Elements of Life

Revision notes

Moles definitions

- Relative atomic mass is the weighted average mass of an atom compared with carbon-12, on a scale where carbon-12 is exactly 12.
- Relative isotopic mass ... of an isotope
- Relative molecular mass ... of a molecule
- Relative formula mass ... of a formula unit

Moles definitions

- **Atomic number is the number of protons in the nucleus of an atom.**
- **Mass number is the total of protons + neutrons in the nucleus of an atom.**
- **Isotopes are atoms with the same atomic number but different mass numbers – ie they have different numbers of neutrons.**
- **The Avogadro constant is the number of entities in one mole of substance.**

  $N_A = 6.02 \times 10^{23}\ mol^{-1}$

Amount of substance

- A mole is the unit of ‘amount of substance’.
- Moles of solid = mass / M_r
- You must be able to do calculations which involve working out reacting masses.
- Empirical formula is the simplest mole ratio of elements in the substance.
- State symbols are (s), (l), (g) and (aq).

Atomic structure

- **Protons: relative mass 1, charge +1**
- **Neutrons: relative mass 1, charge 0**
- **Electrons: relative mass 1/1840, charge -1**
- **Atoms contain a central nucleus surrounded by a cloud of electrons.**
- **The number of electrons each shell can hold is given by the formula $2n^2$ where n is the electron shell (1, 2, 3...).**

Spectra

- **Spectra provide evidence for atomic structure (electron shells).**
  - Atoms contain several electron shells.
  - These are **quantised** (at specific, discrete energy levels, like the rungs on a ladder: electrons can only be on the rungs, not between them.)
  - Electrons are **excited** to higher levels by heat or electricity.
  - Lines in the spectrum represent **transitions** to or from a particular level. Lines become **closer** at higher frequencies.
  - Lines are in the **same position** for a given element.
  - The frequency of the line is given by $\Delta E = h\nu$

Emission and absorption spectra

- **Emission spectra consist of bright lines on a dark background.**
  - When the electrons fall from the excited level to the ground level, they emit light.
- **Absorption spectra consist of dark lines on a coloured background.**
  - When the electrons are excited to higher levels, they absorb the particular frequency of light and therefore there is a black line corresponding to the missing frequency that has been absorbed.

Comparing spectra

- **Similarities between absorption and emission spectra:**
  - Both are line spectra.
  - Lines are in the same position for a given element.
  - Lines become closer at higher frequencies.
  - Sets of lines represent transitions to or from a particular energy level.
- **Differences between the two types of spectra:**
  - Absorption has dark lines on a coloured background.
  - Emission has bright lines on a dark background.

Radioactivity

- **The nuclei of some atoms are unstable. These atoms are radioactive: they decay into other atoms.**
- **α radiation is a helium nucleus:**
  - It is relatively heavy and doesn't travel far. It is highly ionising.
- **β radiation is an electron:**
  - It is light and travels further. It is ionising.
- **γ radiation is an electromagnetic wave:**
  - It travels as a wave. It is non-ionising.

Half life

- **Half life is the time taken for half the radioactive nuclei** (*not atoms*) **in a sample to decay.**
- **Half life is fixed for any given isotope.**
  - Eg: it takes 5700yr for a sample to decay from 100% to 50%;
  - it will take another 5700yr to decay from 50% to 25%;
  - and then another 5700yr to decay from 25% to 12.5%. It will **never** reach zero.

Nuclear processes

- Fission is when a nucleus decays into one or more smaller nuclei, releasing radiation.
- When writing nuclear fission equations you must make sure the atomic numbers <u>and</u> mass numbers balance.
- In fusion reactions, lighter atoms join to give heavier atoms under conditions of high temperature and pressure. This is how certain elements are formed.

Tracers

- **Radioactive isotopes can be used as tracers in the body for medical purposes.**
- **They can also be used to detect leaks, etc.**
- **The half-life of tracers must:**
  - Be of an appropriate length to allow detection, but...
  - Not cause undue damage.
- **Radioisotopes are used in dating of archaeological and geological material using knowledge of half lives.**

Bonding and structure

- **Ionic bonding is the electrostatic attraction of a positive ion and a negative ion.**
  - Ions have gained or lost electrons to get full outer shells.
  - Ionic bonds form between metal ions and non-metal ions.
- **Covalent bonds are shared pairs of electrons.**
  - Covalent substances contain non-metals only.
- **Dative covalent bonds contain electron pairs in which both electrons came from the same atom, rather than being shared.**

Bonding and structure

- **Metallic bonding is the attraction of positive metal ions for a sea of electrons.**

Property	Giant lattice structures			Molecular structure
	Ionic	Metallic	Covalent network	Simple covalent
Melting point	High	High	High	Low
Solubility in water	Generally soluble	Insoluble	Insoluble	Insoluble
Conductivity	Only conduct when molten or dissolved	Conduct when solid or liquid	Do not conduct	Do not conduct

Bonding and structure

- **The electron pair repulsion principle predicts the shapes of molecules:**
  - 2 electron groups: linear 180° eg $BeCl_2$
  - 3 electron groups: trigonal planar 120° eg BF_3
  - 4 electron groups: tetrahedral 109° eg CH_4
  - 6 electron groups: octahedral 90° eg SF_6
- **Lone pairs will affect the shape and the bond angle.**

The periodic table

- The periodic table lists elements in order of atomic number.
- It groups elements according to their common properties.
- The period table shows trends in the properties of substances.
- The group number shows the number of electrons in the outer shell.
- The period number shows how many electron shells the atom contains.

The periodic table

- Mendeleev developed the periodic table by leaving gaps and rearranging some elements from their atomic mass order.
- Subsequent research validated this knowledge.

Group 2 – Mg, Ca, Sr, Ba

- **Group 2 elements get more reactive as you go down the group.**
- **They form compounds containing ions with a 2+ charge, such as Mg^{2+} and Ca^{2+}.**
- **The elements react with water to form a hydroxide and hydrogen:**

$$M(s) + 2H_2O(l) \rightarrow M(OH)_2(aq) + H_2(g)$$

Group 2 – Mg, Ca, Sr, Ba

- **The oxides [MO] and hydroxides [$M(OH)_2$] are basic – they react with acids.**

  $$MO(s) + 2HCl(aq) \rightarrow MCl_2(aq) + H_2O(l)$$

  $$M(OH)_2(s) + 2HCl(aq) \rightarrow MCl_2(aq) + H_2O(l)$$

- **The most strongly basic oxides and hydroxides are those at the bottom of the group.**

Group 2 – Mg, Ca, Sr, Ba

- **The carbonates MCO_3 decompose when heated.**

  $$MCO_3(s) \rightarrow MO(s) + CO_2(g)$$

- **The carbonates become more difficult to decompose as you go down the group. The thermal stability increases as you go down the group.**

Group 2 – Mg, Ca, Sr, Ba

- **The hydroxides become more soluble as you go down the group.**
- **The carbonates become less soluble as you go down the group.**

- **As you go down group 2, the following <u>increase</u>:**
  - Reactivity
  - Thermal stability
  - pH of hydroxide
  - Solubility of hydroxide
- **But the solubility of the carbonates <u>decreases</u>.**

Mass spectrometry

- **A time-of-flight mass spectrometer works by:**
  - Sample injection
  - Ionisation of the sample by high-energy electrons
  - Time measurement: heavy ions travel more slowly than light ions.
  - Detection.
- **Mass spectrometry can be used to identify the abundance of isotopes – eg the mass spectrum of magnesium has three peaks.**

Mass spectrometry

- **Mass spectrometry can be used to identify the abundance of isotopes – eg the mass spectrum of magnesium has three peaks:**
  - 24 relating to ^{24}Mg (80%)
  - 25 relating to ^{25}Mg (10%)
  - 26 relating to ^{26}Mg (10%)
- **This means the A_r of Mg is 24.3.**

  [(80/100)x24] + [(10/100)x25] + [(10/100)x26]

  = 24.3

Mass spectrometry

- **Mass spectrometry can also be used to work out the relative molecular mass of molecules.**
  - The M_r peak is the one with the highest mass value (furthest to the right).
- **Other peaks in the mass spectrum of a molecule are caused by fragmentation of the molecule.**