CHEMISTRY 9701
THEORY QUESTIONS

AS: Atomic Structure

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Question 1

1 **(a)** Successive ionisation energies for the elements magnesium to barium are given in the table.

element	1st ionisation energy / kJ mol^{-1}	2nd ionisation energy / kJ mol^{-1}	3rd ionisation energy / kJ mol^{-1}
Mg	736	1450	7740
Ca	590	1150	4940
Sr	548	1060	4120
Ba	502	966	3390

(i) Explain why the first ionisation energies decrease down the group.

.....

.....

.....

..... [3]

(ii) Explain why, for each element, there is a large increase between the 2nd and 3rd ionisation energies.

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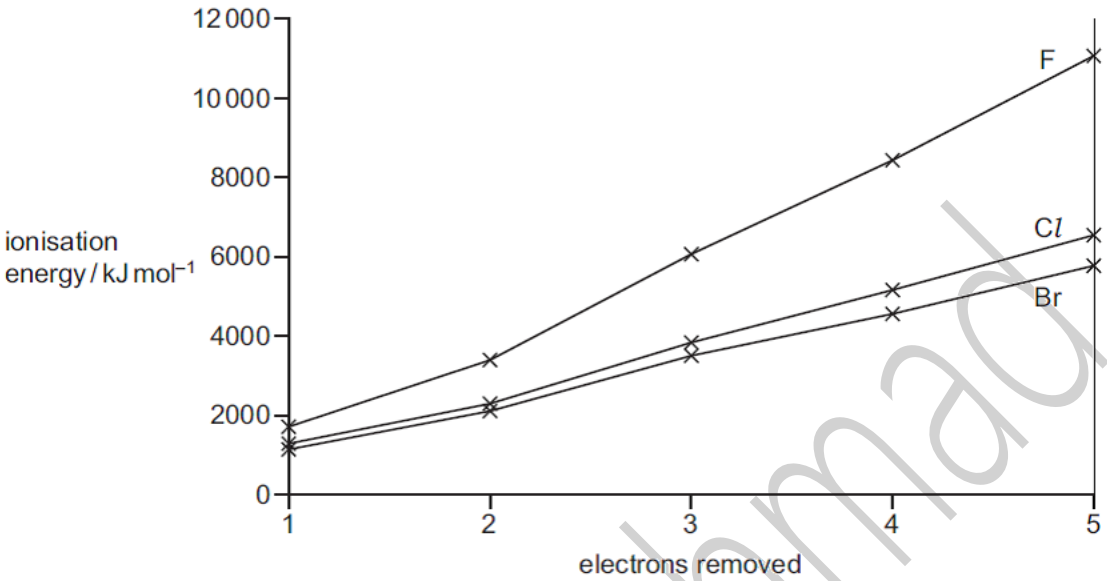
.....

..... [2]

9701_w/14/qp21

Question 2

1 **(a)** Successive ionisation energies for the elements fluorine, F, to bromine, Br, are shown on the graph.



(i) Explain why the first ionisation energies decrease down the group.

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.....

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..... [3]

(ii) Explain why there is an increase in the successive ionisation energies of fluorine.

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..... [2]

9701_w/14/qp23

Question 3

1 **(a)** Explain what is meant by the term *ionisation energy*.

.....

.....

..... [3]

(b) The first seven ionisation energies of an element, **A**, in kJ mol^{-1}, are

1012 1903 2912 4957 6274 21 269 25 398.

(i) State the group of the Periodic Table to which **A** is most likely to belong. Explain your answer.

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.....

.....

..... [2]

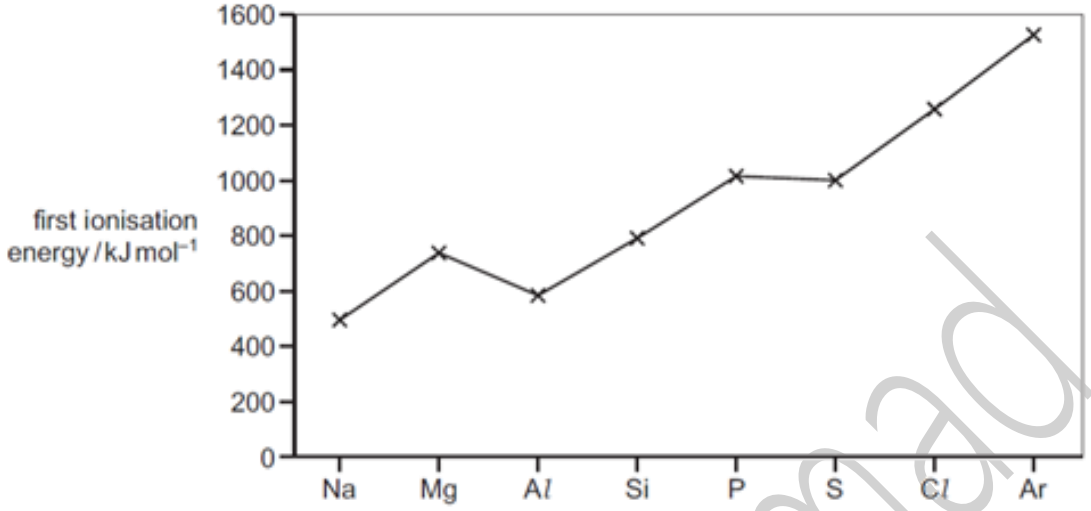
(ii) Complete the electronic configuration of the element in Period 2 that is in the same group as **A**.

$1s^2$ ..... [1]

9701_s/14/qp21

Question 4

(b) The graph below shows the variation of the first ionisation energies across Period 3.



(i) Explain why the first ionisation energy of Ar is greater than that of Cl.

.....

..... [1]

(ii) Explain why the first ionisation energy of Al is less than that of Mg.

.....

..... [1]

(iii) Explain why the first ionisation energy of S is less than that of P.

.....

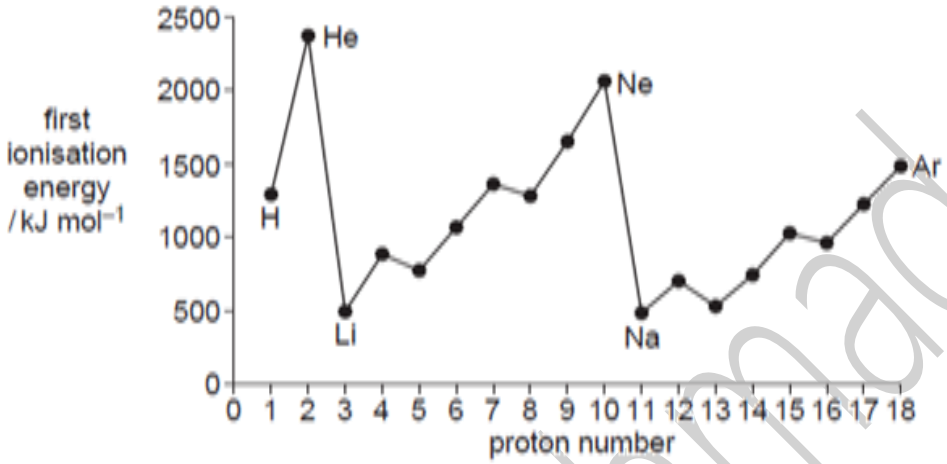
..... [1]

9701_s/14/qp22

Question 5

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.

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

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.....

[8]

9701_w/11/qp23

Question 6

(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.

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

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.

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

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]

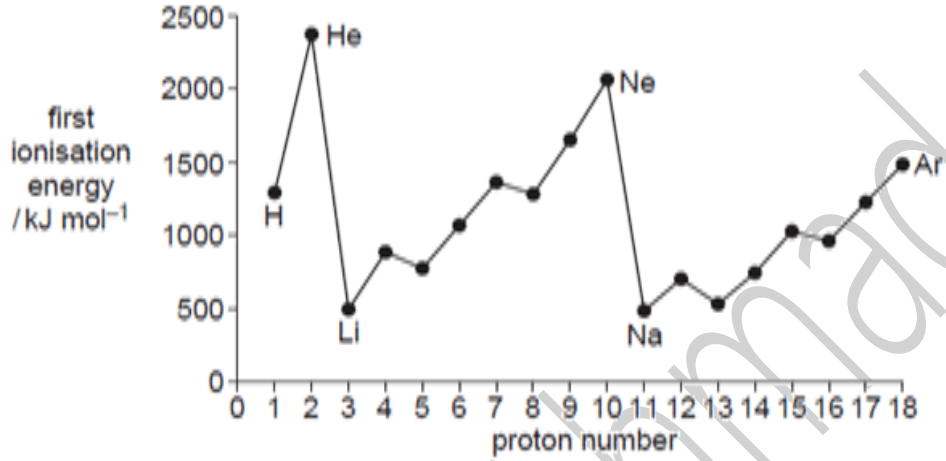
[Total: 10]

9701_w/11/qp23

Question 7

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.

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.

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.....

.....

..... [3]

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

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.....

.....

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

.....

.....

..... [4]

9701_w/11/qp21

Question 8

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

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.

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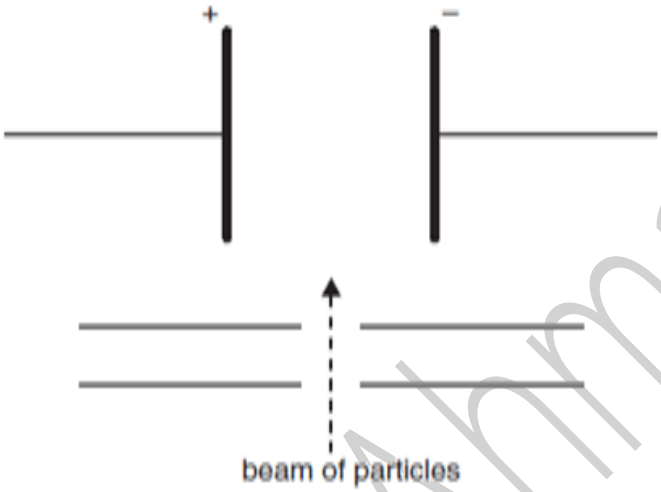
..... [3]

9701_w/09/qp21

Question 9

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.

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.....

[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]

9701_w/06/qp2

Question 10

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.

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..... [4]

[Total: 12]

9701_w/05/qp2

Question 11

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.

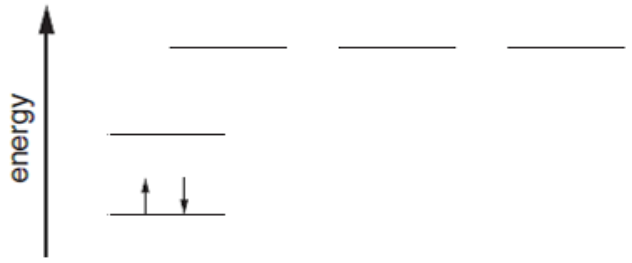
(a) The diagram below represents the energy levels of the orbitals present in atoms of the second period (Li to Ne).

(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.

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.....

[3]

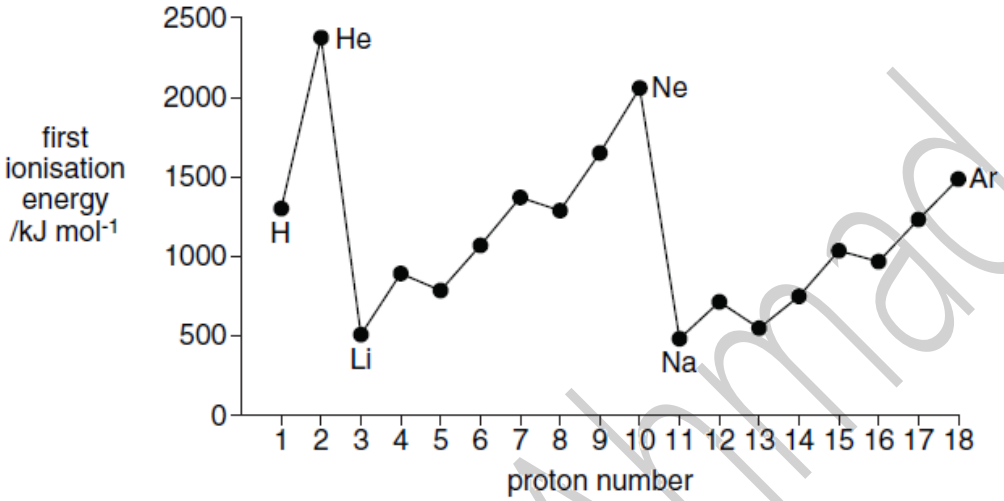
[Total: 9]

9701_s/10/qp22

Question 12

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.

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.....

.....

.....[3]

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

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

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.....

[4]

9701_s/08/qp2

Question 13

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*.

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..... [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]

9701_s/04/qp2

Question 14

1 Sir James Jeans, who was a great populariser of science, once described an atom of carbon as being like six bees buzzing around a space the size of a football stadium.

(a) (i) Suggest what were represented by the six bees in this description.

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(ii) Explain (in terms of an atom of carbon) what stopped the bees from flying away from the space of the football stadium.

.....

.....

(iii) What is missing from Jeans' description when applied to an atom of carbon?

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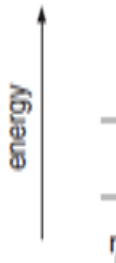
.....

[3]

(b) The diagram below represents the energy levels of the orbitals in atoms of the second period, lithium to neon.

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



(ii) In the space below, sketch the shapes of the two types of orbital.

(iii) Complete the electron configurations of nitrogen and oxygen on the energy level diagrams below, using arrows to represent electrons.

nitrogen oxygen

(iv) Explain, with reference to your answer to **(iii)**, the relative values of the first ionisation energies of nitrogen and oxygen. The values are given in the *Data Booklet* and should be quoted in your answer.

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.....

[6]

(c) (i) State the formulae of the negatively charged ions formed by these elements in simple binary compounds (nitrides and oxides).

.....

(ii) Why do nitrogen and oxygen form negative ions, but not positive ions, in simple binary compounds?

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[2]

[Total : 11]

9701_s/02/qp2

1 This question is about Period 3 elements and their compounds.

(a) Give an explanation for each of the following statements.

(i) The atomic radius decreases across Period 3 (Na to Ar).

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..... [2]

(ii) The first ionisation energy of sulfur is lower than that of phosphorus.

.....

.....

.....

..... [2]

(iii) Sodium is a better electrical conductor than phosphorus.

.....

.....

.....

..... [2]

(iv) Magnesium is a better electrical conductor than sodium.

.....

..... [1]

9701_m16_qp22

1 **(a)** The table shows information about some of the elements in the third period.

element	Na	Mg	Al	P	S	Cl
atomic radius / nm	0.186	0.160	0.143	0.110	0.104	0.099
radius of most common ion / nm	0.095	0.065	0.050	0.212	0.184	0.181
maximum oxidation number of the element in its compounds	+1					+7

(i) Complete the table to show the maximum oxidation number of each element in its compounds. [1]

(ii) Explain why the atomic radius of elements in the third period decreases from Na to Cl.

.....

.....

.....

.....

..... [3]

(iii) The radius of the most common ion of Mg is much smaller than the radius of the most common ion of S.

Identify both ions and explain the difference in their radii.

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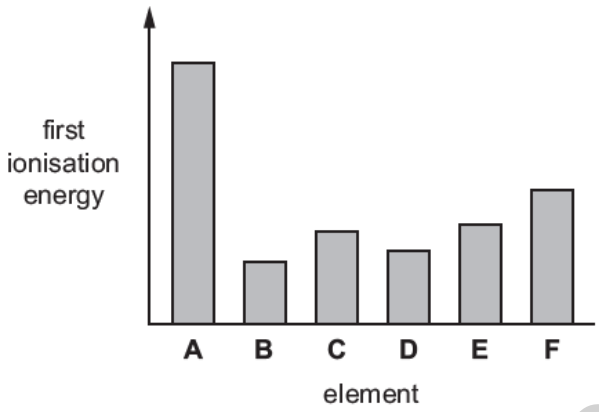
.....

..... [2]

9701_m17_qp22

1 **(a)** The graph shows a sketch of the first ionisation energies of six successive elements in the Periodic Table.

The letters are **not** the symbols of the elements.



(i) Explain what is meant by the term *first ionisation energy*.

.....

.....

.....

..... [3]

(ii) Suggest why the first ionisation energy of **B** is much less than that of **A**.

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.....

..... [3]

9701_m18_qp22

1 Neon is a noble gas.

(a) Complete the full electronic configuration of neon.

$1s^2$ ..... [1]

(b) **(i)** Explain what is meant by the term *first ionisation energy*.

.....

.....

..... [3]

(ii) Explain why the first ionisation energy of neon is greater than that of fluorine.

.....

..... [2]

s/15/qp23

1 **(a)** Complete the table to show the composition and identity of some atoms and ions.

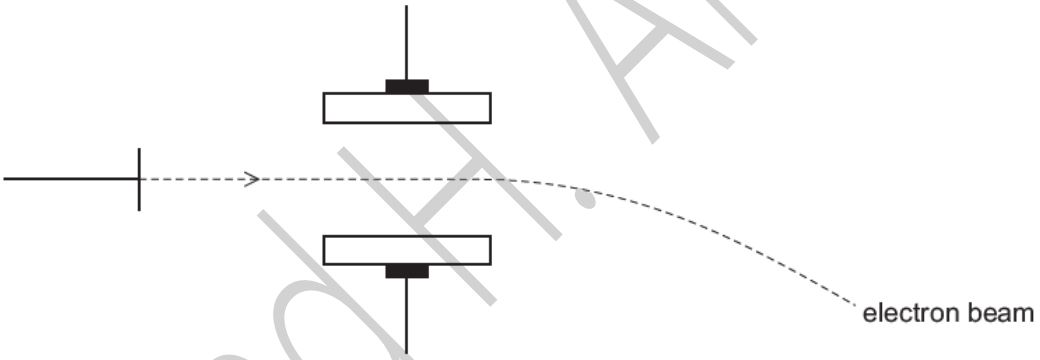
name of element	nucleon number	atomic number	number of protons	number of neutrons	number of electrons	overall charge
lithium	6	3	.....	.....	.....	+1
oxygen	.....	.....	.....	9	10	.....
.....	54	26	26	.....	24	.....
.....	.....	.....	17	18	.....	0

[4]

(b) Beams of protons, neutrons and electrons behave differently in an electric field due to their differing properties.

The diagram shows the path of a beam of electrons in an electric field.

Add and label lines to represent the paths of beams of protons and neutrons in the same field.



[3]

(c) The fifth to eighth ionisation energies of three elements in the third period of the Periodic Table are given. The symbols used for reference are **not** the actual symbols of the elements.

	ionisation energies, kJ mol^{-1}			
	fifth	sixth	seventh	eighth
X	6274	21 269	25 398	29 855
Y	7012	8496	27 107	31 671
Z	6542	9362	11 018	33 606

(i) State and explain the group number of element **Y**.

group number .....

explanation .....

.....

[1]

(ii) State and explain the general trend in **first** ionisation energies across the third period.

.....

.....

..... [2]

(iii) Explain why the **first** ionisation energy of element **Y** is less than that of element **X**.

.....

.....

.....

..... [2]

(iv) Complete the electronic configuration of element **Z**.

$1s^2$ ..... [1]

s/16/qp21

1 **(a)** Complete the table to show the composition and identity of some atoms and ions.

name of element	nucleon number	atomic number	number of protons	number of neutrons	number of electrons	overall charge
boron	10	5	.....	.....	.....	0
nitrogen	.....	.....	.....	8	10	.....
.....	208	82	82	.....	80	.....
.....	.....	.....	3	3	.....	+1

[4]

(b) The fifth to eighth ionisation energies of three elements in the third period of the Periodic Table are given. The symbols used for reference are **not** the actual symbols of the elements.

	ionisation energies, kJ mol^{-1}			
	fifth	sixth	seventh	eighth
X	7012	8496	27 107	31 671
Y	6542	9362	11 018	33 606
Z	7238	8781	11 996	13 842

(i) State and explain the group number of element **Y**.

group number .....

explanation .....

.....

[1]

(ii) State and explain the general trend in **first** ionisation energies across the third period.

.....

.....

..... [2]

(iii) Complete the electronic configuration of element **X**.

$1s^2$ ..... [1]

s/16/qp22

1 The composition of atoms and ions can be determined from knowledge of atomic number, nucleon number and charge.

(a) Complete the table.

atomic number	nucleon number	number of electrons	number of protons	number of neutrons	symbol
3		2			$^{6}_{3}Li^{+}$
		23	26	32	

[2]

s/17/qp22

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1 **(a)** Fill the gaps in the table for each of the given particles.

name of isotope	type of particle	charge	symbol	electron configuration
carbon-13				$1s^2 2s^2 2p^2$
		–1	$^{37}_{17}Cl^{-}$	
sulfur-34	atom	0		
iron-54	cation			$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$

[5]

w/15/qp22

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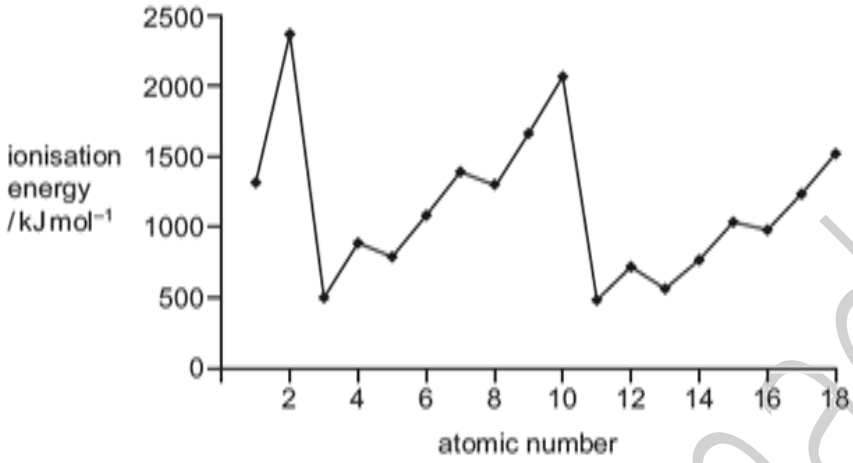
3 The Periodic Table is arranged such that the properties of the elements show a number of trends.

(a) A plot of the first ionisation energies for the first 18 elements is shown.



(i) Explain why the values show a general increase from atomic number 11 to 18.

.....

.....

..... [2]

(ii) Explain the decreases in first ionisation energies between

- atomic numbers 12 and 13,

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.....

.....

- atomic numbers 15 and 16.

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.....

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[4]

(iii) Suggest an explanation for the trend in the first ionisation energies of the elements with atomic numbers 2, 10 and 18.

.....

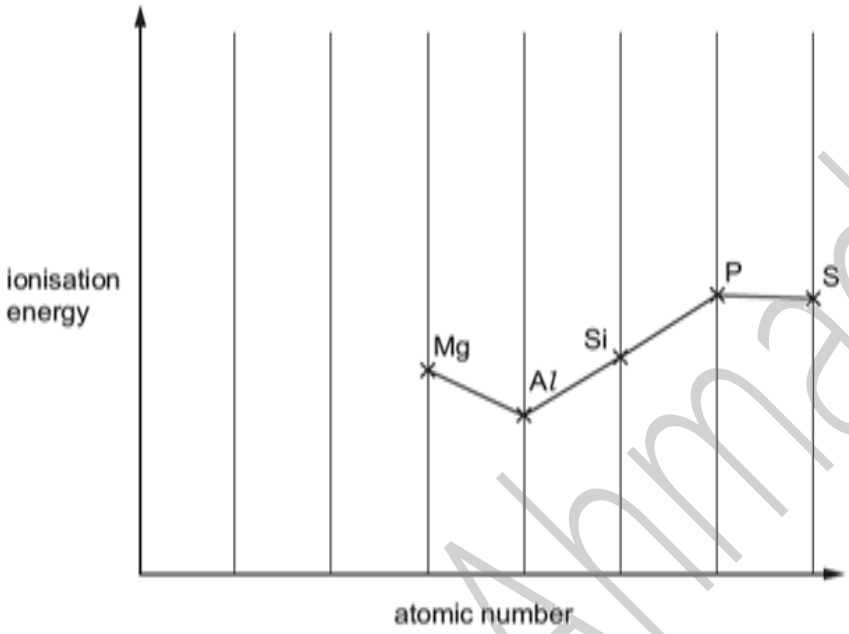
.....

..... [2]

w/16/qp22

2 The elements in the third period, and their compounds, show trends in their physical and chemical properties.

(a) A sketch graph of the first ionisation energies of five successive elements in the third period is shown.



(i) Explain why there is a general increase in the first ionisation energy across the third period.

.....

.....

..... [2]

(ii) Sketch, on the graph, the position of the ionisation energies of the two elements that come before Mg in this sequence. [2]

(iii) Explain, with reference to electron arrangements, the decreases in first ionisation energy between Mg and Al and between P and S.

Mg and Al .....

.....

.....

P and S .....

.....

.....

[4]

w/17/qp21