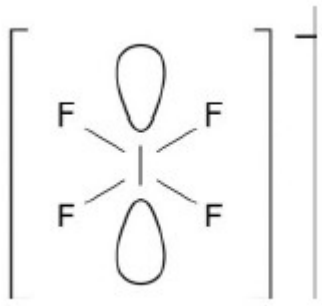
(f)



Allow any shape with 3 bond pairs and 2 lone pairs

1

STEMUP.CO.UK



Allow any shape with 4 bond pairs and 2 lone pairs (e.g. lone pairs in equatorial positions)

1

(g) +5

1

+7

1

[14]

Q10.

C

[1]

Q11.

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

Allow correct numbers that are not superscripted

1

(b) $Ca(s) + 2H_2O(l) \longrightarrow Ca^{2+}(aq) + 2OH^-(aq) + H_2(g)$

State symbols essential

1

(c) Oxidising agent

1

(d) $Ca(g) \longrightarrow Ca^+(g) + e^-$

State symbols essential
Allow 'e' without the negative sign

1

(e) Decrease

If answer to 'trend' is not 'decrease', then chemical error = 0 / 3

1

Ions get bigger / more (energy) shells

Allow atoms instead of ions

1

Weaker attraction of ion to lost electron

1

[7]

STEMUP.CO.UK

Q12.

(a) **Y**

1

(b) **X**

1

(c) Jump in trend of ionisation energies after removal of fifth electron

Fits with an element with 5 outer electrons ($4s^2 3d^3$) like V

1

(d) Explanation: Two different colours of solution are observed

1

Because each colour is due to vanadium in a different oxidation state

1

(e) **Stage 1:** mole calculations in either order

Moles of vanadium = $50.0 \times 0.800 / 1000 = 4.00 \times 10^{-2}$

Extended response
Maximum of 5 marks for answers which do not show a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.

1

Moles of SO_2 = pV / RT = $(98\,000 \times 506 \times 10^{-6}) / (8.31 \times 293)$

$= 2.04 \times 10^{-2}$

1

Stage 2: moles of electrons added to NH_4VO_3

When SO_2 (sulfur(IV) oxide) acts as a reducing agent, it is oxidised to sulfate(VI) ions so this is a two electron change

1

Moles of electrons released when SO_2 is oxidised = $2.04 \times 10^{-2} \times 2$

$= 4.08 \times 10^{-2}$

1

Stage 3: conclusion

But in NH_4VO_3 vanadium is in oxidation state 5

1

4.00×10^{-2} mol vanadium has gained 4.08×10^{-2} mol of electrons therefore 1 mol vanadium has gained $4.08 \times 10^{-2} / 4.00 \times 10 - 2 = 1$ mol of electrons to the nearest integer, so new oxidation state is 5 – 1 = 4

1

[11]

Q13.

STEMUP.CO.UK

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

1

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$

1

If noble gas core used correctly in both then scores 1
Allow subscripts and capitals
Ignore $4s^0$

(b) Sr^{2+}

Ignore name and correct proton/mass number
Allow Sr^{+2}

1

(c) Ca_3P_2

Allow reversed or ionic formula
Ignore name

1

[4]

Q14.

A

[1]

Q15.

(a) $Mg^{(2+)}$ or Magnesium

Na^+ CE=0

1

Because Mg^{2+} has more protons
AND
With the same shielding/screening/electron arrangement/number of electrons (or isoelectronic)

Allow larger/stronger nuclear charge
Ignore atomic radius

1

(b) $Na(g) \rightarrow Na^+(g) + e^-$

1 for correct species and gas phase
Allow e without charge
Allow $Na(g) - e^- \rightarrow Na^+(g)$
$Na(g) + e^- \rightarrow Na^+(g) + 2e^-$

1

(c) Mg between 600-800

1

S between 800-1040

If S not lower than P on graph then M1 only
If no plots on graph must state S below P to access M3 & M4

1

STEMUP.CO.UK

e^- paired in (3)p orbital in S (owtte)

Allow (3)p subshell/sublevel provided pair mentioned

1

Paired e^- repel (so less energy needed to remove)

1

[7]

Q16.

(a) General increase

If not increase then CE

1

Greater nuclear charge / more protons

1

Same shielding / electrons added to same shell

Allow similar

1

Stronger attraction (from nucleus) for outer electron(s)

Allow electron in outer shell

1

(b) Aluminium / Al (lower than Mg)

CE if not Al or S

1

(Outer) electron in (3)p orbital / sub-shell (level)

If 2p or 4p orbital lose M2 and M3

1

(3p) higher in energy

Allow more shielded or weaker nuclear attraction

M3 is dependent on M2

1

or
Sulfur / S (lower than P)
(Outer) electrons in (3)p orbital begin to pair
Repel

If 2p or 4p orbital lose M2 and M3

Allow 2 electrons in (3)p

M3 is dependent on M2

(c) Sulfur / S

CE if not S

1

Large jump after 6^{th} or between 6^{th} and 7^{th}

Do not allow M2 if atom/ion is removed

1

(d) Silicon

CE if not Si

1

Giant covalent structure / macromolecule

1

Covalent (bonds)

Giant covalent scores M2 and M3

1

Many / strong (covalent bonds) or

STEMUP.CO.UK

(covalent bonds) need lots of energy to break

CE for M2-M4 if molecules / metallic / ionic / IMFs mentioned

1

[13]

Q17.

D

[1]

Q18.

(a) Silicon / Si

If not silicon then CE = 0 / 3

1

covalent (bonds)

M3 dependent on correct M2

1

Strong or many of the (covalent) bonds need to be broken / needs a lot of energy to break the (covalent) bonds

Ignore hard to break

1

(b) Argon / Ar

If not argon then CE = 0 / 3. But if Kr chosen, lose M1 and allow M2+M3

1

Large(st) number of protons / large(st) nuclear charge

Ignore smallest atomic radius

1

Same amount of shielding / same number of shells / same number of energy levels

Allow similar shielding

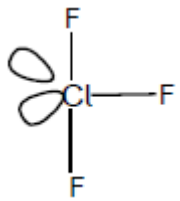
1

(c) Chlorine / Cl

*Not Cl_2, Not C**L**, Not Cl^2*

1

(d) (i)

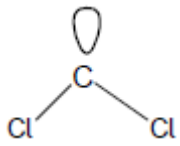


Or any structure with 3 bonds and 2 lone pairs

Ignore any angles shown

1

STEMUP.CO.UK



Or a structure with 2 bonds and 1 lone pair

1

(ii) Bent / v shape

Ignore non-linear, angular and triangular

Apply list principle

1

(iii) $\frac{1}{2}Cl_2 + \frac{3}{2}F_2 \longrightarrow ClF_3$

No multiples

Ignore state symbols

1

[11]

Q19.

(a) (i) 1.6734×10^{-24} (g)

Only.

1.6734×10^{-27} kg

Not 1.67×10^{-24} (g).

1

(ii) **B**

1

(b) (i) $\frac{10x + 11y}{x + y} = 10.8$

OR ratio 10:11 = 1:4 **OR** 20:80 etc

Allow idea that there are 5 × 0.2 divisions between 10 and 11.

1

abundance of ^{10}B is 20(%)

OR

$\frac{10x}{100} + \frac{11(100-x)}{100} = 10.8$

$10x + 1100 - 11x = 1080$

$\therefore x = 1100 - 1080 = 20\%$

Correct answer scores M1 and M2.

1

(ii) Same number of electrons (in outer shell or orbital)

Ignore electrons determine chemical properties.

STEMUP.CO.UK

Same electronic configuration / arrangement

Ignore protons unless wrong.

1

(c) Range between 3500 and 10 000 kJ mol^{-1}

1

(d) $B^{+}(g) \longrightarrow B^{2+}(g) + e^{(-)}$

$B^{+}(g) - e^{(-)} \longrightarrow B^{2+}(g)$

$B^{+}(g) + e^{(-)} \longrightarrow B^{2+}(g) + 2e^{(-)}$

Ignore state symbol on electron even if wrong.

1

(e) Electron being removed from a positive ion (therefore needs more energy) / electron being removed is closer to the nucleus

Must imply removal of an electron.

Allow electron removed from a + particle / species or from a 2+ ion.

Not electron removed from a higher / lower energy level / shell.

Not electron removed from a higher energy sub-level / orbital.

Ignore electron removed from a lower energy sub-level / orbital.

Ignore 'more protons than electrons'.

Not 'greater nuclear charge'.

Ignore 'greater effective nuclear charge'.

Ignore shielding.

1

[8]

Q20.

(a) $Al + 1.5Cl_2 \rightarrow AlCl_3$

Accept multiples.

Also $2Al + 3Cl_2 \rightarrow Al_2Cl_6$

Ignore state symbols.

1

(b) Coordinate / dative (covalent)

If wrong CE=0/2 if covalent mark on.

1

Electron pair on Cl^- donated to Al(Cl_3)

QoL

Lone pair from Cl^- not just Cl

Penalise wrong species.

1

(c) Al_2Cl_6 or $AlBr_3$

STEMUP.CO.UK

Allow Br_3Al or Cl_6Al_2
Upper and lower case letters must be as shown.
Not $2AlCl_3$

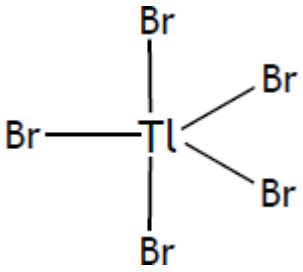
1

(d) $SiCl_4$ / silicon tetrachloride

Accept silicon(4) chloride or silicon(IV) chloride.
Upper and lower case letters must be as shown.
Not silicon chloride.

1

(e)



Accept shape containing 5 bonds and no lone pairs from Tl to each of 5 Br atoms.
Ignore charge.

1

Trigonal bipyramid(al)

1

(f) (i) Cl — Tl — Cl

Accept this <u>linear</u> structure only with no lone pair on Tl

1

(ii) (Two) bonds (pairs of electrons) repel equally / (electrons in) the bonds repel to be as far apart as possible

Dependent on linear structure in (f)(i).
Do not allow electrons / electron pairs repel alone.

1

(g) Second

1

[10]

Q21.

(a) (i) d (block) **OR** D (block)

Ignore transition metals / series.
Do not allow any numbers in the answer.

1

(ii) Contains positive (metal) ions or protons or nuclei and <u>delocalised / mobile / free / sea of</u> electrons

Ignore atoms.

1

STEMUP.CO.UK

Strong attraction between them or strong metallic bonds

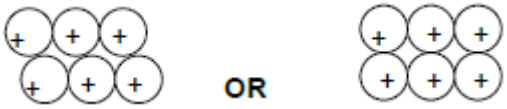
Allow 'needs a lot of energy to break / overcome' instead of 'strong'.

If strong attraction between incorrect particles, then CE = 0 / 2.

If molecules / intermolecular forces / covalent bonding / ionic bonding mentioned then CE=0.

1

(iii)



M1 is for regular arrangement of atoms / ions (min 6 metal particles).

M2 for + sign in each metal atom / ion.

Allow 2^+ sign.

2

(iv) Layers / planes / sheets of atoms or ions can slide over one another

QoL.

1

(b) (i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8\ (4s^0)$

Only.

1

(ii) $NiCl_2.6H_2O$ + **6** $SOCl_2$ ⟶ $NiCl_2$ + **6** SO_2 + **12** HCl

Allow multiples.

1

NaOH / NH_3 / $CaCO_3$ / CaO

Allow any name or formula of alkali or base.

Allow water.

1

[9]

Q22.

(a) (i) Higher than P

1

(ii) $1s^2\ 2s^2\ 2p^6\ 3s^1$

Allow any order

1

(iii) $Al^+(g) + e^{(-)} \longrightarrow Al^{2+}(g) + 2e^{(-)}$

OR

$Al^+(g) \longrightarrow Al^{2+}(g) + e^{(-)}$

OR

$Al^+(g) - e^{(-)} \longrightarrow Al^{2+}(g)$

1

STEMUP.CO.UK

(iv) Electron in Si (removed from) (3)p orbital / electron (removed) from higher energy orbital or sub-shell / electron in silicon is more shielded

Accept converse arguments relating to Al
Penalise incorrect p-orbital

1

(b) Sodium / Na

Allow Na^+

1

Electron (removed) from the 2nd shell / 2p (orbital)

M2 is dependent on M1
Allow electron from shell nearer the nucleus (so more attraction)

1

(c) Silicon / Si

Not SI

1

(d) Heat or energy needed to overcome the attraction between the (negative) electron and the (positive) nucleus or protons

Not breaking bonds
QoL

Or words to that effect eg electron promoted to higher energy level (infinity) so energy must be supplied

1

[8]

Q23.

(a) N^{3-} / N^{-3}

1

(b) F^-/ fluoride

Ignore fluorine/F
Penalise FI

1

(c) Li_3N / NLi_3

1

(d) $\frac{81.1}{40.1}$ $\frac{18.9}{14}$

M1 for correct fractions

1

(=2.02 = 1.35)

1.5 1 or 3 : 2

M2 for correct ratio

1

Ca_3N_2

If Ca_3N_2 shown and with no working award 3 marks

STEMUP.CO.UK

If Ca_3N_2 obtained by using atomic numbers then lose M1

1

(e) $3\ Si + 2\ N_2 \rightarrow Si_3N_4$

Accept multiples

1

[7]

Q24.

(a) 37

These answers only.

Allow answers in words.

1

48

Ignore any sum(s) shown to work out the answers.

1

(b) (i) Electron gun / high speed/high energy electrons

Not just electrons.

Not highly charged electrons.

1

Knock out electron(s)

Remove an electron.

1

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

OR

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

OR

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

Ignore state symbols for electron.

1

(c) Rb is a bigger (atom) / e further from nucleus / electron lost from a higher energy level/ More shielding in Rb / less attraction of nucleus in Rb for outer electron / more shells

Answer should refer to Rb not Rb molecule

If converse stated it must be obvious it refers to Na

Answer should be comparative.

1

(d) (i) s / block s / group s

Only

1

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

Allow $3d^{10}$ before $4s^2$

Allow in any order.

1

(e) $\frac{(85 \times 2.5) + 87 \times 1}{3.5}$

STEMUP.CO.UK

M1 is for top line

1
1

= 85.6

Only

1

OR

$\frac{(58 \times 5) + 87 \times 2}{7}$

M1 ^{85}Rb 71.4% and ^{87}Rb 28.6%
M2 divide by 100

1
1

85.6

M3 = 85.6

1

(f) Detector

Mark independently
Allow detection (plate).

1

Current / digital pulses / electrical signal related to abundance

Not electrical charge.

1

(g) Smaller

Chemical error if not smaller, CE = 0/3
If blank mark on.

1

Bigger nuclear charge / more protons in Sr

Not bigger nucleus.

1

Similar/same shielding

QWC
(Outer) electron entering same shell/sub shell/orbital/same number of shells.
Do not allow incorrect orbital.

1

[16]

Q25.

(a) $Li(g) \rightarrow Li^+(g) + e^-(g)$

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

$Li(g) + e^-(g) \rightarrow Li^+(g) + 2e^-$

One mark for balanced equation with state symbols

STEMUP.CO.UK

Charge and state on electron need not be shown

1

(b) Increases

If trend wrong then CE = 0/3 for (b). If blank mark on.

1

Increasing nuclear charge / increasing no of protons

Ignore effective with regard to nuclear charge

1

Same or similar shielding / same no of shells / electron (taken) from same (sub)shell / electron closer to the nucleus / smaller atomic radius

1

(c) Lower

If not lower then CE = 0/3

1

Paired electrons in a (4) p orbital

If incorrect p orbital then M2 = 0

1

(Paired electrons) repel

If shared pair of electrons M2 + M3 = 0

1

(d) Kr is a bigger atom / has more shells / more shielding in Kr / electron removed further from nucleus/ electron removed from a higher (principal or main) energy level

CE if molecule mentioned

Must be comparative answer

QWC

1

(e) 2 / two / II

1

(f) Arsenic / As

1

[10]

Q26.

(a) Cross between the Na cross and the Mg cross

1

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

One mark for state symbols consequential on getting equation correct.
Electron does not have to have the – sign on it
Ignore (g) if put as state symbol with e^- but penalise state symbol mark if other state symbols on e^-

2

STEMUP.CO.UK

(c) 2nd/second/2/II

Only

1

(d) Paired electrons in (3)p orbital

Penalise wrong number
If paired electrons repel allow M2

1

repel

1

(e) Neon/Ne

No consequential marking from wrong element

1

$1s^2 2s^2 2p^6$/[He}$2s^2 2p^6$

Allow capital s and p
Allow subscript numbers

1

(f) Decreases

CE if wrong

1

Atomic radius increases/electron removed further from nucleus or nuclear charge/electron in higher energy level/Atoms get larger/more shells

Accept more repulsion between more electrons for M2
Mark is for distance from nucleus
Must be comparative answers from M2 and M3
CE M2 and M3 if mention molecules
Not more sub-shells

1

As group is descended more shielding

1

[11]

Q27.

(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

STEMUP.CO.UK

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 <u>charge</u> (from Na to Cl)/more <u>protons</u>

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

STEMUP.CO.UK

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

1

[13]

Q28.

(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 and $Mg^{(2+)}$ 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 fewer protons/smaller nuclear charge/ fewer delocalised electrons;

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

1

STEMUP.CO.UK

Na is a bigger ion/ atom;

1

Smaller attraction between nucleus and delocalised electrons;

If mentioned that charge density of Mg^{2+} is greater then allow first 2 marks.
(ie charge / size / attraction).
M3 allow weaker 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]

Q29.

(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

STEMUP.CO.UK

(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]

Q30.

(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 3s e^-s;

1

STEMUP.CO.UK

(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]

Q31.

D

[1]

Q32.

A

[1]

Q33.

(a) Enthalpy change/required when an electron is removed/knocked out/displaced (Ignore 'minimum' energy)

1

From a gaseous atom
(could get this mark from equation)

1

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

1

Or $Mg^{+}(g) + e^{-} \rightarrow Mg^{2+}(g) + 2e^{-}$ State symbols (*Tied to M1*)

1

(c) Increased/stronger nuclear charge **or** more protons

1

Smaller atom **or** electrons enter the same shell **or** same/similar shielding

1

(d) Electron removed from a shell of lower energy **or** smaller atom **or** e^{-} nearer

1

nucleus **or** e^{-} removed from 2p rather than from 3s
Less shielding
(Do not accept 'e^{-} from inner shell')

STEMUP.CO.UK

1

[8]

Q34.

(a) **4**LiH + $AlCl_3$ → $LiAlH_4$ + **3**LiCl

1

(b) H^- = $1s^2$ **or** $1s_2$

1

(c) Tetrahedral or diagram

(Not distorted tetrahedral)

1

(Equal) repulsion

1

between four bonding pairs / bonds

(Not repulsion between H atoms loses M2 and M3)

(Not 'separate as far as possible')

('4' may be inferred from a correct diagram)

1

(d) Dative (covalent) or coordinate

1

Lone pair **or** non-bonding pair of electron **or** both e^-

1

QoL Donated from H^- to Al **or** shared between H and Al

(tied to M2)

(Not 'from H atom') (Not 'to Al ion') (Not 'e^-s transferred')

1

[8]

Q35.

(a) (i) Atoms with the same number of protons / proton number **(1)**

NOT same atomic number

with different numbers of neutrons **(1)**

***NOT** different mass number / fewer neutrons*

(ii) Chemical properties depend on the number or amount of (outer) electrons **(1)** OR, isotopes have the same electron configuration / same number of e^-

(iii) $23/6.023 \times 10^{23}$ **(1)**

CE = 0 if inverted or multiplied

tied to M1 $3.8(2) \times 10^{-23}$ [2-5 sig figs] **(1)**

5

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

STEMUP.CO.UK

accept subscripted figures

1

(c) Highest energy e^- / outer e^-s / last e^- in (3)d sub-shell **(1)**

<u>OR</u> d sub-shell being filled / is incomplete
<u>OR</u> highest energy sub-shell is (3)d
<u>NOT</u> transition element / e^- configuration ends at 3d
Q of L

1

(d) $^{15}_{7}N$ N correct symbol **(1)**

allow N^{15}_{7}

Mass number = 15 <u>AND</u> atomic number = 7 **(1)**

2

[9]

STEMUP.CO.UK

Q1.

(a) Most students understood that electrons are now arranged in energy levels, although many didn't make reference to sub-atomic particles in their answer. Students did not always make a comparison and it was not always clear which model they were referring to in their responses.

(b) Almost all students (91.3%) were able to write the correct electron configuration in terms of shells and sub-shells, although a few students made no reference to sub-shells.

(c) Many students were able to identify that the two elements were nitrogen and beryllium but many were then unable to write the correct formula of the compound formed between them.

Q2.

(a) Almost all students were able to give the correct Mr for sodium fluoride but many became confused by the different units involved in this question. Students should be advised that they should explain their working for each step in a calculation. When only numbers were provided in an answer, it was not clear what students were calculating in each step.

(b) A good number of students (39.9%) were able to determine the maximum mass of sodium fluoride that a 75.0 kg person could swallow without reaching a toxic concentration, although a few struggled with the conversion to mg.

(c) Many students completed this calculation with the figures upside-down and so were unable to score. A surprisingly high proportion of students (16%) made no attempt whatsoever at this question.

(d) Many students were unable to identify the correct relative sizes – many stated that both ions were the same size because they had the same number of electrons, without considering the impact of the protons. Other students did not appreciate that both ions were isoelectronic.

Q3.

(a) The electron configuration was well known (88.9% correct).

(b) Only the best students gained both marks here (19%); many students focused on whether the electron was being removed from a full or partially full orbital instead of considering why the attraction between the nucleus and the electron might be different.

(c) Less than half of the students (39.5%) could give the correct answer here; lithium was a common error.

(d) The majority of students (76.3%) answered this correctly, although there were quite a number who gave the incorrect formula.

(e) The ionic equation was generally correct and many students could also calculate that barium chloride was in excess. Just under a third of students managed to score all three marks.

(f) Most students could state why isotopes have the same chemical properties. In the calculation, many students gave an algebraic equation with two unknowns and could not proceed any further. The students who gave a correct algebraic expression with one unknown could work through the calculation and generally gained full marks. Some students answered the question by trial and error and this was also given full credit. Pleasingly, 43.7% of students gained all four marks available.

(g) Most students deduced that the mass number of the ion would be 138 but less than 30% of students could give the correct formula for the ion including its charge.

(h) Some students answered this part very well (with 36.6% scoring full marks), but most students scored partial marks or no marks; common errors included failure to use the Avogadro constant, not converting mass to kg, and incorrect rearrangement of expressions.

Q4.

(a) This was surprisingly poorly answered. Many students were unable to write the electronic configuration for Fe^{2+}.

(b) Part (b) was generally well answered, but a significant number of answers had missing state symbols, despite the direct instruction to include them.

(c) Part (c) was quite well answered.

(d) The symbol including mass number was often incorrect. The calculation of A_r was straight- forward and done well by many students.

Q5.

69% of students scored this mark.

Q6.

(a) This was generally well answered, though a few students added the abundances incorrectly.

(b) Most students gave the correct equation, but some used the wrong state symbols or omitted them. The identity of the isotope was well known but some students lost a mark by using the symbol for the atom rather than the *m/z* value.

(c) The most common error was a failure to convert from grams into kilograms.

(d) Only the best students gained all three marks. All marks were available, even for those students who had not answered part (c), or who had the wrong answer for it. Some students were unable to re-arrange the equation. Students who appreciated that the distance travelled was common to both ions usually went on to get the correct answer, but a large number of students scored zero or one mark.

Q13.

Aspects of this question were well done but significant numbers were unable to write the electronic configuration of the Cr^{3+} ion. part (b) was answered well but the unfamiliar formula required in (c) proved tricky for the majority.

Q15.

STEMUP.CO.UK

Most of this question was answered correctly but many students failed to appreciate that the ions compared in part (a) had the same number of electrons therefore 1 mark was scored rather than 2. It was pleasing to see over half the students scoring 3 or more marks on part (c)

Q16.

In part (a) the trend in ionisation energy was explained well with many scoring three or four marks. Many students did not read the question carefully and explained the anomalies in the trend. Those who lost a mark usually omitted the key word 'outer' in respect of the electron being removed. In part (b) many students correctly identified and explained an element that deviated from the general trend. In part (c) most were able to recognise the large jump after the sixth ionisation energy and deduce the element as sulfur. Most students knew that silicon had the highest melting point and went on to score full marks, although aluminium was a common incorrect answer. The quality of language was not always sufficiently clear and some used chemical terms incorrectly such as covalent bonds between molecules or strong van der Waals forces between atoms.

Q18.

The students who selected the correct element in part (a) generally went on to score full marks. However a large number thought that argon had the highest melting point and therefore did not score any marks. In part (b) the majority of students selected argon and gave an explanation of their choice. If the answer was correct the most common problem was missing the shielding factor necessary for the third mark. Part (c) was answered correctly by most students. The shape of ClF_3 was found easier to draw than CCl_2 in part (d)(i) and the name of the shape in (d)(ii) was answered correctly by many students. The most common error in part (d)(iii) was to write an equation to produce two moles rather than one mole as stated in the question.

Q19.

The overall performance in part (a)(i) was disappointing because many students did not know the subatomic particles in the hydrogen atom. The mark in part (a)(ii) was scored by most students. Many students scored both marks in part (b)(i) but several quoted an equation involving *x* and *y* but could not progress beyond that. The majority of students answered part (b)(ii) correctly and part (c) was also generally well done. In part (d), many students used Br instead of B in their equation and some either wrote the wrong ionisation energy or failed to add state symbols. Many answers to part (e) were superficial; many students simply referred to a different proton / electron ratio or the removal of an electron from a different energy level.

Q20.

The equation in part (a) was given correctly by only a few students. Far too many students could not give the correct formula for aluminium chloride. The type of bonding in part (b) was well answered but many students thought that the pair of electrons originated from the Cl atom or from the Al atom. In part (e), the majority of students gave a correct structure and formula. Incorrect answers were due to the insertion of lone pairs of electrons. The linear shape in part (f) was generally answered well but the explanation of the shape often did not refer to repulsion between the bonding electron pairs. The majority of students scored the mark in part (g), realising that the outer electrons are removed first during successive ionisations.

Q21.

STEMUP.CO.UK

This question was generally quite well answered. In part (a)(i), most students knew the correct block in the Periodic Table although some seemed to think that the name 'Transition Metals' was enough to identify the d block. In part (a)(ii), the biggest issue was the omission of 'positive' when describing ions and 'delocalised' when describing the electrons involved in the bonding. The diagrams in part (a)(iii) generally scored highly but some were untidy and failed to show a regular arrangement of ions. Surprisingly, many students did not refer to layers of atoms / ions sliding in part (a)(iv) and therefore did not score the mark. Answers to part (b)(i) were disappointing and showed that students could not write the electron configuration of ions in the d block. Balancing the equation proved difficult but a good number of students did this well and many students could suggest a suitable substance in part (b)(ii).

Q22.

The concept of second ionisation energy discriminated well. Good students could apply their understanding of ionisation energy and gave good answers to this question. Weaker students found much of the question difficult.

In part (a)(i), many students thought incorrectly that the cross was below phosphorus. The electron configuration in part (a)(ii) was well answered and the main error in part (a)(iii) was omitting state symbols. Answers to part (a)(iv) often failed to mention the electron being removed and there were several confused responses with inappropriate use of shell / energy level rather than sub-shell / orbital. A large number of students thought that argon had the highest second ionisation energy and therefore could not score the rest of the marks in part (b). The students who did quote sodium often found the explanation difficult. In part (c), various elements were quoted but it was evident that some students did not know which was Period 3. In part (d), many students simply stated the meaning of endothermic but did not explain why the ionisation was endothermic. Some students had the idea that a bond was broken but failed to extend this to an attraction between the nucleus and the electrons.

Q23.

A lot of correct answers were seen in part (a) although many students found this difficult and answers giving incorrect charges ranging from –1 to +4 were seen. Some students lost marks by trying to write an equation rather than just stating the ion. In part (b), many students did not refer to an ion in their answer. Many students did not appreciate the –ide ending in part (c) and produced formulae such as $LiNO_3$. Many of those who realised that the formula contained only Li and N gave incorrect formulae such as LiN, LiN_3, Li_4N etc. In the empirical formula calculation in part (d), there were many students who could get no further than the 2.02 :1.35 ratio and weaker students divided the percentage of nitrogen by 28 rather than by 14. A small number of students used incorrect fractions by dividing the relative atomic mass by the percentage and getting Ca_2N_3. The equation in part (e) proved demanding with many students writing atomic nitrogen, N and molecular silicon eg Si_2, Si_8. A few incorrect symbols for silicon were seen ie S rather than Si.

Q24.

Part (a) was done very well. In part (b)(i), many students stated that a positive ion was formed but failed to say how. The equation in part (b)(ii) was well done with only a few omitting the state symbols. In part (c), a number of students failed to score the mark since they referred to a rubidium molecule, showing a lack of understanding of the metals given. In part (d)(ii) there were many students who filled the 4d rather than the 5s orbitals and some gave an abbreviated electron structure even though the question asked for the full electron structure. Many students found part (e) difficult although it was pleasing to see some gain full marks. Part (f) was not well understood with many students confusing charge and current. The answers to part (g) were generally good although a few students

STEMUP.CO.UK

did not give complete explanations and lost the last mark.

Q25.

Candidates generally attempted part (a) well although there were some candidates who failed to score the mark since the state symbols were missing or, due to unclear writing, it was impossible to distinguish if the state symbol was an ‘s’ or ‘g’. Part (b) was well answered by most candidates. In order to give a convincing answer in part (c), candidates needed to understand what an orbital is. Many incorrect answers showed that candidates confused principal energy levels and orbitals. Many answers stated that electrons repel and did not refer to repulsion of the paired electrons in the relevant p orbital. There was also confusion between paired electrons repelling and the repulsion of paired electrons that is used to explain molecular shapes. Most candidates answered part (d) well. Parts (e) and (f) discriminated quite well and a range of answers were seen.

Q26.

Part (a) was answered well. The equation in part (b) was generally well known although many candidates lost the second mark for omitting the state symbols or having the electron on the wrong side of the equation. Part (c) was answered correctly by a good number of candidates. The explanation in part (d) was variable with much confusion over paired electrons and lone pairs of electrons. There was much inaccuracy in the use of terminology in candidates' answers. Answers to part (e) were variable and answers included almost every element in period 2. Part (f) was well done by a majority of candidates.

Q27.

Part (a) was answered well by most candidates with some writing the electron configuration of Mg rather than the ion. Some candidates wrote subscripts for the numbers of electrons even though the $1s^2$ was given. In part (b)(i) many candidates could not give a precise definition. The commonest errors were to mix up moles and atoms or to miss out the gaseous state. Many candidates missed the state symbols from the equation in part (b)(ii) and some gave equations showing the removal of 2 electrons. Part (b)(iii) was not well answered. There was a good attempt at part (b)(iv). In part (c) the trend was generally well known as was the increasing nuclear charge. Imprecise technical language cost several candidates a mark -”a bigger nucleus” is not the same as “a nucleus with a bigger charge”. Part (d) was well answered with most candidates knowing the deviation and the explanation. Marks were lost for not stating that the paired electrons were in the p orbital and some thought they were in the 2p orbital. There were many correct answers to part (e).

Q28.

The electronic configuration in part (a) was generally well known. In part (b)(i) the removal of 2 electrons from the neutral atom was a common incorrect answer and in (b)(ii) many candidates missed the effect of change of shielding. Often candidates referred to s and p orbitals with no reference to the number of the principal energy level. Part (b)(iii) was disappointing and showed that many candidates find it difficult to apply concepts to different situations. Part (c) was generally well known although many candidates did not score the second explanation mark. In part (d) many candidates did not realise that metallic bonding, or an explanation of it, was required in the answer. Many thought that van der Waals forces were involved or mentioned losing electrons causing ionisation. In part (e) there were many unclear diagrams and many candidates had the wrong number of lone pairs of electrons. Answers to the shape of the molecule were often incorrect or contradictory e.g. bent-linear. Part (f) was well answered.

Q29.

Candidates tended to score a little better on this question than on question 3 but, overall, the question was not well answered. Part (a) was generally well done, although incomplete answers were quite common. The most common error was to omit reference to *gaseous atoms*.

Parts (b) and (c) were often well answered; however, in part (d) incorrect ionic charges and missing or incorrect state symbols were quite often seen.

Part (e) was poorly done. Many candidates referred to difference in the number of electron shells present in the two species despite being told in the question that they had the same number of electrons. Some candidates attributed the difference to a special stability enjoyed by neon as a consequence of it having a full outer electron shell. Clearly, the majority of candidates failed to appreciate the significance of the two species having the same number of electrons. Many answers referred to ”It’, magnesium or Mg, rather than correctly identifying the species being discussed.

In part (f), candidates are asked to demonstrate their understanding of a trend required in the specification. While part (f)(i) was often competently dealt with, answers in part (f)(ii) frequently lacked sufficient specific detail to be awarded credit. Often, candidates failed to identify the electron pair from which from which the first electron would be removed, or to explain the relatively low first ionisation energy of sulphur in terms of repulsion between the electrons in this electron pair. Vague phrases such as ‘*electron pairs repel’*, or a reference to a more stable half-filled shell being formed, earned no credit.

Q30.

While less able, (or less well prepared,) candidates struggled with this question, the majority coped quite well. The equation in part (a) was usually correct, although it was not unusual to see Al_2, Al^{3+} or Cu_2 in the equation, or for the equation to be incorrectly balanced. Most candidates correctly identified an increase in ionisation energy across the group; however, the explanations in part (b)(ii) were frequently vague and unconvincing. In particular, statements that the electron in aluminium as *easier to remove,* rather than making direct reference to the lower ionisation energy of aluminium, failing to specify the 3p electron as being the first electron to be removed from aluminium or vaguely referring to extra shielding, were quite common. In part (c) some candidates did not start their equation with Al^+ ions and many more either omitted the state symbols completely or used the wrong one. The majority of candidates correctly identified a rising trend in the melting point of the three metals in part (d) but the explanations offered were diverse and frequently incomplete or wrong. Those candidates who did correctly attribute the trend to an increase in proton number or to the number of delocalised electrons often proceeded no further, or simply referred, without explanation, to an increase in metallic bonding. Many explanations were poor, and references to *molecules, ionic bonding, van der Waals' forces* and even *hydrogen bonding* were frequently seen.

Q33.

This question was, in general, poorly answered. In part (a), the definition was not well known, *element* was frequently used in place of *atom*, and the requirement for gaseous conditions was often omitted. In part (b) the equation was frequently correct; however, equations showing Mg going to Mg^{2+} ions were not unusual. Again, the gaseous state symbol was often omitted. In part (c), some candidates based their argument on the stability of the full shell of the Na^+ ion and the lower stability of the incomplete outer shell of the Mg^+ ion. Other candidates suggested that sodium atoms *wanted to lose an electron*. These arguments earned no credit. In part (d) similar incorrect arguments to those used in part (c) were frequently seen, as well as vague references to differences in charge density

STEMUP.CO.UK

and comparisons of metallic bonding strengths.

Q34.

This question was, in general, also poorly answered. Of those candidates who attempted part (a), most were successful; however, a surprisingly large number of candidates made no attempt to balance the equation. Whilst, in part (b), most candidates gave the correct electronic arrangement for the hydride ion; $1s^0$ and $1s^12s^1$ were quite common errors. Candidates encountered many problems in deducing the shape of the $AlCl_4^-$ ion, with *trigonal planar*, *square planar* and *distorted tetrahedral* being the most common errors. Some candidates drew diagrams to illustrate their answer, many of which showed a lone pair on the Al atom. The explanation was frequently incomplete, or incorrectly referred to repulsions between *hydrogen atoms* or *hydride ions*, rather than between four bonding electron pairs. In part (d), many candidates were able to identify the bonding as dative/coordinate but then simply described, in general terms, the formation of such a bond. References to the donation of a lone pair from the hydride ion to the aluminium atom were relatively rare.

Q35.

Many good answers were seen here and high marks were quite common. However, candidates frequently ignored the instruction in (a)(i) to define *isotopes* in terms of fundamental particles, and offered a definition based wholly, or in part, on mass number and atomic number. In (a)(ii), the link between chemical properties and electron configuration was well known but many candidates attempted to establish a link between proton, neutron or mass numbers and chemical properties. The calculation in (a)(iii) was often poorly done, the most common errors being to invert the expression or to multiply the mass number by *L*. Part (b) was generally well answered, although a few candidates gave the electron arrangement showing 23 electrons. Similarly, part (c) was generally well answered, however, some candidates referred to electrons being in the *d block*, while a small minority offered nonsense explanations. Most candidates correctly identified nitrogen as the element in part (d), but $^{14}_{7}N$ was a common error.

STEMUP.CO.UK

Q1.

(a) Assume current model unless otherwise stated.

Statement about the nucleus:
(Central) nucleus contains protons and neutrons.

Allow "protons and neutrons are in the centre of the atom"

1

Statement about electrons
Electrons are now arranged in energy levels/shells/orbitals

Ignore "mostly empty space"

Ignore electrons surround / orbit nucleus

Allow additional statement about neutrons but must be separate from statement about nucleus to score

e.g.

no neutrons in plum pudding / neutrons now recognised

1

(b) $1s^2 2s^2 2p^3$

Ignore commas, capitals and subscripts

Allow $1s^2 2s^2 2px^1 2py^1 2pz^1$

1

(c) (R is N (nitrogen))

Formula Be_3N_2

Accept Be_3R_2 only if stated R = nitrogen

Accept N_2Be_3

1

[4]

Q2.

D

[1]

Q3.

A

[1]

Q4.

(a) ^{24}Mg has 12n; ^{25}Mg has 13n; ^{26}Mg has 14n

OR They have different numbers of neutrons

1

(b) No difference in chemical properties

1

STEMUP.CO.UK

Because all have the same electronic structure (configuration)

OR they have the same number of outer electrons

1

(c) If fraction with mass 24 = x

Fraction with mass 26 = 0.900 − x

Fraction with mass 25 = 0.100

1

A_r = 24x + (25 × 0.100) + 26(0.900 − x)

1

24.3 = 24x + 2.50 + 23.4 −26x

2x = 1.60

x = 0.800 i.e. percentage ^{24}Mg = 80.0(%) (80.0% 3sf)

1

^{26}Mg = 0.900 − 0.800 = 0.100 ie percentage ^{26}Mg = 10.0(%)

1

(d) m = $\frac{25/1000}{6.022 \times 10^{23}}$

1

$v^2 = 2ke/m$ or $v^2 = \frac{2 \times (4.52 \times 10^{-16}) \times (6.022 \times 10^{23})}{25/1000}$

1

$V = \sqrt{2.18 \times 10^{10}} = 1.48 \times 10^5 \ (ms^{-1})$

1

D = vt =1.48 × 10^5 × 1.44 × 10^{-5}

D = 2.13 (m)

1

[11]

Q5.

C

[1]

Q6.

D

[1]

Q7.

A

[1]

STEMUP.CO.UK

Q8.

D

[1]

Q9.

(a) (i) 1.6734×10^{-24} (g)

Only.

1.6734×10^{-27} kg

Not 1.67×10^{-24} (g).

1

(ii) **B**

1

(b) (i) $\frac{10x + 11y}{x + y} = 10.8$

OR ratio 10:11 = 1:4 **OR** 20:80 etc

Allow idea that there are 5 × 0.2 divisions between 10 and 11.

1

abundance of ^{10}B is 20(%)

OR

$\frac{10x}{100} + \frac{11(100-x)}{100} = 10.8$

$10x + 1100 - 11x = 1080$

$\therefore x = 1100 - 1080 = 20\%$

Correct answer scores M1 and M2.

1

(ii) Same number of electrons (in outer shell or orbital)

Ignore electrons determine chemical properties.

Same electronic configuration / arrangement

Ignore protons unless wrong.

1

(c) Range between 3500 and 10 000 kJ mol^{-1}

1

(d) $B^+(g) \longrightarrow B^{2+}(g) + e^{(-)}$

$B^+(g) - e^{(-)} \longrightarrow B^{2+}(g)$

$B^+(g) + e^{(-)} \longrightarrow B^{2+}(g) + 2e^{(-)}$

Ignore state symbol on electron even if wrong.

1

STEMUP.CO.UK

(e) Electron being removed from a positive ion (therefore needs more energy) / electron being removed is closer to the nucleus

Must imply removal of an electron.

Allow electron removed from a + particle / species or from a 2+ ion.

Not electron removed from a higher / lower energy level / shell.

Not electron removed from a higher energy sub-level / orbital.

Ignore electron removed from a lower energy sub-level / orbital.

Ignore 'more protons than electrons'.

Not 'greater nuclear charge'.

Ignore 'greater effective nuclear charge'.

Ignore shielding.

1

[8]

Q10.

(a)

Particle	Relative Charge	Relative mass
Proton	+1	1
Neutron	0	1

1 **1**

Need +1 for proton

(b) d block/ D block;

Or D or d

1

(c) (i) 74;

Not 74.0

1

(ii) 112;

Not 112.0

1

(d) (i) To accelerate/ make go faster;

1

To deflect/ to bend the beam;

Any order
Not just attract to negative plate

1

(ii) Electromagnet / magnet / electric field /accelerating potential or voltage;

Not electric current
Not electronic field

1

STEMUP.CO.UK

(e) None/ nothing;

If blank mark on.
If incorrect CE = 0

1

Same number of electrons (in outer orbital/shell)/ both have 74 electrons/same electron configuration;

Not just electrons determine chemical properties
Ignore protons and neutrons unless wrong statement.

1

(f) $\frac{(182 \times 26.4) + (183 \times 14.3) + (184 \times 30.7) + (186 \times 28.6)}{100}$;

If transcription error then
M1 = AE = –1 and mark
M2 consequentially

1

= 183.90; allow range from 183.90 – 184.00;

1

[12]

Q11.

(a) Number of protons in the nucleus

1

(b) They may have different numbers of neutrons

1

(c) (i) Mass spectrometer

1

(ii) $\frac{\text{Mean mass of an atom}}{\text{Mass of 1 atom of } {}^{12}\text{C}} \times 12$

2

(iii) $A_r = \frac{\text{sum of relative m/z} \times \text{rel. abundance}}{\text{Total abundance}}$

1

= (82 × 12 + 83 × 12 + 84 × 50 + 86 × 26)/100 = 84.16

1

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

1

(e) Krypton was thought to be an inert gas
(or has 8 electrons in outer shell)

1

(f) (i) Krypton has more protons than bromine

1

But its outer electrons are in the same shell
(or have similar shielding)

1

STEMUP.CO.UK

(ii) Al electron is in a 3p orbital, magnesium in 3s

1

Energy of 3p is greater than 3s

1

[13]

Q12.

(penalty for sig fig error =1 mark per question)

(a) neutron: relative mass = 1 relative charge = 0
(not 'neutral')

1

electron: relative mass = 1/1800 → 0/negligible *or*

5.56 × 10–4 → 0 relative charge = –1

1

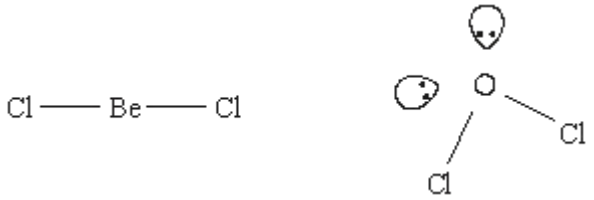
(b) $^{17}O/O^{17}$ mass number (*Do not accept 17.0*)

1

oxygen symbol 'O'
(if 'oxygen' + — 'mass number = 17'(1))
(if 'oxygen'+ — 'mass number = 17'(0))
(if at N^0 given but ≠ 8, treat as 'con' for M2)
(if lp on Be, diagram = 0)
(ignore bond angles)
(not dot and cross diagrams)

1

(c)



2

QoL Linear **(1)** bent / V-shaped / angular **(1)**
(mark name and shape independently)
(accept (distorted) tetrahedral)
(if balls instead of symbols, lose M1 – can award M2)
(penalise missing 'Cl' once only)
(not 'non-linear')

2

(d) M_r ($Mg(NO_3)_2$ = 58(.3) *(if At N^0 used, lose M1 and M2)*

1

moles $Mg(OH)_2$ = 0.0172 (conseq on wrong M2) (answer to 3+ s.f.)

1

moles HCl = 2 × 0.0172 = 0.0344 *or* 0.0343 (mol) *(process mark)*

STEMUP.CO.UK

1

vol HCl = $\frac{0.0343 \times 1000}{1}$ = 34.3 – 34.5 (cm^3) *(unless wrong unit)*

*(if candidate **used** 0.017 or 0.0171 lose M2)*

(just answer with no working, if in range = (4). if, say, 34 then =(2))

(if not 2:1 ratio, lose M3 and M4)

(if work on HCl, CE = 0/4)

1

[12]

Q13.

(a) Proton mass = 1 charge = +1

Electron mass ≤ 1/1800 Or ≤ 5.6×10^{-4} charge = –1

(Do not accept +1 for proton mass or 'g' units)

2

(b) (i) 13

1

(ii) Si

1

Mass number = 28 **and** atomic number = 14

(Do not accept 28.1 or 28.0 or 'Silicon')

5

(c) Mean (average) mass of an atom / all the isotopes

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

Or Mass of 1 mole of atoms of an element **(1)**

1/12th mass of 1 mole of ^{12}C **(1)**

Or Average mass of an atom / all the isotopes **(1)**

relative to the mass of a ^{12}C atom taken as exactly 12 / 12.000 **(1)**

(Penalise 'weight' once only) (Ignore 'average' mass of ^{12}C)

(Do not allow 'mass of average atom')

2

(d) $A_r = (24 \times 0.735) + (25 \times 0.101) + (26 \times 0.164)$ 1 = 24.4 1

(mark M2 conseq on transcription error or incorrect addition of %)

(e) M_r = highest m/z value 1

(NOT 'highest/largest/right-hand' peak)

3

[10]

Q14.

(a)

Particle	Relative charge	Relative mass	
Proton	+1 **or** 1+	1	**(1)**

STEMUP.CO.UK

Neutron	0 **or** no charge/neutral/zero	1 (<u>not</u> – 1)	**(1)**
Electron	–1 or 1–	1/1800 to 1/2000	**(1)**

or negligible
or zero
or 5.0×10^{-4} to 5.6×10^{-4}

if 'g' in mass column - wrong
penalise once

3

(b) $^{38}_{18}Ar$ **(1)(1)**

Allow numbers before or after Ar

2

(c) *S*: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$ **(1)**

Allow upper case letters

S^{2-}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ **(1)**

If use subscript penalise once

2

(d) *Block*: p **(1)**
Explanation: Highest energy or outer orbital is (3) p

OR outer electron, valency electron in (3) p
NOT 2p etc.

2

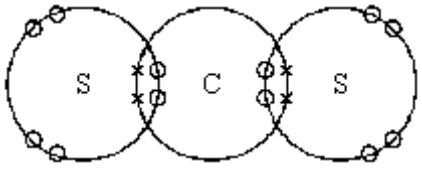
(e) (i) *Bonding in Na_2S*: ionic **(1)**
Bonding in CS_2: covalent **(1)**

ignore other words such as dative / polar / co-ordinate

(ii) Clear indication of electron transfer from Na to S **(1)**
1 e^- from each (of 2) Na atoms or 2 e^- from 2 Na atoms **(1)**

QoL correct English

(iii)



Correct covalent bonds **(1)**
<u>All correct</u> including <u>lone pairs</u> **(1)**

Allow all •s or all ×s
M2 tied to M1
NOT separate e^-s in S•- 2 l p

(iv) $CS_2 + 2H_2O \rightarrow CO_2 + 2H_2S$ **(1)**

Ignore state symbols even if wrong

STEMUP.CO.UK

7

[16]

Q15.

(a) Proton: mass 1, charge + 1 **(1)**
Neutron: mass 1, charge 0 **(1)**
Electron mass 1/1840, charge -1 **(1)**

Allow mass = 0, or negligible, or 1/1800 to 1/2000

Isotopes have the same number of protons **(1)**

OR atomic number

different number of neutrons **(1)**

Isotopes have the same electronic configuration **(1)**

OR same number of electrons

Chemical properties depend on electrons **(1)**

7

(b) $\frac{\text{average (1) mass of an atom/isotopes}}{\text{mass of 1 atom of } {}^{12}C} \times 12$ **(1)**

OR $\frac{\textit{mass of 1 mol of atoms}}{\textit{mass of 1 atom of } {}^{12}C} \times 12$ *or in words*

Spectrum gives (relative) abundance **(1)**

OR % or amount

And *m/z* **(1)**
Multiply *m/z* by relative abundance for each isotope **(1)**

Allow instead of m/z mass no, A_r or actual value from example

Sum these values **(1)**
Divide by the sum of the relative abundances **(1)**

only award this mark if previous 2 given

Max 2 if e.g. has only 2 isotopes

7

[14]

Q16.

C

[1]

STEMUP.CO.UK

Q1.

(a) Most students understood that electrons are now arranged in energy levels, although many didn't make reference to sub-atomic particles in their answer. Students did not always make a comparison and it was not always clear which model they were referring to in their responses.

(b) Almost all students (91.3%) were able to write the correct electron configuration in terms of shells and sub-shells, although a few students made no reference to sub-shells.

(c) Many students were able to identify that the two elements were nitrogen and beryllium but many were then unable to write the correct formula of the compound formed between them.

Q2.

For this question with a 72.6% success rate, A was the commonest incorrect response.

Q3.

While 66.9% of students correctly identified A, there was a fairly even distribution of wrong answers between B, C and D.

Q9.

The overall performance in part (a)(i) was disappointing because many students did not know the subatomic particles in the hydrogen atom. The mark in part (a)(ii) was scored by most students. Many students scored both marks in part (b)(i) but several quoted an equation involving *x* and *y* but could not progress beyond that. The majority of students answered part (b)(ii) correctly and part (c) was also generally well done. In part (d), many students used Br instead of B in their equation and some either wrote the wrong ionisation energy or failed to add state symbols. Many answers to part (e) were superficial; many students simply referred to a different proton / electron ratio or the removal of an electron from a different energy level.

Q10.

In part (a) the majority of the candidates scored full marks with some losing marks by referring to a charge of + rather then +1, or putting a + (plus) or a – (minus) sign in the relative mass column. The answer to part (b) was well done with only a few writing 'Transition metals' rather than stating the block that tungsten is in. Some candidates did not score marks in part (c) since they did not look for the atomic number in the Periodic Table and some could not remember how to calculate the number of neutrons. Candidates generally answered part (d) well although a few put 'detect' as one of their answers and this was given in the stem of the question. Some tried to explain how the ions were formed but this was not asked for. Part d (ii) was well answered. In part (e) candidates lost the second mark by not knowing that the isotopes have the same electron configuration. Many answers just stated that isotopes had different numbers of neutrons and/or same number of protons. The calculation in part (f) was very well done although some candidates lost the second mark by not giving their answer to two decimal places.

Q12.

On the whole, this question was well answered. The relative masses and charges of neutrons and electrons were generally well known but errors were not uncommon. Some candidates reversed the contents of the *mass* and *charge* columns, suggesting that they had rote learned a table with a different layout of columns.

Part (b) was quite well done but errors such as ^{17}Be, ^{13}O, $^{17.0}$O and ^{16}O were not uncommon.

While many candidates correctly deduced the shapes of the molecules in part (c), the presence of a lone pair of electrons on the Be atom, or one/three lone pairs of electrons on the O atom, was quite common. The shape of the $BeCl_2$ molecule was well known but there was considerable confusion regarding the shape of the Cl_2O molecule. Many candidates gave *tetrahedral* as the shape of this molecule. While the distribution of electron pairs around the oxygen atom might be described as *tetrahedral*, this is not the shape produced by the atoms in the molecule. Many candidates described the shape in appropriately by using the terms *bent*, *V-shaped* and *angular*. The use of *tetrahedral* was accepted in this examination but this may not be the case in future examinations. A significant number of candidates used the term *bent linear* when describing the shape of Cl_2O molecules; this was treated as a contradiction and so earned no credit. A significant number of candidates attempted to show the shapes of these molecules using dot-and-cross diagrams; these were not accepted.

The calculation in part (d) was correctly performed by many candidates, but errors such as the use of incorrect *M*r values or the use of an incorrect mole ratio were quite common. A small but significant number of candidates assumed the use of a known mass of HCl and ignore the 1.00 g of $Mg(OH)_2$ stipulated in the question; such answered earned no credit.

Q13.

The fundamental particle data required in part (a) was generally well known; however, relative charges where either the sign or the value was omitted were occasionally seen. Part (b)(i) was well answered, and the majority of candidates coped well with (b)(ii). It was quite common however to see 28.1, rather than the required 28, to be quoted as the mass number of **Q**. Part (c) simply required a standard definition for the A_r to be quoted. Surprisingly, this question was quite poorly done, with attempts being frequently vague and incomplete. The most common error was to omit references to *mean*, *mass* and *atoms* in the definition. Also, it was not uncommon to see a ratio showing single atoms on the top and moles on the bottom. In part (d), the calculation of the A_r of the sample of magnesium was usually correct, however, a significant number of candidates failed to quote their final answer to one decimal place. Some candidates used the sum of the *m/z* values, rather than the sum of the relative abundances (100). Part (e) was very poorly answered. Very few references to *highest m/z value* were seen.

Q14.

Many candidates answered this question quite well but full marks were not that common. Most candidates correctly completed the table in part (a) but it was not unusual for either the signs or the values of the relative charges to be omitted. In a few instances, the values of the electron and the neutron were transposed. Success in part (b) was far from universal. Errors such as 39.9 and 36 for the mass number were quite common, as was the use of Z to represent the element. Part (c) was, in the main, successfully completed but the odd d level was seen, as were configurations for the S^{2-} ion showing $3p^2$ rather than $3p^6$ electrons, or even a $2p^8$ arrangement. While part (d) was also generally well done, some candidates were found to be unfamiliar with this part of the specification and

STEMUP.CO.UK

the suggestion that the element was found in block 6, because it contained 6 outer electrons, was not uncommon. Some candidates incorrectly referred to the p-block or p-shell, rather than using the correct terms sub-level or sub-shell. In part (e), a surprising number of candidates identified incorrectly the bonding in Na_2S as being covalent or metallic, and the bonding in CS_2 as being ionic, molecular or dative. For those candidates who did recognise the ionic nature of the bonding in Na_2S, their descriptions were often vague and they did not express clearly the transfer of electrons which takes place, and the numbers of electrons involved. Many answers could have equally well fitted the description for the formation of a covalent bond. The diagram of the bonding in CS_2 was frequently flawed, with spare electrons being placed around carbon and extra lone pairs on the sulphur atoms. Some candidates showed a single bond between the sulphur and carbon atoms, whilst others only included a single sulphur atom. The equation was almost invariably correct; although, in a few cases, the equation was not balanced.

Q15.

Most candidates scored high marks for part (a) though the final part of the question, requiring an explanation why isotopes have identical chemical properties, was more demanding. Part (b) was also answered well though a considerable number of candidates wasted time by giving detailed but irrelevant information about the operation of the various parts of a mass spectrometer. Candidates were often imprecise about the information that can be obtained from a mass spectrum. Confusion between mass/charge and atomic mass or relative atomic mass was common but did not incur a heavy penalty.

STEMUP.CO.UK

Q1.

(a) = 79 / (1000 × 6.022 × 10^{23}) = 1.31 × 10^{-25} kg

1

Then either follow **method 1** (or **method 2** below)

Do not mix and match methods

Method 1

$V_{79} = \frac{d}{t}$ = 0.950 / 6.69 × 10^{-4}

= 1420 ms^{-1}

In method 1, M2 can be awarded in M3

1

KE = ½ mv^2

= ½ × 1.312 × 10^{-25} × $(1420)^2$

= 1.32 × 10^{-19} J

Mark consequential to their velocity and mass. Allow mass of 79 etc.

1

$V_{81} = \sqrt{(\frac{2KE}{m})}$

= √ 1.963 × 10^6

= 1.40 × 10^3 ms^{-1}

(allow 1.398 × 10^3 - 1.402 × 10^3)

Mark consequential to their velocity and mass. Allow mass of 81 etc.

1

$t = \frac{d}{v} = \frac{0.950}{v_{81}}$

= 6.80 × 10^{-4} s

Mark consequential to their M4

Accept 6.77 – 6.80 × 10^{-4} s

1

Method 2

$m_1(d/t_1)^2 = m_2 (d/t_1)^2$

or

$m_1 / t_1^2 = m_2 / t_2^2$

1

STEMUP.CO.UK

$t_2^2 = t_1^2 (m_2/m_1)$
Or
$t_2^2 = (6.69 \times 10^{-4})2 \times (81/79)$

1

$t_2^2 = 4.59 \times 10^{-7}$

Mark consequential to their M3

1

$t = 6.77 \times 10^{-4}$ s

Mark consequential to their M4
Accept 6.77 – 6.80 × 10^{-4} s

1

(b) ion hits the detector / negative plate and gains an electron

1

Not positive plate

(relative) abundance is proportional to (the size of) the current

1

[7]

Q2.

(a) 3-chloro-2,4-dimethylpentane

This answer only apart from slips with commas and dashes

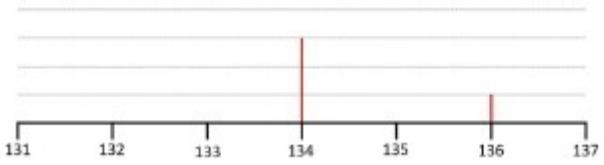
1

(b) **M1** lines at 134 and 136

***M1** is for drawing the correct two lines (if other lines are drawn, penalise **M1** (but ignore any additional very small lines at 135 or 137)*

1

M2 line at 134 to be three times higher than line at 136



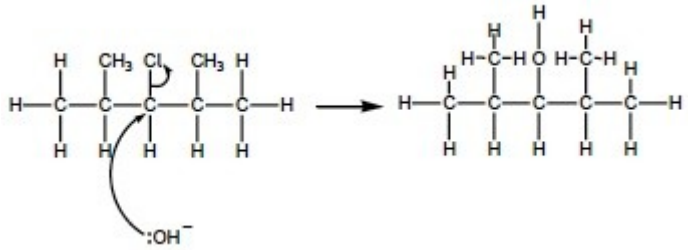
***M2** is for the line at 134 being three times as big as the one at 136 (ignore other lines)*

Accept cross to represent top of lines; if bars drawn – they should be narrow (less than 10% of division) and clear which value they refer to.

1

(c) **M1** nucleophilic substitution

STEMUP.CO.UK



1

M2 curly arrow from lone pair on O of OH^- to C of C–Cl

*For SN2: penalise **M2** for any additional arrow(s) on NaOH, or for covalent NaOH; penalise **M3** for any additional arrow(s) to/from the Cl to/from anything else*

*If curly arrows represent an attempt at an elimination mechanism, cannot score **M2** or **M3***

1

M3 curly arrow from C–Cl bond to the Cl

*Penalise **M3** for formal charge on C and/or Cl of C–Cl or incorrect partial charges on C– Cl; ignore other partial charges on uncharged atoms*

*For SN2: penalise **M2** for any additional arrow(s) on NaOH, or for covalent NaOH; penalise **M3** for any additional arrow(s) to/from the Cl to/from anything else*

*If curly arrows represent an attempt at an elimination mechanism, cannot score **M2** or **M3***

If SN1 mechanism given (loss of Cl first followed by attack by OH^-) then:
***M2** curly arrow from C–Cl bond to the Cl*
***M3** curly arrow from lone pair on O of OH^- to positive C atom of correct carbocation*
*penalise **M2** for any additional arrow(s) to/from the Cl to/from anything else*
*penalise **M3** for any additional arrow(s) on NaOH*

1

M4 correct structure of alcohol (in any form)

***M4** is independent*

***M4** ignore presence of non-organic products*

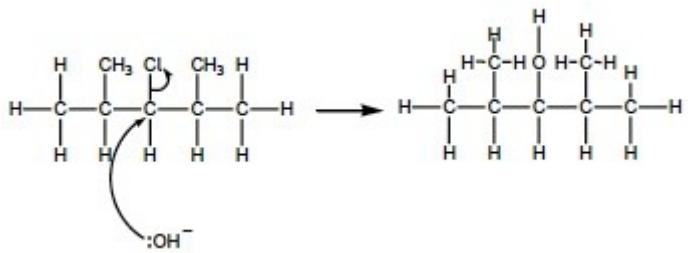
1

(d) **M1** elimination

***M1** allow base elimination (but nothing else)*

1

M2 base



STEMUP.CO.UK

M2 *allow proton acceptor*

1

M3 curly arrow from lone pair on O of OH^- to H on one of the C atoms adjacent to the C–Cl

*If curly arrows represent an attempt at a substitution mechanism, cannot score **M3** or **M4***

1

M4 curly arrow from a correct C-H bond adjacent to the C–Cl to a correct C-C bond. Only award if an arrow is shown attacking the H atom of a correct adjacent C-H bond in **M3**

*If curly arrows represent an attempt at a substitution mechanism, cannot score **M3** or **M4***

1

M5 curly arrow from C–Cl bond to the Cl (mark is independent

Penalise M5 for formal charge on C and/or Cl of C–Cl or incorrect partial charges on C–Cl; ignore other partial charges on uncharged atoms

1

M6 correct structure of alkene (in any form)

M6 *is independent*

M6 *ignore presence of non-organic products*

If E1 mechanism given (loss of Cl first followed by attack by OH^-) then:
M3 *curly arrow from C–Cl bond to the Cl*
M4 *curly arrow from lone pair of OH^- to a correct H on the correct C adjacent to C^+ on the carbocation*
M5 *curly arrow from a correct C-H bond to a correct C-C bond*
*penalise **M3** for any additional arrow(s) to/from the Cl to/from anything else*
*penalise **M4** for any additional arrow(s) on KOH*

1

(e) C as C=C 1620-1680 cm^{-1} OR no O-H 3230-3550 cm^{-1}

need the correct compound and an explanation

full wavenumber range or value(s) within the range

on this occasion candidates do not need to refer to the O-H bond being O-H alcohol as opposed to O-H acid – just reference to O-H with wavenumbers is required

1

(f) <u>C–Br</u> is weaker than <u>C–Cl</u> or

<u>C–Br</u> has lower bond enthalpy than <u>C–Cl</u> or

<u>C–Br</u> breaks more easily <u>C–Cl</u>

Must compare the C–Br and C–Cl bonds specifically

Ignore references to bond length, size of atoms, shielding, electronegativity and polarity

Penalise idea that bromine is more reactive than chlorine

1

STEMUP.CO.UK

[15]

Q3.

B

[1]

Q4.

(a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ (4s^0)$

1

(b) **M1** In $Ca^{(+)}$ (outer) electron(s) is further from nucleus

Or $Ca^{(+)}$ loses electron from a higher (energy) orbital

Or $Ca^{(+)}$ loses electron from a 4(s) orbital or 4th energy level or 4th energy shell and $K^{(+)}$ loses electron from a 3(p) orbital or 3rd energy level or 3rd energy shell

Must be comparative

Allow converse arguments

1

M2 More shielding (in Ca^{+})

1

(c) Be /Beryllium

1

(d) $Mg(OH)_2$

1

(e) $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

Ignore state symbols

1

n $BaCl_2$ $(6/1000 \times 0.25) = 1.5 \times 10^{-3}$ and n Na_2SO_4 $= (8/1000 \times 0.15) = 1.2 \times 10^{-3}$

and $BaCl_2$ /barium chloride in excess

Working required or 3×10^{-4} of $BaCl_2$

1

10 cm^3 (of 0.15 mol dm^{-3} sodium sulfate)

or $0.01dm^3$

1

(f) **M1** Same electronic configuration / same number of electrons (in outer shell) / all have 37 electrons (1)

Ignore protons and neutrons unless incorrect numbers

Not just electrons determine chemical properties

1

M2 $\frac{86x + 87x + 88(100-2x)}{100} = 87.7$

Alternative M2:

STEMUP.CO.UK

$$\frac{86 + 87 + 88y}{1 + 1 + y} = 87.7$$

1

M3 x = 10% (or × = 0.1)

M3 y = 8

1

M4 (% abundance of 88 isotope is 100 – 2x10) = 80(.0)%

M4 % of 88 isotope is 100 – 10y = 80(.0) %

Allow other alternative methods

1

(g) $^{138}Ba^{+}$

1

(h) **M1** $\text{mass} = \frac{137 \times 10^{-3}}{6.022 \times 10^{23}}$ = 2.275 × 10^{-25} (kg)

Calculation of m in kg

If not converted to kg, max 4

If not divided by L lose M1 and M5, max 3

1

M2 $v^2 = \frac{2KE}{m} = \frac{2 \times 3.65 \times 10^{-16}}{2.275 \times 10^{-25}}$ = 3.2088 × 10^{9}

For re-arrangement

1

M3 $v = \sqrt{2KE/m}$ (v = 5.6646 × 10^{4})

For expression with square root

1

M4 v = d/t or d = vt or with numbers

1

M5 d = (5.6646 × 10^{4} × 2.71 × 10^{-5}) = 1.53 - 1.54 (m)

M5 must be to 3sf

If not converted to kg, answer = 0.0485-0.0486 (3sf). This scores 4 marks

1

Alternative method

M1 $m = \frac{137 \times 10^{-3}}{6.022 \times 10^{23}}$ = 2.275 × 10^{-25}

M1 Calculation of m in kg

1

M2 v = d/t

M2, M3 and M4 are for algebraic expressions or correct expressions with numbers

STEMUP.CO.UK

1

M3 $d^2 = \frac{KE \times 2t^2}{m}$

1

M4 $d = \sqrt{\frac{KE \times 2t^2}{m}}$ $(= \sqrt{(3.65 \times 10^{-16} \times 2 \times (2.71 \times 10^{-5})^2 / 2.275 \times 10^{-25})})$

1

M5 d = 1.53 – 1.54 (m)

M5 must be to 3sf

1

[18]

Q5.

(a) Cl^- $1s^2 2s^2 2p^6 3s^2 3p^6$

1

Fe^{2+} $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$

1

If [Ne] or [Ar] used then Max 1if both correct
Ignore $4s^0$
Allow subscripts

(b) $Mn^{2+}(g) \longrightarrow Mn^{3+}(g) + e^-$

1

States symbols are required
Allow $Mn^{2+}(g) - e^- \longrightarrow Mn^{3+}(g)$
Negative charge needed on electron

(c) Al

Mg then CE = 0

1

(Outer) electron in (3)p sublevel / orbital

Not just level or shell

1

Higher in energy / further from the nucleus
so easier to remove OWTTE

Both required for M3

1

Ignore shielding

(d) $^{58}Ni^+$

M1 needs mass and charge – allow subscripts

1

A_r= [(58 × 61.0) + (60 × 29.1) + (61 × 9.9)] / 100

1

A_r= 58.9 must be to 1dp

1

[9]

Q6.

STEMUP.CO.UK

A

[1]

Q7.

B

[1]

Q8.

(a) $\frac{(46 \times 9.1) + (47 \times 7.8) + (48 \times 74.6) + (49 \times 8.5)}{100} = \frac{4782.5}{100}$

1

= 47.8

Correct answer scores 2 marks.
Allow alternative methods.
Allow 1dp or more.
Ignore units

1

(b) $Ti(g) \longrightarrow Ti^{+}(g) + e^{-}$

or $Ti(g) + e^{-} \longrightarrow Ti^{+}(g) + 2e^{-}$

or $Ti(g) - e^{-} \longrightarrow Ti^{+}(g)$

State symbols essential
Allow electrons without $^{-}$ charge shown.

1

46

1

(c) $8.1(37) \times 10^{-26}$

1

(d) M1 is for re-arranging the equation

$d = t\sqrt{\frac{2E}{m}}$ or $d = \frac{t}{\sqrt{\frac{m}{2E}}}$ or $d^2 = t^2 \times \frac{2E}{m}$

Allow t α square root of m

1

$d = t_{47}\sqrt{\frac{2E}{47 \times 10^{-3} / L}} = t_{49}\sqrt{\frac{2E}{49 \times 10^{-3} / L}}$

Or

d = 1.5(47)

This scores 2 marks
Allow this expression for M2

STEMUP.CO.UK

$$\frac{t_{47}}{\sqrt{47}} = \frac{t_{49}}{\sqrt{49}}$$

1

$= 9.6(14) \times 10^{-7}$

Correct answer scores 3 marks.

1

[8]

Q9.

(a) ^{24}Mg has 12n; ^{25}Mg has 13n; ^{26}Mg has 14n

OR They have different numbers of neutrons

1

(b) No difference in chemical properties

1

Because all have the same electronic structure (configuration)

OR they have the same number of outer electrons

1

(c) If fraction with mass 24 = x

Fraction with mass 26 = 0.900 − x

Fraction with mass 25 = 0.100

1

$A_r = 24x + (25 \times 0.100) + 26(0.900 - x)$

1

$24.3 = 24x + 2.50 + 23.4 - 26x$

$2x = 1.60$

$x = 0.800$ i.e. percentage ^{24}Mg = 80.0(%) (80.0% 3sf)

1

^{26}Mg = 0.900 − 0.800 = 0.100 ie percentage ^{26}Mg = 10.0(%)

1

(d) $m = {}^{25/1000}/_{6.022 \times 10^{23}}$

1

$v^2 = 2ke/m$ or $v^2 = \dfrac{2 \times (4.52 \times 10^{-16}) \times (6.022 \times 10^{23})}{25/1000}$

1

$V = \sqrt{2.18 \times 10^{10}} = 1.48 \times 10^{5}\ (ms^{-1})$

1

$D = vt = 1.48 \times 10^{5} \times 1.44 \times 10^{-5}$

$D = 2.13$ (m)

1

STEMUP.CO.UK

[11]

Q10.

C

[1]

Q11.

(a) $\frac{(82 \times 5) + (83 \times 3) + (84 \times 26) \times (86 \times 7)}{41} = \frac{3445}{41}$

1

84.0

1

Kr

1

(b) $82/(1.243 \times 10^{-5})^2 = 86 / t^2$

So $t^2 = 86 / 82 \times (1.243 \times 10^{-5})^2$

1

$t^2 = 1.6204 \times 10^{-10}$

1

$t = 1.273 \times 10^{-5}$ (s)

1

[6]

Q12.

(a) $Cl\bullet + O_3 \longrightarrow ClO\bullet + O_2$

Allow dot in free-radical on either O or Cl.

1

$ClO\bullet + O_3 \longrightarrow 2O_2 + Cl\bullet$

1

(b) (KOH acts as a) base

1

(propan-1-ol acts as a) solvent.

Allow product of reaction between KOH and propan-1-ol / $CH_3CH_2CH_2O^-$ acts as base.

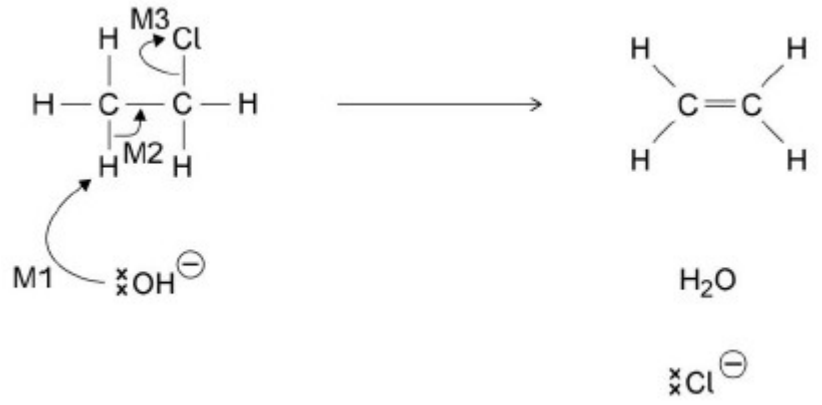
1

(c) (Name of mechanism) Elimination

1

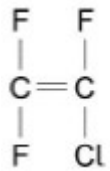
mechanism: 3 arrows (1 mark each).

STEMUP.CO.UK



3

(d)



1

(e) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3

All stages are covered & the explanation of each stage is generally correct and virtually complete. Stages 1 and 2 are supported by correct data. Answer communicates the whole process coherently and shows a logical progression from stage 1 to stage 2 and then stage 3.

Steps in stage 3 are in logical order and working is shown. If there is no working for ratio or statement of ratio then full marks cannot be awarded.

If the formulae of the three molecular ions are not correct (2d) then the student can't access Level 3 (any incorrect chemistry drops the student to the bottom mark within the level they have achieved).

5-6 marks

Level 2

Stage 2 is attempted (**2a-2c** do not need to be explicitly stated) but the calculation may contain inaccuracies **OR** the explanation may be incomplete **OR** first two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows a progression through the first two stages. Some steps in each stage may be incomplete.

If percentage of carbon is missing or incorrect (1a) then student can't access Level 2.

3-4 marks

Level 1

Stage 1 needs to be attempted but may contain inaccuracies.

OR

STEMUP.CO.UK

Stage 3 attempted but may contain inaccuracies / molecular formula not determined.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

1-2 marks

Level 0

Insufficient correct chemistry to warrant a mark.

0 marks

Indicative Chemistry content

Stage 1 (determines empirical formula)

1a *16.3% carbon*

1b *Divide by* A_r

1c *Divide by smallest (0.904)*

1d *Convert ratio in simplest integer (x 2)*

C	Cl	F
$\frac{16.3}{12.0} = 1.358$	$\frac{32.1}{35.5} = 0.904$	$\frac{51.6}{19.0} = 2.716$
$\frac{1.358}{0.904}$	$\frac{0.904}{0.904}$	$\frac{2.716}{0.904}$
3	2	6

Stage 2 (determines formulae of three molecular ions)

2a *For E.F.* M_r *(corresponds to the molecule) = 221*

2b *since* M_r *= 221 lies within molecular ion range 220–224*

2c *Thus empirical formula = molecular formula*

2d *Three correct formulae*

2e *Correct* M_r *for each of three molecules*

$C_3{}^{35}Cl_2F_6^+$	$C_3{}^{35}Cl^{37}ClF_6^+$	$C_3{}^{37}Cl_2F_6^+$
220	222	224

Stage 3 (explains the ratio of 3 molecular ion peaks)

3a *Working*

2b *Correct (simplified) ratio* ***9:6:1***

Note: 9:3:1 will be a common incorrect answer (max 5).

Working:

$C_3{}^{35}Cl_2F_6^+$	$C_3{}^{35}Cl^{37}ClF_6^+$	$C_3{}^{37}Cl_2F_6^+$
220	222	224

STEMUP.CO.UK

$^{35}Cl_2 = \left(\frac{3}{4}\right)^2 = \frac{9}{16}$	$^{35}Cl^{37}Cl$ and $^{37}Cl^{35} = 2 \times \frac{1}{4} \times \frac{3}{4} = \frac{6}{16}$	$^{37}Cl_2 = \left(\frac{1}{4}\right)^2 = \frac{1}{16}$

[15]

Q13.

(a) **Gas chromatography explanation**

Different retention times / dipeptides appear at different times.

1

Different balance between solubility in the moving phase / gas carrier **and** retention by the stationary phase / column **OR** different relative affinity for mobile and stationary phases.

1

Mass spectrometry explanation

Same *m/z* values.

1

(Both) dipeptides / **J** and **K** have same molecular formula / M_r.

1

(b) ser-ala

1

ala-lys

1

ser-ala-lys

This order only.

1

[7]

Q14.

(a) Abundance of third isotope = 100 – 91.0 –1.8 = 7.2%

1

$$\frac{(32 \times 91) + (33 \times 1.8) + (y \times 7.2)}{100} = 32.16$$

1

$7.2y = 32.16 \times 100 – 32 \times 91 – 33 \times 1.8 = 244.6$

1

$y = 244.6 / 7.2 = 33.97$

$y = 34$

Answer must be rounded to the nearest integer

1

(b) (for electrospray ionisation)

STEMUP.CO.UK

A high voltage is applied to a sample in a polar solvent

1

the sample molecule, M, gains a proton forming MH^+

1

OR

(for electron impact ionisation)

the sample is bombarded by high energy electrons

1

the sample molecule loses an electron forming M^+

1

(c) Ions, not molecules, will interact with and be accelerated by an electric field

1

Only ions will create a current when hitting the detector

1

[8]

Q15.

D

[1]

Q16.

(a) $[CH_3OCOCOOH]^+$

Allow names

1

$[CH_3OCOCOOCH_3]^+$

Do not allow molecular formula

1

(b) Positive ions are accelerated by an electric field

1

To a constant kinetic energy

1

The positive ions with m / z of 104 have the same kinetic energy as those with m / z of 118 and move faster

1

Therefore, ions with m / z of 104 arrive at the detector first

1

[6]

Q17.

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

1

STEMUP.CO.UK

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$

1

If noble gas core used correctly in both then scores 1
Allow subscripts and capitals
Ignore $4s^0$

(b) Sr^{2+}

Ignore name and correct proton/mass number
Allow Sr^{+2}

1

(c) Ca_3P_2

Allow reversed or ionic formula
Ignore name

1

[4]

Q18.

(a) (Ions accelerated by) attraction to negatively charged plate / electric field

Mark independently

1

Ions detected by gaining electrons

Allow the transfer of electrons

1

Abundance determined by (size) of current flowing (or amount of electrons gained) in the detector

Allow current is proportional to abundance

1

(b) Mass = $\frac{52/1000}{6.022 \times 10^{23}}$

Mass = $8.6(4) \times 10^{-26}$

1

(c) $V^2 = (2 \times 1.269 \times 10^{-13}) / 8.64 \times 10^{-26}$

Allow correct rearrangement for V or V^2

1

$V = 1.71 \times 10^6\ ms^{-1}$

Allow ecf from (b) (note if 8.6×10^{-23} in (b) leads to approx. $5.4 \times 10^4\ ms^{-1}$)

1

(d) Sketch with peaks at 158, 160, 162

Mark independently

1

STEMUP.CO.UK

In ratio 25%:50%:25%

Allow approx. ratio 1:2:1

1

(e) % abundance ^{m}Xe = 20(%)

Working must be shown

1

131.31 = (0.28*129) + (0.25*131) + (0.27*132) + (0.20*m)

1

131.31 – 104.51 = 0.2m

1

Mass number = 134

Answer must be an integer

1

[12]

Q19.

D

[1]

Q20.

C

[1]

Q21.

(a) $5s^2\ 4d^{10}\ 5p^4$ / $4d^{10}\ 5s^2\ 5p^4$

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^4$
or $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^4$

Allow any order but must finish with $5p^4$

1

(b) (i) $\frac{(124\times2)+(126\times4)+(128\times7)+(130\times6)}{19}$ or $\frac{2428}{19}$

M1 for top line

1

$\underline{127.8}$

M2 for correct denominator

1

127.8 with no working shown scores 3 marks

1

Or

$$\frac{(124\times10.5)+(126\times21.1)+(128\times36.8)+(130\times31.6)}{100}$$

1

Mark for 100 dependent on top line correct

1

STEMUP.CO.UK

127.8

1

(ii) Other isotopes present / some isotopes absent / different abundances of isotopes

1

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

Ignore state symbols

Allow $Te^{2+} + 2e^{(-)} \rightarrow Te$

1

(d) 128

Only

1

Most abundant ion (QoL − superlative)

M2 dependent on correct M1

1

(e) 2+ ion formed / 2 electrons removed

Due to $^{128}Te^{2+}$ *= 2 marks*

1

From ^{128} (Te)

Mark independently

1

(f) Same

If not same CE = 0 / 2

1

(Each isotope has the) same number of protons / same nuclear charge and same number of electrons / electronic configuration

Ignore more neutrons in ^{130}Te

1

[12]

Q22.

(a) (i) 1.6734×10^{-24} (g)

Only.

1.6734×10^{-27} kg

Not 1.67×10^{-24} *(g).*

1

(ii) **B**

1

(b) (i) $\frac{10x + 11y}{x + y} = 10.8$

OR ratio 10:11 = 1:4 **OR** 20:80 etc

Allow idea that there are 5 × 0.2 divisions between 10 and 11.

1

STEMUP.CO.UK

abundance of ^{10}B is 20(%)

OR

$$\frac{10x}{100} + \frac{11(100-x)}{100} = 10.8$$

$10x + 1100 - 11x = 1080$

$\therefore x = 1100 - 1080 = 20\%$

Correct answer scores M1 and M2.

1

(ii) Same number of electrons (in outer shell or orbital)

Ignore electrons determine chemical properties.

Same electronic configuration / arrangement

Ignore protons unless wrong.

1

(c) Range between 3500 and 10 000 kJ mol^{-1}

1

(d) $B^{+}(g) \longrightarrow B^{2+}(g) + e^{(-)}$

$B^{+}(g) - e^{(-)} \longrightarrow B^{2+}(g)$

$B^{+}(g) + e^{(-)} \longrightarrow B^{2+}(g) + 2e^{(-)}$

Ignore state symbol on electron even if wrong.

1

(e) Electron being removed from a positive ion (therefore needs more energy) / electron being removed is closer to the nucleus

Must imply removal of an electron.

Allow electron removed from a + particle / species or from a 2+ ion.

Not electron removed from a higher / lower energy level / shell.

Not electron removed from a higher energy sub-level / orbital.

Ignore electron removed from a lower energy sub-level / orbital.

Ignore 'more protons than electrons'.

Not 'greater nuclear charge'.

Ignore 'greater effective nuclear charge'.

Ignore shielding.

1

[8]

Q23.

(a) Average / mean mass of 1 atom (of an element)

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

STEMUP.CO.UK

If moles and atoms mixed, max = 1

1

Mark top and bottom line independently.
All key terms must be present for each mark.

1

OR

Average / mean mass of atoms of an element
1/12 mass of one atom of ^{12}C

OR

Average / mean mass of atoms of an element ×12
mass of one atom of ^{12}C

OR

(Average) mass of one mole of atoms
1/12 mass of one mole of ^{12}C

OR

(Weighted) average mass of all the isotopes
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

This expression = 2 marks.

(b) $$\frac{(70 \times 3) + (72 \times 4) + 73 + (74 \times 5)}{13} = \frac{941}{13}$$

1
1

= 72.4

72.4 only

1

(c) $^{(72)}Ge^{+}$ or germanium^{+}

Must show '+' sign.
Penalise wrong mass number

1

(d) 70

If M1 incorrect or blank CE = 0/2
Ignore symbols and charge even if wrong.

1

Lowest mass / lowest m/z

Accept lightest.
Accept fewest neutrons.

1

STEMUP.CO.UK

(e) Electron(s) transferred / flow (at the detector)

M1 must refer to electron flow at the detector.

If M1 incorrect CE = 0/2

1

(From detector / plate) to the (+) ion

Do not allow from a charged plate.

1

(f) They do not have the same electron configuration / they have different number of electrons (in the outer shell)

Ignore electrons determine the properties of an atom.

Ignore they are different elements or different number of protons.

1

[11]

Q24.

(a) 37

These answers only.

Allow answers in words.

1

48

Ignore any sum(s) shown to work out the answers.

1

(b) (i) Electron gun / high speed/high energy electrons

Not just electrons.

Not highly charged electrons.

1

Knock out electron(s)

Remove an electron.

1

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

OR

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

OR

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

Ignore state symbols for electron.

1

(c) Rb is a bigger (atom) / e further from nucleus / electron lost from a higher energy level/ More shielding in Rb / less attraction of nucleus in Rb for outer electron / more shells

Answer should refer to Rb not Rb molecule

If converse stated it must be obvious it refers to Na

Answer should be comparative.

1

(d) (i) s / block s / group s

Only

STEMUP.CO.UK

1

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

Allow $3d^{10}$ before $4s^2$

Allow in any order.

1

(e) $\frac{(85 \times 2.5) + 87 \times 1}{3.5}$

M1 is for top line

1

1

$= \underline{85.6}$

Only

1

OR

$\frac{(58 \times 5) + 87 \times 2}{7}$

M1 ^{85}Rb 71.4% and ^{87}Rb 28.6%

M2 divide by 100

1

1

$\underline{85.6}$

M3 = <u>85.6</u>

1

(f) Detector

Mark independently

Allow detection (plate).

1

Current / digital pulses / electrical signal related to abundance

Not electrical <u>charge</u>.

1

(g) Smaller

Chemical error if not smaller, CE = 0/3

If blank mark on.

1

Bigger nuclear charge / more protons in Sr

Not bigger nucleus.

1

Similar/same shielding

QWC

(Outer) <u>electron</u> entering same shell/sub shell/orbital/same number of shells.

Do not allow incorrect orbital.

1

[16]

STEMUP.CO.UK

Q25.

(a) (Total number of) protons and neutrons (in nucleus of atom)

(number of) nucleons

1

(b) Zn

Do not allow Zn^{-1} or Zn^{+1} or ZN
Ignore numbers

1

(c) (i) P = ionise (sample)

Allow removing an electron / forms (+) ions

1

Q = accelerate (sample)

Allow speeds (ions) up
Penalise molecules / atoms

1

(ii) m / z

Allow mass / charge

1

(relative) abundance / (relative) intensity

QoL
Allow M1 + M2 in any order

1

(d) (i) $\frac{206 + 207 + (208 \times 2)}{4} = \frac{(829)}{4}$

M1 = topline

1

M2 = ÷ 4

1

= 207.3

Only
207.3 = 3 marks

1

(ii) Lead / Pb

Not PB

1

(iii) Same number of electrons (in outer shell) / same electronic configuration

Ignore electrons determine chemical properties
Ignore reference to p and n if correct
Penalise if incorrect

1

[11]

Q26.

(a) **2**$Ca_5F(PO_4)_3$+ 9SiO_2 +**15**C9$CaSiO_3$ + CaF_2 +**15**CO + **6**P

1

STEMUP.CO.UK

(b) **M1** (P_4 =) **0**

M2 (H_3PO_4 =) **(+) 5**

*Accept Roman numeral V for **M2***

2

(c) H_2SO_4

***Both numbers** required*

M_r = 2(1.00794) + 32.06550 + 4(15.99491)
= **98.06102 or 98.0610 or 98.061 or 98.06 or 98.1**

Calculations not required

and

H_3PO_4

M_r = 3(1.00794) + 30.97376 + 4(15.99491)
= **97.97722 or 97.9772 or 97.977 or 97.98 or 98.0**

1

(d) (i) A substance that speeds up a reaction OR alters / increases the rate of a reaction **AND** is chemically unchanged at the end / not used up.

***Both ideas** needed*

Ignore reference to activation energy or alternative route.

1

(ii) The addition of water (**QoL**) to a molecule / compound

QoL- for the underlined words

1

(iii) **M1** $CH_3CH{=}CH_2 + H_2O \rightarrow CH_3CH(OH)CH_3$

(C_3H_6)

*For **M1** insist on correct structure for the alcohol but credit correct equations using either C_3H_6 or double bond not given.*

M2 propan-2-ol

2

[8]

Q27.

(a) $\dfrac{(82\times2)+(83\times2)+(84\times10)+(86\times3)}{17}$ $\qquad$ $\dfrac{(1428)}{(17\quad)}$

M1 for the top line
M2 is for division by 17

1

= 84.0

Not 84
No consequential marking from M1 or M2
Ignore units

1

STEMUP.CO.UK

The A_r in the Periodic table takes account of the <u>other isotopes</u> / <u>different amounts of isotopes</u> (or words to that effect regarding isotopes)

Award independently

Comparison implied

Isotope(s) alone, M4 = 0

1

(b) (Beam of electrons from) an electron gun / high speed / high energy electrons

1

Knocks out electron(s) (to form a positive ion)

1

$Kr(g) + e^- \rightarrow Kr^+(g) + 2e(^-)$

State symbols must clearly be (g)

1

OR

$Kr(g) \rightarrow Kr^+(g) + e(^-)$ / $Kr(g) - e(^-) \rightarrow Kr^+(g)$

The ^{84}Kr isotope

One mark for identifying the 84 isotope

1

Has 2 electrons knocked out / gets a 2+ charge

One mark for the idea of losing 2 electrons (from this isotope)

1

[9]

Q28.

(a) (i) Different number / amount of neutrons

Not different neutrons

Ignore same protons and/or electrons

CE incorrect statement relating to protons / electrons

1

(ii) Same electron configuration / same number of electrons (in the outer shell)

Ignore same no of protons

Ignore electrons determine chemical properties

CE if wrong statement relating to protons / neutrons

1

(b) <u>Average mass of 1 atom (of an element)</u>
1/12 mass atom of ^{12}C

OR

<u>Average/mean mass of atoms of an element</u>
1/12 mass of one atom of ^{12}C

OR

STEMUP.CO.UK

(Average) mass of one mole of atoms
1/12 mass of one mole of ^{12}C

OR

(Weighted) average mass of all the isotopes
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

If moles and atoms mixes Max = 1
Mark top and bottom line independently
1/12 on bottom line can be represented as x 12 on top line
This expression = 2 marks

2

(c) (i)

$$\frac{(64\times12)+(66\times8)+(67\times1)+(68\times6)}{27}\ \frac{(=1771)}{27}$$

= 65.6

If not 27 max 1 mark (for top line)
Mark is for dividing by 27 or string
*If **evidence** of arithmetic or transcription error seen in M1 or M2 allow consequential M3 and consequential (c)(ii)*
65.6 = 3 marks

3

(ii) $^{64}Zn^{+}$

M1 for identifying Zn / zinc
M2 is for the + sign and the 64
M2 is dependent on M1

2

(d) Size of the charge (on the ion) / different charges / different m/z

Allow forms 2+ ions
QWC

1

(e) (ions hit detector and) cause current/(ions) accept electrons/cause electron flow/electric pulse caused
bigger current = more of that isotope/current proportional to abundance

Implication that current depends on the number of ions
M2 dependent on M1

2

[12]

Q29.

Mass number = number of protons + neutrons (in the nucleus/atom)

Not in a substance or compound or element

STEMUP.CO.UK

1

7 protons and 7 electrons

1

8 neutrons

1

[3]

Q30.

(a) Average/mean mass of (1) atom(s) (of an element)

1

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

Accept answer in words
Can have top line × 12 instead of bottom line ÷ 12

1

OR

(Average) mass of one mole of atoms
1/12 mass of one mole of ^{12}C

OR

(Weighted) average mass of all the isotopes
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

$$\frac{(95.12 \times 14) + (4.88 \times 15)}{100}$$

Allow 95.12 + 4.88 instead of 100

1

= 14.05

If not to 2 d.p. then lose last mark
Not 14.04

1

(b) ^{15}N is heavier/^{15}N has a bigger m/z/different m/z values

Not different no's of neutrons
Not ionisation potential

1

Electromagnet/electric field/magnet/accelerating potential or voltage/electric current

1

(c) No difference

1

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

STEMUP.CO.UK

M2 dependent on M1
Not just electrons determine chemical properties
Ignore protons

1

[8]

Q31.

(a) Percentage of oxygen is 36.4%

% of oxygen stated or shown in calculation.

1

Correct calculation of ratios (C 4.54, H 9.10, O 2.28)

Mark is for correct method, dividing % by A_r

1

Empirical formula C_2H_4O

Allow consequential answer from wrong percentage of oxygen (max 2 marks).

1

(b) 88

Accept 88.0

Do not penalise correct answer in g.

1

(c) Ratio MF / EF of 2 (88 / 44.0 = 2)

If use 132 / 44 = 3, molecular formula $C_6H_{12}O_3$ scores 2 marks.

1

Molecular formula is $C_4H_8O_2$

Accept consequential answers from (a) and (b)

1

[6]

Q32.

(a) <u>Average/mean mass of (1) atom(s) (of an element)</u>
1/12 mass of one atom of ^{12}C

1

If moles and atoms mixes Max = 1

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

STEMUP.CO.UK

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

This expression = 2 marks

(b) d block

Allow 3d/D
Other numbers lose M1
Ignore transition metals

1

[Ar] $3d^2 4s^2$

1

Can be written in full
Allow subscripts
$3d^2$ and $4s^2$ can be in either order

27

1

(c) $\frac{(90 \times 9) + (91 \times 2) + (92 \times 3) + (94 \times 3)}{17}$

(= 1550)

1

(or ∑ their abundances)

If one graph reading error lose M1 and allow consequential M2 and M3.
If 2 GR errors penalise M1 and M2 but allow consequential M3
If not 17 or ∑ their abundances lose M2 and M3

1

= 91.2

91.2 = 3 marks provided working shown.

1

Zr/Zirconium

M4 -allow nearest consequential element from M3
accept Zr in any circumstance

1

(d) High energy electrons/bombarded or hit with electrons

accept electron gun

1

knocks out electron(s) (to form ions)

1

Z^+ = 90 deflected most

If not 90 lose M3 and M4
If charge is wrong on 90 isotope lose M3 only
Accept any symbol in place of Z

1

since lowest mass/lowest m/z

STEMUP.CO.UK

Allow lightest

1

(e) (ions hit detector and) cause current/(ions) accept electrons/cause electron flow

QWC

1

bigger current = more of that isotope/current proportional to abundance

Implication that current depends on the number of ions

1

[15]

Q33.

(a)

Particle	Relative Charge	Relative mass
Proton	+1	1
Neutron	0	1

1

1

Need +1 for proton

(b) d block/ D block;

Or D or d

1

(c) (i) 74;

Not 74.0

1

(ii) 112;

Not 112.0

1

(d) (i) To accelerate/ make go faster;

1

To deflect/ to bend the beam;

Any order
Not just attract to negative plate

1

(ii) Electromagnet / magnet / electric field /accelerating potential or voltage;

Not electric current
Not electronic field

1

(e) None/ nothing;

If blank mark on.
If incorrect CE = 0

1

Same number of electrons (in outer orbital/shell)/ both have 74 electrons/same electron configuration;

STEMUP.CO.UK

Not just electrons determine chemical properties
Ignore protons and neutrons unless wrong statement.

1

(f) $\frac{(182 \times 26.4) + (183 \times 14.3) + (184 \times 30.7) + (186 \times 28.6)}{100}$;

If transcription error then
M1 = AE = –1 and mark
M2 consequentially

1

= 183.90; allow range from 183.90 – 184.00;

1

[12]

Q34.

(a) Number of protons in the nucleus

1

(b) They may have different numbers of neutrons

1

(c) (i) Mass spectrometer

1

(ii) $\frac{\text{Mean mass of an atom}}{\text{Mass of 1 atom of } {}^{12}C} \times 12$

2

(iii) $A_r = \frac{\text{sum of relative m/z x rel. abundance}}{\text{Total abundance}}$

1

= (82 × 12 + 83 × 12 + 84 × 50 + 86 × 26)/100 = 84.16

1

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

1

(e) Krypton was thought to be an inert gas
(or has 8 electrons in outer shell)

1

(f) (i) Krypton has more protons than bromine

1

But its outer electrons are in the same shell
(or have similar shielding)

1

(ii) Al electron is in a 3p orbital, magnesium in 3s

1

Energy of 3p is greater than 3s

1

[13]

STEMUP.CO.UK

Q35.

(penalty for sig fig error =1 mark per question)

(a) neutron: relative mass = 1 relative charge = 0
(not 'neutral')

1

electron: relative mass = 1/1800 → 0/negligible *or*

5.56 × 10–4 → 0 relative charge = –1

1

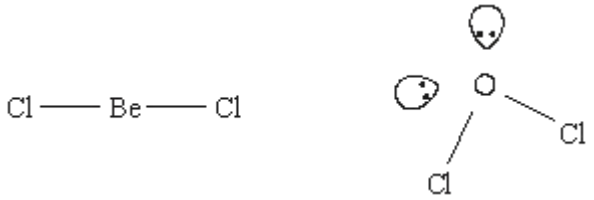
(b) $^{17}O/O^{17}$ mass number (*Do not accept 17.0*)

1

oxygen symbol 'O'
(if 'oxygen' + — 'mass number = 17'(1))
(if 'oxygen'+ — 'mass number = 17'(0))
(if at N⁰ given but ≠ 8, treat as 'con' for M2)
(if lp on Be, diagram = 0)
(ignore bond angles)
(not dot and cross diagrams)

1

(c)



2

QoL Linear **(1)** bent / V-shaped / angular **(1)**
(mark name and shape independently)
(accept (distorted) tetrahedral)
(if balls instead of symbols, lose M1 – can award M2)
(penalise missing 'Cl' once only)
(not 'non-linear')

2

(d) M_r ($Mg(NO_3)_2$ = 58(.3) *(if At N⁰ used, lose M1 and M2)*

1

moles $Mg(OH)_2$ = 0.0172 (conseq on wrong M2) (answer to 3+ s.f.)

1

moles HCl = 2 × 0.0172 = 0.0344 *or* 0.0343 (mol) *(process mark)*

1

vol HCl = $\frac{0.0343 \times 1000}{1}$ = 34.3 – 34.5 (cm^3) *(unless wrong unit)*
*(if candidate **used** 0.017 or 0.0171 lose M2)*
(just answer with no working, if in range = (4).
if, say, 34 then =(2))

STEMUP.CO.UK

(if not 2:1 ratio, lose M3 and M4)
(if work on HCl, CE = 0/4)

1

[12]

STEMUP.CO.UK

Q1.

(a) This question proved demanding for most students. A good number were able to calculate the mass of the $^{79}Br^+$ ion. Very few students realised that most of the quantities cancelled down during the calculation and took time to calculate the velocity of the $^{79}Br^+$ ion in order to then work out the kinetic energy. This velocity was frequently calculated well but the remaining marks then proved a challenge for students. Some completed numerous calculation steps only to give a time for the $^{81}Br^+$ ion that was the same as the time for the $^{79}Br^+$ ion.

(b) Only a few students understood that when the ion reaches the detector it gains an electron, whereas many understood that the size of the current was proportional to the abundance of the ion.

Q2.

(a) Most students (56.1%) could name compound **A** correctly.

(b) This question proved to be demanding. The calculation of the M_r of individual molecules containing different isotopes was a challenge for many students. 61.8% of students either failed to score or made no attempt; 33.4% did, however, score both marks.

(c) The nucleophilic substitution mechanism was well-answered; 45.6% of students scored full marks here.

(d) The elimination mechanism was more challenging, and many students did not know the role of the hydroxide ion. This question discriminated particularly well.

(e) Just under half of students could determine that the IR spectrum was of an alkene rather than an alcohol and explain this by reference to the absorption for a bond and its wavenumber range.

(f) Students struggled to explain the relative rates of reaction of the halogenoalkanes. The most common answer incorrectly referred to the reactivity of the elements bromine and chlorine, rather than looking at the C-Br and C-Cl bond strengths. Only 28.6% of students gained this mark.

Q3.

The most common answer, **C**, was incorrect. Students believed that 500 cm^3 of water should be added to the 10 cm^3 of solution, rather than adding 490 cm^3 to make the total volume 500 cm^3.

Q4.

(a) The electron configuration was well known (88.9% correct).

(b) Only the best students gained both marks here (19%); many students focused on whether the electron was being removed from a full or partially full orbital instead of considering why the attraction between the nucleus and the electron might be different.

STEMUP.CO.UK

(c) Less than half of the students (39.5%) could give the correct answer here; lithium was a common error.

(d) The majority of students (76.3%) answered this correctly, although there were quite a number who gave the incorrect formula.

(e) The ionic equation was generally correct and many students could also calculate that barium chloride was in excess. Just under a third of students managed to score all three marks.

(f) Most students could state why isotopes have the same chemical properties. In the calculation, many students gave an algebraic equation with two unknowns and could not proceed any further. The students who gave a correct algebraic expression with one unknown could work through the calculation and generally gained full marks. Some students answered the question by trial and error and this was also given full credit. Pleasingly, 43.7% of students gained all four marks available.

(g) Most students deduced that the mass number of the ion would be 138 but less than 30% of students could give the correct formula for the ion including its charge.

(h) Some students answered this part very well (with 36.6% scoring full marks), but most students scored partial marks or no marks; common errors included failure to use the Avogadro constant, not converting mass to kg, and incorrect rearrangement of expressions.

Q5.

(a) This was surprisingly poorly answered. Many students were unable to write the electronic configuration for Fe^{2+}.

(b) Part (b) was generally well answered, but a significant number of answers had missing state symbols, despite the direct instruction to include them.

(c) Part (c) was quite well answered.

(d) The symbol including mass number was often incorrect. The calculation of A_r was straight- forward and done well by many students.

Q6.

48.5% of students scored this mark; the most common wrong answer was D, showing that some students thought that a magnetic field is involved in TOF mass spectrometry.

Q7.

Only 26.2% of students selected the correct answer here, with all three distractors attracting significant numbers of students. Although this example is commonly taught, there are clearly not many students who can either remember the example or work out the probabilities for themselves.

Q8.

(a) This was generally well answered, though a few students added the abundances incorrectly.

(b) Most students gave the correct equation, but some used the wrong state symbols or omitted them. The identity of the isotope was well known but some students lost a

STEMUP.CO.UK

mark by using the symbol for the atom rather than the *m/z* value.

(c) The most common error was a failure to convert from grams into kilograms.

(d) Only the best students gained all three marks. All marks were available, even for those students who had not answered part (c), or who had the wrong answer for it. Some students were unable to re-arrange the equation. Students who appreciated that the distance travelled was common to both ions usually went on to get the correct answer, but a large number of students scored zero or one mark.

Q17.

Aspects of this question were well done but significant numbers were unable to write the electronic configuration of the Cr^{3+} ion. part (b) was answered well but the unfamiliar formula required in (c) proved tricky for the majority.

Q18.

For Question (a) many students wrote a lot of unnecessary detail about aspects of a time of flight mass spectrometer but on the whole it was quite well answered. Questions (b) and (c) proved mathematically difficult for many although consequential marking allowed large numbers to score on (c). The use of probability to predict the ratio of peaks in question (d) proved very difficult for students. Some scored 1 mark for giving three peaks but the 1:2:1 ratio was only seen from 11.3% of students. Question (e) was answered well with over 60% of students scoring all 4 marks.

Q21.

Students found part (a) tricky and many did not realise the significance of the [Kr] given; however some students answered very well and had all the sublevels in the correct order. Part (b)(i) was answered very well by most students. Common mistakes included failed attempts to express the data as percentages and not giving the answer to the required number of decimal places. There were many confused answers to part (d)(ii) and these included references to impurities and the size of the sample rather than the fact that the Periodic Table takes into account all isotopes whereas the sample didn't. The equation in part (c) was often given the wrong way round showing that students did not understand the process occurring at the detector; many students used Tl rather than Te in their equations. In part (e) the majority of students chose the correct answer and gave a good explanation of their choice. The most common error was choosing 130 and stating that it had the biggest value. Many students thought that the atomic radius of the two isotopes in part (f) was the same but did not then give a complete explanation; many only referred to the number of protons in the nucleus.

Q22.

The overall performance in part (a)(i) was disappointing because many students did not know the subatomic particles in the hydrogen atom. The mark in part (a)(ii) was scored by most students. Many students scored both marks in part (b)(i) but several quoted an equation involving *x* and *y* but could not progress beyond that. The majority of students answered part (b)(ii) correctly and part (c) was also generally well done. In part (d), many students used Br instead of B in their equation and some either wrote the wrong ionisation energy or failed to add state symbols. Many answers to part (e) were superficial; many students simply referred to a different proton / electron ratio or the removal of an electron from a different energy level.

STEMUP.CO.UK

Q23.

The definition in part (a) is still not well known. Average or mean was often omitted as was mass. Part (b) was well done although a few students still chose to divide by 100. In part (c), the charge on the ion was often missed out. The most common wrong answer in part (d) was 74 since students were obviously confusing deflection with detection. The majority who chose 70 carried on to give the correct explanation. Answers to part (e) were poor with many students not referring to electrons at all. Most students scored the mark in part (f).

Q24.

Part (a) was done very well. In part (b)(i), many students stated that a positive ion was formed but failed to say how. The equation in part (b)(ii) was well done with only a few omitting the state symbols. In part (c), a number of students failed to score the mark since they referred to a rubidium molecule, showing a lack of understanding of the metals given. In part (d)(ii) there were many students who filled the 4d rather than the 5s orbitals and some gave an abbreviated electron structure even though the question asked for the full electron structure. Many students found part (e) difficult although it was pleasing to see some gain full marks. Part (f) was not well understood with many students confusing charge and current. The answers to part (g) were generally good although a few students did not give complete explanations and lost the last mark.

Q25.

In part (a), a significant number of students struggled with a definition of mass number and many defined Ar instead. The majority of students could answer part (b) well. The answers to part (c)(i) were well known although many students gave too much detail. In some cases, this extra detail was contradictory and, therefore, lost the marks. In part (c)(ii), weaker students thought that mass and charge could be recorded separately. Answers to part (d) were generally good although many failed to read the instruction to quote the answer to 1 decimal place. Answers to part (d)(iii) were generally good although there were many irrelevant references to protons. Weaker students simply quoted that electrons determine chemical properties but did not refer to the isotopes of **R**.

Q26.

Balancing the equation in part (a) taxed some students but most were able to score at least one mark in part (b). There was a need for students to use correct chemical terminology in part (d), requiring, for example, reference to the "addition of water" in part (d)(ii). It was surprising to see how many made simple errors in the relatively straightforward part (d)(iii), for example, naming the alcohol as propanol rather than propan–2–ol.

Q27.

The majority of students calculated the relative atomic mass of krypton but then failed to quote their answer to the precision stated in the question. The last mark in part (a) proved more difficult with many students suggesting errors in measurements or precision. Part (b) gave a good spread of marks. The first three marks were gained by most students but some failed to give state symbols in their equation. The last two marks were more difficult and many references to the atom being split in two were seen rather than being ionised twice.

Q28.

Part (a)(i) was well done although many candidates gave a lot of unnecessary extra

STEMUP.CO.UK

information about protons and electrons. In part (a)(ii) there were quite a lot of answers which simply stated that a variation in neutron number had no effect on chemical properties; this approach was not an answer to the question. Answers to part (b) showed that some candidates fail to learn definitions accurately. In part (c)(i) several candidates divided by 100 rather than by 27 and a few failed to give their answer to one decimal place. There were very few correct answers to part (c)(ii). Even when zinc was identified the + sign was often missed. The most common incorrect answer was copper. Part (d) was well done but part (e) was not well understood. Electric charge was often mentioned and many thought that positive ions flowed into the computer.

Q29.

Generally well done by a large number of candidates. However the definition of mass number was often confused with relative atomic mass and a surprising number did not state the correct numbers of protons, neutrons and electrons.

Q30.

Answers to the definition in part (a) were variable as always. The most common errors were to miss out the word average/mean on the top line and 1 atom on the bottom line. The calculation was attempted well although some candidates did not give their answer to 2 decimal places. Part (b) was generally well answered. Part (c) answers were varied. Some candidates thought that natural and synthetic compounds would react differently and the ones who knew the reactions were identical often failed to qualify their answer sufficiently well to gain full maks.

Q31.

Few candidates could not make some progress in the empirical formula calculation in this part (a), but many were unable to deduce a M_r value from the spectrum in this part (b). The provision of dummy data in this part (c) allowed most candidates to score at least one of the marks.

Q32.

A substantial number of candidates were not able to produce an exact definition in part (a). Many marks were lost through the omission of vital words such as “mass” or “atom”, or mixing moles and atoms in their answer.

Part (b) was moderately well done but many candidates identified the element rather than the block it was in. The electron configuration was generally well known with the commonest errors being [Ar] $4s^2$ $4d^2$ and $3d^4$. A significant number of candidates could not calculate the number of neutrons and many gave non-integer answers such as 25.9.

In part (c) many candidates were able to calculate the relative atomic mass correctly but did not then identify the element. Weaker candidates included 93 × 0 = 93 in their calculation or divided by 100. A small number used 91.2 as the atomic number and therefore identified protactinium.

The great majority of candidates scored the first 2 marks in part (d). However, many did not actually identify the isotope, often merely stating that it would be the lightest that would be deflected the most. A disappointing number misinterpreted the mass spectrum and selected 91 because it had the least abundance. A surprising number wrote that the heaviest ions would be deflected the most.

Part (e) was not well answered. Although many candidates knew that detection of ions

STEMUP.CO.UK

involved the production of a current, relatively few mentioned the relationship between the size of current and the abundance of ion. Common incomplete answers included “the more ions that hit the detector, the greater the abundance”. A very small number of candidates thought a current was produced by the ion giving electrons to the detector.

Q33.

In part (a) the majority of the candidates scored full marks with some losing marks by referring to a charge of + rather then +1, or putting a + (plus) or a – (minus) sign in the relative mass column. The answer to part (b) was well done with only a few writing ‘Transition metals’ rather than stating the block that tungsten is in. Some candidates did not score marks in part (c) since they did not look for the atomic number in the Periodic Table and some could not remember how to calculate the number of neutrons. Candidates generally answered part (d) well although a few put ‘detect’ as one of their answers and this was given in the stem of the question. Some tried to explain how the ions were formed but this was not asked for. Part d (ii) was well answered. In part (e) candidates lost the second mark by not knowing that the isotopes have the same electron configuration. Many answers just stated that isotopes had different numbers of neutrons and/or same number of protons. The calculation in part (f) was very well done although some candidates lost the second mark by not giving their answer to two decimal places.

Q35.

On the whole, this question was well answered. The relative masses and charges of neutrons and electrons were generally well known but errors were not uncommon. Some candidates reversed the contents of the *mass* and *charge* columns, suggesting that they had rote learned a table with a different layout of columns.

Part (b) was quite well done but errors such as ^{17}Be, ^{13}O, $^{17.0}$O and ^{16}O were not uncommon.

While many candidates correctly deduced the shapes of the molecules in part (c), the presence of a lone pair of electrons on the Be atom, or one/three lone pairs of electrons on the O atom, was quite common. The shape of the $BeCl_2$ molecule was well known but there was considerable confusion regarding the shape of the Cl_2O molecule. Many candidates gave *tetrahedral* as the shape of this molecule. While the distribution of electron pairs around the oxygen atom might be described as *tetrahedral*, this is not the shape produced by the atoms in the molecule. Many candidates described the shape in appropriately by using the terms *bent*, *V-shaped* and *angular*. The use of *tetrahedral* was accepted in this examination but this may not be the case in future examinations. A significant number of candidates used the term *bent linear* when describing the shape of Cl_2O molecules; this was treated as a contradiction and so earned no credit. A significant number of candidates attempted to show the shapes of these molecules using dot-and-cross diagrams; these were not accepted.

The calculation in part (d) was correctly performed by many candidates, but errors such as the use of incorrect *M*r values or the use of an incorrect mole ratio were quite common. A small but significant number of candidates assumed the use of a known mass of HCl and ignore the 1.00 g of $Mg(OH)_2$ stipulated in the question; such answered earned no credit.

STEMUP.CO.UK

Q1.

B

[1]

Q2.

(a) Proton mass = 1 charge = +1
Electron mass ≤ 1/1800 Or ≤ 5.6×10^{-4} charge = –1
(Do not accept +1 for proton mass or 'g' units)

2

(b) (i) 13

1

(ii) Si

1

Mass number = 28 **and** atomic number = 14
(Do not accept 28.1 or 28.0 or 'Silicon')

5

(c) Mean (average) mass of an atom / all the isotopes
1/12th mass of atom of ^{12}C
Or Mass of 1 mole of atoms of an element **(1)**
1/12th mass of 1 mole of ^{12}C **(1)**
Or Average mass of an atom / all the isotopes **(1)**
relative to the mass of a ^{12}C atom taken as exactly 12 / 12.000 **(1)**
(Penalise 'weight' once only) (Ignore 'average' mass of ^{12}C)
(Do not allow 'mass of average atom')

2

(d) $A_r = (24 \times 0.735) + (25 \times 0.101) + (26 \times 0.164)$ 1 = 24.4 1
(mark M2 conseq on transcription error or incorrect addition of %)

(e) M_r = highest m/z value 1
(NOT 'highest/largest/right-hand' peak)

3

[10]

Q3.

(a) (i) Atoms with the same number of protons / proton number **(1)**
NOT same atomic number

with different numbers of neutrons **(1)**
***NOT** different mass number / fewer neutrons*

(ii) Chemical properties depend on the number or amount of (outer) electrons **(1)** OR, isotopes have the same electron configuration / same number of e^-

STEMUP.CO.UK

(iii) $23/6.023 \times 10^{23}$ **(1)**

CE = 0 if inverted or multiplied

tied to M1 $3.8(2) \times 10^{-23}$ [2-5 sig figs] **(1)**

5

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

accept subscripted figures

1

(c) Highest energy e^- / outer e^-s / last e^- in (3)d sub-shell **(1)**

OR d sub-shell being filled / is incomplete
OR highest energy sub-shell is (3)d
NOT transition element / e^- configuration ends at 3d
Q of L

1

(d) $^{15}_{7}N$ N correct symbol **(1)**

allow N^{15}_{7}

Mass number = 15 AND atomic number = 7 **(1)**

2

[9]

Q4.

(a) Proton: mass 1, charge + 1 **(1)**
Neutron: mass 1, charge 0 **(1)**
Electron mass 1/1840, charge -1 **(1)**

Allow mass = 0, or negligible, or 1/1800 to 1/2000

Isotopes have the same number of protons **(1)**

OR atomic number

different number of neutrons **(1)**

Isotopes have the same electronic configuration **(1)**

OR same number of electrons

Chemical properties depend on electrons **(1)**

7

(b) $\dfrac{\text{average (1) mass of an atom/isotopes}}{\text{mass of 1 atom of } ^{12}C} \times 12$ **(1)**

OR $\dfrac{\text{mass of 1 mol of atoms}}{\text{mass of 1 atom of } ^{12}C} \times 12$ *or in words*

Spectrum gives (relative) abundance **(1)**

OR % or amount

And *m/z* **(1)**
Multiply *m/z* by relative abundance for each isotope **(1)**

STEMUP.CO.UK

Allow instead of m/z mass no, A_r or actual value from example

Sum these values **(1)**
Divide by the sum of the relative abundances **(1)**

only award this mark if previous 2 given

Max 2 if e.g. has only 2 isotopes

7

[14]

Q5.

D

[1]

STEMUP.CO.UK

Q2.

The fundamental particle data required in part (a) was generally well known; however, relative charges where either the sign or the value was omitted were occasionally seen. Part (b)(i) was well answered, and the majority of candidates coped well with (b)(ii). It was quite common however to see 28.1, rather than the required 28, to be quoted as the mass number of **Q**. Part (c) simply required a standard definition for the A_r to be quoted. Surprisingly, this question was quite poorly done, with attempts being frequently vague and incomplete. The most common error was to omit references to *mean*, *mass* and *atoms* in the definition. Also, it was not uncommon to see a ratio showing single atoms on the top and moles on the bottom. In part (d), the calculation of the A_r of the sample of magnesium was usually correct, however, a significant number of candidates failed to quote their final answer to one decimal place. Some candidates used the sum of the *m/z* values, rather than the sum of the relative abundances (100). Part (e) was very poorly answered. Very few references to *highest m/z value* were seen.

Q3.

Many good answers were seen here and high marks were quite common. However, candidates frequently ignored the instruction in (a)(i) to define *isotopes* in terms of fundamental particles, and offered a definition based wholly, or in part, on mass number and atomic number. In (a)(ii), the link between chemical properties and electron configuration was well known but many candidates attempted to establish a link between proton, neutron or mass numbers and chemical properties. The calculation in (a)(iii) was often poorly done, the most common errors being to invert the expression or to multiply the mass number by *L*. Part (b) was generally well answered, although a few candidates gave the electron arrangement showing 23 electrons. Similarly, part (c) was generally well answered, however, some candidates referred to electrons being in the *d block*, while a small minority offered nonsense explanations. Most candidates correctly identified nitrogen as the element in part (d), but $^{14}_{7}N$ was a common error.

Q4.

Most candidates scored high marks for part (a) though the final part of the question, requiring an explanation why isotopes have identical chemical properties, was more demanding. Part (b) was also answered well though a considerable number of candidates wasted time by giving detailed but irrelevant information about the operation of the various parts of a mass spectrometer. Candidates were often imprecise about the information that can be obtained from a mass spectrum. Confusion between mass/charge and atomic mass or relative atomic mass was common but did not incur a heavy penalty.

STEMUP.CO.UK