**Q1.** This question is about the elements in Group 2 and their compounds.

(a) Use the Periodic Table to deduce the full electron configuration of calcium.

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**(1)**

(b) Write an ionic equation, with state symbols, to show the reaction of calcium with an excess of water.

.....

**(1)**

(c) State the role of water in the reaction with calcium.

.....

**(1)**

(d) Write an equation to show the process that occurs when the first ionisation energy of calcium is measured.

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**(1)**

(e) State and explain the trend in the first ionisation energies of the elements in Group 2 from magnesium to barium.

Trend .....

Explanation .....

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**(3)**

**(Total 7 marks)**

**Q2.** This question is about the elements in Period 3 of the Periodic Table.

(a) State the element in Period 3 that has the highest melting point.
Explain your answer.

Element .....

Explanation .....

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**(3)**

(b) State the element in Period 3 that has the highest first ionisation energy.
Explain your answer.

Element .....

Explanation .....

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**(3)**

(c) Suggest the element in Period 3 that has the highest electronegativity value.

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**(1)**

(d) Chlorine is a Period 3 element.
Chlorine forms the molecules $ClF_3$ and $CCl_2$

(i) Use your understanding of electron pair repulsion to draw the shape of $ClF_3$ and the shape of $CCl_2$
Include any lone pairs of electrons that influence the shape.

Shape of $ClF_3$ Shape of $CCl_2$

**(2)**

(ii) Name the shape of $CCl_2$

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**(1)**

(iii) Write an equation to show the formation of one mole of $ClF_3$ from its elements.

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**(1)**

**(Total 11 marks)**

**Q3.**(a) **Table 1** shows some data about fundamental particles in an atom.

**Table 1**

| **Particle** | proton | neutron | electron |
|---|---|---|---|
| **Mass / g** | $1.6725 \times 10^{-24}$ | $1.6748 \times 10^{-24}$ | $0.0009 \times 10^{-24}$ |

(i) An atom of hydrogen can be represented as $^{1}H$

Use data from **Table 1** to calculate the mass of this hydrogen atom.

.....

**(1)**

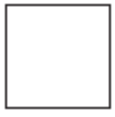
(ii) Which **one** of the following is a fundamental particle that would **not** be deflected by an electric field?

**A** electron

**B** neutron

**C** proton

Write the correct letter, **A**, **B** or **C**, in the box.



**(1)**

(b) A naturally occurring sample of the element boron has a relative atomic mass of 10.8.
In this sample, boron exists as two isotopes, $^{10}B$ and $^{11}B$

(i) Calculate the percentage abundance of $^{10}B$ in this naturally occurring sample of boron.

.....

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**(2)**

(ii) State, in terms of fundamental particles, why the isotopes $^{10}B$ and $^{11}B$ have similar chemical reactions.

.....

.....

.....

**(1)**

(c) Complete **Table 2** by suggesting a value for the third ionisation energy of boron.

**Table 2**

| | **First** | **Second** | **Third** | **Fourth** | **Fifth** |
|---|---|---|---|---|---|
| **Ionisation energy / kJ mol$^{-1}$** | 799 | 2420 | | 25 000 | 32 800 |

**(1)**

(d) Write an equation to show the process that occurs when the **second** ionisation energy of boron is measured. Include state symbols in your equation.

.....

**(1)**

(e) Explain why the second ionisation energy of boron is higher than the first ionisation energy of boron.

.....

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**(1)**
**(Total 8 marks)**

**Q4.**(a) Nickel is a metal with a high melting point.

(i) State the block in the Periodic Table that contains nickel.

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**(1)**

(ii) Explain, in terms of its structure and bonding, why nickel has a high melting point.

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**(2)**

(iii) Draw a labelled diagram to show the arrangement of particles in a crystal of nickel.
In your answer, include at least six particles of each type.

**(2)**

(iv) Explain why nickel is ductile (can be stretched into wires).

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**(1)**

(b) Nickel forms the compound nickel(II) chloride ($NiCl_2$).

(i) Give the full electron configuration of the $Ni^{2+}$ ion.

.....

**(1)**

(ii) Balance the following equation to show how anhydrous nickel(II) chloride can be obtained from the hydrated salt using $SOCl_2$
Identify **one** substance that could react with both gaseous products.

.....$NiCl_2.6H_2O(s)$ + ..... $SOCl_2(g)$ ⟶ .....$NiCl_2(s)$ + .....$SO_2(g)$ + .....$HCl(g)$

Substance .....

**(2)**
**(Total 9 marks)**

**Q5.** Aluminium and thallium are elements in Group 3 of the Periodic Table.
Both elements form compounds and ions containing chlorine and bromine.

(a) Write an equation for the formation of aluminium chloride from its elements.

.....

**(1)**

(b) An aluminium chloride molecule reacts with a chloride ion to form the $AlCl_4^-$ ion.

Name the type of bond formed in this reaction. Explain how this type of bond is formed in the $AlCl_4^-$ ion.

Type of bond .....

Explanation .....

.....

.....

**(2)**

(c) Aluminium chloride has a relative molecular mass of 267 in the gas phase.

Deduce the formula of the aluminium compound that has a relative molecular mass of 267

.....

**(1)**

(d) Deduce the name or formula of a compound that has the same number of atoms, the same number of electrons and the same shape as the $AlCl_4^-$ ion.

.....

**(1)**

(e) Draw and name the shape of the $TlBr_5^{2-}$ ion.

Shape of the $TlBr_5^{2-}$ ion.

Name of shape .....

**(2)**

(f) (i) Draw the shape of the $TlCl_2^+$ ion.

**(1)**

(ii) Explain why the $TlCl_2^+$ ion has the shape that you have drawn in part (f)(i).

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**(1)**

(g) Which **one** of the first, second or third ionisations of thallium produces an ion with the electron configuration [Xe] $5d^{10}6s^1$?

Tick (✓) one box.

First ☐

Second ☐

Third ☐

**(1)**
**(Total 10 marks)**

**Q6.** Which change requires the largest amount of energy?

**A** $He^+(g) \longrightarrow He^{2+}(g) + e^-$ ⬭

**B** $Li(g) \longrightarrow Li^+(g) + e^-$ ⬭

**C** $Mg^+(g) \longrightarrow Mg^{2+}(g) + e^-$ ⬭

**D** $N(g) \longrightarrow N^+(g) + e^-$ ⬭

**(Total 1 mark)**

**Q7.** The table below shows some successive ionisation energy data for atoms of three different elements **X**, **Y** and **Z**.

Elements **X**, **Y** and **Z** are Ca, Sc and V but not in that order.

| | First | Second | Third | Fourth | Fifth | Sixth |
|---|---|---|---|---|---|---|
| **X** | 648 | 1370 | 2870 | 4600 | 6280 | 12 400 |
| **Y** | 590 | 1150 | 4940 | 6480 | 8120 | 10 496 |
| **Z** | 632 | 1240 | 2390 | 7110 | 8870 | 10 720 |

(a) Which element is calcium?

**X** ⬭

**Y** ⬭

**Z** ⬭

**(1)**

(b) Which element is vanadium?

**X** ⬭

**Y** ⬭

**Z** ⬭

**(1)**

(c) Justify your choice of vanadium in part (b)

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**(1)**

(d) An acidified solution of $NH_4VO_3$ reacts with zinc.

Explain how observations from this reaction show that vanadium exists in at least two different oxidation states.

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**(2)**

(e) The vanadium in 50.0 $cm^3$ of a 0.800 mol $dm^{-3}$ solution of $NH_4VO_3$ reacts with 506 $cm^3$ of sulfur(IV) oxide gas measured at 20.0 °C and 98.0 kPa.

Use this information to calculate the oxidation state of the vanadium in the solution after the reduction reaction with sulfur(IV) oxide.
Explain your working.
The gas constant $R$ = 8.31 J $K^{-1}$ $mol^{-1}$.

Oxidation state = .....

**(6)**
**(Total 11 marks)**