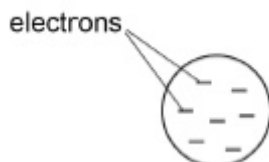


**Q21.**

This question is about atomic structure.

In the nineteenth century JJ Thomson discovered the electron. He suggested that negative electrons were found throughout an atom like 'plums in a pudding of positive charge'.

The diagram shows an atom of element **R** using the 'plum pudding' model.
An atom of **R** contains seven electrons.



- (a) State **two** differences between the 'plum pudding' model and the model of atomic structure used today.

1. _____

2. _____

(2)

- (b) Deduce the full electron configuration of an atom of element **R**.

(1)

- (c) Identify **R** and deduce the formula of the compound formed when **R** reacts with the Group 2 metal in the same period as **R**.

(1)

(Total 4 marks)

**Q22.**

This question is about sodium fluoride (NaF).

Some toothpastes contain sodium fluoride.

The concentration of sodium fluoride can be expressed in parts per million (ppm).

1 ppm represents a concentration of 1 mg in every 1 kg of toothpaste.

- (a) A 1.00 g sample of toothpaste was found to contain 2.88×10^{-5} mol of sodium fluoride.

Calculate the concentration of sodium fluoride, in ppm, for the sample of toothpaste.

Give your answer to 3 significant figures.

Concentration of sodium fluoride _____ ppm

(4)

- (b) Sodium fluoride is toxic in high concentrations.
Major health problems can occur if concentrations of sodium fluoride are greater than 3.19×10^{-2} g per kilogram of body mass.

Deduce the maximum mass of sodium fluoride, in mg, that a 75.0 kg person could swallow without reaching the toxic concentration.

Mass of sodium fluoride _____ mg

(1)

- (c) The concentration of sodium fluoride in a prescription toothpaste is 2800 ppm.

Use your answer to Question (b) to deduce the mass of toothpaste, in kg, that a 75.0 kg person could swallow without reaching the toxic concentration.

Mass of toothpaste _____ kg

(1)



- (d) Identify the diagram in the figure below that shows the correct relative sizes of the ions in sodium fluoride.
Justify your answer.

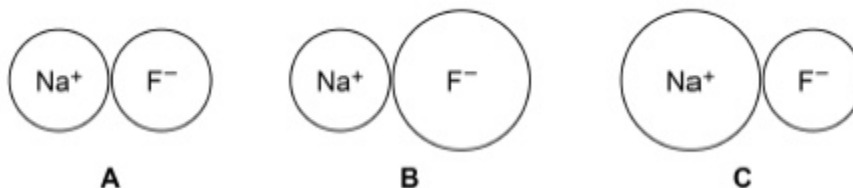


Diagram _____

Justification _____

(3)
(Total 9 marks)

Q23.

This question is about s-block metals.

- (a) Give the full electron configuration for the calcium ion, Ca^{2+}

(1)

- (b) Explain why the second ionisation energy of calcium is lower than the second ionisation energy of potassium.

(2)



- (c) Identify the s-block metal that has the highest first ionisation energy.

(1)

- (d) Give the formula of the hydroxide of the element in Group 2, from Mg to Ba, that is least soluble in water.

(1)

- (e) A student added 6 cm³ of 0.25 mol dm⁻³ barium chloride solution to 8 cm³ of 0.15 mol dm⁻³ sodium sulfate solution.

The student filtered off the precipitate and collected the filtrate.

Give an ionic equation for the formation of the precipitate.

Show by calculation which reagent is in excess.

Calculate the total volume of the other reagent which should be used by the student so that the filtrate contains only one solute.

Ionic equation _____

Reagent in excess _____

Total volume of other reagent _____

(3)



- (f) A sample of strontium has a relative atomic mass of 87.7 and consists of three isotopes, ^{86}Sr , ^{87}Sr and ^{88}Sr
In this sample, the ratio of abundances of the isotopes $^{86}\text{Sr} : ^{87}\text{Sr}$ is 1:1

State why the isotopes of strontium have identical chemical properties.
Calculate the percentage abundance of the ^{88}Sr isotope in this sample.

Why isotopes of strontium have identical chemical properties

Percentage abundance of ^{88}Sr _____ %

(4)

- (g) A time of flight (TOF) mass spectrum was obtained for a sample of barium that contains the isotopes ^{136}Ba , ^{137}Ba and ^{138}Ba

The sample of barium was ionised by electron impact.

Identify the ion with the longest time of flight.

(1)



- (h) A $^{137}\text{Ba}^+$ ion travels through the flight tube of a TOF mass spectrometer with a kinetic energy of $3.65 \times 10^{-16} \text{ J}$
This ion takes $2.71 \times 10^{-5} \text{ s}$ to reach the detector.

$$\text{KE} = \frac{1}{2} mv^2 \quad \text{where } m = \text{mass (kg) and } v = \text{speed (m s}^{-1}\text{)}$$

The Avogadro constant, $L = 6.022 \times 10^{23} \text{ mol}^{-1}$

Calculate the length of the flight tube in metres.

Give your answer to the appropriate number of significant figures.

Length of flight tube _____ m

(5)

(Total 18 marks)

Q24.

This question is about atomic structure.

- (a) Write the full electron configuration for each of the following species.

Cl^- _____

Fe^{2+} _____

(2)

- (b) Write an equation, including state symbols, to represent the process that occurs when the third ionisation energy of manganese is measured.

(1)



- (c) State which of the elements magnesium and aluminium has the lower first ionisation energy.

Explain your answer.

(3)

- (d) A sample of nickel was analysed in a time of flight (TOF) mass spectrometer. The sample was ionised by electron impact ionisation. The spectrum produced showed three peaks with abundances as set out in the table.

m/z	Abundance / %
58	61.0
60	29.1
61	9.9

Give the symbol, including mass number, of the ion that would reach the detector first in the sample.

Calculate the relative atomic mass of the nickel in the sample.

Give your answer to one decimal place.

Symbol of ion _____

Relative atomic mass _____

(3)

(Total 9 marks)

**Q25.**

Which of these has the highest first ionisation energy?

- A Na
- B Al
- C Si
- D Cl

(Total 1 mark)

Q26.

A sample of titanium was ionised by electron impact in a time of flight (TOF) mass spectrometer. Information from the mass spectrum about the isotopes of titanium in the sample is shown in the table.

m/z	46	47	48	49
Abundance / %	9.1	7.8	74.6	8.5

- (a) Calculate the relative atomic mass of titanium in this sample.

Give your answer to one decimal place.

Relative atomic mass of titanium in this sample _____

(2)

- (b) Write an equation, including state symbols, to show how an atom of titanium is ionised by electron impact and give the m/z value of the ion that would reach the detector first.

Equation _____

m/z value _____

(2)



- (c) Calculate the mass, in kg, of one atom of ^{49}Ti

The Avogadro constant $L = 6.022 \times 10^{23} \text{ mol}^{-1}$

Mass _____ kg

(1)

- (d) In a TOF mass spectrometer the time of flight, t , of an ion is shown by the equation

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

In this equation d is the length of the flight tube, m is the mass, in kg, of an ion and E is the kinetic energy of the ions.

In this spectrometer, the kinetic energy of an ion in the flight tube is $1.013 \times 10^{-13} \text{ J}$

The time of flight of a $^{49}\text{Ti}^+$ ion is $9.816 \times 10^{-7} \text{ s}$

Calculate the time of flight of the $^{47}\text{Ti}^+$ ion.

Give your answer to the appropriate number of significant figures.

Time of flight _____ s

(3)

(Total 8 marks)

**Q27.**

Element Q forms a sulfate with formula QSO_4 .

Which of these could represent the electronic configuration of an atom of Q?

- A [Ne]3s¹
- B [Ne]3s²
- C [Ne]3s²3p¹
- D [Ne]3s¹3p²

(Total 1 mark)

Q28.

Bromine exists as two isotopes ^{79}Br and ^{81}Br , which are found in almost equal abundance.

Which of the statements is correct?

- A The first ionisation energy of ^{79}Br is less than the first ionisation energy of ^{81}Br
- B The atomic radius of ^{79}Br is less than the atomic radius of ^{81}Br
- C The mass spectrum of $\text{C}_3\text{H}_7\text{Br}$ has two molecular ion peaks at 122 and 124
- D ^{79}Br is more reactive than ^{81}Br

(Total 1 mark)

Q29.

This question is about the element iodine and its compounds.

- (a) Iodine is in Group 7 of the Periodic Table.

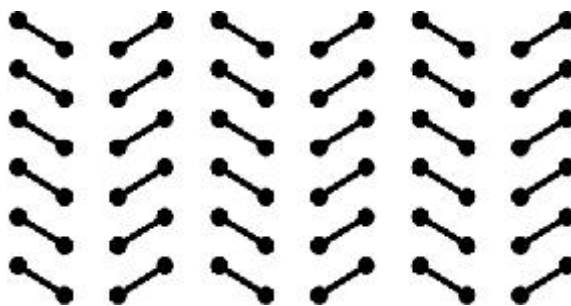
Complete the electron configuration of an iodine atom.

[Kr] _____

(1)



- (b) Part of the structure of an iodine crystal is shown in the diagram.



Use your knowledge of structure and bonding to explain why the melting point of iodine is low (113.5 °C) and why that of hydrogen iodide is very low (−50.8 °C).

(6)

- (c) State why iodine does **not** conduct electricity.

(1)

- (d) Deduce an equation for the formation of hydrogen iodide from its elements.

(1)

- (e) The triiodide ion is formed when an iodine molecule is bonded to an iodide ion.

What is the formula of ammonium triiodide?

Tick (✓) **one** box.

NH₃I₃

NH₃I₄

NH₄I

NH₄I₃

(1)



- (f) Draw the shape of the IF_3 molecule and the shape of the IF_4^- ion. Include any lone pairs of electrons that influence each shape.

(2)

- (g) Deduce the oxidation state of iodine in the following species.

$\text{Ba}(\text{IO}_3)_2$ _____

$[\text{H}_4\text{IO}_6]^-$ _____

(2)

(Total 14 marks)

Q30.

What is the electron configuration of Cu^{2+} ?

A $[\text{Ar}]3d^94s^2$

B $[\text{Ar}]3d^{10}4s^1$

C $[\text{Ar}]3d^9$

D $[\text{Ar}]3d^{10}$

(Total 1 mark)



Mark Scheme

Q21.

- (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) $1s^22s^22p^3$

Ignore commas, capitals and subscripts

Allow $1s^22s^22px^12py^12pz^1$

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]

Q22.

- (a) $M_r \text{ NaF} = 42(.0)$

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

$M3 = M2 \times 1000$ (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



(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) $\div 2800$ (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]

Q23.

(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) $\text{Mg}(\text{OH})_2$

1

(e) $\text{Ba}^{2+} + \text{SO}_4^{2-} \rightarrow \text{BaSO}_4$



Ignore state symbols

1

$n \text{ BaCl}_2 (6/1000 \times 0.25) = 1.5 \times 10^{-3}$ and $n \text{ Na}_2\text{SO}_4 = (8/1000 \times 0.15) = 1.2 \times 10^{-3}$
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 0.01 dm^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:

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

1

M3 $x = 10\%$ (or $x = 0.1$)

$M3 y = 8$

1

M4 (% abundance of 88 isotope is $100 - 2 \times 10 = 80(.0)\%$)

M4 % of 88 isotope is $100 - 10y = 80(.0)\%$

Allow other alternative methods

1

- (g) $^{138}\text{Ba}^+$

1

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

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

For re-arrangement

1

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

For expression with square root

1



M4 $v = d/t$ or $d = vt$ or with numbers 1

M5 $d = (5.6646 \times 10^4 \times 2.71 \times 10^{-5}) = 1.53 - 1.54$ (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 $d = \sqrt{\frac{KE \times 2t^2}{m}}$ ($= \sqrt{(3.65 \times 10^{-16} \times 2 \times (2.71 \times 10^{-5})^2 / 2.275 \times 10^{-25})}$) 1

M5 $d = 1.53 - 1.54$ (m)
M5 must be to 3sf 1

[18]

Q24.

(a) $\text{Cl}^- 1s^2 2s^2 2p^6 3s^2 3p^6$ 1

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

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

Ignore $4s^0$

Allow subscripts

(b) $\text{Mn}^{2+}(\text{g}) \rightarrow \text{Mn}^{3+}(\text{g}) + \text{e}^-$ 1

States symbols are required

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

Negative charge needed on electron

(c) Al 1

Mg then CE = 0

(Outer) electron in (3)p sublevel / orbital 1



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) $^{58}\text{Ni}^+$

M1 needs mass and charge – allow subscripts

1

$$A_r = [(58 \times 61.0) + (60 \times 29.1) + (61 \times 9.9)] / 100$$

1

$$A_r = 58.\underline{9} \text{ must be to 1dp}$$

1

[9]

Q25.

D

[1]

Q26.

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

1

$$= 47.8$$

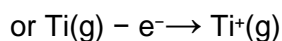
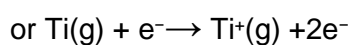
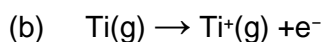
Correct answer scores 2 marks.

Allow alternative methods.

Allow 1dp or more.

Ignore units

1



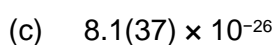
State symbols essential

Allow electrons without - charge shown.

1

46

1



1

(d) M1 is for re-arranging the equation



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

Allow t a 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

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

Correct answer scores 3 marks.

1

[8]

Q27.

B

[1]

Q28.

C

[1]

Q29.

(a) [Kr] 5s² 4d¹⁰5p⁵

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 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

I₂ 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.

I₂ bigger molecule than HI so I₂ has more electrons.

Stage 3

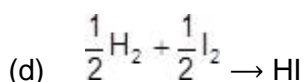
Therefore stronger van der Waals between molecules in I₂ that need more energy to break causing the melting point to be higher.

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

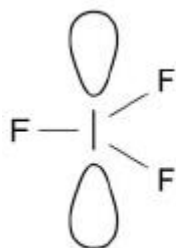


Allow multiples

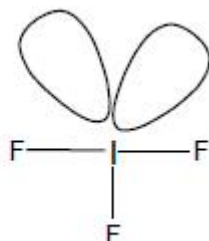
1

(e) NH₄l₃

1



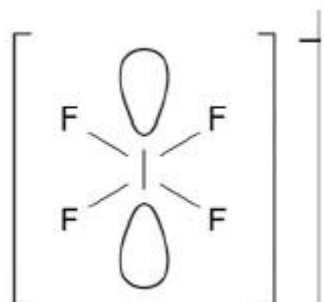
or



(f)

Allow any shape with 3 bond pairs and 2 lone pairs

1



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

(g) +5

1

+7

1

1

[14]

Q30.

C

[1]