Atomic structure

Name: _____

Class: _____

Date: _____

Time: **204 min.**

Marks: **182 marks**

Comments:

Q1.

This question is about atomic structure.

(a) Define the term mass number.

_____

_____

(1)

(b) Complete **Table 1** for two of the fundamental particles in an atom.

Table 1

	Relative mass	**Relative charge**
Neutron		
Electron		

A sample of calcium consists of ^{40}Ca, ^{42}Ca and one other isotope.

(2)

(c) Predict whether the atomic radius of ^{40}Ca is larger than, smaller than or the same as the atomic radius of ^{42}Ca

Explain your answer.

Atomic radius of ^{40}Ca compared to ^{42}Ca _____

Explanation _____

_____

_____

_____

(2)

(d) The relative abundances of two of these calcium isotopes are shown in **Table 2**.

Table 2

Mass number of isotope	40	42
Relative abundance / %	96.80	0.19

Determine the relative abundance of the third calcium isotope.

The sample of calcium has a relative atomic mass of 40.12

Use your answer and the data in **Table 2** to determine the mass number of the third isotope.

Give the mass number to the nearest integer.

Relative abundance _____

Mass number _____

(4)

(e) Calculate the mass, in kg, of one atom of ^{42}Ca

The Avogadro constant L = 6.02×10^{23} mol^{-1}

Mass _____ kg

(1)

(f) In a time of flight (TOF) mass spectrometer, a $^{42}Ca^{+}$ ion with a kinetic energy (KE) of 1.164×10^{-13} J takes 9.130×10^{-7} s to reach the detector.

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

$$V = \frac{d}{t}$$

m = mass / kg
v = velocity / ms^{-1}
d = length of flight tube / m
t = time of flight / s

Use the equations and your answer to question (e) to calculate the length, in m, of the flight tube.

Give your answer to **three** significant figures.

(If you could not answer question (e) you should assume a mass of 3.08×10^{-25} kg This is **not** the correct answer.)

Length _____ m

(3)

(Total 13 marks)

Q2.

This question is about the elements in Period 3 of the Periodic Table.

(a) Write an equation, including state symbols, for the first ionisation energy of magnesium.

(1)

(b) Explain why the first ionisation energy of aluminium is less than the first ionisation energy of magnesium.

(2)

(c) Identify the element in Period 3 with the largest atomic radius.

Explain your answer.

Element _____

Explanation _____

(3)

(d) Silicon has the highest melting point of the elements in Period 3.

Explain this statement in terms of structure and bonding.

(3)

(Total 9 marks)

Q3.

What is the formula of rubidium nitride?

A Rb_5N ○

B RbN ○

C Rb_3N ○

D RbN_3 ○

(Total 1 mark)

Q4.

Which atom contains the most neutrons?

A ^{59}Co ○

B ^{64}Ni ○

C ^{63}Cu ○

D ^{64}Zn ○

(Total 1 mark)

Q5.

The highest oxidation state of an element is +4

What is the electron configuration of this element?

A $1s^2\ 2s^2$ ○

B $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$ ○

C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$ ○

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^4\ 4s^2$ ○

(Total 1 mark)

Q6.

(a) Give the meaning of the term isotopes in terms of fundamental particles.

_____

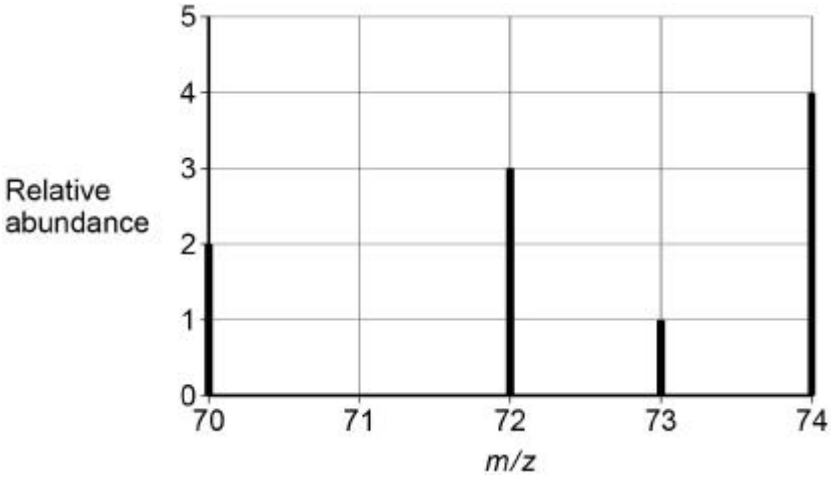
_____

_____

_____

(2)

The mass spectrum of a sample of germanium is shown in the graph below.



(b) Calculate the relative atomic mass of this sample of germanium.

_____

Relative atomic mass _____

(2)

(c) Complete the electron configuration of the Ge^+ ion.

[Ar] _____

(1)

(d) Write an equation to represent the process that occurs when the first ionisation energy of germanium is measured.
Include state symbols in your equation.

_____

(1)

(e) Calculate the mass, in kg, of a $^{72}Ge^+$ ion.
The Avogadro constant $L = 6.02 \times 10^{23}$ mol^{-1}

Mass _____ kg

(1)

(f) In a time of flight (TOF) mass spectrometer, the kinetic energy (KE) of a $^{72}Ge^+$ ion is 1.318×10^{-14} J.

Use your answer to part (e) to calculate the velocity of this $^{72}Ge^+$ ion.

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

(m = mass / kg and v = velocity / ms^{-1})

(If you could not answer to part (e) you should assume a mass of 9.80×10^{-24} kg This is **not** the correct answer.)

Velocity _____ m s^{-1}

(2)

(g) State why the chemical properties of ^{72}Ge and ^{74}Ge are the same.

_____

_____

(1)

(Total 10 marks)

Q7.

Which element is in the p block of the Periodic Table?

A Technetium ⬭

B Terbium ⬭

C Thallium ⬭

D Thorium ⬭

(Total 1 mark)

Q8.

(a) Give the meaning of the term **relative atomic mass**.

_____

_____

_____

_____

(2)

(b) A sample of nickel was ionised by electron impact in a time of flight (TOF) mass spectrometer to produce Ni^+ ions. The relative abundance of each isotope is shown in the table below.

m/z	58	60	62

Relative abundance	19	8	3

Calculate the relative atomic mass of nickel in the sample.

Give your answer to one decimal place.

Relative atomic mass _____

(2)

(c) State why the inside of a TOF mass spectrometer is operated under vacuum.

_____

_____

_____

(1)

(d) Complete the electron configuration of the $^{58}Ni^{+}$ ion.

$1s^2$ _____

(1)

(e) Calculate the mass, in kg, of a $^{58}Ni^{+}$ ion.

Give your answer to three significant figures.

The Avogadro constant, $L = 6.02 \times 10^{23}$ mol^{-1}

Mass _____ kg

(1)

(f) ° A $^{58}Ni^{+}$ ion travels down the flight tube of a TOF mass spectrometer with constant kinetic energy.
The flight tube is 1.80 m long and the $^{58}Ni^{+}$ ion takes 5.82×10^{-7} s to reach the detector.

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

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

where KE = kinetic energy (J)
m = mass (kg)
v = velocity (m s^{-1})
d = length of the flight tube (m)
t = time (s)

Use your answer to part (e) to calculate the kinetic energy, in J, of the $^{58}Ni^{+}$ ion as it travels down the flight tube.

(If you were unable to answer part (e), you should use the value 7.37×10^{-25} kg. This is **not** the correct answer.)

Give your answer to three significant figures.

Kinetic energy _____ J

(3)

(Total 10 marks)

Q9.

(a) Complete the electron configuration for the aluminium ion, Al^{3+}

$1s^2$ _____

(1)

(b) Write an equation, including state symbols, to represent the process for which the energy change is the second ionisation energy of aluminium.

_____

(1)

(c) Explain why the second ionisation energy of aluminium is greater than the first ionisation energy of aluminium.

_____

_____

(1)

(d) An element, **Z**, in Period 2 of the Periodic Table has the successive ionisation energies shown in the table.

	First	Second	Third	Fourth	Fifth
Ionisation energy / kJ mol^{-1}	1090	2350	4610	6220	37 800

Choose the correct identity of the Period 2 element **Z**.
Tick (✓) the correct box.

Boron ☐

Carbon ☐

Nitrogen ☐

Silicon ☐

(1)

(Total 4 marks)

Q10.

(a) The abundance of each isotope in a time of flight (TOF) mass spectrum of a sample of germanium is shown in the table.

m/z	70	72	74
Abundance (%)	24.4	32.4	43.2

Give the formula of the ion that will reach the detector first.

_____

(1)

(b) Use the data in Table above to calculate the relative atomic mass of this sample of germanium.

Give your answer to one decimal place.

Relative atomic mass = _____

(2)

(c) Explain how the abundance of each isotope is determined in a TOF mass spectrometer.

_____

_____

_____

_____

_____

(2)

(d) Calculate the mass, in kg, of one atom of ^{72}Ge
The Avogadro constant = 6.02×10^{23} mol^{-1}.

Give your answer to the appropriate number of significant figures.

Mass = _____ kg

(2)

(e) In a TOF mass spectrometer, the ions are accelerated to the same kinetic energy (KE).

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

$v = \frac{d}{t}$ where d = distance (m) and t = time (s)

A $^{72}Ge^+$ ion is accelerated to a kinetic energy of 3.98×10^{-16} J as it travels down the flight tube that is 3.00 m long.

Calculate the time taken for the $^{72}Ge^+$ ion to reach the detector.
Use your answer to part (d) in your calculation.

Time = _____ s

(3)

(Total 10 marks)