Chemistry
A - LEVEL

CAMBRIDGE UNIVERSITY EXAMINATIONS

General Certificate of Education Advanced Subsidiary Level
and Advanced Level (As Level and A Level)
Paper 4 Structured Questions

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Chapter 7

Atomic Structure

Paper 2

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1 Complete the electronic configuration of the following elements

H ☐

He ☐

Li ☐ ☐

Be ☐ ☐

B ☐ ☐ ☐ ☐ ☐

C ☐ ☐ ☐ ☐ ☐

N ☐ ☐ ☐ ☐ ☐

O ☐ ☐ ☐ ☐ ☐

F ☐ ☐ ☐ ☐ ☐

Ne ☐ ☐ ☐ ☐ ☐

Na ☐ ☐ ☐ ☐ ☐ ☐

Mg ☐ ☐ ☐ ☐ ☐ ☐

Al ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Si ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

P ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

S ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Cl ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Ar ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

2 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.

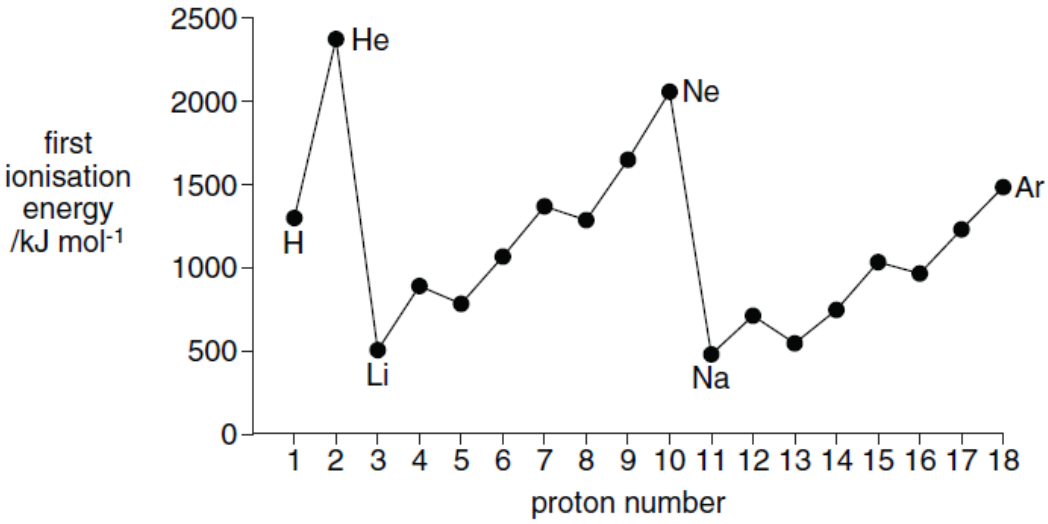
Use the *Data Booklet* to complete the table below to show the atomic structure of ^{56}Fe and of ^{59}Co.

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

[3]

3 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.

.....

.....

.....

4

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

.....

.....

.....

[4]

4 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]

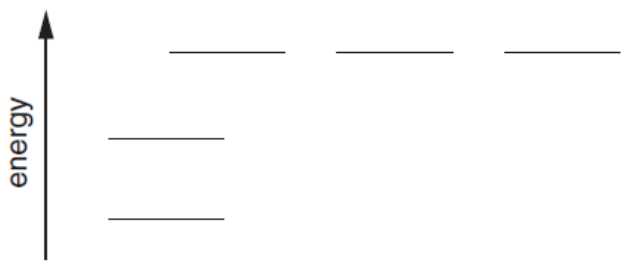
Aluminium reacts with chlorine.

5 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).

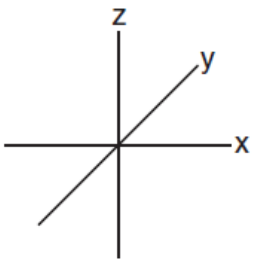
(i) Label the energy levels to indicate the principal quantum number **and** the type of orbital at each energy level.

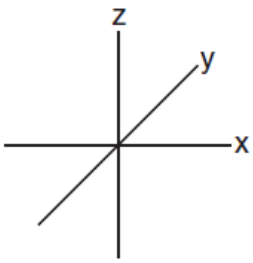


5

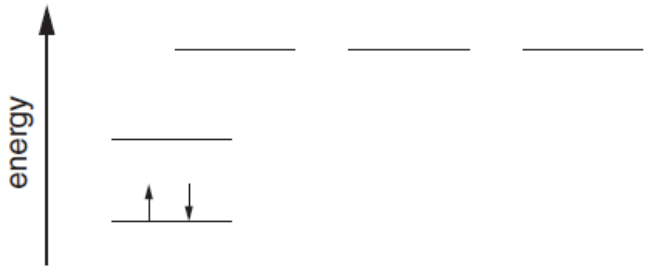
(ii) On the axes below, draw a sketch diagram of **one** of each **different type (shape)** of orbital that is occupied by the electrons in a second-period element.

Label each type.

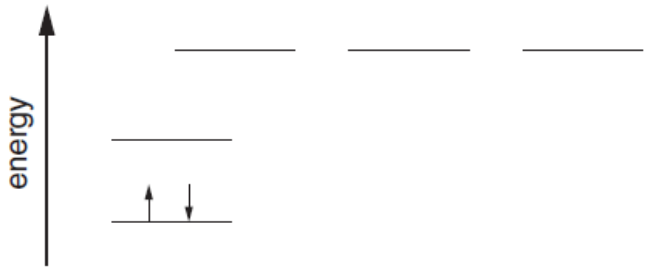




(iii) Complete the electronic configurations of nitrogen atoms and oxygen atoms on the energy level diagrams below.
Use arrows to represent electrons.



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.

.....

.....

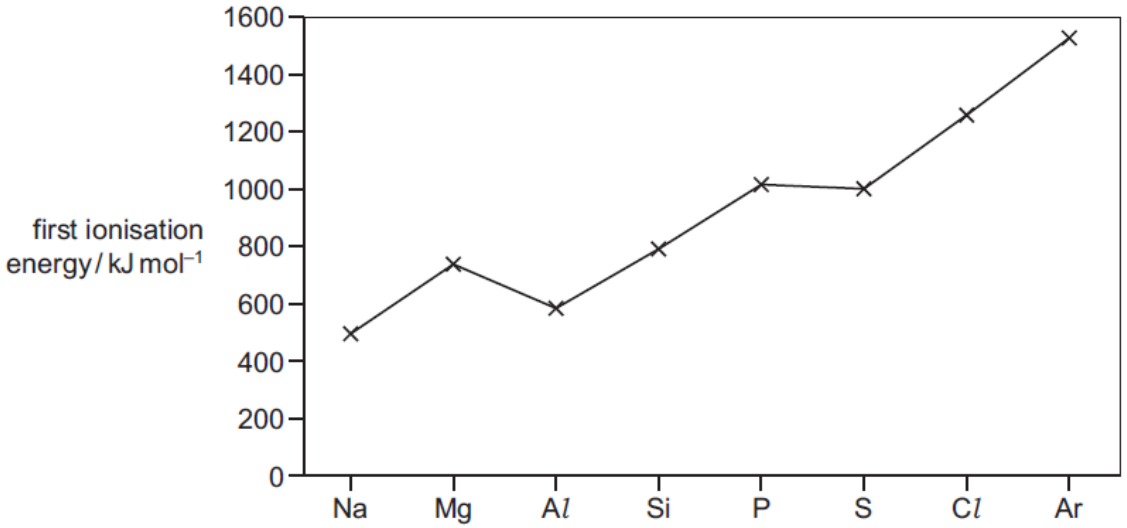
.....

[3]

[Total: 9]

6

(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]

7

(a) Chemists recognise that atoms are made of three types of particle.

Complete the following table with their names and properties.

name of particle	relative mass	relative charge
		+1
	1/1836	

[3]

(b) Most elements exist naturally as a mixture of isotopes, each with their own relative isotopic mass. The mass spectrum of an element reveals the abundances of these isotopes, which can be used to calculate the relative atomic mass of the element.

Magnesium has three stable isotopes. Information about two of these isotopes is given.

isotope	relative isotopic mass	percentage abundance
^{24}Mg	24.0	79.0
^{26}Mg	26.0	11.0

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

.....

.....

..... [2]

(ii) The relative atomic mass of magnesium is 24.3.

Calculate the percentage abundance and hence the relative isotopic mass of the third isotope of magnesium. Give your answer to **three** significant figures

percentage abundance = ...

isotopic mass = ...

[3]

8

(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]

(c) A sample of oxygen exists as a mixture of three isotopes. Information about two of these isotopes is given in the table.

mass number	16	17
abundance	99.76%	0.04%

(i) Calculate the abundance of the third isotope.

abundance = ... % [1]

(ii) The relative atomic mass of this sample of oxygen is 16.0044.

Calculate the mass number of the third isotope. You **must** show your working.

mass number = ... [2]

[Total: 11]

9

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

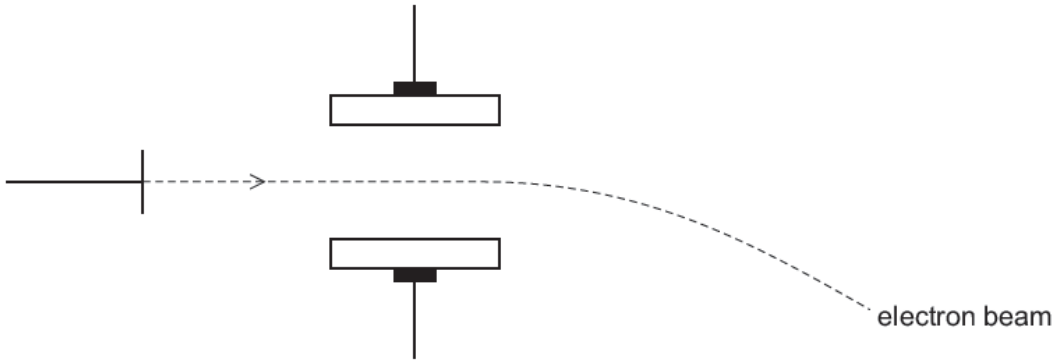
name of element	nucleon number	atomic number	number of protons	number of neutrons	number of electrons	overall charge
lithium	6	3	.....	.....	.....	+1
oxygen	.....	.....	.....	9	10	.....
.....	54	26	26	.....	24	.....
.....	.....	.....	17	18	.....	0

[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]

(d) A sample of strontium exists as a mixture of four isotopes. Information about three of these isotopes is given in the table.

mass number	86	87	88
abundance	9.86%	7.00%	82.58%

(i) Calculate the abundance of the fourth isotope.

abundance = ... % [1]

(ii) The relative atomic mass of this sample of strontium is 87.71.

Calculate the mass number of the fourth isotope.

10
11
12
13
14
15
16
17
18
19
20
21
22
23

2 **(a)** same proton no./atomic no./no. of protons **(1)**
different mass no./nucleon no./no. of neutrons **(1)** **[2]**

(b)

	number of		
isotope	protons	neutrons	electrons
^{56}Fe	**26**	**30**	**26**
^{59}Co	**27**	**32**	**27**
	(1)	**(1)**	**(1)**

give one mark for each correct column
allow **(1)** if no column is correct but one row is correct **[3]**

3 **(a)** $F(g) \rightarrow F^+(g) + e^-$

correct equation (1)

correct state symbols (1) [2]

(b) from Na to Ar, electrons

are added to the same shell/have same shielding (1)

are subject to increasing nuclear charge/proton number (1)

are closer to the nucleus **or** atom gets smaller (1) [3]

(c) (i) Al and Mg

in Al outermost electron is in 3p rather than 3s (1)

3p electron is at higher energy
or is further away/is more shielded from nucleus (1)

(ii) P and S

for P 3p sub-shell is singly filled
and for S one 3p orbital has paired electrons (1)

paired electrons repel (1) [4]

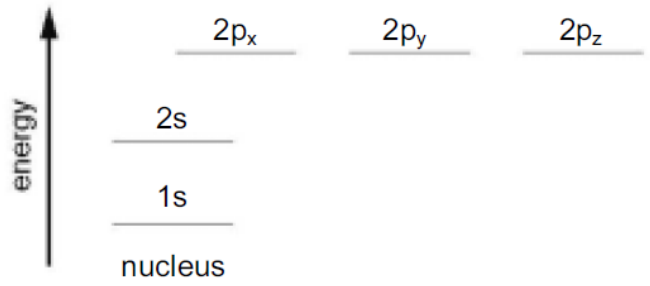
4 **(a)** Al $1s^2\ 2s^2 2p^6\ 3s^2 3p^1$ (1)

Ti $1s^2\ 2s^2 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$ **or**

$1s^2\ 2s^2 2p^6\ 3s^2\ 3p^6\ 4s^2 3d^2$ penalise any error (1) [

5

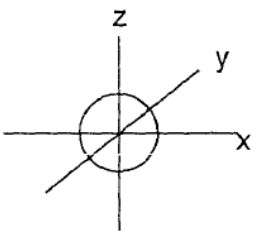
(a) (i)



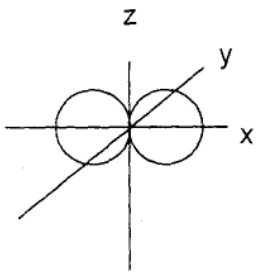
correct 1s and 2s (1)

correct $2p_x$, $2p_y$ and $2p_z$ (1)

(ii)



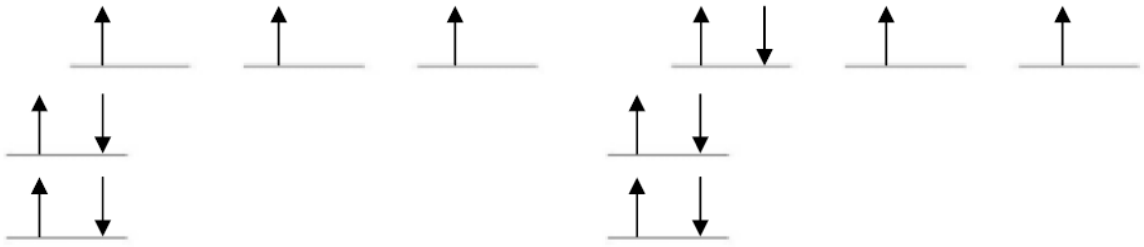
spherical s orbital (1)



double lobed p orbital along one axis (1)

both orbitals correctly labelled (1)

(iii)



nitrogen oxygen

both correct (1) [6]

(b) (i) N 1400 kJ mol^{-1} O 1310 kJ mol^{-1} **both** (1)

(ii) N is all singly filled 2p orbitals **or** O has one filled/paired 2p orbital (1)
these paired 2p electrons in the O atom repel one another (1) [3]

[Total: 9]

6

(b) (i)	Nuclear charge (in Ar) greater (than Cl) **AND** same shielding owtte	1	1
(ii)	p subshell / orbital in Al at higher energy (than s subshell in Mg) **ora** **OR** p subshell / orbital more shielded **ora**	1	1
(iii)	repulsion due to electron pair (in same / p orbital)	1	1

15

7

1 (a)

name of particle	relative mass	relative charge		
proton	**1**	+1	[1]	
electron	1/1836	**–1**	[1]	
neutron	**1**	**0**	[1]	[3]

(b) (i) Mass of an atom(s) [1]

relative to 1 / 12^{th} (the mass) of (an atom of) carbon-12
OR
relative to carbon-12 which is (exactly) 12 [1] [2]

8

Question	Answer	Mark	Total
1 (a)			

name of element	nucleon number	atomic number	number of protons	number of neutrons	number of electrons	overall charge	
boron	10	5	5	5	5	0	[1]
nitrogen	15	7	7	8	10	–3	[1]
lead	208	82	82	126	80	+2	[1]
lithium	6	3	3	3	2	+1	[1] [4]

(b) (i)	Group 17 / VII / 7 AND big (owtte) increase / big difference / big gap / big jump / jump in increase / jump in difference after 7th IE	[1] [1]	[1]
(ii)	increases across period due to increasing attraction (of nucleus for electrons) due to increasing nuclear charge / atomic / proton number AND constant / similar shielding / same (outer) shell / energy level	[1] [1]	[2]
(iii)	$1s^2 2s^2 2p^6 3s^2 3p^4$	[1]	[1]
(c) (i)	(100 – 99.76 – 0.04=) 0.2	[1]	[1]
(ii)	$\frac{0.2x + (99.76 \times 16) + (0.04 \times 17)}{100} = 16.0044$ x = 18	[1] [1]	[2]
			[Total 11]

9

Question	Mark Scheme	Mark	Total
1 (a)	<table><tr><th>name of element</th><th>nucleon no.</th><th>atomic no.</th><th>no. of protons</th><th>no. of neutrons</th><th>no. of electrons</th><th>overall charge</th></tr><tr><td>lithium</td><td>6</td><td>3</td><td>3</td><td>3</td><td>2</td><td>+1</td></tr><tr><td>oxygen</td><td>17</td><td>8</td><td>8</td><td>9</td><td>10</td><td>–2</td></tr><tr><td>iron</td><td>54</td><td>26</td><td>26</td><td>28</td><td>24</td><td>+2</td></tr><tr><td>chlorine</td><td>35</td><td>17</td><td>17</td><td>18</td><td>17</td><td>0</td></tr></table>	[1] [1] [1] [1]	[4]
(b)	line straight on labelled 'neutrons' line (curving) up labelled 'protons' proton line clearly shows less (overall) deflection than electron curve	[1] [1] [1]	[3]
(c) (i)	Group 16/6/VI AND Big (owtte) increase/big difference/big gap/big jump/jump in increase/jump in difference after 6th IE	[1]	[1]
(ii)	increases (across period) due to increasing attraction (of nucleus for electrons) due to increasing nuclear charge/atomic/proton number AND constant/similar shielding/same (outer/number of) shell/energy level	[1] [1]	[2]
(iii)	electron (pair) repulsion (Y has a) pair of electrons in a (3)p orbital/a (3)p orbital is full ORA	[1] [1]	[2]
(iv)	$(1s^2)2s^2 2p^6 3s^2 3p^5$	[1]	[1]
(d) (i)	0.56(%)	[1]	[1]
(ii)	$\frac{(A\times 0.56)+(86\times 9.86)+(87\times 7.00)+(88\times 82.58)}{100} = 87.71$ $A = 84$	[1] [1]	[2]
			[16

10