Atomic structure Part one (answers)

IB CHEMISTRY SL

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

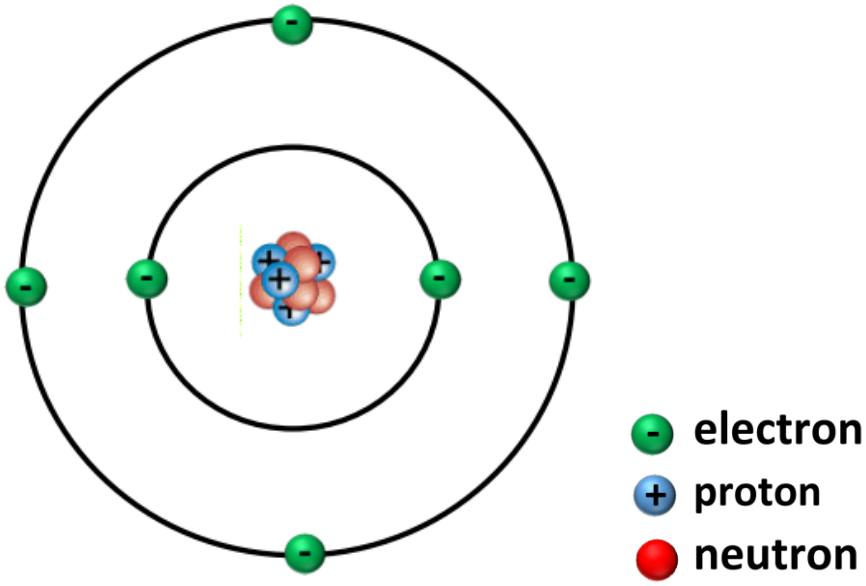
- Calculations involving non-integer relative atomic masses and abundance of isotopes from given data, including mass spectra.
- Use the following notation ${}^{A}_{Z}\mathrm{X}$ to deduce the number of protons, neutrons and electrons in atoms and ions.

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

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:

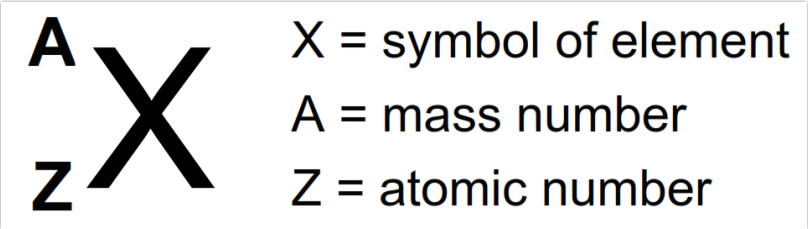
Particle	Relative mass	Relative charge
proton	1	1+
neutron	1	neutral
electron	1/2000	1-

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

The nucleus contains the protons and neutrons (nucleons) that have much higher relative masses than the electrons that are found in energy levels around the nucleus.

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 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

Atomic number is the number of protons in the nucleus of an atom.

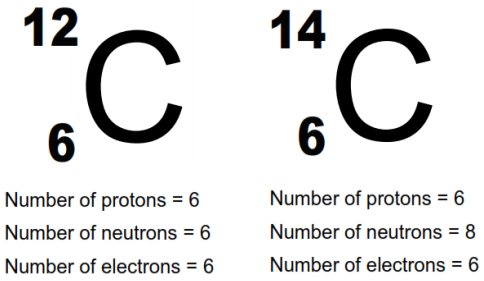
Mass number is the number of protons plus the number of neutrons in the nucleus of an atom.

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

A neutral atom contains the same number of positively charged protons and negatively charged electrons making the atom neutral overall.

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.



- 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.

Isotopes are atoms of the same element have the same atomic number (same number of protons) but a different mass number (different numbers of neutrons).

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

a) ^{2}H 1 proton, 1 neutron, 1 electron

b) ^{14}C 6 protons, 8 neutrons, 6 electrons

c) ^{14}N 7 protons, 7 neutrons, 7 electrons

d) ^{40}Ca 20 protons, 20 neutrons, 20 electrons

e) ^{37}Cl 17 protons, 20 neutrons, 17 electrons

f) ^{79}Br 35 protons, 44 neutrons, 35 electrons

g) ^{206}Pb 82 protons, 124 neutrons, 82 electrons

h) ^{235}U 92 protons, 143 neutrons, 92 electrons

Relative atomic mass (A_r)

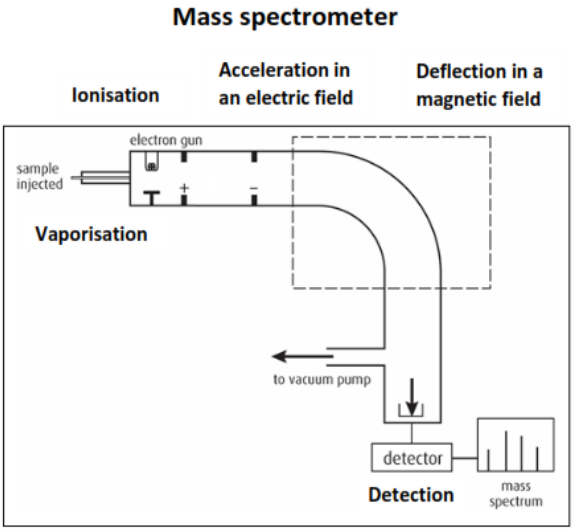
- Because the mass of atoms is so small (in the range of 10^{-24} to 10^{-22} kg) a relative scale is used.
- The agreed standard for the relative scale is carbon-12, which is given a relative mass of exactly 12.00.

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

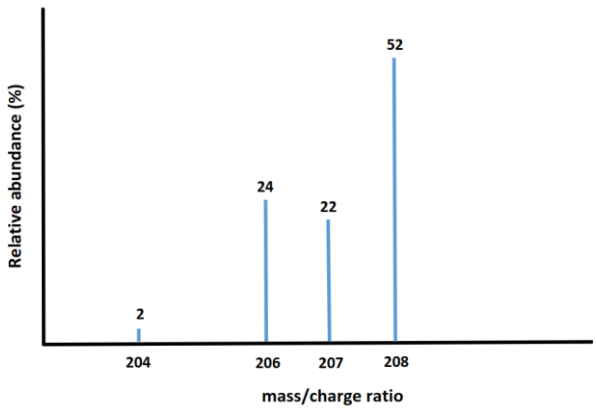
- Relative atomic masses do not have units because it is a relative scale.

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%

A_r = (185 × 37.40) + (187 × 62.60) ÷ 100

A_r = 186.25

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%

$$\frac{27.13\times142+12.18\times143+23.80\times144+8.30\times145+17.19\times146+5.76\times148+5.64\times150}{100}$$

$$= 144.33$$

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.

$$\frac{151x+153(100-x)}{100} = 151.96$$

$$x = 52$$

48% Eu-153 and 52% Eu-151