IB · HL · Chemistry

3 hours 20 questions

Structured Questions

Electronic Configurations

The Electromagnetic Spectrum / Emission Spectra / Energy Levels, Sublevels & Orbitals / Writing Electron Configurations / Ionisation Energy from an Emission Spectrum (HL) / Successive Ionisation Energies (HL)

Easy (6 questions)	/39
Medium (8 questions)	/75
Hard (6 questions)	/47
Total Marks	**/161**

Scan here to return to the course
or visit savemyexams.com

Easy Questions

1 (a) Describe what is meant by the term orbital.

.....

(1 mark)

(b) Draw the shapes of the s, p_x, p_y and p_z orbitals.

.....

.....

(2 marks)

(c) State the maximum number of electrons in the n = 4 energy level.

.....

(1 mark)

(d) List the d, f, p and s orbitals in order of decreasing energies.

.....

.....

(2 marks)

2 (a) Write the full electronic configurations for the following species

i) K

[1]

ii) Sr^{2+}

[1]

.....

.....

(2 marks)

(b) Write the condensed electronic configurations for the following species

i) Na

[1]

ii) Al^{3+}

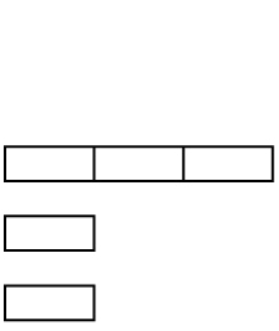
[1]

.....

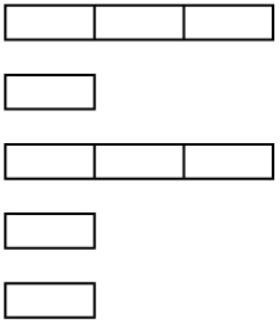
.....

(2 marks)

(c) Complete the orbital diagrams of phosphorus and fluorine as shown in the diagram below.



Fluorine



Phosphorus

.....

.....

(2 marks)

(d) Give the number of each type of orbital in the first four energy levels.

.....

.....

(2 marks)

3 (a) Using sections 1 and 5 of the data booklet describe how the following change in moving from the infrared region of the electromagnetic spectrum to the radio region of the electromagnetic spectrum.

i) Wavelength

[1]

ii) Frequency

[1]

iii) Energy

[1]

.....

.....

.....

(3 marks)

(b) Describe the process occurring in an atom to produce a single line on an emission spectrum.

.....

.....

.....

(3 marks)

(c) Distinguish between a *continuous spectrum* and a *line spectrum*.

.....

.....

(2 marks)

Describe the emission spectrum of hydrogen. Outline how this spectrum is related to the energy levels in the hydrogen atom.

.....

(d) **(3 marks)**

4 (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.

.....

(1 mark)

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

.....

(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.

.....

(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.

.....

(1 mark)

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

.....

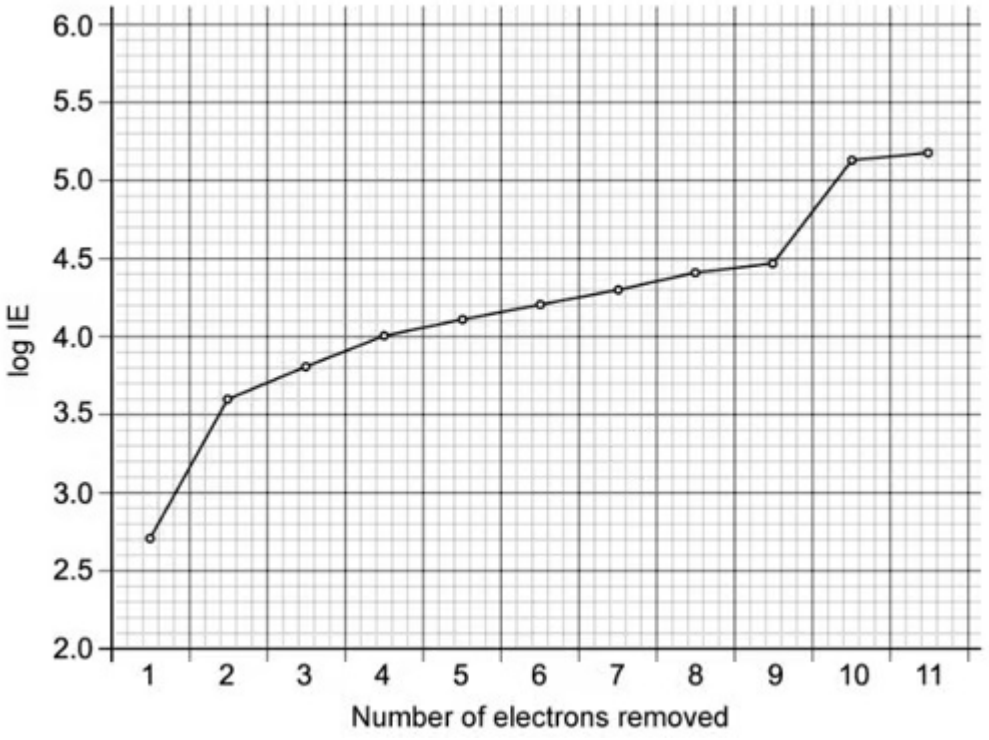
5 (a) **(1 mark)**

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

.....

(1 mark)

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



State how many shells element X has.

.....

(1 mark)

(d) Deduce which group element X is in.

.....

(1 mark)

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

.....

(1 mark)

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

.....

.....

(2 marks)

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

.....

.....

(2 marks)

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

.....

(1 mark)

Medium Questions

1 (a) The element chromium has several naturally occurring isotopes whose abundances are shown in **Table 1**.

Table 1

Mass number	% abundance
50	4.345
52	83.789
53	9.501
54	2.365

Calculate the relative atomic mass of chromium to two decimal places.

.....

.....

(2 marks)

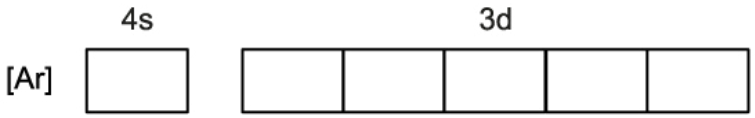
(b) State the full electron configuration for chromium.

.....

(1 mark)

(c) State the meaning of **[Ar]** and complete the orbital diagram shown below for chromium.

Figure 1



.....

.....

(2 marks)

(d) This question is about the chromium(III) ion, $^{52}_{24}Cr^{3+}$.

i) State the number of protons, electrons, and neutrons in the chromium(III) ion.

[1]

ii) Write the full electron configuration for the chromium(III) ion.

[1]

.....

.....

(2 marks)

2 (a) This question is about line emission spectra of elements.

i) Explain the difference between a *continuous spectrum* and a *line spectrum.*

[2]

ii) Draw a labelled diagram that shows electron transitions in a hydrogen atom in the ultraviolet and visible regions of the electromagnetic spectrum. Include three electron transitions for each region.

[4]

.....

.....

.....

.....

.....

.....

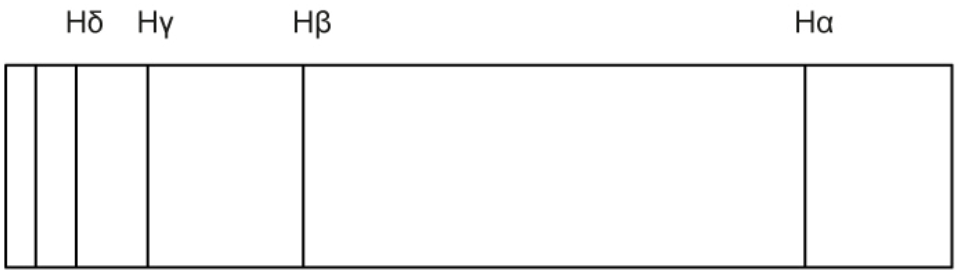
(6 marks)

(b) The visible line emission spectrum of hydrogen is shown below in **Figure 1** and the wavelengths of the first four lines are listed in **Table 1**.

i) Use the information provided and Sections 1 and 2 of the IB data booklet to determine the frequency of the red line.

[1]

Figure 1



The visible line emission spectrum hydrogen

Table 1

Balmer spectral line	Wavelength in nm	Colour
Hα	656	Red
Hβ	486	Blue(cyan)
Hγ	434	Blue
Hδ	410	Violet

ii) Which spectral line carries more energy, Hα or Hδ?

[1]

.....

.....

(2 marks)

(c) Draw the shape of a 1s atomic orbital and 2p atomic orbital.

.....

(1 mark)

(d) Describe the relationship between colour, energy, frequency, and wavelength in the visible spectrum.

.....

.....

(2 marks)

3 (a) Electron configurations give you a summary of where you can find an electron around the nucleus of an atom. They can also be determined for an ion after an atom loses or gains electrons.

i) State the full electron configuration of the rubidium ion, $^{85}_{37}Rb^{+}$.

[1]

ii) State and explain the relative size of a rubidium ion compared to a krypton atom.

[2]

.....

.....

.....

(3 marks)

(b) The element rubidium has two naturally occurring isotopes of ^{85}Rb and ^{87}Rb. The relative atomic mass of rubidium is 85.47. Calculate the percentage abundance of each isotope.

.....

.....

(2 marks)

(c) The electrons in an atom are found in orbitals around the nucleus, which have different energy levels sometimes called shells.

i) The fourth shell consists of the atomic orbitals 4d, 4f, 4p and 4s. List these orbitals in order of increasing energy.

[1]

ii) State the number of atomic orbitals present in 4d, 4f, 4p and 4s.

[1]

.....

.....

(2 marks)

(d) Rubidium forms an ionic compound with selenium, Rb_2Se.

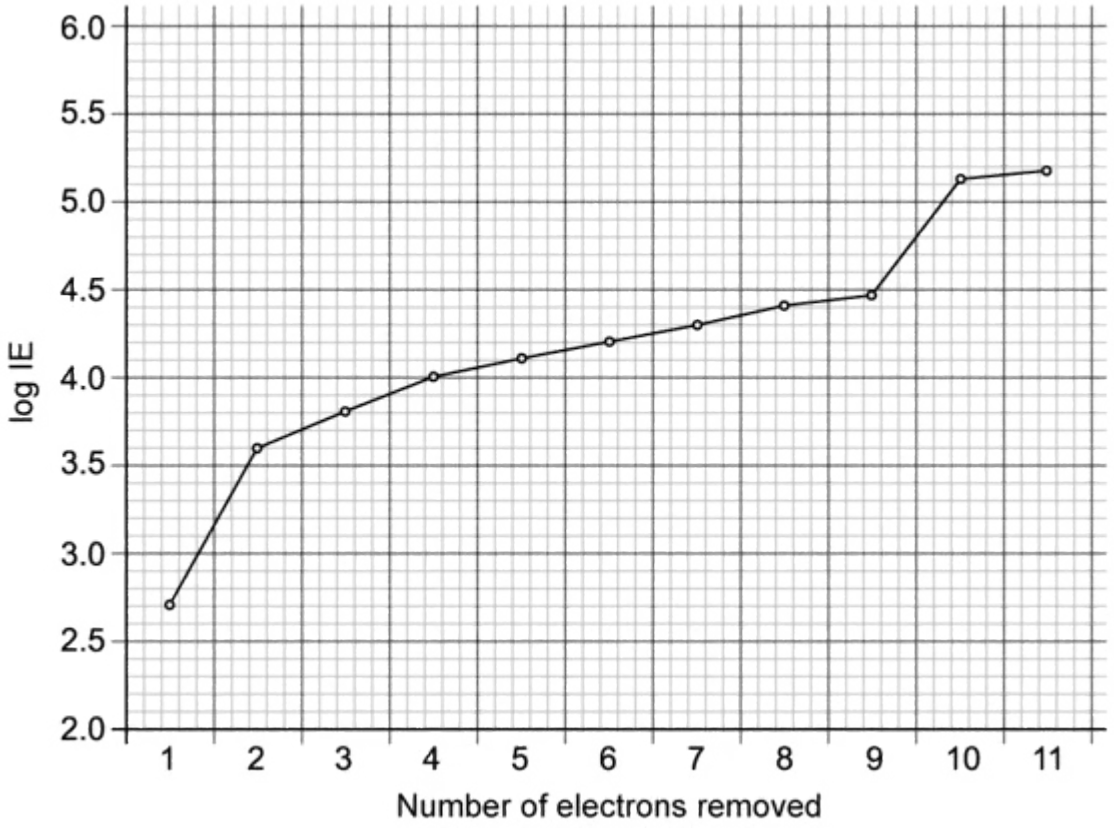
Using boxes to represent orbitals and arrows to represent electrons, sketch the orbital diagram of the selenium atom's **valence shell** in Figure 1.

Figure 1

.....

(1 mark)

4 (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.

.....

.....

(2 marks)

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

.....

.....

.....

(3 marks)

(b)

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

.....

.....

(c) **(2 marks)**

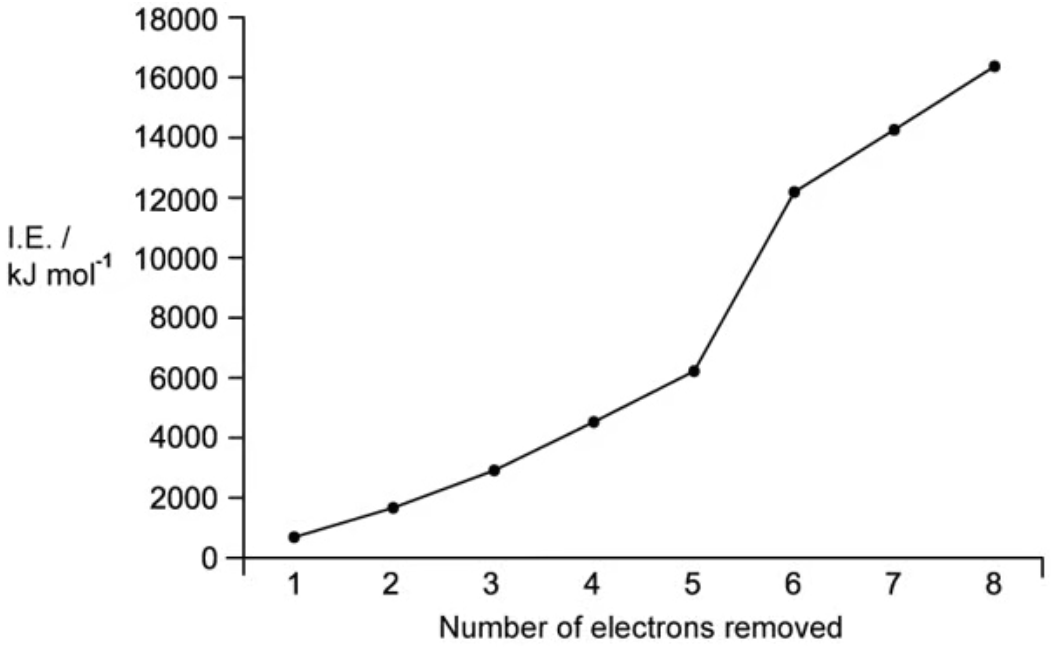
Explain why the first ionisation energy of sulfur is lower than the first ionisation energy of phosphorus.

.....

.....

(d) **(2 marks)**

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



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

.....

.....

(2 marks)

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

.....

.....

(2 marks)

(b)

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

.....

.....

(c) .....

(3 marks)

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

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

.....

.....

(2 marks)

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

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

[1]

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

[1]

.....

.....

(2 marks)

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.

.....

.....

(b) **(2 marks)**

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.

.....

.....

.....

(c) **(3 marks)**

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.

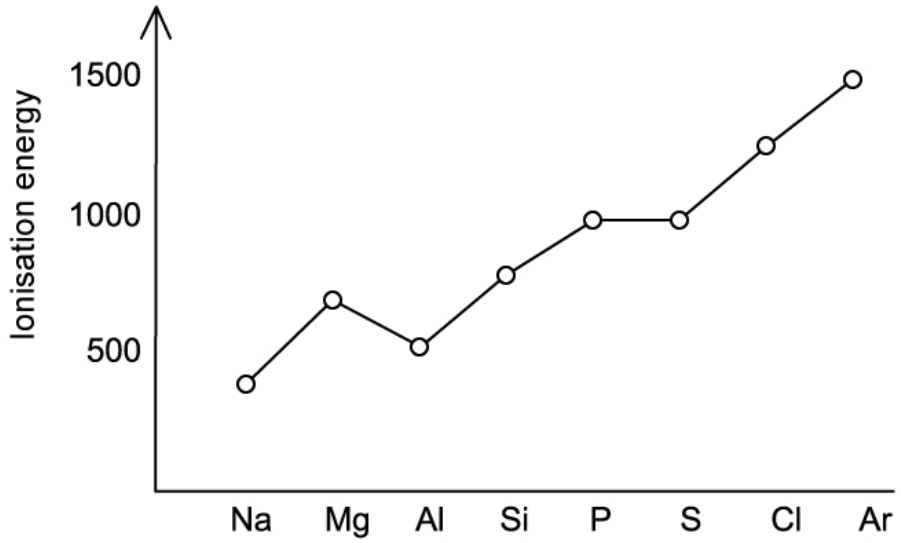
.....

.....

(d) .....

(3 marks)

7 (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.

.....

.....

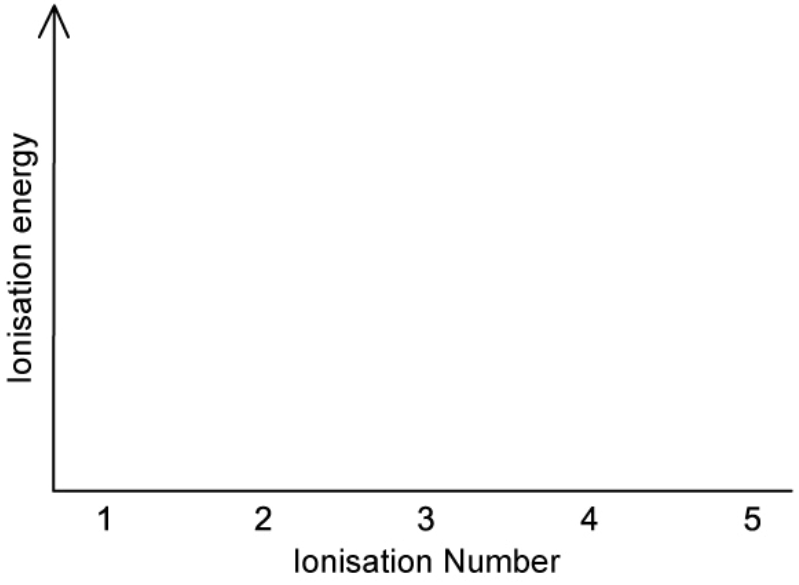
.....

(3 marks)

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

(2 marks)

(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)

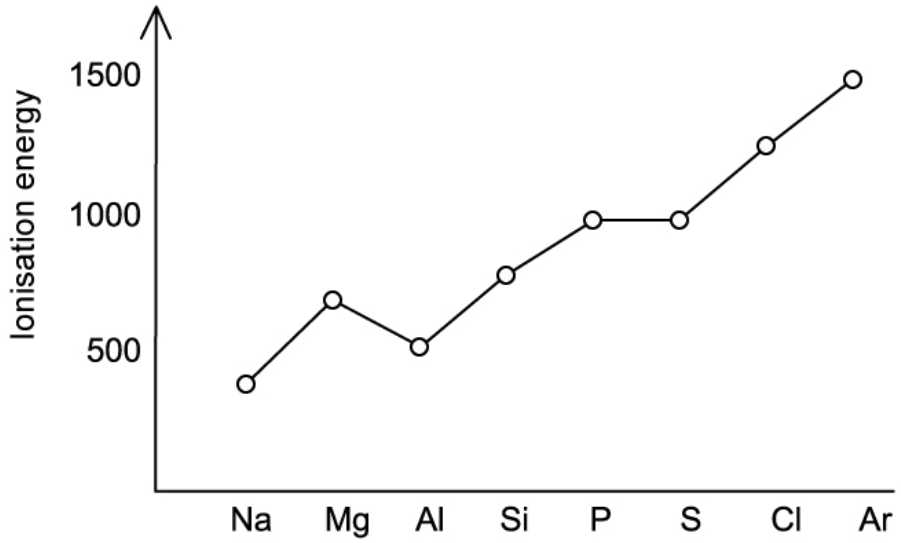
The wavelength of a line in the Balmer series of hydrogen is 726.2 m. Calculate the energy of photons emitted, in kJ, using Sections 1 and 2 of the Data Booklet.

.....

.....

(d) **(2 marks)**

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



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

.....

.....

(2 marks)

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

.....

.....

.....

(3 marks)

(b)

(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.

[1]

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

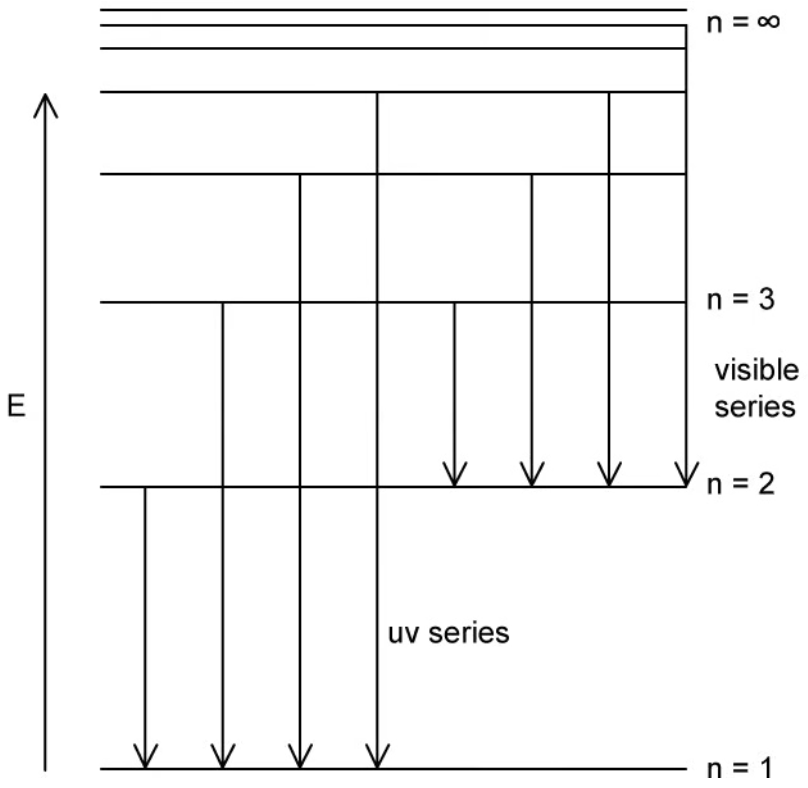
[1]

.....

.....

(2 marks)

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



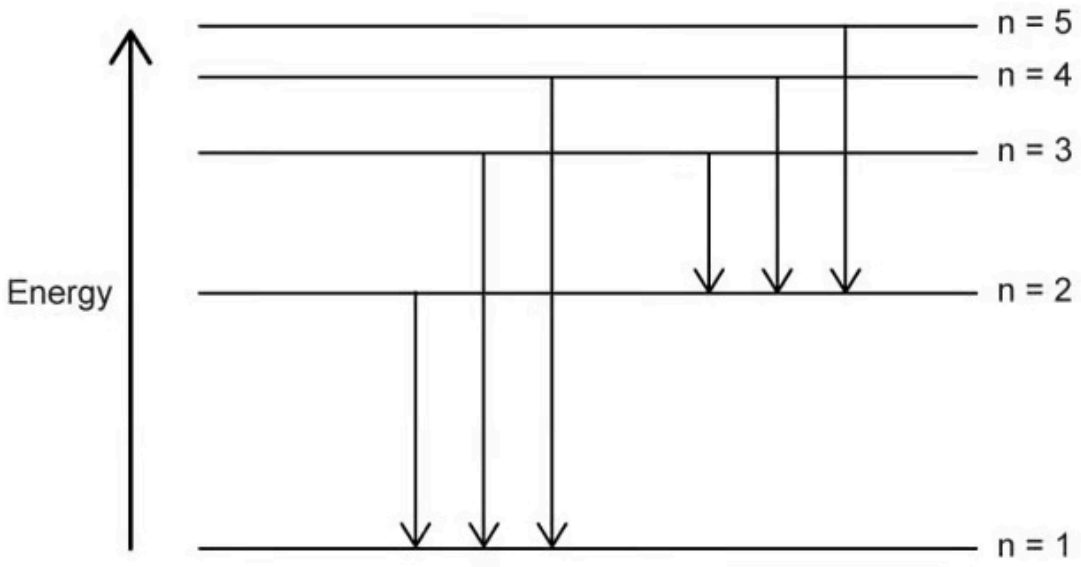
.....

.....

(d) **(2 marks)**

Hard Questions

1 (a) The diagram below shows electron transitions in a hydrogen atom in two regions of the electromagnetic spectrum.



Using section 5 of the Data booklet, predict which electron transition is most likely to correspond to the emission of red light.

.....

(1 mark)

(b) Using sections 1 and 5 of the data booklet, predict which electron transition will correspond to the greatest frequency of light emitted.

.....

(1 mark)

(c) The wavelengths of the first four lines for the Balmer series are shown below.

Balmer spectral line	Wavelength in nm	Colour
H_α	656	red
H_β	486	cyan(blue)
H_γ	434	blue
H_δ	410	violet

Using section 1 of the Data booklet, determine the ratio of the frequencies H_α to H_γ to 2 decimal places.

.....

(1 mark)

2 (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]

.....

.....

.....

.....

(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.

.....

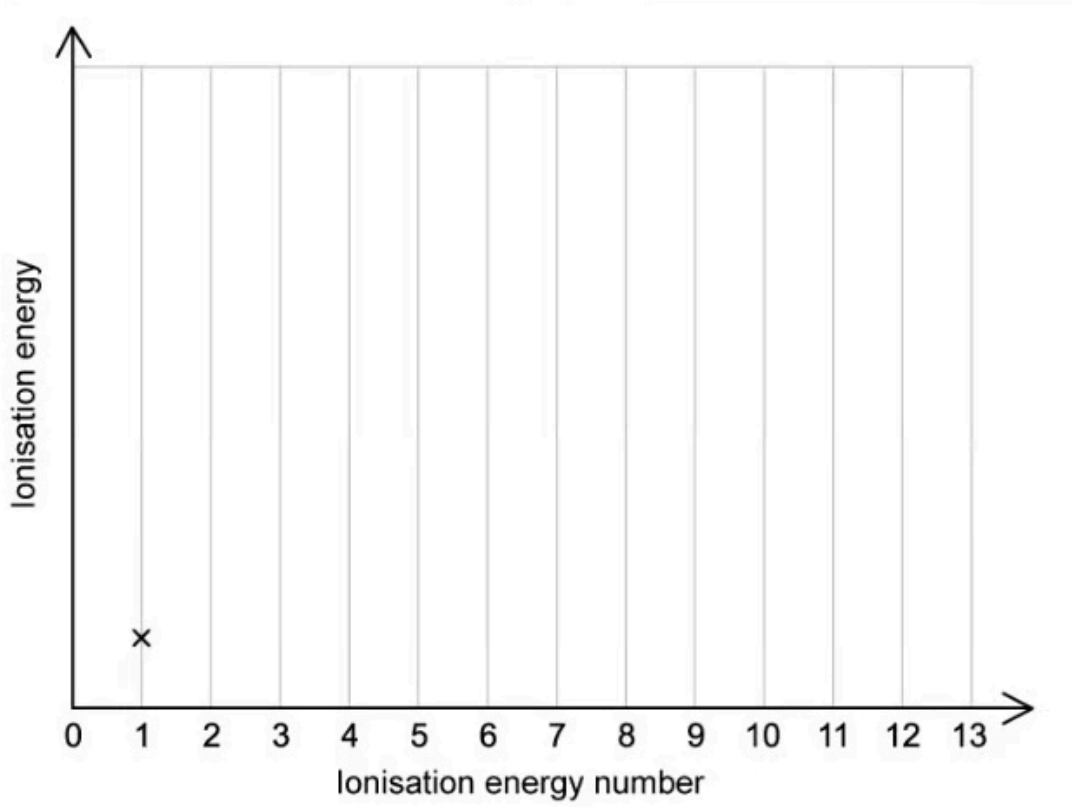
.....

(2 marks)

3 (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.



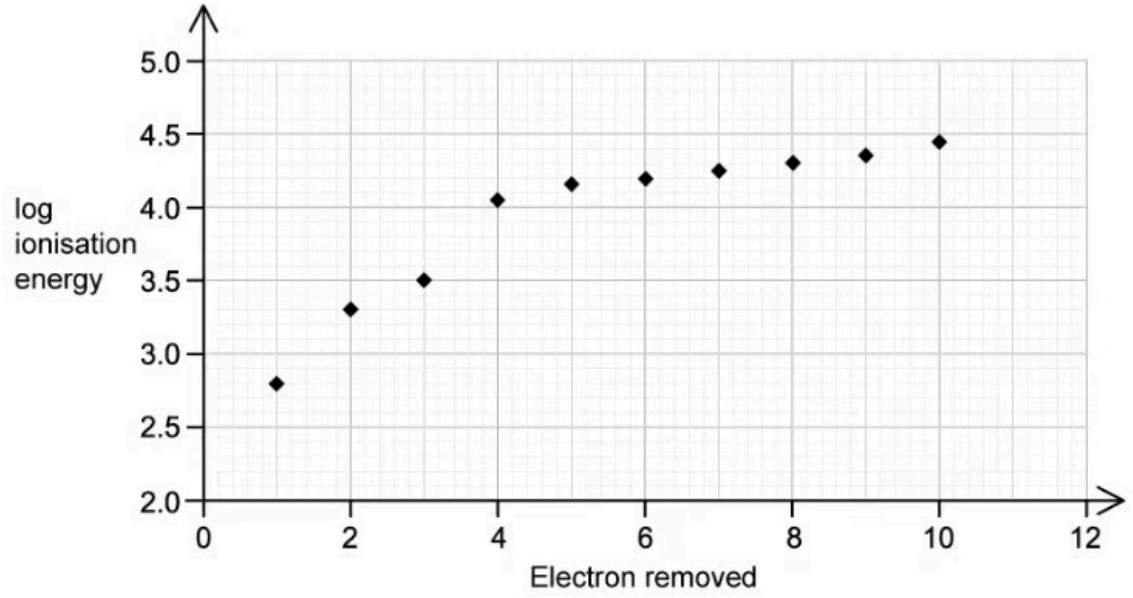
.....

.....

(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.

.....

(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**.

[2]

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

[2]

.....

.....

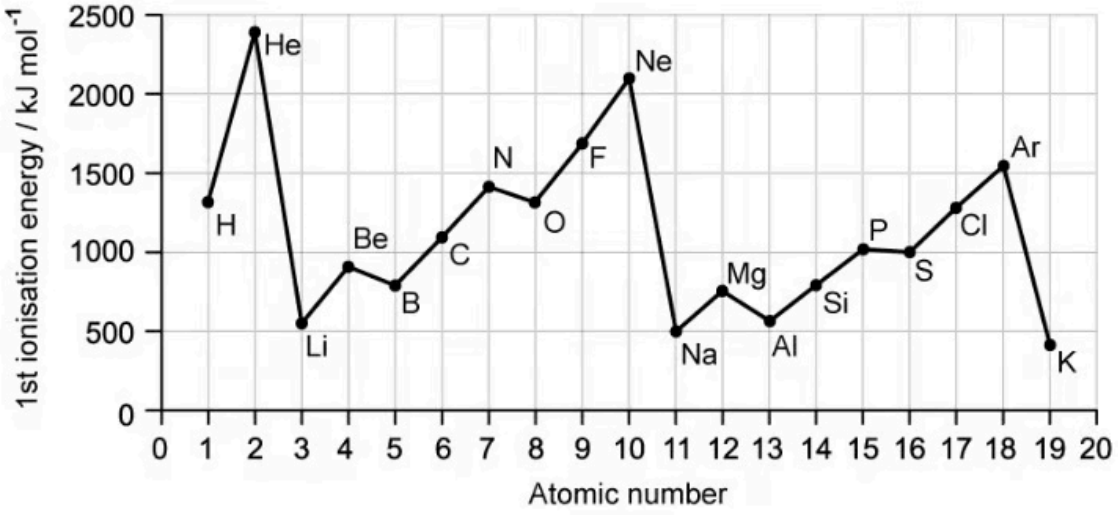
.....

.....

.....

(5 marks)

4 (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

.....

.....

.....

.....

(4 marks)

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

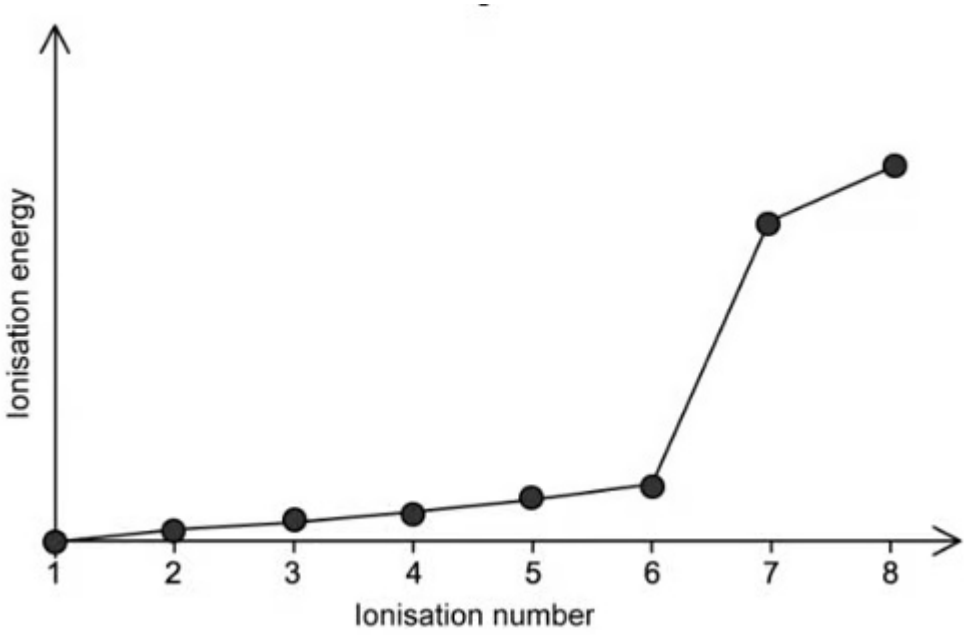
Energy number	1st	2nd	3rd	4th	5th
Ionisation energy value / kJ mol^{-1}	738	1450	7733	10543	13630

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

.....

(1 mark)

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



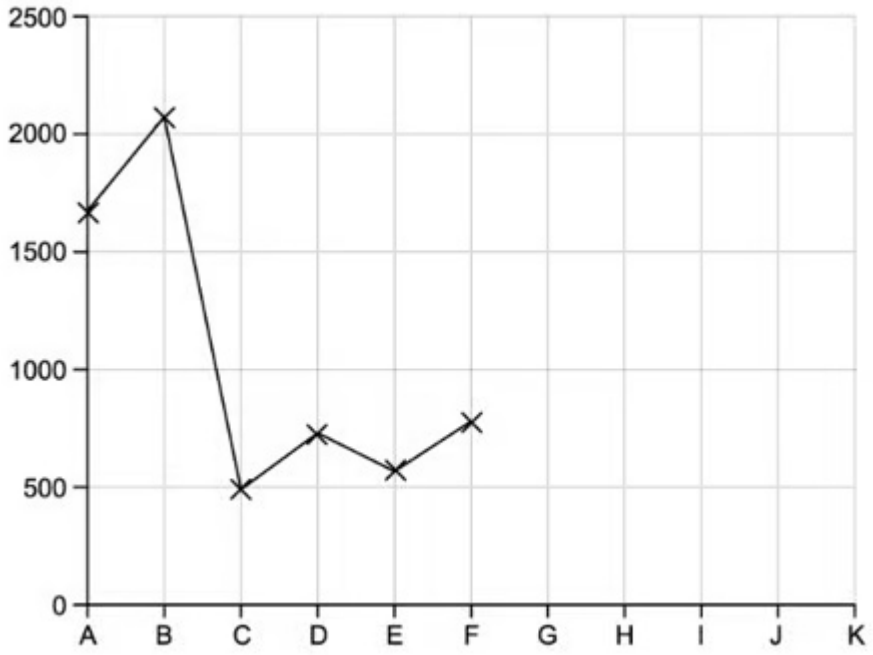
With reference to electronic structures, state the identity of this element and explain your answer.

.....

.....

(2 marks)

5 (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]

.....

.....

.....

.....

.....

(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, 2 and 3 of the data booklet, calculate the frequency, in THz, of the convergence limit of a single atom of element C.

(1 mark)

6 (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.

.....

.....

.....

(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.

.....

.....

.....

(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]

.....

.....

.....

.....

(4 marks)