**Q1.**

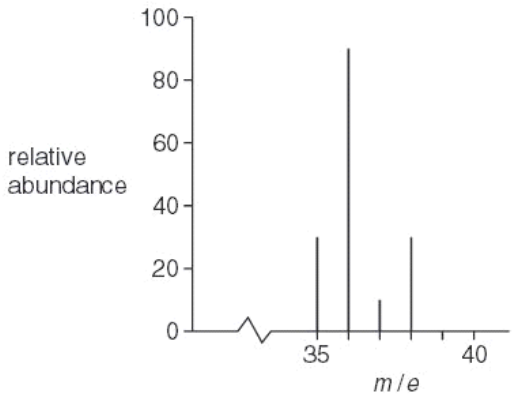
1 **(a)** Define *an isotope* in terms of its sub-atomic particles.

.....

.....

[1]

**(b)** In a mass spectrometer some hydrogen chloride molecules will split into atoms. The mass spectrum of HC*l* is given. Chlorine has two isotopes. The hydrogen involved here is the isotope $^{1}_{1}H$ only.



**(i)** What particle is responsible for the peak at mass 35? .....

**(ii)** What particle is responsible for the peak at mass 38? .....

[2]

**(c)** Use the relative heights of the peaks to determine the proportions of the two isotopes of chlorine. Explain simply how you obtained your answer.

[2]

**(d)** Use your answer to **(c)** to explain why chlorine has a relative atomic mass of 35.5.

[1]

[Total : 6]

## Q2.

**1** Iron and cobalt are adjacent elements in the Periodic Table. Iron has three main naturally occurring isotopes, cobalt has one.

**(a)** Explain the meaning of the term *isotope*.

.....

.....

..... [2]

**(b)** The most common isotope of iron is $^{56}Fe$; the only naturally occurring isotope of cobalt is $^{59}Co$.

Use the *Data Booklet* to complete the table below to show the atomic structure of $^{56}Fe$ and of $^{59}Co$.

| | number of | | |
|---|---|---|---|
| isotope | protons | neutrons | electrons |
| $^{56}Fe$ | | | |
| $^{59}Co$ | | | |

[3]

**(c)** A sample of iron has the following isotopic composition by mass.

| isotope mass | 54 | 56 | 57 |
|---|---|---|---|
| % by mass | 5.84 | 91.68 | 2.17 |

**(i)** Define the term *relative atomic mass*.

.....

.....

.....

.....

**(ii)** By using the data above, calculate the relative atomic mass of iron to **three** significant figures.

[5]

[Total: 10]

**Q3.**

Hydrogen sulphide is a weak diprotic (dibasic) acid. Its solution in water contains $HS^-$ and a few $S^{2-}$ ions.

**(e)** **(i)** What is meant by the term *weak acid*?

.....

.....

**(ii)** Write an equation, with state symbols, for the **first** ionisation of $H_2S$ when it dissolves in water.

..... [3]

**Q4.**

3 This question is about the elements in Group II of the Periodic Table, magnesium to barium.

**(a)** Complete the table below to show the electronic configuration of calcium atoms and of strontium ions, $Sr^{2+}$.

| | 1s | 2s | 2p | 3s | 3p | 3d | 4s | 4p | 4d |
|---|---|---|---|---|---|---|---|---|---|
| Ca | 2 | 2 | 6 | | | | | | |
| $Sr^{2+}$ | 2 | 2 | 6 | | | | | | |

[2]

**(b)** Explain the following observations.

**(i)** The atomic radii of Group II elements increase down the Group.

.....

.....

**(ii)** The strontium ion is smaller than the strontium atom.

.....

.....

**(iii)** The first ionisation energies of the elements of Group II decrease with increasing proton number.

.....

.....

.....

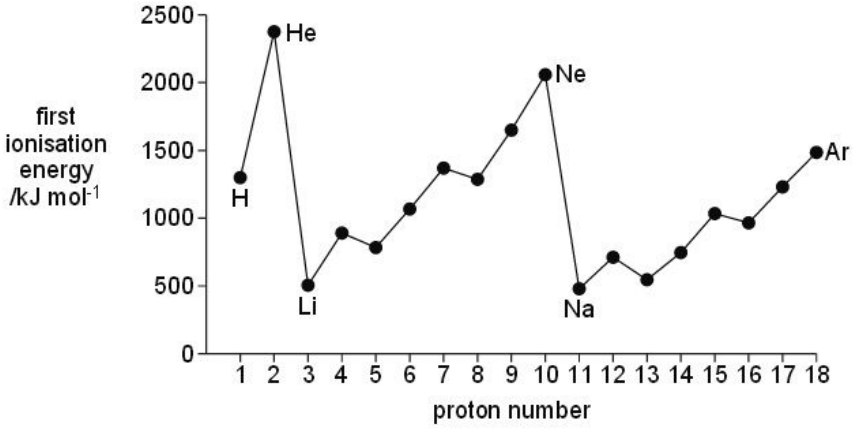
.....

[4]

**Q5.**

2 The Periodic Table we currently use is derived directly from that proposed by Mendeleev in 1869 after he had noticed patterns in the chemical properties of the elements he had studied.

The diagram below shows the first ionisation energies of the first 18 elements of the Periodic Table as we know it today.




**(a)** Give the equation, including state symbols, for the first ionisation energy of fluorine.

.....[2]

**(b)** Explain why there is a general increase in first ionisation energies from sodium to argon.

.....

.....

.....

.....[3]

**(c)** **(i)** Explain why the first ionisation energy of aluminium is less than that of magnesium.

.....

.....

.....

**(ii)** Explain why the first ionisation energy of sulphur is less than that of phosphorus.

.....

.....

.....

**[4]**

**Q6.**

Copper and titanium are each used with aluminium to make alloys which are light, strong and resistant to corrosion.

Aluminium, Al, is in the third period of the Periodic Table; copper and titanium are both transition elements.

**(a)** Complete the electronic configuration of aluminium and of titanium, proton number 22.

| | |
|---|---|
| Al | $1s^2$ |
| Ti | $1s^2$ |

**[1]**

Phosphorus is a very reactive non-metallic element which readily forms ionic compounds with metals such as calcium and covalent compounds with non-metals such as chlorine and oxygen.

*For Examiner Use*

**(a)** **(i)** Write an equation, with state symbols, for the **second** ionisation energy of calcium.

.....

**(ii)** Use the *Data Booklet* to calculate the enthalpy change that occurs when one mole of gaseous calcium ions, $Ca^{2+}$, is formed from one mole of gaseous calcium atoms.
Include a sign in your answer.

enthalpy change = ..... kJ $mol^{-1}$ **[3]**

**Q7.**

Use

**1** In the 19th and 20th centuries, experimental results showed scientists that atoms consist of a positive, heavy nucleus which is surrounded by electrons.

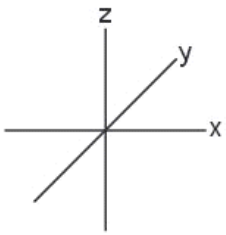
Then in the 20th century, theoretical scientists explained how electrons are arranged in orbitals around atoms.

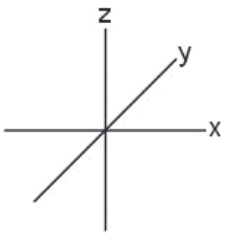
**(a)** The diagram below represents the energy levels of the orbitals present in atoms of the second period (Li to Ne).

**(i)** Label the energy levels to indicate the principal quantum number **and** the type of orbital at each energy level.

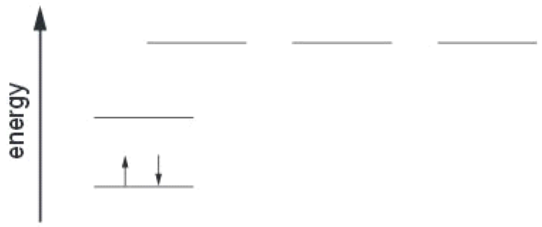

**(ii)** On the axes below, draw a sketch diagram of **one** of each **different type (shape)** of orbital that is occupied by the electrons in a second-period element.

Label each type.

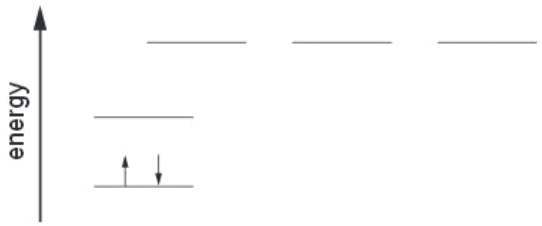


**(iii)** Complete the electronic configurations of nitrogen atoms and oxygen atoms on the energy level diagrams below.
Use arrows to represent electrons.




nitrogen




oxygen

[6]

**(b)** **(i)** Use the *Data Booklet* to state the value of the first ionisation energy of nitrogen and of oxygen.

N ..... kJ $mol^{-1}$ O ..... kJ $mol^{-1}$

**(ii)** Explain, with reference to your answer to **(a)(iii)**, the relative values of these two ionisation energies.

.....

.....

.....

[3]

[Total: 9]

**Q8.**

2 The alkali metals are a series of six elements in Group I of the Periodic Table. The first ionisation energy of these elements shows a marked trend as the Group is descended.

For Examiner Use

**(a)** Define the term *first ionisation energy*.

.....

.....

..... [2]

**(b)** **(i)** State and explain the trend in first ionisation energy as Group I is descended.

.....

.....

.....

**(ii)** Suggest how this trend helps to explain the increase in the reactivity of the elements as the Group is descended.

.....

.....

[3]

**(c)** In a redox reaction, 0.83 g of lithium reacted with water to form 0.50 $dm^3$ of aqueous lithium hydroxide.

$$2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$$

**(i)** Calculate the amount, in moles, of lithium that reacted.

**(ii)** Calculate the volume of hydrogen produced at room temperature and pressure.

**(iii)** Calculate the concentration, in mol $dm^{-3}$, of the LiOH(aq) formed.

[5]

**(d)** When heated in chlorine, all of the alkali metals react to form the corresponding chloride.

Describe what you see when sodium is heated in chlorine and write a balanced equation for the reaction.

description

.....

.....

.....

equation

.....

[2]

[Total: 12]

**Q9.**

**1** The first six ionisation energies of an element X are given below.

| ionisation energy / kJ mol$^{-1}$ | | | | | |
|---|---|---|---|---|---|
| first | second | third | fourth | fifth | sixth |
| 950 | 1800 | 2700 | 4800 | 6000 | 12300 |

**(a)** Define the term *first ionisation energy*.

.....

.....

.....

..... [3]

**(b)** Write an equation, with state symbols, for the **second** ionisation energy of element X.

..... [2]

**(c)** Use the data given above to deduce in which Group of the Periodic Table element X is placed. Explain your answer.

Group .....

explanation .....

.....

.....

..... [3]

The first ionisation energies (I.E.) for the elements of Group IV are given below.

| element | C | Si | Ge | Sn | Pb |
|---|---|---|---|---|---|
| 1st I.E. / kJ mol$^{-1}$ | 1090 | 786 | 762 | 707 | 716 |

**(d)** Explain the trend shown by these values in terms of the atomic structure of the elements.

.....

.....

.....

.....

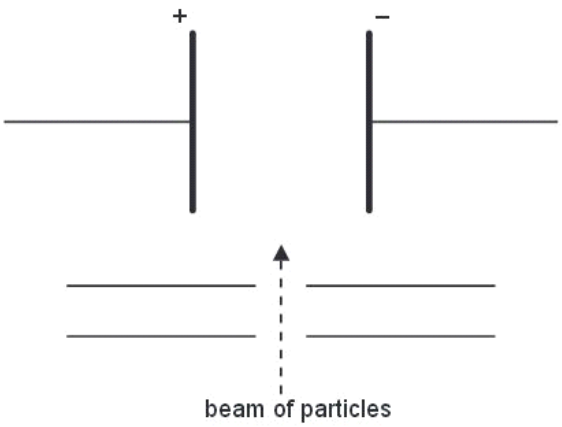
..... [4]

[Total: 12]

**Q10.**

**1** In the 19th and 20th centuries, scientists established the atomic theory and showed that three sub-atomic particles, electron, neutron and proton, exist. The masses and charges of these three particles were subsequently determined.

When separate beams of electrons, neutrons or protons are passed through an electric field in the apparatus below, they behave differently.




**(a) (i)** Which of these three particles will be deflected the most by the electric field?

.....

**(ii)** In which direction will this particle be deflected?

.....

**(iii)** Explain your answer.

.....

.....

[4]

**(b) (i)** Define the term *proton number*.

.....

.....

**(ii)** Why is the proton number of an atom of an element usually different from the nucleon number of an atom of the element?

.....

.....

[2]

**(c)** Protons and neutrons have been used in nuclear reactions which result in the formation of artificial elements. In such processes, protons or neutrons are accelerated to high speeds and then fired like 'bullets' at the nucleus of an atom of an element.

Suggest why neutrons are more effective than protons as 'nuclear bullets'.

.....

..... [2]

**(d)** In some cases, when neutrons are fired at atoms of an element, the neutrons become part of the nucleus of those atoms.

What effect does the presence of an extra neutron have on the chemical properties of the new atoms formed? Explain your answer.

.....

.....

..... [2]

[Total: 10]

**Q11.**

1 Magnesium, Mg, and radium, Ra, are elements in Group II of the Periodic Table.

Magnesium has three isotopes.

**(a)** Explain the meaning of the term *isotope*.

.....

.....

..... [2]

A sample of magnesium has the following isotopic composition by mass.

| isotope mass | 24 | 25 | 26 |
|---|---|---|---|
| % by mass | 78.60 | 10.11 | 11.29 |

**(b)** Calculate the relative atomic mass, $A_r$, of magnesium to **four** significant figures.

$A_r$ = .....
[2]

Radium, proton number 88, and uranium, proton number 92, are radioactive elements.

*For Examiner Use*

The isotope $^{226}Ra$ is produced by the radioactive decay of the uranium isotope $^{238}U$.

**(c)** Complete the table below to show the atomic structures of the isotopes $^{226}Ra$ and $^{238}U$.

| | number of | | |
|---|---|---|---|
| isotopes | protons | neutrons | electrons |
| $^{226}Ra$ | | | |
| $^{238}U$ | | | |

[3]

**(d)** Radium, like other Group II elements, forms a number of ionic compounds.

**(i)** What is the formula of the radium cation?

.....

**(ii)** Use the *Data Booklet* to suggest a value for the energy required to form one mole of the gaseous radium cation you have given in **(i)** from one mole of gaseous radium atoms. Explain your answer.

.....

.....

..... [3]

[Total: 10]

**Q12.**

**1** The element magnesium, Mg, proton number 12, is a metal which is used in many alloys which are strong and light.

Magnesium has several naturally occurring isotopes.

**(a)** What is meant by the term *isotope*?

.....

.....

.....[2]

**(b)** Complete the table below for two of the isotopes of magnesium.

| isotope | number of protons | number of neutrons | number of electrons |
|---|---|---|---|
| $^{24}Mg$ | | | |
| $^{26}Mg$ | | | |

[2]

A sample of magnesium had the following isotopic composition:
$^{24}Mg$, 78.60%; $^{25}Mg$, 10.11%; $^{26}Mg$, 11.29%.

**(c)** Calculate the relative atomic mass, $A_r$, of magnesium in the sample.
Express your answer to an appropriate number of significant figures.

[2]

Antimony, Sb, proton number 51, is another element which is used in alloys.

Magnesium and antimony each react when heated separately in chlorine.

**(d)** Construct a balanced equation for the reaction between magnesium and chlorine.

.....[1]

When a 2.45 g sample of antimony was heated in chlorine under suitable conditions, 4.57 g of a chloride **A** were formed.

**(e)** **(i)** Calculate the amount, in moles, of antimony atoms that reacted.

**(ii)** Calculate the amount, in moles, of chlorine atoms that reacted.

**(iii)** Use your answers to **(i)** and **(ii)** to determine the empirical formula of **A**.

**(iv)** The empirical and molecular formulae of **A** are the same.

Construct a balanced equation for the reaction between antimony and chlorine.

.....[5]

**(f)** The chloride **A** melts at 73.4 °C while magnesium chloride melts at 714 °C.

**(i)** What type of bonding is present in magnesium chloride?

.....

**(ii)** Suggest what type of bonding is present in **A**.

.....[2]

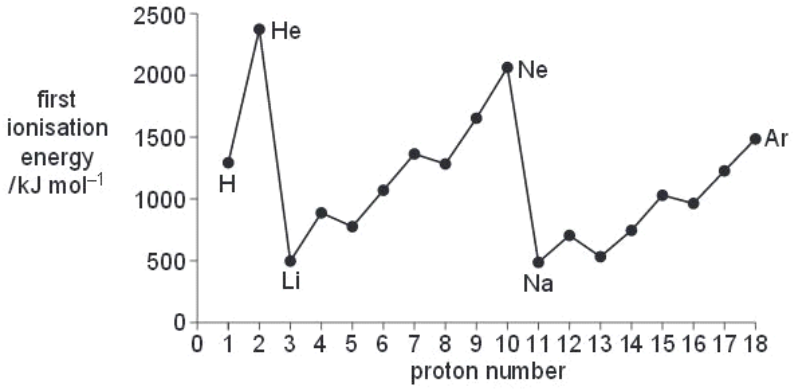
[Total: 14]

**Q13.**

2 The Periodic Table we currently use is derived directly from that proposed in 1869 by Mendeleev who had noticed patterns in the physical and chemical properties of the elements he had studied.

For Examiner Use

The diagram below shows the first ionisation energies of the first 18 elements of the Periodic Table.




**(a)** Give the equation, including state symbols, for the first ionisation energy of sulfur.

..... [2]

**(b)** Explain why there is a **general** increase in first ionisation energies across the Period from sodium to argon.

.....

.....

.....

..... [3]

**(c)** **(i)** Explain why the first ionisation energy of magnesium is greater than that of aluminium.

.....

.....

.....

**(ii)** Explain why the first ionisation energy of phosphorus is greater than that of sulfur.

.....

.....

..... [4]

**Q14.**

**1** Sulfur, S, and polonium, Po, are both elements in Group VI of the Periodic Table.

Sulfur has three isotopes.

**(a)** Explain the meaning of the term *isotope*.

.....

.....

.....[2]

**(b)** A sample of sulfur has the following isotopic composition by mass.

| isotope mass | 32 | 33 | 34 |
|---|---|---|---|
| % by mass | 95.00 | 0.77 | 4.23 |

Calculate the relative atomic mass, $A_r$, of sulfur to **two** decimal places.

$A_r$ = .....

[2]

**(c)** Isotopes of polonium, proton number 84, are produced by the radioactive decay of several elements including thorium, Th, proton number 90.

The isotope $^{213}$Po is produced from the thorium isotope $^{232}$Th.

Complete the table below to show the atomic structures of the isotopes $^{213}$Po and $^{232}$Th.

| | number of | | |
|---|---|---|---|
| isotope | protons | neutrons | electrons |
| $^{213}$Po | | | |
| $^{232}$Th | | | |

[3]

Radiochemical reactions, such as nuclear fission and radioactive decay of isotopes, can be represented by equations in which the nucleon (mass) numbers must balance and the proton numbers must also balance.

For example, the nuclear fission of uranium-235, $^{235}_{92}U$, by collision with a neutron, $^{1}_{0}n$, produces strontium-90, xenon-143 and three neutrons.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{90}_{38}Sr + ^{143}_{54}Xe + 3\,^{1}_{0}n$$

In this equation, the nucleon (mass) numbers balance because: 235 + 1 = 90 + 143 + (3x1).

The proton numbers also balance because: 92 + 0 = 38 + 54 + (3x0).

**(d)** In the first stage of the radioactive decay of $^{232}_{90}Th$, the products are an isotope of element *E* and an alpha-particle, $^{4}_{2}He$.

**(i)** By considering nucleon and proton numbers only, construct a balanced equation for the formation of the isotope of *E* in this reaction.

$$^{232}_{90}Th \rightarrow \text{.....} + ^{4}_{2}He$$

Show clearly the nucleon number and proton number of the isotope of *E*.

nucleon number of the isotope of *E* .....

proton number of the isotope of *E* .....

**(ii)** Hence state the symbol of the element *E*.

.....

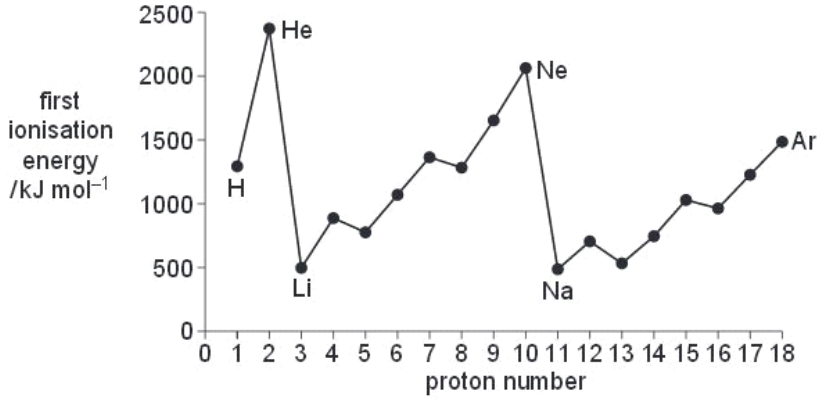
[3]

[Total: 10]

**Q15.**

3 The Periodic Table we currently use is derived directly from that proposed in 1869 by Mendeleev who had noticed patterns in the physical and chemical properties of the elements he had studied.

The diagram below shows the first ionisation energies of the first 18 elements of the Periodic Table.




**(a)** Give the equation, including state symbols, for the first ionisation energy of carbon.

..... [2]

**(b)** **(i)** Explain why sodium has a lower first ionisation energy than magnesium.

.....

.....

**(ii)** Explain why magnesium has a higher first ionisation energy than aluminium.

.....

.....

**(iii)** Explain why helium, He, and neon, Ne, occupy the two highest positions on the diagram.

.....

.....

**(iv)** Explain why the first ionisation energy of argon, Ar, is lower than that of neon, which is lower than that of helium.

.....

.....

.....

[8]

**(c)** **(i)** The first ionisation energies of the elements Na to Ar show a variation. Some physical properties show similar variations.

The atomic radius of the elements decreases from Na to Cl.

Give a brief explanation of this variation.

.....

.....

**(ii)** The cations formed by the elements Na to Al are smaller than the corresponding atoms.

Give a brief explanation of this change.

.....

.....

[3]

**(d)** The oxides of the elements of the third Period behave differently with NaOH(aq) and HCl (aq). In some cases, no reaction occurs.

Complete the table below by writing a balanced equation for any reaction that occurs, with heating if necessary. If you think no reaction takes place write 'no reaction'.

You do not need to include state symbols in your answers.

| |
|---|
| .....MgO(s) + .....NaOH (aq) → |
| .....MgO(s) + .....HCl (aq) → |
| .....$Al_2O_3$(s) + .....NaOH (aq) + .....$H_2O$ (l) → |
| .....$Al_2O_3$(s) + .....HCl (aq) → |
| .....$SO_2$(g) + .....NaOH (aq) → |
| .....$SO_2$(g) + .....HCl (aq) → |

[6]

[Total: 19]

**Q16.**

**1** Although the actual size of an atom cannot be measured exactly, it is possible to measure the distance between the nuclei of two atoms. For example, the 'covalent radius' of the Cl atom is assumed to be half of the distance between the nuclei in a $Cl_2$ molecule. Similarly, the 'metallic radius' is half of the distance between two metal atoms in the crystal lattice of a metal. These two types of radius are generally known as 'atomic radii'.
The table below contains the resulting atomic radii for the elements of period three of the Periodic Table, Na to Cl.

| element | Na | Mg | Al | Si | P | S | Cl |
|---|---|---|---|---|---|---|---|
| atomic radius / nm | 0.186 | 0.160 | 0.143 | 0.117 | 0.110 | 0.104 | 0.099 |

**(a) (i)** Explain qualitatively this variation in atomic radius.

.....

.....

.....

.....

.....

**(ii)** Suggest why it is not possible to use the same type of measurement for argon, Ar.

.....

.....

[4]

**(b) (i)** Use the *Data Booklet* to complete the following table of radii of the cations and anions formed by some of the period three elements.

| radius of cation / nm | | | radius of anion / nm | | |
|---|---|---|---|---|---|
| $Na^+$ | $Mg^{2+}$ | $Al^{3+}$ | $P^{3-}$ | $S^{2-}$ | $Cl^-$ |
| | | | | | |

**(ii)** Explain the differences in size between the cations and the corresponding atoms.

.....

.....

.....

**(iii)** Explain the differences in size between the anions and the corresponding atoms.

.....

.....

.....

[5]

Exa