IB · DP · Chemistry

2 hours 14 questions

Structured Questions: Paper 2

2.1 Atomic & Electronic Structure

2.1.1 The Nuclear Atom / 2.1.2 Deducing Subatomic Particles / 2.1.3 Relative Atomic Mass Calculations / 2.1.4 The Electromagnetic Spectrum / 2.1.5 Emission Spectra / 2.1.6 Energy Levels & Sublevels / 2.1.7 Sublevels & Orbitals / 2.1.8 Writing Electron Configurations

Easy (5 questions)	/37
Medium (5 questions)	/42
Hard (4 questions)	/30
Total Marks	**/109**

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

Easy Questions

1 (a) Deduce the missing information using section 5 of the data booklet, and complete the following table.

Symbol	Protons	Neutrons	Electrons
^{23}Na			
$^{32}S^{2-}$			
$^{86}Sr^{2+}$			

(3 marks)

(b) A sample of Rh contains the following isotopes. Calculate the relative atomic mass of Rh in the sample. Give your answer to 2 dp.

Isotope	% Abundance
^{101}Rh	85
^{102}Rh	15

(2 marks)

(c) Deduce the number of protons, neutrons and electrons in an atom of ^{102}Rh.

(2 marks)

(d) Give the atomic symbol of an element which has more protons than neutrons. Use its most common isotope.

.....

(1 mark)

2 (a) The atomic mass of each element in the periodic table is based on the carbon-12 scale.

Describe the composition of an atom of carbon-12.

.....

(1 mark)

(b) Carbon also exists as the isotope ^{14}C. How does the composition of this isotope differ from that of carbon-12.

.....

(1 mark)

(c) The relative abundance of isotopes in a sample of carbon is 94% ^{12}C and 6% ^{14}C.

How would this information be obtained.

.....

(1 mark)

(d) Calculate the relative atomic mass of the carbon sample in part c)

.....

(1 mark)

3 (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 orbitals in the n = 4 energy level.

.....

(1 mark)

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

.....

.....

(2 marks)

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

i) K

ii) Sr^{2+}

.....

.....

(2 marks)

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

i) Na

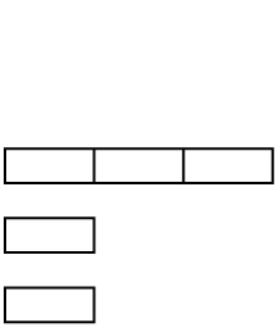
ii) Al^{3+}

.....

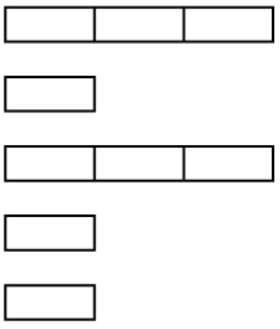
.....

(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)

5 (a) Using sections 1 and 3 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

ii) Frequency

iii) Energy

(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)

Medium Questions

1 (a) Using your knowledge of atomic structure, complete **Table 1** below for the particles found in an atom.

Table 1

Particle	Relative charge	Relative mass
Proton		
Neutron		
Electron		

.....

.....

.....

(3 marks)

(b) The actual mass of protons, neutrons and electrons is given in **Table 2**.

Table 2

	Proton	Neutron	Electron
Mass (kg)	1.672622×10^{-27}	1.674927×10^{-27}	9.109383×10^{-31}

Calculate the mass, in g, of a nitrogen molecule.

.....

(1 mark)

(c) Oxygen consists of three stable isotopes, oxygen-16, oxygen-17, and oxygen-18.

State the particles present in each isotope and outline what differences would be expected in the chemical reactivity of the three isotopes.

.....

.....

(2 marks)

(d) Suggest why some elements have several isotopes and others, like fluorine, have only one known isotope (known as monoisotopic elements).

.....

(1 mark)

2 (a) Nitrous oxide is used as a sedative in dentistry and has the formula N_2O.
Different sources of N_2O contain different ratios of ^{14}N and ^{15}N.

State the name of the instrument used to distinguish between ^{14}N and ^{15}N and outline two characteristic differences seen in the analysis of ^{14}N and ^{15}N.

.....

.....

(2 marks)

(b) A sample of nitrous oxide was enriched so that it contained 4% by mass of ^{15}N. Calculate the relative molecular mass of the resulting nitrous oxide.

.....

.....

(2 marks)

(c) Predict and explain, giving two reasons, how the first ionization energy of ^{15}N would be different to ^{14}N.

.....

.....

.....

(3 marks)

(d) An atom has twice as many protons, and twice as many neutrons, as an atom of ^{15}N.

Determine the chemical symbol for this atom, including the mass number, and deduce the number of electrons.

.....

.....

(2 marks)

3 (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)

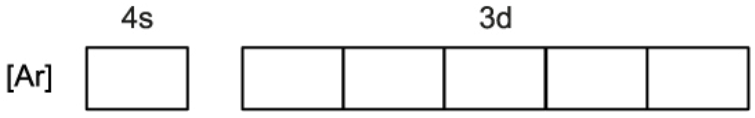
(b) State the full electron configuration for chromium.

.....

(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.

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

(2 marks)

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

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

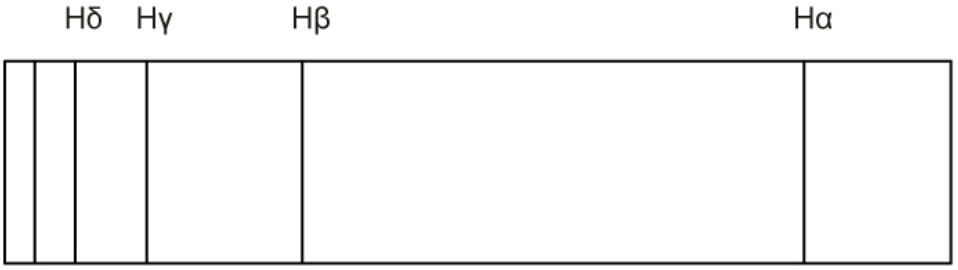
ii) Draw a labelled diagram that shows electron transitions in a hydrogen atom in the ultraviolet and visible regions of the electromagnetic spectrum. Include three electron transitions for each region.

(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.

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?

.....

.....

(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)

5 (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, $^{85}_{37}Rb^{+}$.

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

.....

.....

.....

(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.

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

.....

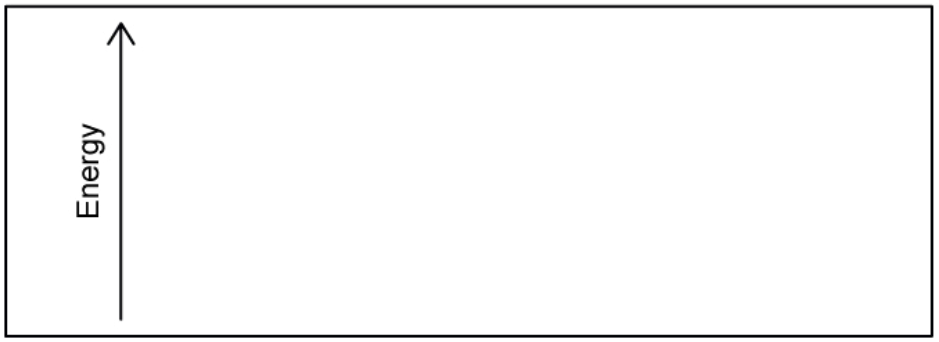
.....

(2 marks)

(d) Rubidium forms an ionic compound with selenium, Rb_2 Using boxes to represent orbitals and arrows to represent electrons, sketch the orbital diagram of the **valence shell** of

selenium on the axis provided.

Figure 1



.....

(1 mark)

Hard Questions

1 (a) Give the full electron configuration of the following atoms and ions.

ii) Zinc (II) ion, Zn^{2+}

[1]

iii) Copper (II) ion, Cu^{2+}

[1]

.....

.....

(2 marks)

(b) Chlorine has two naturally occurring isotopes, ^{35}Cl with a mass of 34.969 and ^{37}Cl with a mass of 36.966. The relative atomic mass of Cl is 35.5. Calculate the percentage abundance of each isotope.

.....

.....

.....

(3 marks)

(c) Predict whether the atomic radius of ^{35}Cl or ^{37}Cl would be the greater and give a reason for your answer.

.....

.....

(2 marks)

(d) A sample of cerium, Ce, was analysed in a mass spectrometer. The relative abundances of three of the four main isotopes that were identified are shown in the table below.

A sample of cerium, Ce, has four isotopes that have a known relative abundance. This sample has an A_r of 140.12.

Isotope	^{136}Ce	^{138}Ce	^{140}Ce	^{m}Ce
Abundance (%)	0.19	0.25	88.45	To be calculated

Use the data from the table to calculate m, the mass number and the percentage abundance of isotope ^{m}Ce.

(4 marks)

2 (a) A sample of element Z was extracted from a meteorite. The table shows the relative abundance of each isotope in a mass spectrum of this sample of Z. Calculate the relative atomic mass of Z and suggest an identity of Z. Give your answer to 1 d.p.

m/z value	64	66	67	68
Relative abundance (%)	38.9	27.8	14.7	18.6

[3]

.....

.....

.....

(3 marks)

(b) A naturally occurring sample of the element boron, B, has two isotopes of mass 10 and 11, and a relative atomic mass of 10.8.

Calculate the relative abundances of both isotopes in the sample of boron, B.

.....

.....

.....

(3 marks)

(c) Give the full electron configuration of the Cu^{+} ion.

.....

(1 mark)

(d) Calculate the percentage abundance of ^{63}Cu with a mass of 62.9296 and ^{65}Cu with a mass of 64.9278, when the average mass of the Cu isotope is 63.546. Give your answer to an appropriate number of significant figures.

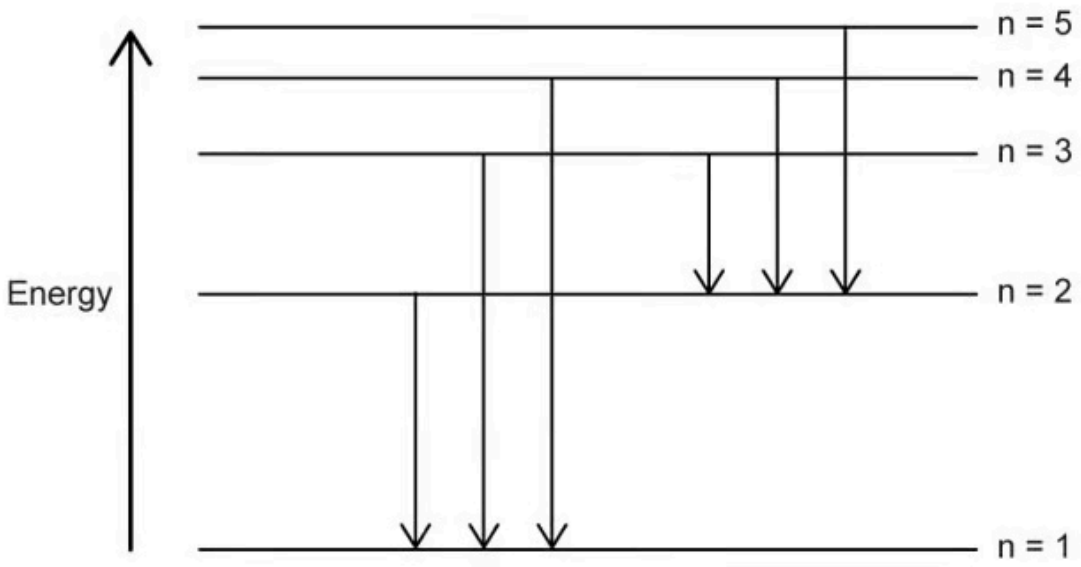
.....

.....

.....

(3 marks)

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



Using section 3 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 3 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)

(d) 2-chloro-2-methylbutane contains some molecules with a molar mass of approximately 106 g mol^{-1} and some with a molar mass of approximately 108 g mol^{-1}.

Outline why there are molecules with different molar masses.

.....

(1 mark)

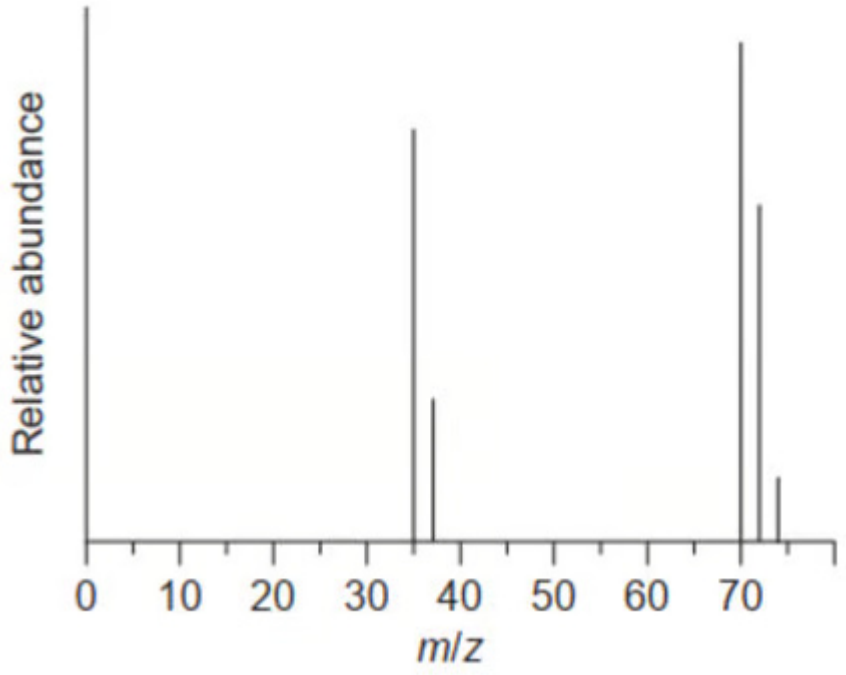
4 (a) Outline why the chlorine atom has a smaller atomic radius than the sulfur atom.

.....

.....

(2 marks)

(b) The mass spectrum of chlorine gas is shown.



Outline the reason for the two peaks at m/z=35 and 37.

.....

(1 mark)

(c) Explain the presence and relative abundance of the peak at m/z=74.

.....

.....

(2 marks)