Elements from the Sea

Revision notes

Amount of substance

- A mole is the unit of 'amount of substance'.
- Moles of solid = mass / M_r
- 1 mole of any gas is 24dm^3 at r.t.p.
- Concentration is measured in mol dm^{-3}.
- Moles of solution = conc x vol/1000
- So conc = moles x 1000/vol
- You must be able to complete titration calculations.

Atomic structure

- An orbital is the area in which an electron spends 95% of its time.
- There are four main types of atomic orbitals: s, p, d and f.
- s-orbitals hold 2 electrons; p-orbitals hold 6 electrons; d-orbitals hold 10 electrons
- They are filled in the following order: 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p.
- You need to be able to give electron configurations up to krypton.

Bonding and structure

- An ionic bond is the attraction between a positive and a negative ion.
- A covalent bond is a shared pair of electrons.
- A dative covalent bond occurs when both electrons come from the same atom.
- You need to be able to draw ionic, covalent and dative covalent bonds.

Bonding and structure

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

Bonding and structure

- Electronegativity is the tendency to attract electrons within a covalent bond.
- The most electronegative atoms are in the top right of the periodic table.
- Electronegativity results in polar bonds.
- Some molecules with polar bonds have no overall polarity because they are symmetrical: the dipoles cancel out.

Bonding and structure

- Instantaneous dipoles are caused by the random movement of electrons in atoms and molecules. They occur in all molecules but are weak.
- Instantaneous dipoles can induce dipoles in neighbouring molecules.
- This causes a weak instantaneous dipole – induced dipole bond.
- The larger the molecule, the greater the effect of instantaneous dipole – induced dipole bonds.

Bonding and structure

- Molecules with an electronegative atom have permanent dipoles.
- They have permanent dipole - permanent dipole intermolecular bonds, which are stronger than instantaneous dipole – induced dipole bonds.
- The stronger the intermolecular forces, the higher the boiling point of the substance.

Oxidation and reduction

- Oxidation is the loss of electrons, reduction is gain (OILRIG).
- Half equations represent the electron loss or gain in a reaction
- $Mg + ½ O_2 \rightarrow MgO$
- $Mg \rightarrow Mg^{2+} + 2e^-$ OXIDATION
- $½ O_2 + 2e^- \rightarrow O^{2-}$ REDUCTION

Oxidation and reduction

- **Oxidation number is used to apply redox theory to non-ionic compounds.**
  - SO_2 sulphur +4
  - H_2S sulphur -2
  - H_2SO_4 sulphur +6
  - SO_4^{2-} sulphur +6
  - H_2SO_3 sulphur +4
  - H_2SO_4 is sulphuric(VI) acid.
  - H_2SO_3 is sulphuric(IV) acid.

The periodic table

- **Group 1-3 form ions with charges +1, +2, +3.**
- **Group 5-7 form ions with charges -3, -2, -1.**
- **You need to know the names and formulae of:**
  - NO_3^- nitrate(V)
  - SO_4^{2-} sulphate(VI)
  - CO_3^{2-} carbonate
  - OH^- hydroxide
  - NH_4^+ ammonium
  - HCO_3^- hydrogencarbonate

The periodic table

- Ionisation enthalpy is the enthalpy change when 1 electron is removed from each atom in a mole of gaseous atoms:

$$M(g) \rightarrow M^{+}(g) + e^{-}$$

- Successive ionisation energies of an atom give evidence for electron shells (2.8.8 arrangement).
- Ionisation energies across a period give evidence for subshells (s and p).

The periodic table

- **The halogens decrease in volatility and reactivity (oxidising power) as you go down the group.**
  - Fluorine, F_2, yellow gas at room temperature
  - Chlorine, Cl_2, green gas at room temperature
  - Bromine, Br_2, brown liquid at room temperature
  - Iodine, I_2, grey solid at room temperature
  - Astatine, At_2, black solid at room temperature
- **As you go down the group, instantaneous dipole – induced dipole bonds get stronger because there are more electrons in the molecules.**

The periodic table

- **Halogens are more soluble in organic solvents than in water.**
- **Iodine is brown in water, purple in cyclohexane.**
- **Chlorine is a stronger oxidising agent than bromine or iodine, and can displace them:**

$$Cl_2(aq) + 2I^-(aq) \rightarrow 2Cl^-(aq) + I_2(aq)$$ ✓

$$I_2(aq) + 2Br^-(aq) \rightarrow 2I^-(aq) + Br_2(aq)$$ ✗

The periodic table

- **$Cl_2(aq) + 2I^-(aq) \rightarrow 2Cl^-(aq) + I_2(aq)$**
- **Half equations are:**

  $Cl_2(aq) + 2e^- \rightarrow 2Cl^-$ RIG / oxidation no. 0 to -1

  $2I^-(aq) \rightarrow I_2(aq) + 2e^-$ OIL / oxidation no. -1 to 0
- **Chlorine has oxidised the iodide ions (not the iodine).**
- **In electrolysis of halide solutions, the following half equation occurs at the anode:**

  $2Br^- \rightarrow Br_2 + 2e^-$ OIL / oxidation no. -1 to 0

The periodic table

- **Halide ions can be detected by the following precipitation reactions using silver nitrate:**

$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ white ppt

$Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$ cream ppt

$Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$ yellow ppt

- **State symbols are essential in precipitation reactions.**

The periodic table

- **Halogens are hazardous, especially the gaseous ones, as they are all toxic (and the gaseous ones can diffuse a long way).**
- **However they have many uses (learn these):**
  - Fluorine: making PTFE, HCFCs, in toothpaste
  - Chlorine: making PVC, bleach
  - Bromine: medicines, flame retardants
  - Iodine: medicines, human nutrient

Industrial processes

- **Atom economy = $\frac{M_r \text{ of useful product}}{M_r \text{ of all reactants}} \times 100$**
- **Percentage yield = $\frac{\text{actual yield}}{\text{expected yield}} \times 100$**
- **The following need to be considered in developing a manufacturing process:**

Batch/continuous process

Cost of process + raw materials

Safety

Siting the plant

Waste disposal

Organic functional groups

- Halogenoalkanes R-X
- Alcohols R-OH
- Ethers R-O-R
- Alkanes – saturated hydrocarbons
- Alkenes – unsaturated hydrocarbons
- Arenes – hydrocarbons containing a benzene ring.

Organic reactions

- **Production of a halogenoalkane from an alcohol (nucleophilic substitution):**

$$C_2H_5OH + HCl \rightarrow C_2H_5Cl + H_2O$$

- **To purify an organic product:**
  - Shake with sodium hydrogencarbonate ($NaHCO_3$) to remove acidic impurities.
  - Separate from immiscible liquids using a separating funnel.
  - Dry with anyhydrous sodium sulphate.
  - Distil to allow collection of the pure product.

Organic reactions

- **Boiling points of halogenoalkanes increases as you go down the group.**
- **Iodo compounds are most susceptible to substitution as the C-I bond is the weakest C-Hal bond. (Bond strength is more important than bond polarity.)**
- **Other nucleophilic substitutions:**

$RX + OH^- \rightarrow ROH + X^-$ alcohol produced

$RX + H_2O \rightarrow ROH + HX$ alcohol produced

$RX + NH_3 \rightarrow RNH_2 + HX$ amine produced

Reaction mechanisms

- A nucleophile is a species with a lone pair that can form a dative covalent bond.
- The carbon atom in the C-Hal bond is slightly positive as halogens are more electronegative than carbon. Nucleophiles are attracted to this slightly positive carbon atom.
- A curly arrow represents the movement of a pair of electrons.

Reaction mechanisms

- A curly arrow goes from the lone pair on the nucleophile to the carbon atom, representing the formation of the dative covalent bond.
- At the same time, a curly arrow goes from the C-Hal bond to the halogen atom, representing the breaking of this bond.
- The products are R-Nu and the halide ion.

Reaction mechanisms

- If water or ammonia is the nucleophile, an intermediate +ve ion is formed (O or N is carrying the positive charge).
- Then one of the O-H or N-H bond breaks. A curly arrow goes from the bond to the O or N atom.
- This releases an H^+ ion.
- The products are then R-OH + HHal or R-NH_2 + HHal.