Mark schemes

Q1.

(a) Current model includes: neutrons <u>and</u> protons

Rutherford model does not include neutrons and protons

1

Current model shows electrons in different energy levels/orbitals

Rutherford model does not show electrons in different orbitals/energy levels

Allow 1st energy level only holds 2 electrons

1

(b) M1: $^{112}Sn^+$

1

M2 missing abundance = 30.84%

M3

If M2 missing then allow M3 if denominator = 69.16

1

$$RAM = \frac{(112 \times 22.41) + (114 \times 11.78) + (117 \times 34.97) + (120 \times 30.84)}{100}$$

1

M4 RAM = <u>116.5</u> answer must be to 1dp

Allow M4 ecf

1

[6]

Q2.

D

$X(g) + H^+ \rightarrow XH^+(g)$

[1]

Q3.

A

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

[1]

Q4.

D

$^{34}_{16}S$

[1]

Q5.

C

Silicon

[1]

Q6.

(a) Number of protons + neutrons (in the nucleus of the atom)

Do not allow reference to mass or average

Ignore references to C-12 being 12

1

(b)

	Number of protons	**Number of neutrons**	**Number of electrons**
^{46}Ti	22	**24**	**22**
$^{49}Ti^{2+}$	22	**27**	**20**

Mark as rows

1

1

(c) Let ^{49}Ti be y

M1 $47.8 = \frac{(46 \times 2y) + (47 \times 2y) + (48 \times (100 - 5y)) + (49 \times y)}{100}$

$47.8 = \frac{235y + 4800 - 240y}{100}$

Allow

M1 $47.8 = \frac{(46 \times 2) + (47 \times 2) + (48 \times n) + 49}{(5 + n)}$

1

M2 5y = 20 OR y = 4

M2 0.2n =4 or n=20

1

M3 abundance of ^{46}Ti = 8%

M3 % $^{46}Ti = \frac{2}{25} \times 100 = 8\%$

1

[6]

Q7.

C

Se^{2-}

[1]

Q8.

(a) The average mass of an atom of an element

(Weighted) average mass of all isotopes of an element

1

Compared to 1/12th the mass of an atom of carbon-12

1

(b) R.A.M. = $\frac{(82 \times 6) + (83 \times 1) + (84 \times 28) + (86 \times 8)}{43}$

***M1** for working*

1

= 3615 / 43
= 84.1

***M2** for answer to 1 decimal place 36.2 scores 1/2*

1

(c) **M1** m = (84/1000)/6.02 x 10^{23} (= 1.395 x 10^{-25} kg)

Alternative method

***M1**: m = (84/1000)/6.02 x 10^{23} (= 1.395 x 10^{-25} kg)*

M2 v^2 = 2ke/m = 2 x (4.83 × 10^{-16}) / (1.395 x 10^{-25})

***M2**: $d^2 = 2\ ke\ t^2/m$*

M3 v = √(6924731183) = 83214.97

***M3**: d^2 = 2 x (4.83 × 10^{-16}) x (1.73 x 10^{-5})^2 / 1.395 x 10^{-25} d^2 = 2.07*

M4 d = v x t = 83214.97 x 1.72 × 10^{-5} = 1.43 (m)

***M4** = 1.44 (m)*

Allow answers in range 1.43 – 1.44 m

If m not converted to kg, then d = 0.045 m for max 3

4

[8]

Q9.

D

^{4}Li

[1]

Q10.

B

$1s^2 2s^2 2p^4$

[1]

Q11.

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

1

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

1

If moles and atoms mixed, max = 1

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

OR

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

OR

$$\frac{\text{Average / mean mass of atoms of an element} \times 12}{\text{mass of one atom of } ^{12}\text{C}}$$

OR

$$\frac{\text{(Average) mass of one mole of atoms}}{\text{1/12 mass of one mole of } ^{12}\text{C}}$$

OR

$$\frac{\text{(Weighted) average mass of all the isotopes}}{\text{1/12 mass of one atom of } ^{12}\text{C}}$$

OR

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

This expression = 2 marks

(b) **M1** % of ^{50}Cr and ^{53}Cr = 13.9%

Let % of ^{53}Cr = x% and Let % of ^{50}Cr = (13.9 - x)%

*If x used for ^{50}Cr and ^{53}Cr or x and y, max 2 marks = **M1** and **M4***

*Alternative **M2***

Let % of ^{53}Cr = (13.9%-x)% and % of ^{50}Cr = x%

1

M2 $52.1 = \frac{50(13.9 - x) + (52 \times 86.1) + 53(x)}{100}$

OR

3x = 37.8

M2 $52.1 = \frac{53(13.9 - x)+(52 \times 86.1)+50x}{100}$

OR

3x = 3.9

1

M3 x = % of ^{53}Cr = 12.6%

1

M4 % of ^{50}Cr = 1.3%

__M4__ = __M1__- __M3__

1

(c) **M1** (Same) number of protons <u>OR</u> electrons

Do not allow same electronic configuration for __M1__

1

M2 (Different) number of neutrons

1

(d) **M1** (Ions will interact with and) be <u>accelerated</u> (by an electric field)

Allow (ions) accelerated to a negative plate

Do not allow magnetic field

1

M2 Ions create a current when hitting the detector OR ions create a current in the detector/electron multiplier.

Allow (ions) can be detected

1

(e) **M1** Mass of ion = <u>8.8. x 10^{-26}</u> kg

__M1__ Mass of ion in kg

1

M2 $v^2 = \frac{2KE}{m} = v^2 = \frac{2 \times 1.102 \times 10^{-13}}{8.8. \times 10^{-26}}$ (= 2.504 x 10^{12})

__M2__ Rearrangement

Alternative __M2__ $v = \sqrt{\frac{2KE}{m}}$

1

M3 $v = \sqrt{\left(\frac{2 \times 1.102 \times 10^{-13}}{8.8. \times 10^{-26}}\right)}$ = 1.58 x 10^{6} (ms^{-1})

__M3__: Calculating v by taking $\sqrt{v}$

1

M4 $v = \frac{d}{t}$

__M4__: Recall of v = d/t

1

M5 *t* = 7.9(0) x 10^{-7} (s) (2sf or more)

__M5__: Calculating t

1

Alternative

M1 Mass of ion = <u>8.8. x 10^{-26}</u> kg

Alternative

M1 Mass of ion in kg

1

M2 $KE = \frac{md^2}{2t^2}$ or $v = \frac{d}{t}$

M2 Recall of v = d/t

1

M3 $t^2 = \frac{md^2}{2KE}$ OR $\frac{8.8. \times 10^{-26} \times 1.25^2}{2 \times 1.102 \times 10^{-13}}$

M3 Rearrangement

1

M4 $t^2 = 6.24 \times 10{-}13$

M4: Correct calculation to get t^2

1

M5 $t = 7.9(0) \times 10^{-7}$ (s) (2sf or more)

*M5: Calculating t by taking square root of **M4***

*Allow answers consequential on incorrect **M1** If mass in g calculated = $8.8. \times 10^{-23}$, then $t = 2.5 \times 10^{-5}$ s (4 marks)*

1

[15]

Q12.

B

[1]

Q13.

(a) (Sample is) dissolved (in a volatile solvent)

Allow named solvent (eg water/methanol)

1

(Injected through) needle/nozzle/capillary at high voltage/positively charged

Ignore pressure

1

Each molecule/particle gains a proton/H^+

Allow M3 from a suitable equation (ignore state symbols)

Do not allow atoms gain a proton for M3

Ignore references to electron gun ionisation

Mark each point independently

1

(b) $C_3H_6O_2N^+$ / $C_3H_5O_2NH^+$

Must be charged

1

(c) $Ge(g) + e^- \rightarrow Ge^+(g) + 2\,e^-$

OR

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

State symbols essential

(d) **M1** $v = length/t = 0.96 / 4.654 \times 10^{-6}$

$v = 206274\ m\ s^{-1}$

$m = 2KE/v^2$

***M1** = working (or answer)*

1

M2 mass of one ion = 1.146×10^{-25} kg

M2** = answer conseq on **M1

1

M3 mass of 1 mole ions = $1.146 \times 10^{-25} \times 6.022 \times 10^{23}$ = (0.06901 kg)

***M3** = **M2** × 6.022×10^{23}*

1

M4 = 69(.01) g

***M4** = **M3** × 1000*

***M3**/**M4** could be in either order*

1

M5 mass number = 69

***M5** must have whole number for mass no*

1

[10]

Q14.

This question is marked using Levels of Response.	
Level 3: ALL Stages with matching justifications All stages are covered and the explanation of each stage is generally correct and virtually complete. Answer is well structured with no repetition or irrelevant points. Accurate and clear expression of ideas with no errors in use of technical terms.	5-6 marks
Level 2: TWO Stages with matching justifications OR THREE Stages with incomplete justifications. 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.	3-4 marks

Answer shows some attempt at structure Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points. Some minor errors in use of technical terms.	
Level 1: ONE Stage with matching justification OR TWO Stages with incomplete justifications 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 isolated statements but these are not presented in a logical order or show confused reasoning. Answer may contain valid points which are not clearly linked to an argument structure. Errors in the use of technical terms.	1-2 marks
Insufficient correct chemistry to gain a mark.	0 marks

Indicative Chemistry Content

Stage 1: General Trend (Li → Ne)
1a. 1st IE increases
1b. More protons/increased nuclear charge
1c. Electrons in same energy level / shell
1d. No extra/similar shielding
1e. Stronger attraction between nucleus and <u>outer</u> e OR <u>outer</u> e closer to nucleus (ignore radius decreases)

Stage 2: Deviation Be → B
2a. B lower than Be
2b. Outer electron in (2)p
2c. higher in energy than (2)s

If Al vs Mg then do not award 2a or 2b

Stage 3: Deviation N → O
3a. O lower than N
3b. 2 electrons in (2)p need to pair
3c. pairing causes repulsion (do not award if it is clear reference to repulsion is in s orbital)

If S vs P then do not award 3a or 3b

[6]

Q15.

(a) **M1**: P dissolved or put in/added to a solvent

__M1__: Allow named solvent eg water or methanol

1

M2: (injected through) a needle or nozzle or capillary <u>and</u> at high voltage/4000 volts or high potential

M2: Allow needle is positively charged

1

M3: Gains a proton / H^+

M3: Not atoms gain a proton

M3: Could be scored from equation

1

M4: $P + H^+ \rightarrow PH^+$

*Correct equation gains **M3** and **M4***

Ignore state symbols

1

(b) 555

1

(c) **M1** $V = d/t$ or $= 1.22 \times 10^5$ ms^{-1}

Recall this equation

1

M2 $m = \frac{2KE}{v^2}$ or $\frac{2 \times 2.09 \times 10^{-15}}{(1.22 \times 10^5)^2}$

or

M2 $m = \frac{2KE \times t^2}{d^2}$ or $\frac{2 \times 2.09 \times 10^{-15} \times (1.23 \times 10^{-5})^2}{1.50^2}$

Rearrangement to give m

1

M3 $m = \underline{2.8(1) \times 10^{-25}}$ (kg)

M3: Calculation of m.

1

M4 $= 2.81 \times 10^{-25}$ $\underline{\times L}$ $= 0.169$

*M4: Allow **M3** × L*

1

M5 0.169 $\underline{\times 1000}$ = 169.(2)

*M5: Allow **M4** × 1000*

169 only scores 5 marks

Allow answers to 2 significant figures or more ignore units

1

[10]

Q16.

B

[1]

Q17.

(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]

Q18.

(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.<u>9</u> must be to 1dp

1

[9]

Q19.

B

[1]

Q20.

D

[1]

Q21.

(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) × 10^{-26}

1

(d) M1 is for re-arranging the equation

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

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]

Q22.

(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 × 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

[11]

Q23.

B

[1]

Q24.

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

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]

Q25.

C

[1]

Q26.

(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]

Q27.

(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 × 100 – 32 × 91 – 33 × 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)

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]

Q28.

(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]