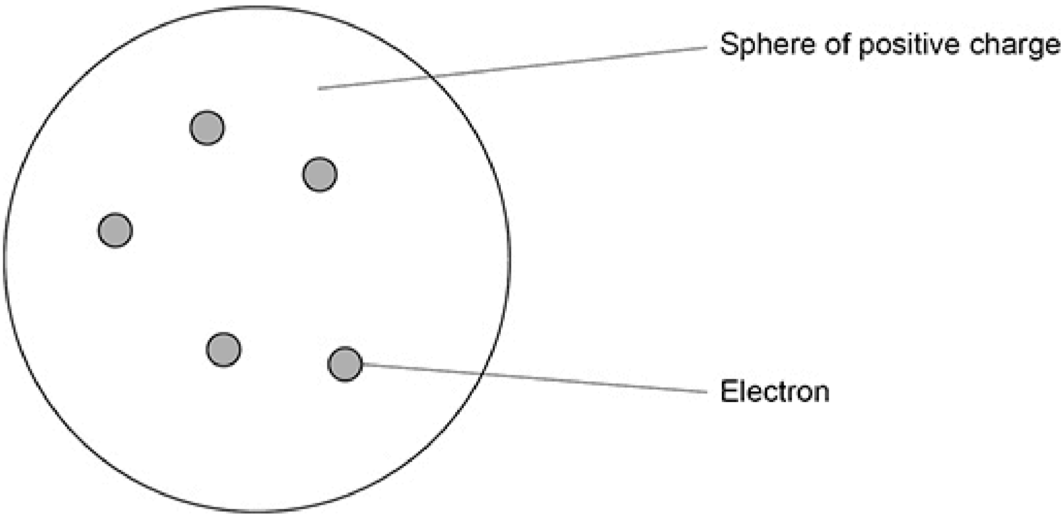
This question is about atomic structure.

(a) In 1897 JJ Thomson discovered the electron. He suggested that atoms were positively charged spheres with electrons embedded within them.

The diagram below represents an atom using Thomson's model.




Suggest the identity of this atom.

Give **two** differences between the modern model of an atom and the Thomson model of an atom.

Identity ____________________________________________

Difference 1 ____________________________________________

____________________________________________

Difference 2 ____________________________________________

____________________________________________

(b) Tellurium has a relative atomic mass of 127.6
Iodine has a relative atomic mass of 126.9

Define relative atomic mass.

Suggest **one** property of tellurium that justifies its position before iodine in the modern Periodic Table.

Definition ____________________________________________

____________________________________________

____________________________________________

Justification ____________________________________________

____________________________________________

____________________________________________

(c) A sample of tellurium is analysed in a time of flight (TOF) mass spectrometer using electron impact ionisation.

Give an equation, including state symbols, for this ionisation.

____________________________________________________________

(d) In the TOF mass spectrometer an ion of an isotope of tellurium, with mass number **y**, travels along a 1.25 m flight tube with a kinetic energy of $1.88 \times 10^{-12}$ J

The ion takes $3.00 \times 10^{-7}$ s to reach the detector.

$$KE = \frac{1}{2} mv^2$$

$KE$ = kinetic energy / J
$m$ = mass / kg
$v$ = speed / m $s^{-1}$

Calculate the mass, in g, of 1 mole of these tellurium ions.

Use your answer to suggest the mass number **y** of the tellurium isotope.

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

Mass _______________ g

Mass number **y** _______________

(e) Tellurium has several other isotopes.
Two of these isotopes are $^{126}Te$ and $^{124}Te$
A different sample of tellurium is analysed using a TOF mass spectrometer.

Which statement about kinetic energy (*KE*) is correct?

Tick (✓) **one** box.

The *KE* of $^{126}Te^+$ is greater than the *KE* of $^{124}Te^+$ ☐

The *KE* of $^{126}Te^+$ is the same as the *KE* of $^{124}Te^+$ ☐

The *KE* of $^{126}Te^+$ is less than the *KE* of $^{124}Te^+$ ☐

(a) B/Boron

**Any 2 from:**

Protons in the centre of the atom/nucleus

Electrons are in shells/energy levels (around the nucleus)

Neutrons in the centre of the atom/nucleus

Most of the atom is empty space/most of mass in nucleus

3

(b) **Definition**

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

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

**Justification**

Tellurium has Z = 52 but iodine has Z = 53
Or
Te has **one** fewer proton than I / I has **one** more proton
Or
Tellurium has 6 outer shell electrons/valence electrons but iodine has 7
Or
Te has similar chemistry/chemical properties to other Group 6 elements
Or
I has similar chemistry/chemical properties to other Group 7 elements

3

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

Or

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

1

(d)

M1 $v = \frac{d}{t} = 4.17 \times 10^6$ (m $s^{-1}$)

M2 $m = \frac{2KE \times t^2}{d^2}$ or $m = \frac{2KE}{v^2}$ or $\frac{2 \times 1.88 \times 10^{-12}}{(4.17 \times 10^6)^2}$

**M3** m = $2.16 \times 10^{-25}$ to $2.17 \times 10^{-25}$ (kg)

**M4** mass of 1 mole of ions = *L* × 1000 × M3 = 130.4 (g)

*M4 Allow 130 to 131 (3 or more significant figures)*

**M5** y = 130 or 131

*M5 Must be an integer*

5

(e) The *KE* of $^{126}Te^+$ is the same as the *KE* of $^{124}Te^+$

1

**[13]**

---

**End of Question**

## Question - 02



Which has the electron configuration of a noble gas?

**A** $H^+$ ⬭

**B** $O^-$ ⬭

**C** $Se^{2-}$ ⬭

**D** $Zn^{2+}$ ⬭

C

$Se^{2-}$

**End of Question**

# Question - 03



Which does **not** involve the absorption of ultraviolet radiation or visible light?

**A** The blue appearance of copper(II) sulfate solution in daylight.

**B** The breakdown of ozone in the upper atmosphere.

**C** The ionisation of a molecule in a mass spectrometer.

**D** The reaction between chlorine and methane at room temperature.

C

*the ionisation of a molecule in a mass spectrometer*

---

**End of Question**

This question is about atomic structure.

(a) Define the mass number of an atom.

______________________________________________________________________

______________________________________________________________________

**(1)**

(b) Complete the table below to show the numbers of neutrons and electrons in the species shown.

| | **Number of protons** | **Number of neutrons** | **Number of electrons** |
|---|---|---|---|
| $^{46}Ti$ | 22 | | |
| $^{49}Ti^{2+}$ | 22 | | |

**(2)**

(c) A sample of titanium contains four isotopes, $^{46}Ti$, $^{47}Ti$, $^{48}Ti$ and $^{49}Ti$
This sample has a relative atomic mass of 47.8
In this sample the ratio of abundance of isotopes $^{46}Ti$, $^{47}Ti$ and $^{49}Ti$ is 2:2:1

Calculate the percentage abundance of $^{46}Ti$ in this sample.

Abundance of $^{46}Ti$ _______________ %

**(3)**

(a) <u>Number</u> 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 $47.8 = \dfrac{(46 \times 2y) + (47 \times 2y) + (48 \times (100 - 5y)) + (49 \times y)}{100}$

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

*Allow*

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

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

**End of Question**

Which statement is correct about the Group 1 elements?

**A** The $Cs^+$ ion has a more negative enthalpy of hydration than the $Rb^+$ ion.

**B** The enthalpy of atomisation for potassium is greater than the enthalpy of atomisation for sodium.

**C** The melting point of potassium is higher than the melting point of sodium.

**D** The second ionisation energy of rubidium is lower than the second ionisation energy of lithium.

**D**

*The second ionisation energy of rubidium is lower than the second ionisation energy of lithium.*

---

**End of Question**

# Question - 06



Which ionisation needs less energy than this process?

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

**A** $Al(g) \rightarrow Al^{+}(g) + e^{-}$

**B** $Ar(g) \rightarrow Ar^{+}(g) + e^{-}$

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

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

**A**

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

**End of Question**

# Question - 07



Which atom in the ground state contains at least one unpaired p electron?

**A** Na

**B** Ne

**C** O

**D** Sc

**C**

O

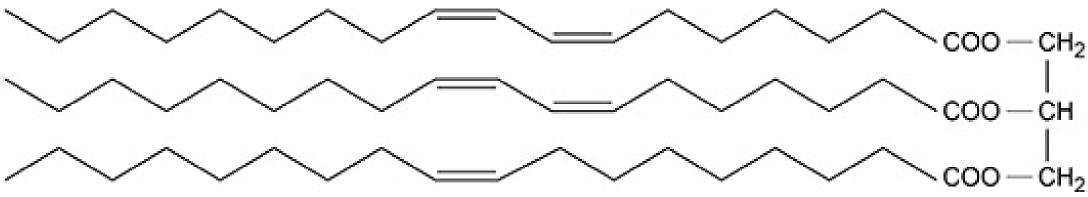
---

**End of Question**

This question is about olive oil.

A sample of olive oil is mainly the unsaturated fat **Y** mixed with a small amount of inert impurity.

The structure of **Y** in the olive oil is shown.
**Y** has the molecular formula $C_{57}H_{100}O_6$ ($M_r$ = 880).




The amount of **Y** is found by measuring how much bromine water is decolourised by a sample of oil, using this method.

- Transfer a weighed sample of oil to a 250 $cm^3$ volumetric flask and make up to the mark with an inert organic solvent.
- Titrate 25.0 $cm^3$ samples of the olive oil solution with 0.025 mol $dm^{-3}$ $Br_2$(aq).

(a) A suitable target titre for the titration is 30.0 $cm^3$ of 0.025 mol $dm^{-3}$ $Br_2$(aq).

Justify why a much smaller target titre would **not** be appropriate.

Calculate the amount, in moles, of bromine in the target titre.

Justification ______________________________________________

______________________________________________

______________________________________________

______________________________________________

Amount of bromine ____________________ mol

**(2)**

(b) Calculate a suitable mass of olive oil to transfer to the volumetric flask using your answer to part (a) and the structure of **Y**.
Assume that the olive oil contains 85% of **Y** by mass.

(If you were unable to calculate the amount of bromine in the target titre, you should assume it is 6.25 ×$10^{-4}$ mol. This is **not** the correct amount.)

Mass of olive oil _______________ g

**(5)**

The olive oil solution can be prepared using this method.

- Place a weighing bottle on a balance and record the mass, in g, to 2 decimal places.
- Add olive oil to the weighing bottle until a suitable mass has been added.
- Record the mass of the weighing bottle and olive oil.
- Pour the olive oil into a 250 $cm^3$ volumetric flask.
- Add organic solvent to the volumetric flask until it is made up to the mark.
- Place a stopper in the flask and invert the flask several times.

(c) Suggest an extra step to ensure that the mass of olive oil in the solution is recorded accurately.

Justify your suggestion.

Extra step ___________________________________________

___________________________________________

___________________________________________

Justification ___________________________________________

___________________________________________

___________________________________________

**(2)**

(d) State the reason for inverting the flask several times.

___________________________________________

___________________________________________

___________________________________________

**(1)**

(e) A sample of the olive oil was dissolved in methanol and placed in a

mass spectrometer. The sample was ionised using electrospray ionisation.
Each molecule gained a hydrogen ion ($H^+$) during ionisation.

The spectrum showed a peak for an ion with $\frac{m}{z}$ = 345 formed from an impurity in the olive oil.
The ion with $\frac{m}{z}$ = 345 was formed from a compound with the empirical formula $C_5H_{10}O$

Deduce the molecular formula of this compound.

Show your working.

Molecular formula ______________________________

**(2)**

(a) Smaller titre will increase (%) uncertainty / error

1

amount $Br_2 = 0.025 \times \frac{30}{1000} = 7.5 \times 10^{-4}$ mol

*Or 0.00075*

1

(b) Ratio Y :bromine

M1 1 : 5

*Alternative calc using supplied answer*

M1

M2 n Y in 25 cm$^3$ oil = $\frac{7.5 \times 10^{-4}}{5} = 1.5 \times 10^{-4}$

*n Y in 25 cm$^3$ oil = $\frac{6.25 \times 10^{-4}}{5} = 1.25 \times 10^{-4}$*

If no ratio must state n Y for M2

M2

M3 n Y in 250 cm$^3$ = M2 × 10 = ($1.5 \times 10^{-3}$)

*n Y in 250 cm$^3$ = $1.25 \times 10^{-4} \times 10 = (1.25 \times 10^{-3})$*

M3

M4 Mass = M3 × 880 = (1.32 g)

*Mass = $1.25 \times 10^{-3} \times 880$ = (1.1 g)*

M4

M5 Total mass oil needed = M4 × $\frac{100}{85}$ = 1.55 g

*Total mass oil needed = 1.1 × $\frac{100}{85}$ = 1.29g*

M5

*If wrong ratio used treat as AE and mark ECF*

(c) Extra step: Weigh the bottle after oil transfer (and record the mass)

*OR Rinse the bottle with solvent after transfer and add the washings (to the volumetric flask)*

**M1**

Justification: Not all of the oil is transferred
Or so that the mass of oil left in the bottle is accounted for Or find the exact mass of oil used

*To ensure all the oil is transferred*

*M2 is dependent on M1*

**M2**

(d) To ensure the solution is homogeneous

*Allow evenly mixed/ distributed OWTTE*

*Uniform solution*

**1**

(e) $M_r = 345 - 1$

*Must show workings in both M1 and M2*

**M1**

$M_r\ (C_5H_{10}O) = 86$

$\frac{M1}{86} = 4$ Hence $C_{20}H_{40}O_4$

**M2**

Rhenium has an atomic number of 75

(a) Define the term relative atomic mass.

___

___

___

**(2)**

(b) The relative atomic mass of a sample of rhenium is 186.3

The table below shows information about the two isotopes of rhenium in this sample.

| **Relative isotopic mass** | **Relative abundance** |
|---|---|
| 185 | 10 |
| To be calculated | 17 |

Calculate the relative isotopic mass of the other rhenium isotope. Show your working.

Relative isotopic mass ___

**(2)**

(c) State why the isotopes of rhenium have the same chemical properties.

___

___

**(1)**

A sample of rhenium is ionised by electron impact in a time of flight (TOF) mass spectrometer.

(d) A $^{185}Re^{+}$ ion with a kinetic energy of $1.153 \times 10^{-13}$ J travels through a 1.450 m flight tube.

The kinetic energy of the ion is given by the equation $KE = \frac{1}{2}mv^2$

where
$m$ = mass / kg
$v$ = speed / m $s^{-1}$
$KE$ = kinetic energy / J

Calculate the time, in seconds, for the ion to reach the detector.

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

Time _______________ s

**(5)**

(e) State how the relative abundance of $^{185}Re^{+}$ is determined in a TOF mass spectrometer.

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

___________________________________________________________________

**(2)**

(a) average/mean mass of 1 atom (of an element)
1/12 mass of one atom of $^{12}C$
**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

*M1 = top line* 1

*M2 = bottom line* 1

*if moles and atoms/isotopes mixed max = 1*

(b) **M1** $186.3 = \frac{(185 \times 10) + (\mathbf{X} \times 17)}{27}$

*correct expression* 1

**M2** (relative isotopic mass) = 187(.1) 1

(c) same electron configuration

*allow same number of electrons*
*allow same electron structure*
*ignore same number of protons*
*ignore different number of neutrons*
*do **not** accept same number of neutrons* 1

(d) **M1** mass $^{185}Re \left( = \frac{185}{6.02 \times 10^{23} \times 1000} \right) = 3.072 \times 10^{-25}$

*calculate mass in kg* 1

**M2** $v = \frac{d}{t}$

*recall of $v = d/t$* 1

**M3** $v^2 = \frac{2KE}{m}$ **or** $7.5(0) \times 10^{11}$

*rearrangement to get $v^2$* 1

**M4** $v = \sqrt{\frac{2KE}{m}}$ **or** 8.66 × 10$^5$

*allow* $\sqrt{\frac{2 \times 1.153 \times 10^{-13}}{M1}}$

1

**M5** $t\left(= \frac{1.45}{8.66 \times 10^5}\right) = 1.67 \times 10^{-6}$ (s)

*M5* $t = \frac{1.45}{M4}$

*allow* $1.67 \times 10^{-6}$ *to* $1.68 \times 10^{-6}$ *(s)*

1

**alternative method:**

**M1** mass $^{185}$Re $\left(= \frac{185}{6.02 \times 10^{23} \times 1000}\right) = 3.072 \times 10^{-25}$

*calculate mass in kg*

1

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

*recall of* $v = d/t$

1

**M3** $t^2 = \frac{md^2}{2KE}$

*rearrangement to get* $t^2$

1

**M4** $t = d\sqrt{\frac{m}{2KE}}$ **or** $\sqrt{\frac{md^2}{2KE}}$ **or** $\sqrt{\frac{3.072 \times 10^{-25}}{2 \times 1.153 \times 10^{-13}}}$

*allow* $\sqrt{\frac{M1}{2 \times 1.153 \times 10^{-13}}}$

1

**M5** $t = 1.67 \times 10^{-6}$ (s)

*allow* $1.67 \times 10^{-6}$ *to* $1.68 \times 10^{-6}$ *(s)*

1

(e) at the detector/(negative) plate the ions/Re$^+$ gain an electron

1

(relative) abundance depends on the size of the current

1

*alternative answer*

*M1 ion knocks out an electron into electron multiplier*

*M2 signal from electron multiplier proportional to number of ions*

# Question - 10



Which row shows the number of each fundamental particle in one $^{25}Mg^{2+}$ ion?

| | protons | neutrons | electrons |
|---|---|---|---|
| **A** | 12 | 12 | 10 |
| **B** | 14 | 11 | 12 |
| **C** | 12 | 13 | 10 |
| **D** | 12 | 13 | 12 |

C

| | | | |
|---|---|---|---|
| C | 12 | 13 | 10 |

**End of Question**

# Question - 11



This is a question about time of flight (TOF) mass spectrometry.

(a) Give the equation, including state symbols, for the formation of $Sr^+$ ions from Sr atoms by electron impact.

___________________________________________________________________

**(1)**

(b) A sample of strontium is analysed by TOF mass spectrometry.
The sample is ionised using electron impact.

The ions are accelerated to have a kinetic energy (*KE*) of $7.02 \times 10^{-20}$ J.
An ion takes $9.47 \times 10^{-4}$ s to travel along a 95.0 cm flight tube.

$$KE = \frac{1}{2}mv^2$$

where $m$ = mass (kg) and $v$ = speed (m $s^{-1}$)

Use the information given to deduce the mass number of this ion.

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

Mass number ____________________

**(5)**

(c) Explain how the ions are detected in the TOF mass spectrometer.

State how the relative abundance of the ions is determined.

How ions are detected ___________________________________________

___________________________________________________________________

How relative abundance is determined ____________________________

___________________________________________________________________

___________________________________________________________________

**(2)**

(d) A sample of strontium contains three isotopes, $^{86}Sr$, $^{87}Sr$ and $^{88}Sr$
82% of the sample is $^{88}Sr$

The other isotopes are in a 1:2 ratio of $^{86}Sr$ : $^{87}Sr$

Calculate the percentage abundance of $^{87}Sr$ in this sample.

Use your answer to deduce the relative atomic mass ($A_r$) of the sample.
Give your answer to 1 decimal place.

Abundance of $^{87}Sr$ ____________________ %

$A_r$ ____________________

**(3)**

(e) Electrospray ionisation is used instead of electron impact for the ionisation of a protein in a mass spectrometry experiment.

Suggest why.

___

___

___

**(1)**

(a) $Sr(g) + e^- \rightarrow Sr^+(g) + 2e^-$

*Allow* $Sr(g) \rightarrow Sr^+(g) + e^-$

1

(b) M1 $V = (d \div t =)\ 0.950 \div 9.47 \times 10^{-4}$ OR $1003\ m\ s^{-1}$

*Recall and conversion of d into metres*

M2 $m = \frac{2KE}{v^2}$ or $\frac{2 \times 7.02 \times 10^{-20}}{1003^2}$ $(= 1.396 \times 10^{-25}\ kg)$

*Allow* $\frac{2 \times 7.02 \times 10^{-20}}{M1^2}$ *or* $\frac{2KE\ t^2}{d^2}$

M3 mass of ion = $1.396 \times 10^{-22}$ (g)

*M3 = M2 x1000*

M4 mass of one mol of ions in g =

$1.396 \times 10^{-22} \times 6.022 \times 10^{23}$ (= 84.04)

*M4 = M3 x Avogadro's number*

*Conversion to g may be seen in M4*

M5 mass number = 84

*Answer as whole number*

5

(c) **M1** (Ions hit a detector/electron multiplier and) each ion gains an electron (generating a current)

**M2** current is proportional to abundance

2

(d) **M1** Abundance $^{87}Sr = 2 \times 18 \div 3$ = 12(%)

**M2** $A_r = \frac{(82 \times 88) + (12 \times 87) + (6 \times 86)}{100}$

**M3** = 87.8

*Answer to 1 decimal place*

3

(e) the protein (ion) does not break up/fragment

1

**End of Question**