FACTFILE:
GCE CHEMISTRY

5.11 CHEMISTRY IN MEDICINE

Rewarding Learning

Polymer chemistry

Learning Outcomes

5.11.1 recall the use of digestion remedies, for example hydroxides and carbonates, to cure excess acid in the stomach (link with Section 1.9);

5.11.2 use a back titration to determine the percentage of an active ingredient in an indigestion remedy (link with Section 5.3.4);

5.11.3 recall methods to deal with excessive pH values of skin and explain the use of corrosive chemicals in removing warts (link with Section 1.9);

5.11.4 recall and explain the use of silver nitrate in the treatment of eye diseases;

5.11.5 explain the action of anticancer drugs, for example cisplatin in preventing DNA replication in cancer cells and how varying the structure of cisplatin affects the efficiency of anticancer activity;

5.11.6 use volumetric analysis to determine the concentration of aspirin in solution (link with Section 5.3);

5.11.7 recall the synthesis of aspirin from salicylic acid using ethanoic anhydride and reasons for its use as a sodium salt;

5.11.8 use TLC and GLC-MS to identify drugs and their purity (link with Section 5.4);

5.11.9 explain the role of iron(II) in haemoglobin in the transportation of oxygen in blood and the poisonous nature of carbon monoxide (link with Section 2.3.5); and

5.11.10 explain the role of edta in sequestering calcium ions and thus preventing the clotting of blood (link with Section 5.5.7).

Digestion remedies

Indigestion is a burning sensation caused by excess acid in the stomach. Indigestion tablets neutralise some of this acid. Indigestion tablets contain bases such as calcium carbonate, magnesium hydroxide and aluminium hydroxide which react readily with hydrochloric acid in the stomach. It is possible to carry out a back titration to determine the percentage of an active ingredient eg calcium carbonate in an indigestion remedy. See fact sheet 5.3 on volumetric analysis.

A variety of products intended to relieve excess indigestion. Also called heartburn, this is normally due to excess gastric acid (HCl) reflux.

Skin pH.

Typically healthy skin has a slight acidic pH average of 5.5, which helps it ward off the effects of harmful bacteria and fungi. Dry skin is not only dry, but too alkaline Oily skin is categorized as not only being oily but too acidic.

Most skin problems occur when pH is out of balance. It can become imbalanced by direct results of poor diet, stress, lifestyle, smoking, consuming alcohol, lack of exercise, too much sun exposure, poor skin care and not drinking enough water. The food we eat plays a big factor in our skins pH balance. Consuming foods such as apples, citrus fruits, blackberries and tomatoes can naturally assist in the balancing our skins pH.

Many soaps also tend to be more alkaline (high in pH) therefore affecting your skins natural balance. Skin care products with pH balancers are best at controlling the skins natural pH balance.

Removing warts

Warts can be removed by adding corrosive chemicals.

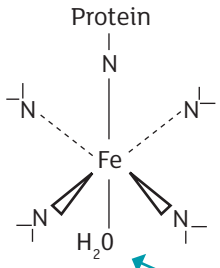
Salicylic acid is often used to remove warts. Salicylic acid is corrosive, and capable of penetrating and breaking down fats and lipids in the skin, making it capable of causing moderate chemical burns of the skin and so 'burning' away the wart, at very high concentrations. 17% - 27% salicylic acid is often sold for wart removal and it destroys the living tissue of the wart and around it, killing the virus

Silver nitrate in eye disease

Silver salts have antiseptic properties. Until the development and widespread adoption of antibiotics, dilute solutions of $AgNO_3$ used to be dropped into new-born babies' eyes at birth to prevent contraction of gonorrhoea from the mother and to prevent neonatal conjunctivitis. Eye infections and blindness of new-borns was reduced by this method; incorrect dosage, however, could cause blindness in extreme cases. Antibiotics are now more commonly used.

Role of iron(II) in haemoglobin

In the protein haemoglobin there is an iron(II) ion surrounded by a complicated molecule called **haem**. This is a ring of carbon and hydrogen atoms, at the centre of which are 4 nitrogen atoms with lone pairs of electrons which form 4 coordinate bonds to the iron(II) ion.



This water molecule is replaced by O_2

Iron still has space to form two more coordinate bonds - one above and one below the plane of the ring.The protein globin attaches to one of these positions using a lone pair on one of the nitrogens in one of its amino acids and a water ligand also coordinately bonds to the iron ion.

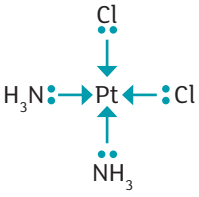
The water molecule easily replaced by an oxygen molecule (again via a lone pair on one of the oxygens in O_2) . The complex formed is oxyhaemoglobin, and this is how oxygen gets carried around the blood by When the oxygen gets to where it is needed, it breaks away from the haemoglobin which returns to the lungs to get some more.

Carbon monoxide is poisonous because it forms a very stable complex with haemoglobin. It bonds to the same site that would otherwise be used by the oxygen The carbon monoxide doesn't break away again, and that makes that haemoglobin molecule useless for any further oxygen transfer.

Anticancer drugs

Cisplatin is an effective anticancer drugs.

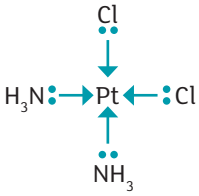
Cisplatin is a neutral platinum complex, $Pt(NH_3)_2Cl_2$. It is neutral because the 2+ charge of the original platinum(II) ion is exactly cancelled by the two negative charges supplied by the chloride ions.



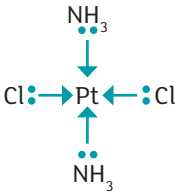
$Pt(NH_3)_2Cl_2$

The platinum, the two chloro ligands, and the two ammonia ligands are all in the same plane. The shape is squre planar.

Cisplatin has **geometric isomerism**. The two structures below are non superimposeable. The first isomer shown is the Z isomer as the



the 'cis' form



the 'trans' form

ammonia molecules are next to each to each other – this is also called the 'cis' isomer, and hence the name cisplatin. In the E isomer the ammonia molecules are arranged opposite to each other, as are the chloro ligands – this is also called the 'trans' isomer, trans meaning opposite. Transplatin is inactive against cancer.

Action of cisplatin

A cancerous cell is a cell in which cell division is uncontrolled, and it continues to divide to form a tumour. Before cell division occurs, a copy of the DNA in the cell is made – this is DNA replication.

DNA replication is the process by which a double stranded DNA molecule is copied to produce two identical DNA molecules

After cell division two new cells are formed each containing the same DNA. Cancer is spread through an organism when a cancerous cell divides and reproduces, forming a tumor. Cisplatin acts by binding to the DNA in cancer cells – a coordinate bond forms between the platinium and the nitrogen atom in guanine in DNA. As a result of this, DNA replication is prevented.

Role of edta in sequestering

Chemicals that combine with metal ions and remove them from their sphere of action, are called sequestrants. Because of its strong complexing ability for most metal ions, edta is used as a sequestering agent and in particular is used in sequestering calcium ions.

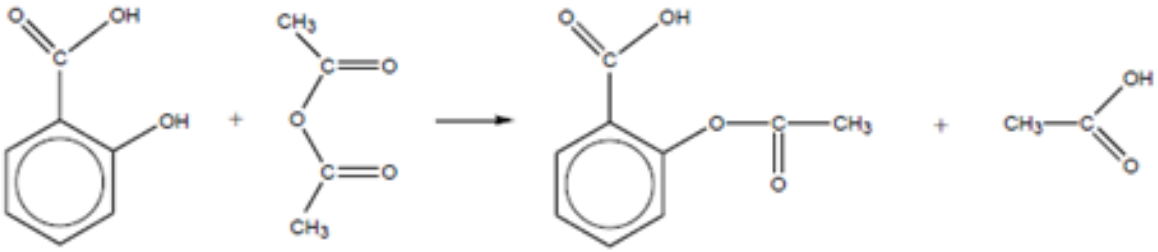
Blood transfusion bags, and medical and surgical equipment will get clogged up and become non-operational if blood is allowed to clot and solidify. Chemicals can be added to stop blood clotting. Most of these chemicals work by binding calcium ions, preventing the coagulation proteins from using them. Edta strongly and irreversibly binds calcium ions – i.e it sequesters calcium ions and prevents the blood from clotting.

Blood collection tubes are pre-sprayed with edta on the inside, to prevent clotting.

Synthesis of aspirin

Aspirin (acetylsalicylic acid) is an aromatic compound containing both a carboxylic acid functional group and an ester functional group. Aspirin is manufactured by acylating 2-hydroxybenzenoic acid (salicylic acid) using ethanoic anhydride.

Acylation is the process of replacing a hydrogen atom in certain molecules by an acyl group(RCO-).



Organic solids, such as aspirin must be produced in as pure a state as possible. The following method can be used to prepare aspirin, or any organic solid in the laboratory the method is

- Place 1.0 g of 2-hydroxybenzoic acid in a pear shaped flask and add 2 cm^3 of ethanoic anhydride ($(CH_3CO)_2O$). Note that ethanoic anhydride reacts readily with water so all the apparatus must be
- dry
- Safely add 8 drops of of concentrated phosphoric(V) acid and heat under reflux for 30 minutes.
- Add water to hydrolyse any unreacted ethanoic anhydride to ethanoic acid, and pour the mixture unto 400 g of crushed ice in a beaker.
- The product is removed by suction filtration, recrystallised from water and dried in a desiccator. The produce is **white crystals**.
- The melting point is then determined.

$HOOCC_6H_4OH + (CH_3CO)_2O \rightarrow HOOCC_6H_4OCOCH_3 + CH_3COOH$

Aspirin in slightly soluble in water due to the OH group which can form hydrogen bonds with water. The sodium salt of aspirin is more soluble as it can form stronger ion – dipole interactions with water. The ionic salts of aspirin are marketed as soluble asprin . The more soluble a medicine is, the more quickly it passes from the digestive system into the bloodstream after being swallowed.

Volumetric analysis can be used to determine the concentration of aspirin in solution - refer to fact sheet 5.3 on volumetric analysis.

Using GLC-MS to identify drugs and their purity (link with Section 5.4);
GLC can separate the components in a mixture but cannot identify them conclusively.
Mass spectrometry can provide detailed structural information on most compounds, which leads to exact identification but it cannot separate them.

By combining the two techniques – separating the components in a mixture using GLC (retention time gives a preliminary identification) and then directing the components into a mass spectrometer, a positive identification can occur. The mass spectrometer is capable of identifying the substances represented by the peaks in the GLC. The substance causing each peak in the graph from GLC will give a mass spectrum which can be compared with a computer database of known patterns. This technique is called gas-liquid chromatography mass spectromentry (GLC-MC).

A gas chromatography machine (left) connected to a mass spectrometer (right) in a forensic laboratory. This equipment is sensitive enough to detect minute quantities of illegal drugs in the hair of a suspect - weeks after any drugs were taken.

Revision Questions

1 Explain the role of edta in treating blood.

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2 Succinic acid can be analysed by converting it to the diethyl ester and submitting the ester to GLC analysis.

i) Why is it better to use the ester rather than the acid in GLC analysis?

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ii) Explain the results expected if the sample of the ester was 90% pure.

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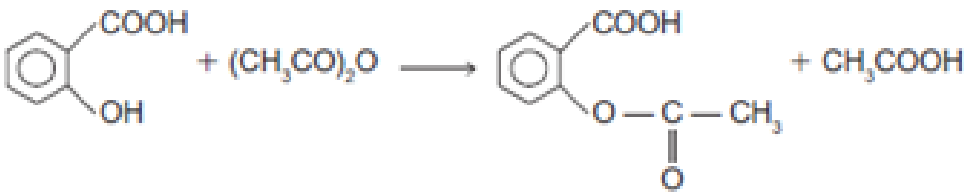
3 Aspirin can be prepared by reacting 2-hydroxybenzoic acid with ethanoic anhydride in the presence of concentrated phosphoric(V) acid. The product has a melting point of 135°C.



The following method can be used:
Place 20.0 g of 2-hydroxybenzoic acid in a pear-shaped flask and add 40 cm^3 of ethanoic anhydride. Safely add 5 cm^3 of concentrated phosphoric(V) acid to the mixture. Heat under reflux. Add water to hydrolyse any unreacted ethanoic anhydride to form ethanoic acid. Pour the mixture onto 400 g of crushed ice in a beaker. The product is removed by suction filtration, recrystallised from water and dried in a desiccator. The melting point is then determined.

a) i) Suggest the role of the concentrated phosphoric(V) acid.

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Revision Questions

a) ii) Explain how you would safely add the concentrated phosphoric(V) acid.

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b) i) What is meant by the term **reflux**?

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ii) Draw a labelled diagram showing the apparatus used for refluxing.

[4]

c) Write an equation for the hydrolysis of ethanoic anhydride.

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d) Why is the mixture poured onto ice?

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e) Why is suction filtration used rather than gravity filtration?

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f) Describe how the impure product is recrystallised.

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Revision Questions

g) Assuming 65% yield, calculate the mass of 2-hydroxybenzoic acid required to form 5.0 g of pure aspirin with an excess of ethanoic anhydride.

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4 Draw the structure of cisplatin and explain how it acts as an anticancer drug.

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