IB · DP · Chemistry

2 hours 13 questions

Structured Questions: Paper 2

12.1 Electrons in Atoms

Easy (3 questions)	/14
Medium (5 questions)	/49
Hard (5 questions)	/43
Total Marks	**/106**

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Easy Questions

1 (a) An element Y has the following first six ionisation energies in kJ mol^{-1}. These are shown in the table below.

	1st	2nd	3rd	4th	5th	6th
Ionisation energy (kJ mol^{-1})	577	1820	2740	11600	14800	18400

State what group of the Periodic Table this element belongs to.

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(1 mark)

(b) State what can be determined from the frequency of the convergence limit in a hydrogen emission spectrum.

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(1 mark)

(c) Hydrogen spectral data give the frequency of 3.30×10^{15} Hz for its convergence limit.

Calculate the ionisation energy, in J, for a single atom of hydrogen using Sections 1 and 2 of the Data Booklet.

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(1 mark)

(d) Calculate the wavelength, in m, for the electron transition corresponding to the frequency in part (c) using Section 1 of the Data Booklet.

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(1 mark)

State which element in Period 2 will have the highest first ionisation energy value.

2 (a) .....

(1 mark)

(b) Write an equation, including state symbols, for the third ionisation energy of beryllium.

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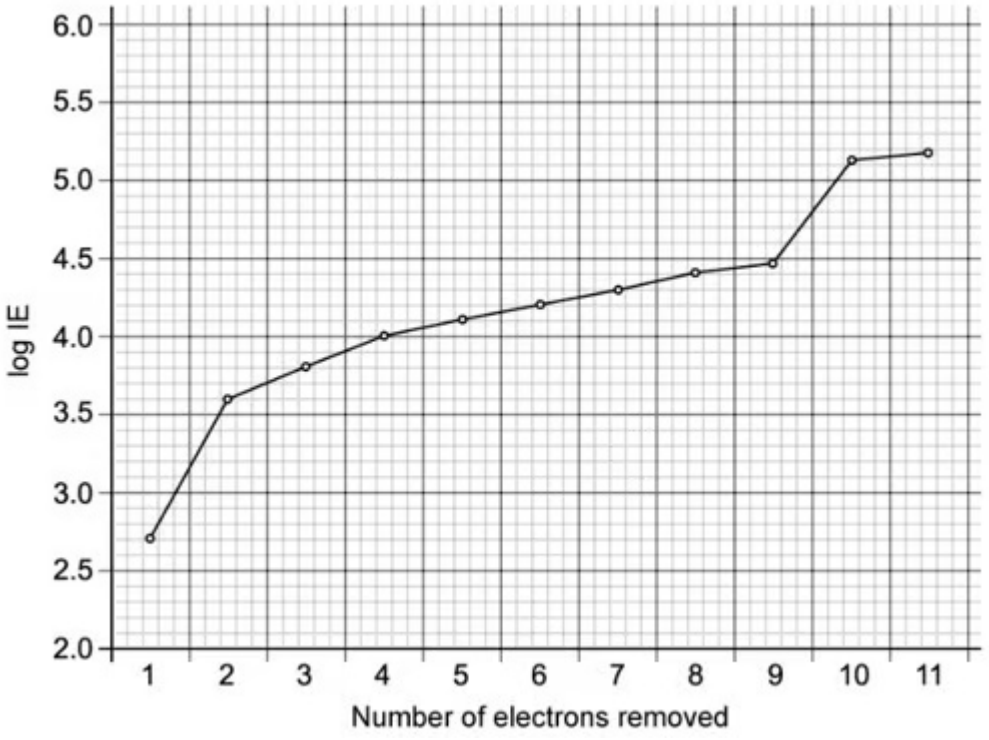
(1 mark)

(c) The successive ionisation energies of an element, X, are shown below.



State how many shells element X has.

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(1 mark)

(d) Deduce which group element X is in.

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(1 mark)

3 (a) State the general trend in first ionisation energies across Period 3.

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(1 mark)

(b) The first ionisation energy of aluminium is lower than magnesium. Write the full electron configurations of aluminium and magnesium.

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(2 marks)

(c) Using the electron configurations from part (b), explain why the first ionisation energy of aluminium is lower than magnesium.

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(2 marks)

(d) Write the equation, including state symbols, for the second ionisation energy of aluminium.

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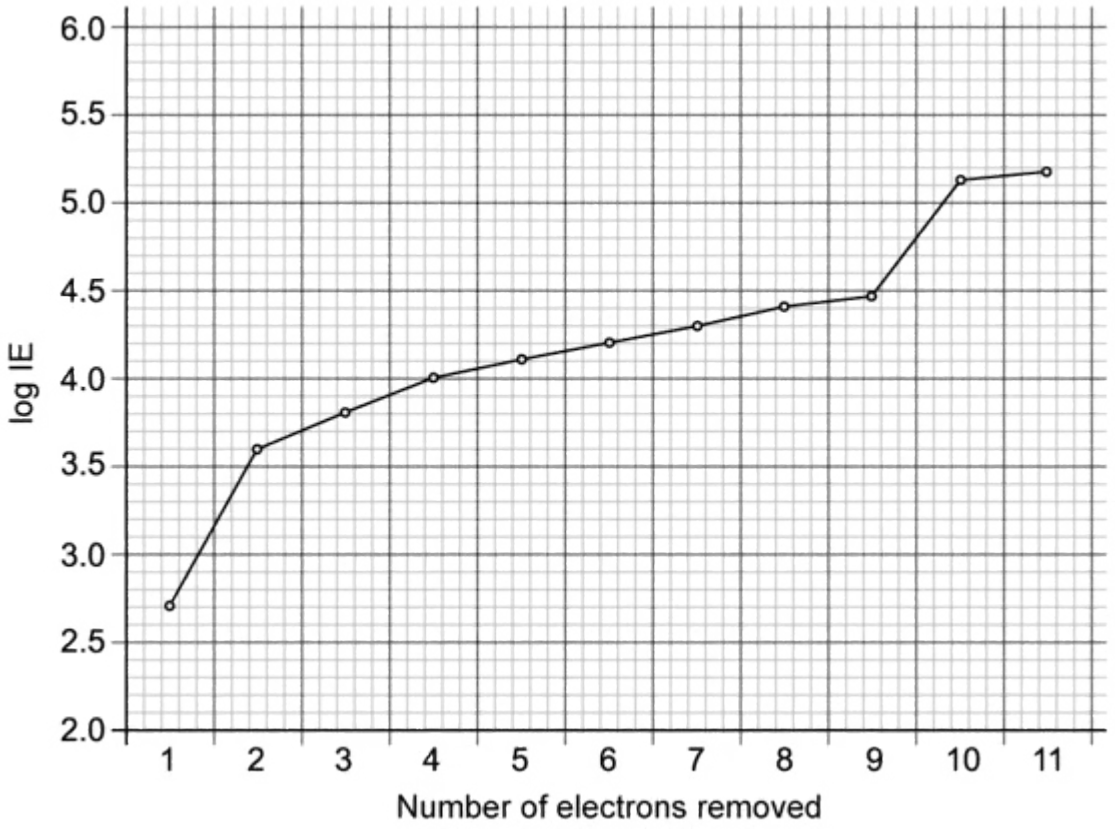
(1 mark)

Medium Questions

1 (a) a) The successive ionisation energies of an element, X, are shown below. The vertical axis plots log (ionisation energy) instead of ionisation energy to represent the data without an unreasonably long vertical axis.



Identify element X and give its full electron configuration.

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(2 marks)

(b) b) Explain how the successive ionisation energy data for the element X are related to its electron configuration.

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(3 marks)

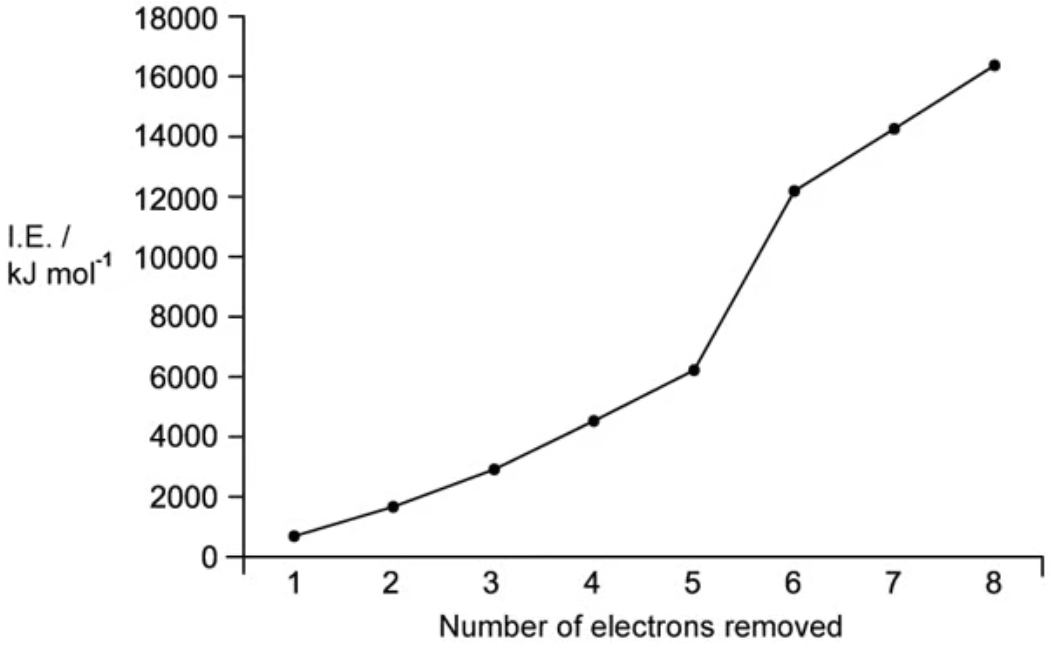
(c) c) Explain why the first ionisation energy of aluminium is lower than the first ionisation energy of magnesium.

(2 marks)

(d) d) Explain why the first ionisation energy of sulfur is lower than the first ionisation energy of phosphorus.

(2 marks)

2 (a) a) The successive ionisation energies of vanadium are shown.



State the sub-levels from which each of the first four electrons are lost

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(2 marks)

(b) b) Outline why there is an increase in ionisation energy from electron 3 to electron 5.

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(2 marks)

(c) c) Explain why there is a large increase in the ionisation energy between electrons 5 and 6.

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(3 marks)

d) The first six ionisation energies, in kJ mol^{-1}, of an element are shown below

(d)

IE_1	IE_2	IE_3	IE_4	IE_5	IE_6
578	1816	2744	11576	14829	18375

Explain the large increase in ionisation energy from IE_3 to IE_4

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(2 marks)

3 (a) a) Emission spectra provide experimental evidence for the existence of atomic energy levels.

i) Explain the convergence of lines in a hydrogen emission spectrum.

ii) State what can be determined from the frequency of the convergence limit.

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(2 marks)

(b) b) Determine the energy, in J, of a photon of red light, correct to two significant figures, given that the wavelength is 650.0 nm using Sections 1 and 2 of the Data Booklet.

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(2 marks)

(c) c) Calculate the first ionisation energy, in kJ mol^{-1}, for hydrogen given that its shortest wavelength in the Lyman series is 91.16 nm using Sections 1 and 2 of the Data Booklet.

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(3 marks)

(d) d) Describe why the energy required to reach the convergence limit on an emission spectrum is considered the ionisation energy for an atom. You should refer to the appearance of the spectrum, frequency, and energy in your answer.

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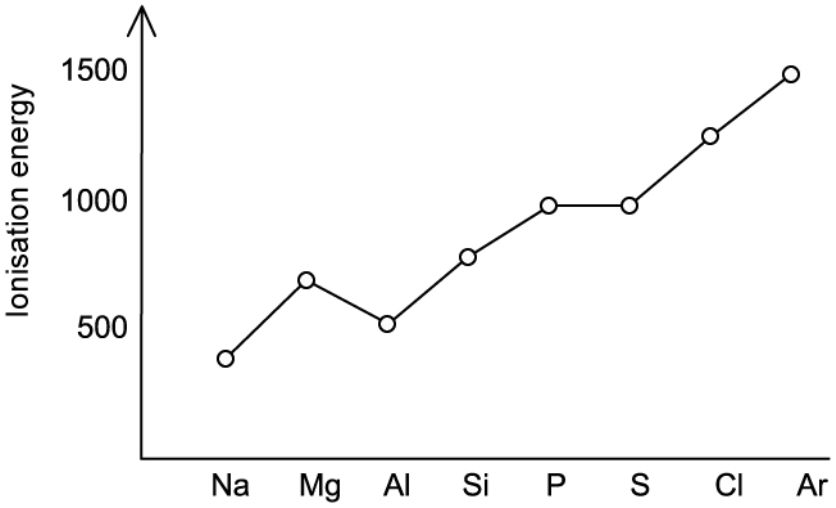
(3 marks)

4 (a) a) The first ionisation energies of the elements in period 3 are shown below.



Explain the general trend seen in ionisation energy across period 3.

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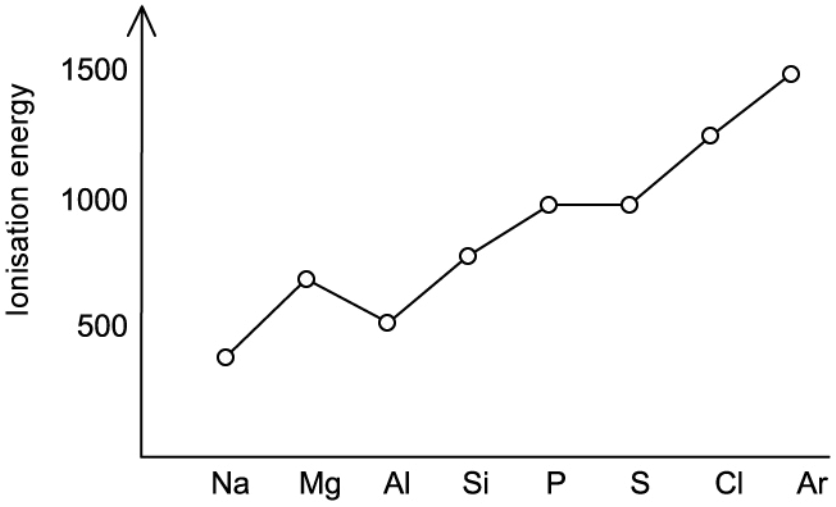
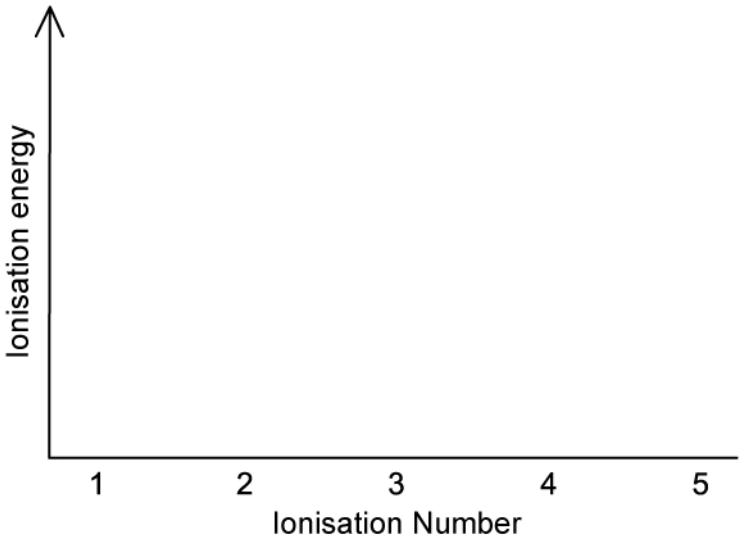
(3 marks)

(b) b) On the diagram below, sketch the line for the first ionisation energies of period 2 elements



(2 marks)

(c) c) Sketch a graph of ionisation energy versus the number of electrons removed for five ionisations of silicon. Explain the shape of the trend you have drawn.

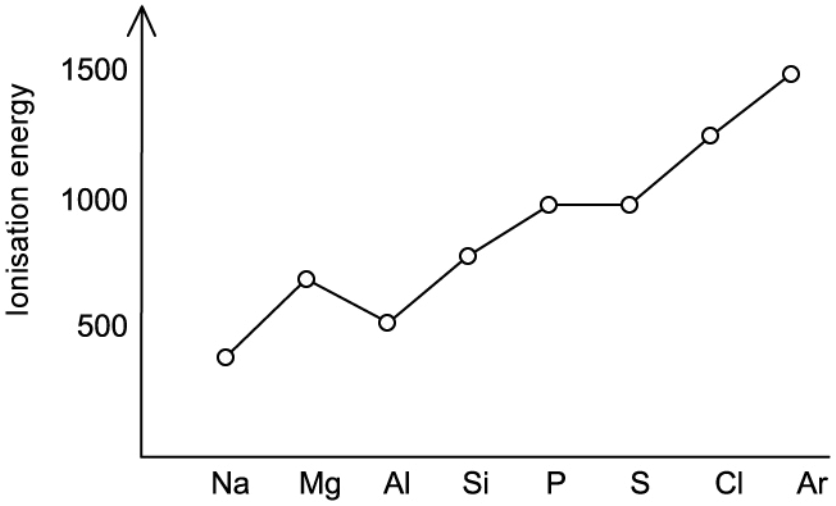


(5 marks)

(d) d) The wavelength of a line in the Balmer series of hydrogen is 726.2 m. Calculate the energy of photons emitted, in kJ, using Sections 1 and 2 of the Data Booklet.

(2 marks)

5 (a) a) The first ionisation energies of the elements in period 3 are shown.



Draw a graph on the diagram to to show the second ionisation energies of the period 3 elements

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(2 marks)

(b) b) Explain the differences seen in first and second ionisation energies of the elements in period 3.

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(3 marks)

(c) c) Hydrogen spectral data give the frequency of 3.28×10^{15} s^{-1} for its convergence limit.

i) Calculate the ionisation energy, in J, for a single atom of hydrogen using Sections 1 and 2 of the Data Booklet.

ii) Calculate the wavelength, in nm, for the electron transition corresponding to the frequency in part (i) using Section 1 of the Data Booklet.

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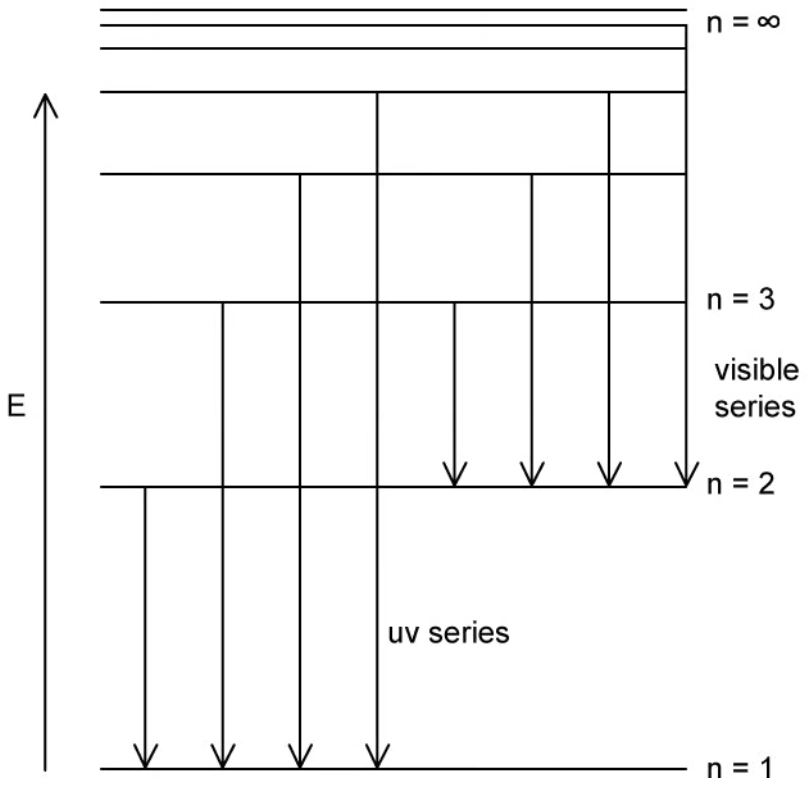
(2 marks)

(d) d) On the diagram below, draw a line that corresponds to the first ionisation energy of hydrogen and explain your reasoning.



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(2 marks)

Hard Questions

1 (a) Successive ionisation energies provide evidence for the arrangement of electrons in atoms. In the table below the successive ionisation energies of oxygen are given.

Ionisation number	1	2	3	4	5	6	7	8
Ionisation energy (kJ mol^{-1})	1314	3388	5301	7469	10989	13327	71337	84080

i) Give the equation, including state symbols for the **third** ionisation energy of oxygen.

[2]

ii) Explain how this data shows evidence of two energy shells in oxygen.

[2]

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(4 marks)

(b) Amorphous(unorganized solid form) boron is used as a rocket fuel igniter and in pyrotechnic flares.

i) Write an equation, including state symbols to show the process that occurs for first ionisation of boron, B.

[1]

ii) Suggest why the ionisation energy of boron is lower than that of beryllium going against the general trend in ionisation energies across the period.

[2]

(3 marks)

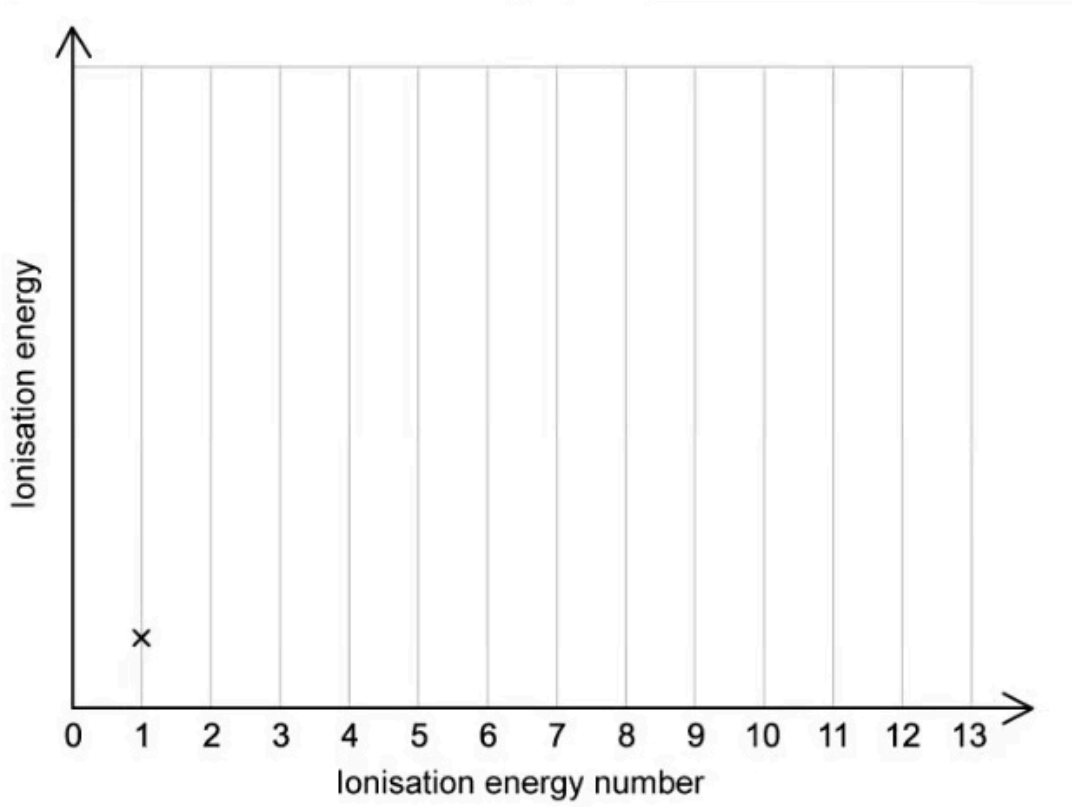
(c) Using the table in part (a) and sections 1 and 2 of the data booklet, calculate the wavelength, in nm, of the convergence limit in the spectral lines of an oxygen atom.

(2 marks)

2 (a) Aluminium has 13 successive ionisation energies.

On the figure below, add crosses to show the 13 successive ionisation energies of aluminium. The value for the first ionisation energy is already completed.

You do not have to join the crosses.



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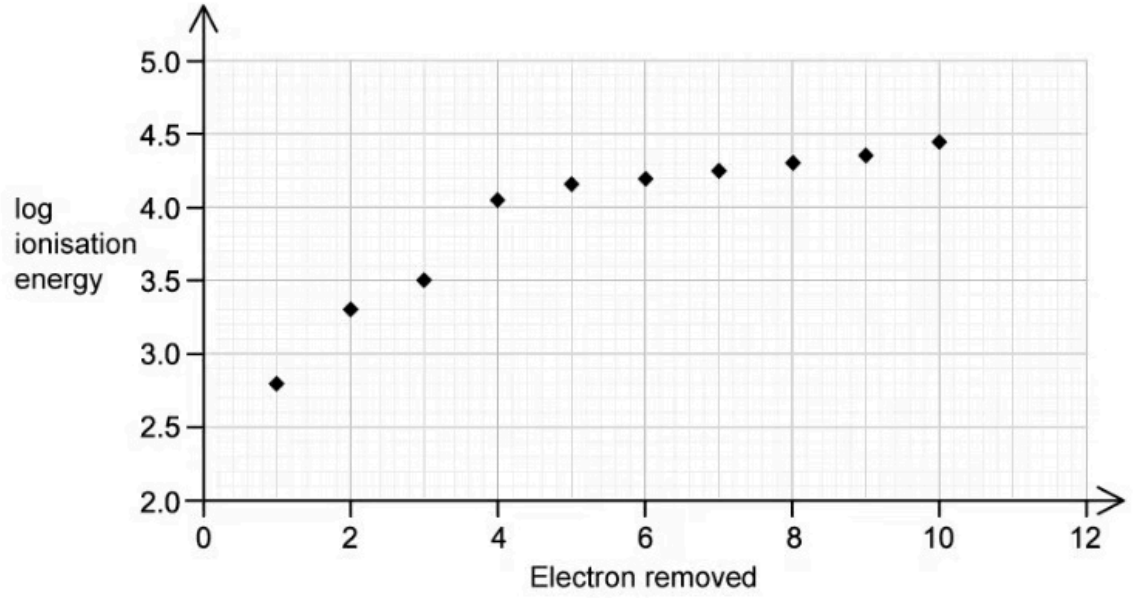
(2 marks)

(b) This question is about ionisation energies of an element, **X**.

The figure below represents the log of the first ten successive ionisation energies of **X** plotted against the number of electrons removed.



State the group of the periodic table where element **X** is found.

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(1 mark)

(c) Element **A** has the following first six ionisation energies in kJ mol^{-1}.

577, 1820, 2740, 11 600, 14 800, 18 400

i) Explain how you know that element **A** is in group 3 of the periodic table.

[1]

ii) Two elements **B** and **C** are in the same period as **A**, but **B** is in the group before **A** and **C** is in the group after **A** in the periodic table.
Give approximate first ionisation energies for elements **B** and **C**.

[1]

iii) Explain, using ideas of electronic structure, the difference in ionisation energy values of element **A** compared to elements **B** and **C**.

[2]

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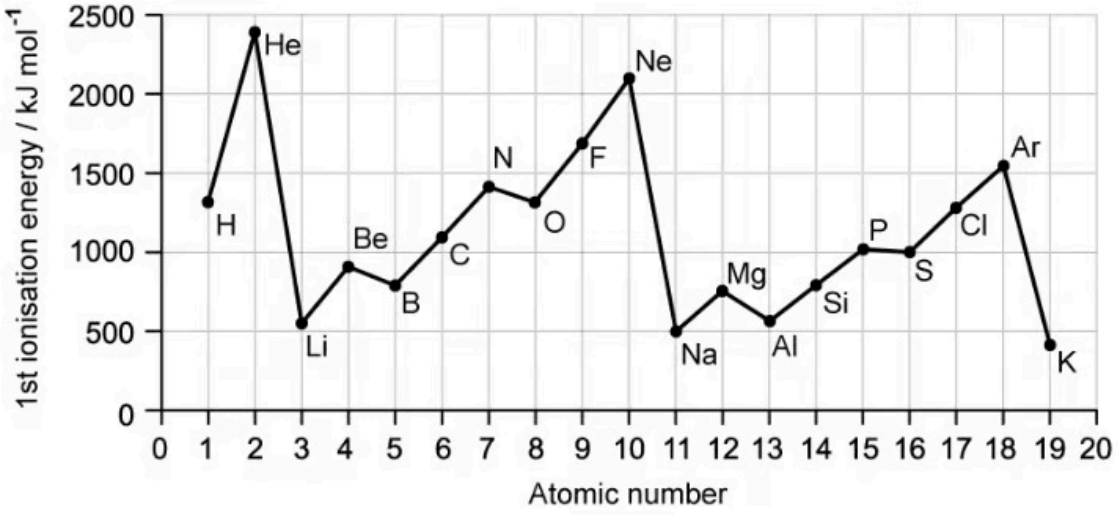
(4 marks)

3 (a) The first ionisation energies of the elements H to K are shown below in the figure below



State and explain the trend in first ionisation energies shown by the elements with the atomic numbers 2, 10 and 18

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(4 marks)

(b) Compound **J** reacts with chlorine. The first five successive ionisation energies for an element **J**, are shown in the table below.

Energy number	1st	2nd	3rd	4th	5th
Ionisation energy value / kJ mol^{-1}	738	1450	7733	10543	13630

State the formula of the compound when element **J** reacts with chlorine.

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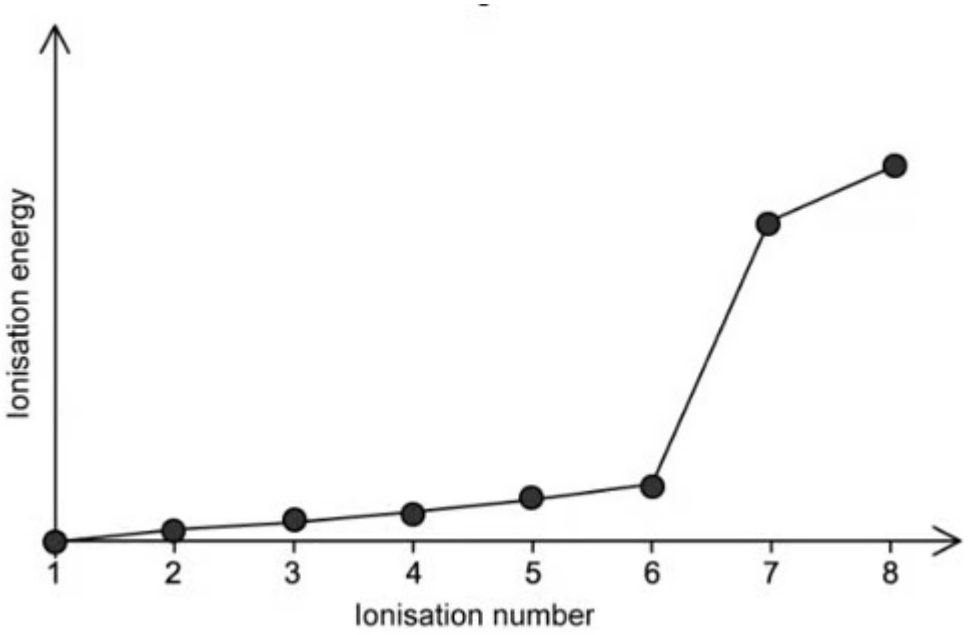
(1 mark)

(c) The figure below shows the successive ionisation energies for a period 2 element.



With reference to electronic structures, state the identity of this element and explain your answer.

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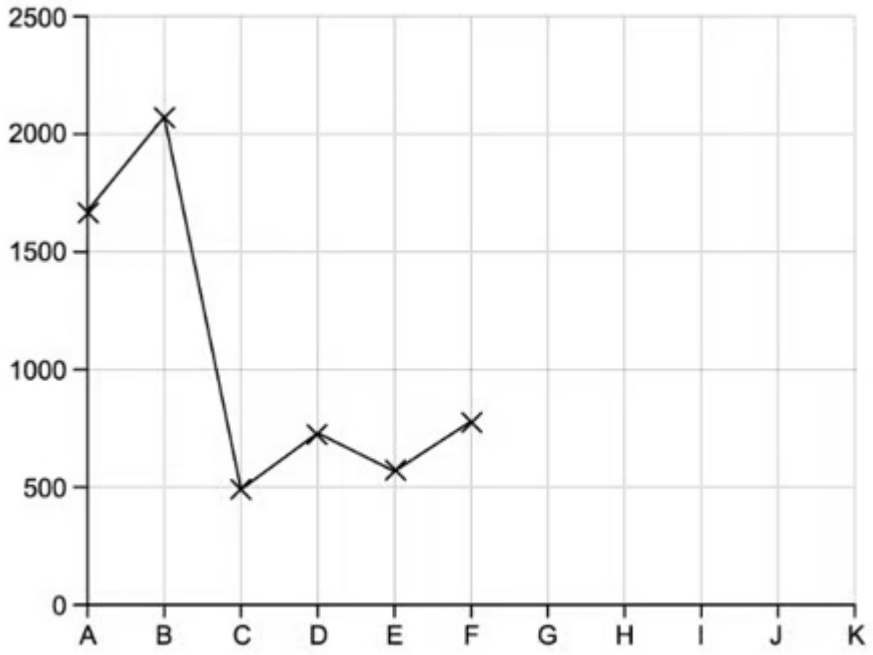
(2 marks)

4 (a) Electrons in atoms occupy orbitals. The figure below shows the first ionisation energies for six consecutive elements labelled **A**–**F** in kJ mol^{-1}.



i) Complete the graph of the first ionisation energies for the next five elements.

[3]

ii) Explain why the value of the first ionisation energy for D is greater than for C.

[2]

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(5 marks)

(b) The sequence of the first three elements in the Periodic Table is hydrogen, helium and then lithium.

Explain why the first ionisation energy of hydrogen is less than that of helium but greater than that of lithium.

(4 marks)

(c) Using the figure in part (a) and sections 1 and 2 of the data booklet, calculate the frequency, in THz, of the convergence limit of a single atom of element C.

The prefix Tera, T, corresponds to a power of 10^{12}.

(1 mark)

5 (a) The table below shows the successive ionisation energies of an unknown element, **X**.

Ionisation number	Ionisation energy / kJ mol^{-1}
1st	578
2nd	1817
3rd	2745
4th	11577
5th	14842
6th	18379

Deduce the group number and identity of element **X** and explain your answer with reference to its electron configuration.

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(3 marks)

(b) First ionisation energies decrease down groups in the Periodic Table.

Explain this trend and the effect on the reactivity of groups containing metals.

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(3 marks)

(c) The ionisation energy values show a general increase across period 4 from gallium to krypton.

i) State and explain how selenium deviates from this trend.

[3]

ii) Give one other element from period 2 or 3 which also deviates from this general trend, similar to selenium.

[1]

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(4 marks)