F321: Atoms, Bonds and Groups
Electron Structure

84 Marks

1. Modern plasma television screens emit light when mixtures of noble gases, such as neon and xenon, are ionised.

The first ionisation energies of neon and xenon are shown in the table below.

element	1st ionisation energy / kJ mol^{-1}
neon	+2081
xenon	+1170

Explain why xenon has a lower first ionisation energy than neon.

.....

.....

.....

.....

.....

.....

.....

.....

.....

[Total 3 marks]

2. The electron configuration of bromine contains outermost electrons in the 4th shell.

Using your knowledge of Group 7 elements, complete the electron configuration of bromine.

$1s^2 2s^2 2p^6 3s^2 3p^6$ .....

[Total 1 mark]

3. Ammonia reacts with hydrogen chloride, HC*l*, to form ammonium chloride, NH_4Cl.

NH_4Cl is an ionic compound containing NH_4^+ and Cl^- ions.

(i) Complete the electron configuration of the Cl^- ion.

$1s^2$ .....

[1]

(ii) Draw a '*dot-and-cross*' diagram to show the bonding in NH_4^+.

Show **outer** electrons only.

[1]

(iii) State the shape of, and bond angle in, an NH_4^+ ion.

shape: .....

bond angle: .....

[2]

(iv) A student investigated the conductivity of ammonium chloride.

She noticed that when the ammonium chloride was solid it did **not** conduct electricity. However, when ammonium chloride was dissolved in water, the resulting solution did conduct electricity.

Explain these observations.

.....

.....

.....

.....

.....

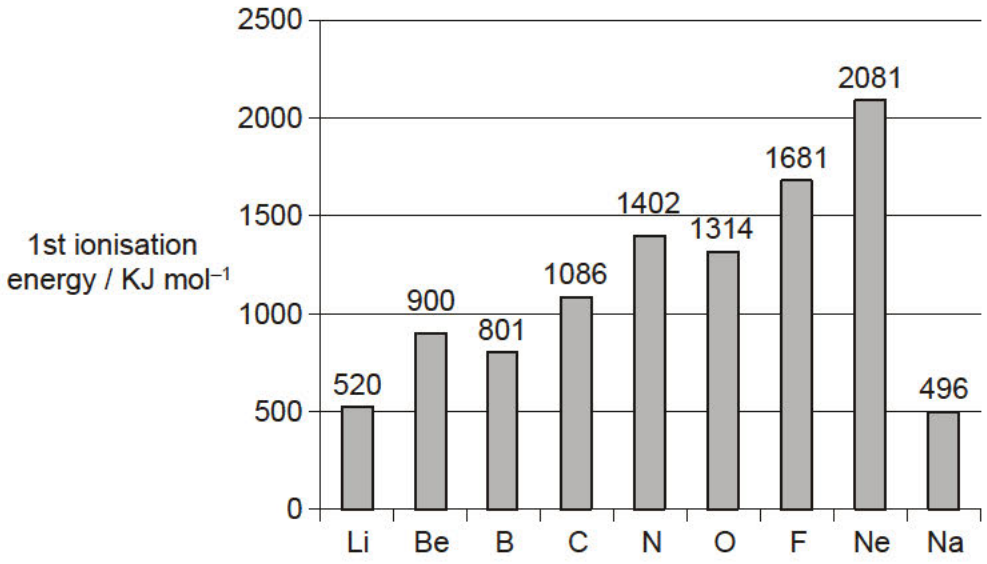
.....

[2]

[Total 6 marks]

4. Ionisation energies have been used to develop the model of the atom.

The first ionisation energies of the elements Li to Na are shown in the figure below.



Define the term *first ionisation energy*.

.....

.....

.....

.....

[Total 3 marks]

5. The first ionisation energy of oxygen is 1314 kJ mol^{-1} and the second ionisation energy of oxygen is 3388 kJ mol^{-1}.

(i) Write an equation to represent the **second** ionisation energy of oxygen.

Include state symbols.

.....

[1]

(ii) Suggest why the second ionisation energy of oxygen has a greater value than the first ionisation energy of oxygen.

.....

.....

.....

.....

[1]

[Total 2 marks]

6. The Periodic Table is a table of elements arranged in order of atomic number. The elements are classified into blocks.

(i) State what is meant by the term *atomic number*.

.....

[1]

(ii) Complete the full electron configuration for a titanium atom.

$1s^2$ .....

[1]

(iii) Identify the **seventh** element in the **fourth** period.

State which block this element is in.

element ..... block .....

[1]

[Total 3 marks]

7. The Group 7 element bromine was discovered by Balard in 1826. Bromine gets its name from the Greek *bromos* meaning stench.

Bromine consists of a mixture of two isotopes, ^{79}Br and ^{81}Br.

(i) What is meant by the term *isotopes*?

.....

.....

[1]

(ii) Complete the table below to show the atomic structures of the bromine isotopes.

	protons	**neutrons**	**electrons**
^{79}Br			
^{81}Br			

[2]

(iii) Write the full electronic configuration of a bromine atom.

$1s^2$ .....

[1]

[Total 4 marks]

8. Electrons are arranged in energy levels.

(a) An orbital is a region in which an electron may be found.

Draw diagrams to show the shape of an s orbital and of a p orbital.

s orbital	p orbital

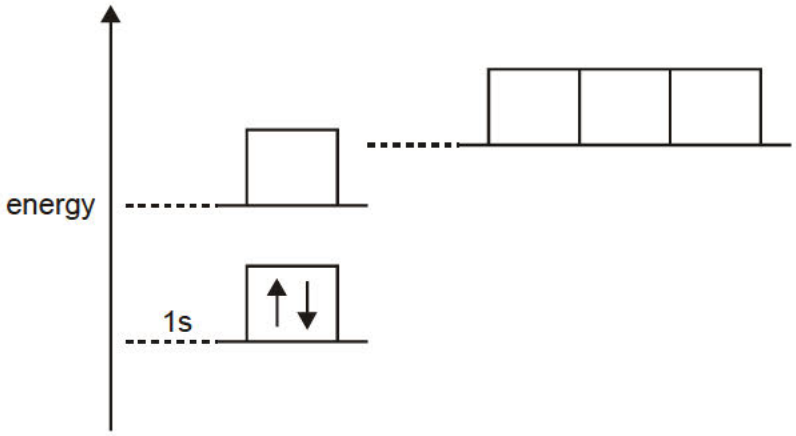
[2]

(b) Complete the table below to show how many electrons **completely** fill each of the following.

	number of electrons
a d **orbital**	
a p **sub-shell**	
the third **shell** (n = 3)	

[3]

(c) The energy diagram below is for the eight electrons in an oxygen atom. The diagram is incomplete as it only shows the two electrons in the 1s level.



Complete the diagram for the oxygen atom by:

(i) adding labels for the other sub-shell levels,

[1]

(ii) adding arrows to show how the other electrons are arranged.

[1]

[Total 7 marks]

9. Successive ionisation energies provide evidence for the arrangement of electrons in atoms. The table below shows the eight successive ionisation energies of oxygen.

ionisation number	1st	2nd	3rd	4th	5th	6th	7th	8th
ionisation energy / kJ mol^{-1}	1 314	3 388	5 301	7 469	10 989	13 327	71 337	84 080

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

.....

.....

.....

.....

[3]

(ii) Write an equation, with state symbols, to represent the **third** ionisation energy of oxygen.

.....

[2]

(iii) Explain how the information in the table above provides evidence for two electron shells in oxygen.

.....

.....

.....

.....

[2]

[Total 7 marks]

10. Magnesium exists naturally as a mixture of its isotopes, ^{24}Mg, ^{25}Mg and ^{26}Mg.

The isotopes in magnesium can be separated by mass spectrometry. The diagram below shows a mass spectrometer.

(i) Complete the table below to show the composition of the ^{25}Mg and ^{26}Mg isotopes.

	protons	neutrons	electrons
^{25}Mg			
^{26}Mg			

[2]

(ii) Complete the electronic configuration of an atom of ^{24}Mg.

$1s^2$ .....

[1]

(iii) Results from the mass spectrum of a sample of magnesium are shown below.

isotope	^{24}Mg	^{25}Mg	^{26}Mg
relative isotopic mass	24.00	25.00	26.00
% abundance	78.60	10.11	11.29

Calculate the relative atomic mass of the sample of magnesium.
Give your answer to two decimal places.

answer .....

[2]

[Total 5 marks]

11. In this question, you are provided with information about ionisation energies of elements. You are also provided with some additional information that will help you answer part (b).

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

.....

.....

.....

.....

[3]

(b) In this question, one mark is available for the quality of use and organisation of scientific terms.

Table 1 provides data on elements in **Period 2** of the Periodic Table.

Table 2 shows the first 6 successive ionisation energies of an element **X**, which is in **Period 3** of the Periodic Table.

- Using Table 1, describe and explain the trend in first ionisation energies shown by the Period 2 elements, Li–N.
- Using Table 2, identify element **X**. Explain how you decided on your answer.

[10]

element	Li	Be	B	C	N
number of protons	3	4	5	6	7
electron configuration	$1s^2\ 2s^1$	$1s^2\ 2s^2$	$1s^2\ 2s^2\ 2p^1$	$1s^2\ 2s^2\ 2p^2$	$1s^2\ 2s^2\ 2p^3$
1st ionisation energy / kJ mol^{-1}	520	900	801	1086	1402

Table 1

element	ionisation energy / kJ mol^{-1}					
	1st	2nd	3rd	4th	5th	6th
X	578	1817	2745	11 578	14 831	18 378

Table 2

[Total 13 marks]

12. In their reactions, calcium and strontium each lose electrons to form ions with a 2+ charge. The first and second ionisation energies of calcium and strontium are shown below.

	1st ionisation energy / kJ mol^{-1}	2nd ionisation energy / kJ mol^{-1}
calcium	590	1145
strontium	550	1064

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

.....

[2]

(ii) Why are the second ionisation energies of calcium and strontium greater than their first ionisation energies?

.....

.....

.....

[1]

(iii) Explain why the first and second ionisation energies of strontium are less than those of calcium.

.....

.....

.....

.....

.....

.....

[3]

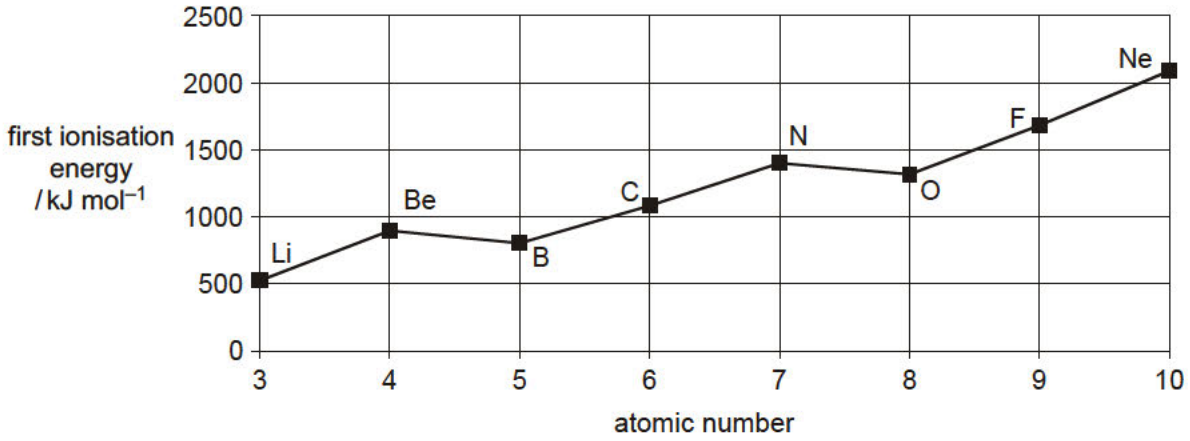
[Total 6 marks]

13. Complete the electronic configuration of carbon.

$1s^2$ .....

[Total 1 mark]

14. The diagram below shows the variation in the first ionisation energies of elements across Period 2 of the Periodic Table.



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

.....

.....

.....

[3]

(ii) Explain why the first ionisation energies show a **general** increase across Period 2.

.....

.....

.....

[2]

(iii) Explain why the first ionisation energy of B is **less** than that of Be.

.....

.....

.....

[2]

[Total 7 marks]

15. Complete the electronic configuration of a titanium atom.

$1s^2 2s^2 2p^6$ .....

[Total 1 mark]

16. Reactions of the Group 2 metals involve removal of electrons. The electrons are removed more easily as the group is descended and this helps to explain the increasing trend in reactivity.

(i) The removal of one electron from each atom in 1 mole of gaseous radium atoms

is called the .....

[2]

The equation for this process in radium is:

.....

[2]

(ii) Atoms of radium have a greater nuclear charge than atoms of calcium.

Explain why, despite this, **less** energy is needed to remove an electron from a radium atom than from a calcium atom.

.....

.....

.....

.....

[3]

[Total 7 marks]

17. The electronic configuration of a bromine atom can be written in terms of sub-shells.

(i) Complete the electronic configuration of a bromine atom.

$1s^2 2s^2 2p^6 3s^2 3p^6$ .....

[2]

(ii) Why is bromine classified as a p-block element?

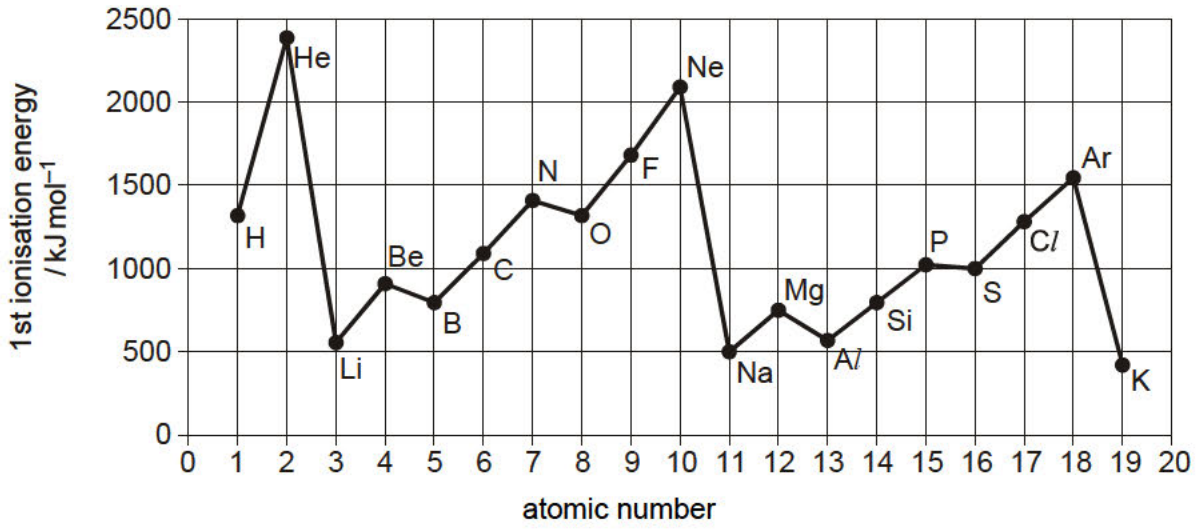
.....

.....

[1]

[Total 3 marks]

18. The first ionisation energies of the elements H to K are shown below. Use this diagram to help with your answers to this question.



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

.....

.....

.....

.....

[3]

(b) Explain why the first ionisation energies show a **general** increase across Period 2 (Li to Ne).

.....

.....

.....

[2]

[Total 5 marks]