Chemistry

STANDARD LEVEL

Worksheet 2.2

Chapter 2: Atomic structure – fast facts

2.1 The atom

- Protons and neutrons are present in the nucleus of an atom; electrons are in orbits or energy levels around the nucleus.
- The relative masses and relative charges of the sub-atomic particles are:

	Relative mass	Relative charge
Proton	1	+1
Neutron	1	0
Electron	5×10^{-4}	–1

- **Atomic number (Z)** = number of protons. It is the fundamental characteristic of an element.
- **Mass number (A)** = number of (protons + neutrons).
- **Isotopes** are atoms with the same atomic number, different mass number OR the same number of protons, but a different number of neutrons.
- For a species ${}^{A}_{Z}X^{q}$

  number of protons = Z

  number of electrons = Z – q

  number of neutrons = A – Z
- **Isotopes** differ in physical properties that depend on mass such as density, rate of diffusion, etc. This difference is very significant for the isotopes of hydrogen as deuterium ${}^{2}_{1}H$ has the twice the mass of the more abundant ${}^{1}_{1}H$. As isotopes have the same electron arrangement they have the same chemical properties.
- Examples of the uses of radioisotopes: C-14 in radiocarbon dating, CO-60 in radiotherapy and I-131 and I-125 as medical tracers.

2.2 The mass spectrometer

- Stages of operation: **vaporization** of sample, **ionization** to produce M^+ ions by electron bombardment, **acceleration** of positive ions by electric field, **deflection** of ions by magnetic field perpendicular to their path, **detection** of ions.
- Degree of deflection depends on the charge/mass ratio: the smaller the mass or the greater the charge: the greater the deflection.

- For an element, the mass spectrum gives two important pieces of information: the number of isotopes, and the abundance of each isotope. This allows the relative average atomic mass, A_r, to be calculated.
- **Relative atomic mass** (A_r) of an element is the average mass of an atom according to the relative abundances of its isotopes, on a scale where the mass of one atom of $^{12}_{6}C$ is 12 exactly.

  For example for Cl which has two isotopes $^{35}_{17}Cl$ (75 %) and $^{35}_{17}Cl$ (25 %).

  $$A_r = \frac{(35 \times 75) + (37 \times 25)}{100}$$

- For a molecule, the peak with largest mass represents the molecular (parent) ion and its mass gives the relative molecular mass (Mr) of the compound. The fragmentation pattern can help determine molecular structure (See Chapter 12).

2.3 Electron arrangement

- The electromagnetic spectrum includes waves in order of decreasing frequency/energy, γ rays, X-rays, ultraviolet radiation, visible light, IR radiation, microwaves, and radio waves. (See Table 3 of the IB Data booklet).
- Frequency (f) and wavelength (λ) are related by: c (speed of light) = $f\lambda$.
- The energy of a photon (E_{photon}) is related to the frequency (f) of the radiation by Planck's equation: $E_{photon} = hf$ (The equation is given in Table 1of the IB Data booklet). h is Planck's constant (Table 2 of the IB Data booklet).
- A **continuous spectrum** contains light of all wavelengths in the visible range.
- A **line spectrum** consists of a few lines of different wavelengths/frequencies.

  The lines in an emission spectrum are produced by excited electrons falling from higher to lower energy levels: $\Delta E_{atom} = hf = hc/\lambda$.

  As the energy levels converge at higher energy as they are further from the nucleus; the lines in the spectrum also converge at higher energy/frequency.

- The hydrogen spectrum:

Series	Region	Electron falls to
Lyman	UV	n = 1
Balmer	Visible	n = 2
Paschen	IR	n = 3–

- The ionization energy of hydrogen corresponds to the convergence limit of the Lyman series.
- The electron arrangement indicates the number of electrons in each energy level.

Element	Electron arrangement
H	1
He	2
Li	2, 1
Ne	2, 8

Element	Electron arrangement
Na	2, 8, 1
Ar	2, 8, 8
K	2, 8, 8, 1
Ca	2, 8, 8. 2