Atomic structure
Part one

IB CHEMISTRY SL

25	16		6	2	25
Mn	**S**	**J**	**C**	**He**	**Mn**
Manganese	Sulfur		Carbon	Helium	Manganese
54.938045	32.065		12.0107	4.002602	54.938045

2.1 The nuclear atom

Understandings:

- Atoms contain a positively charged dense nucleus composed of protons and neutrons (nucleons).
- Negatively charged electrons occupy the space outside the nucleus.
- The mass spectrometer is used to determine the relative atomic mass of an element from its isotopic composition.

Applications and skills:

- Calculations involving non-integer relative atomic masses and abundance of isotopes from given data, including mass spectra.
- Use the following notation ${}^{A}_{Z}\mathrm{X}$ to deduce the number of protons, neutrons and electrons in atoms and ions.

Guidance:

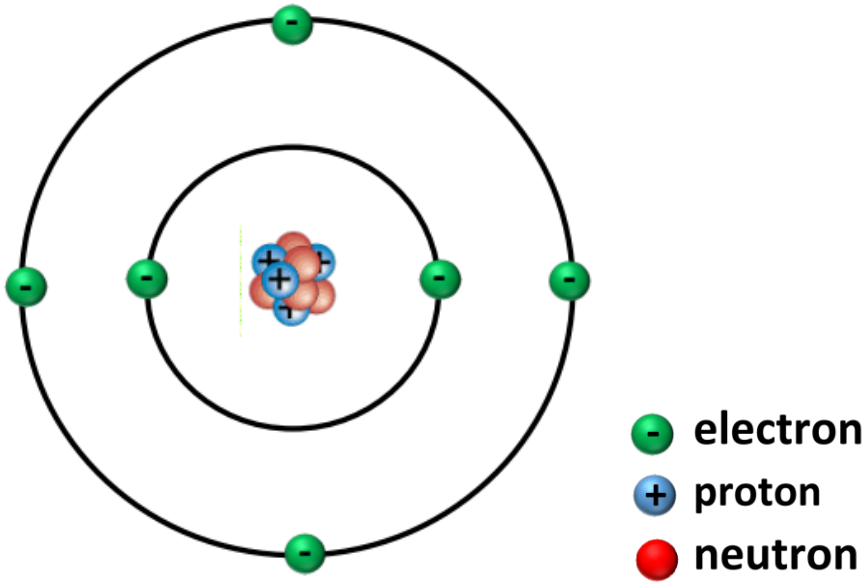
- Relative masses and charges of the subatomic particles should be known, actual values are given in section 4 of the data booklet. The mass of the electron can be considered negligible.
- Specific examples of isotopes need not be learned.
- The operation of a mass spectrometer is not required

Syllabus checklist

Objective	I am confident with this	I need to review this	I need help with this
State the name and location of the sub-atomic particles in an atom			
State the relative charge and relative mass of the sub-atomic particles			
State the meaning of the terms *atomic number* (*Z*) and *mass number* (*A*)			
Determine the number of protons, neutrons and electrons in an atom (or ion) from the atomic number and mass number			
State the meaning of the term *isotope* and *isotopic mass*			
Outline the concept of relative atomic mass (A_r)			
Calculate the relative atomic mass of an atom given % abundance and isotopic mass data			
Calculate the % abundance given relative atomic mass and isotopic mass data			

Inside the atom – the sub-atomic particles

- The three sub-atomic particles are the proton, neutron and the electron.
- Protons and neutrons (nucleons) are located in the nucleus of the atom.
- The nucleus is very dense as it contains almost all of the mass of an atom.
- The electrons are located in energy levels within the atom.
- Most of the atom is empty space.



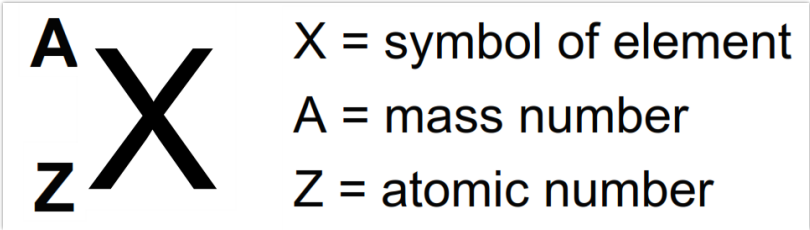
Complete the table below:

Particle	Relative mass	Relative charge

Concept check: Explain why the nucleus is the most dense part of the atom.

Atomic number (*Z*) and mass number (*A*)

- The atomic number (or proton number) is the number of protons in the nucleus of an atom and gives the atom its identity.
- The mass number is the number of protons and neutrons (nucleons) in the nucleus of an atom.
- To find the number of neutrons, subtract the atomic number from the mass number.
- The notation used for mass number and atomic number is shown below:



Example:

$^{4}_{2}\mathrm{He}$ has a mass number (A) of 4 and an atomic number (Z) of 2.
It has 2 protons and (4-2) 2 neutrons in its nucleus.

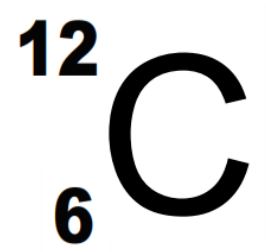
Concept check:

1) Define the term atomic number and mass number

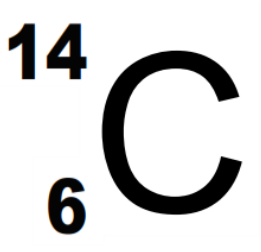
2) A neutral atom contains the same number of which particles? Explain your answer.

Isotopes

- Isotopes are defined as atoms of the same element that have the same number of protons but a different number of neutrons.
- Isotopes have the same atomic number (Z) but different a mass number (A).
- The two isotopes shown below, carbon-12 and carbon-14, have the same number of protons but a different number of neutrons.



Number of protons = 6
Number of neutrons = 6
Number of electrons = 6



Number of protons = 6
Number of neutrons = 8
Number of electrons = 6

- Isotopes have the same chemical properties but different physical properties such as density and boiling point.
- Many isotopes are radioactive (known as radioisotopes)
- Examples include cobalt-60, carbon-14 and I-131.

Concept check:

1) Define the term isotope.

2) Deduce the number of protons, neutrons and electrons in the following isotopes:

a) $^{2}_{1}\mathrm{H}$

b) $^{14}_{6}\mathrm{C}$

c) $^{14}_{7}\mathrm{N}$

d) $^{40}_{20}\mathrm{Ca}$

e) $^{37}_{17}\mathrm{Cl}$

f) $^{79}_{35}\mathrm{Br}$

g) $^{206}_{82}\mathrm{Pb}$

h) $^{235}_{92}\mathrm{U}$

Relative atomic mass (A_r)

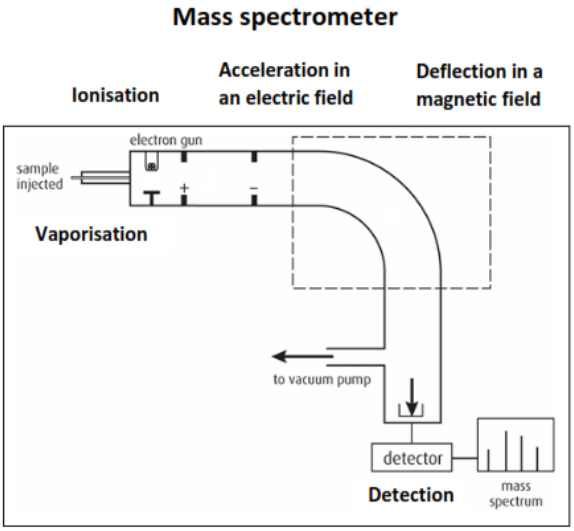
- Because the mass of atoms is so small (in the range of 10^{-24} to 10^{-22} kg) a relative scale is used.
- The agreed standard for the relative scale is carbon-12, which is given a relative mass of exactly 12.00.

> The relative atomic mass is the weighted average mass of an atom compared to an atom of the isotope carbon-12.

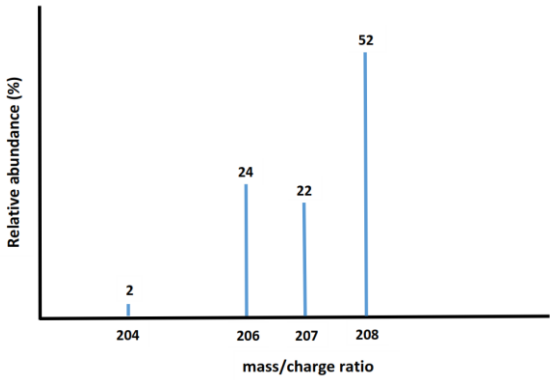
- Relative atomic masses do not have units because it is a relative scale.

The mass spectrometer (note that the operation of mass spectrometer is not required)

- Relative atomic masses are determined using a mass spectrometer.



- They produce a mass spectrum which shows relative abundance (y axis) against mass to charge ratio (x axis). The mass spectrum for lead (Pb) is shown below:



- The positive ions in a mass spectrometer are separated according to their mass to charge ratio (m/z).
- Ions with a lower mass to charge ratio are deflected more than ions with a higher mass to charge ratio which are deflected less.

Calculating relative atomic mass

1) In each of the following cases work out the relative atomic mass of the element to two decimal places:

a) Rhenium has two naturally occurring isotopes with natural abundances:

^{185}Re 37.40% ^{187}Re 62.60%

b) Neodymium has seven naturally occurring isotopes with abundances:

^{142}Nd 27.13% ^{146}Nd 17.19%

^{143}Nd 12.18% ^{148}Nd 5.76%

^{144}Nd 23.80% ^{150}Nd 5.64 ^{145}Nd 8.30%

2) Europium has two naturally occurring isotopes, Eu-151 and Eu-153, and a relative atomic mass of 151.96. Calculate the percentage abundance of each isotope of europium.