Chemistry in your cupboard: Gaviscon

Introduction

Heartburn occurs when hydrochloric acid from the stomach escapes into the oesophagus. The Gaviscon® brand of products uses chemistry to 'keep the acid where it works not where it hurts'. The active ingredient in Gaviscon liquid is sodium alginate, a linear polymer of sugar-like monomers which is derived from seaweed and cross links to form a layer on top of the stomach contents and prevent the hydrochloric acid escaping. Gaviscon liquid also has a small effect on the pH of the stomach contents but not to the same extent as Milk of Magnesia.

Links to the curriculum

This section contains information relevant to the following areas of your chemistry curriculum:

- Acid-base neutralisation
- Weak acids
- Bonding
- Carboxylic acids

GAVISCON

Heartburn

Heartburn is an unpleasant condition which can be extremely painful, so much so that some people describe the sensation as feeling like they are experiencing a heart attack. Hydrochloric acid is naturally present in the stomach to help us digest our food and kill bacteria. In heartburn this acid, mixed with other stomach contents such as food, pepsin and bile escapes into the oesophagus, (the food pipe which leads from the mouth into the stomach).

This process is called reflux and may be caused by a weakness in the sphincter, (a band of muscle that controls the opening at the bottom of the oesophagus) being over weight, pregnancy, hernia, stress and some foods and medications. The stomach lining is protected from the acid it contains by a thick neutral layer of mucus, but the oesophagus is more vulnerable. Stomach acid acting on the vulnerable lining of the oesophagus can cause the burning pain and inflammation sometimes known as oesophagitis (Figure 1).

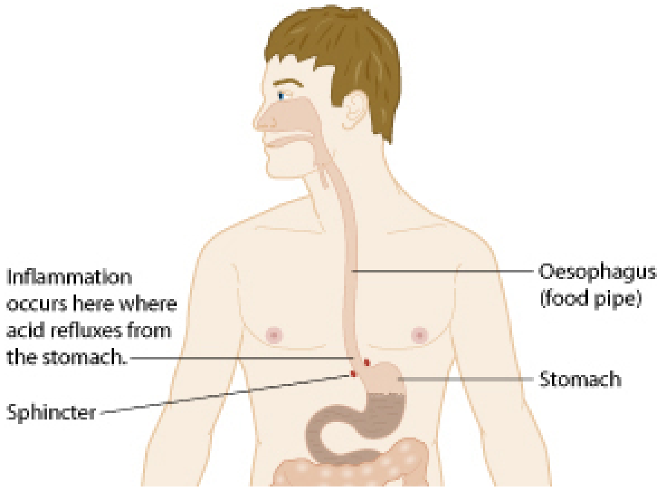


Figure 1: Inflammation of the oesophagus can be caused by acid reflux from the stomach.

Gaviscon liquid (Figure 2) is an over-the-counter remedy for heartburn and other symptoms associated with reflux.

Figure 2: Gaviscon Original liquid.

It uses some simple but clever chemistry to treat the symptoms of this condition. It is made as a liquid suspension and a dose of 10−20 ml (two to four 5 ml spoonfuls) is taken by mouth. It is also available as chewable tablets.

Treating heartburn

The acid in the stomach is hydrochloric acid, HCl, and has a pH of about 2.

Question 1
Hydrochloric acid, HCl is a strong acid.
a) Explain the terms 'strong' and 'weak' in relation to acids. Make it clear how these terms differ from 'concentrated' and 'dilute'.
b) What is the concentration of hydrogen ions in stomach acid if it is hydrochloric acid of pH 2?

Acid of pH 2 can be quite corrosive – observe the effect of placing an iron nail in 0.01 mol dm^{-3} hydrochloric acid, Figure 3.

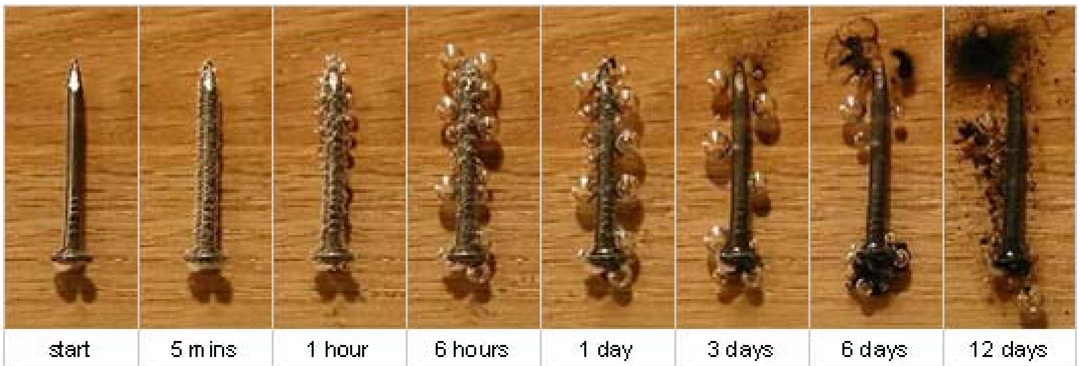


Figure 3: An iron nail in hydrochloric acid.

One simple treatment for heartburn symptoms is to take a simple antacid – a substance that will reduce the concentration of acid in the stomach by reacting with some of it.

Question 2
A simple antacid tablet, Milk of Magnesia, has the following active ingredient, 250 mg of magnesium hydroxide ($Mg(OH)_2$), and the label suggests a dose of two tablets.
a) Write an equation for the reaction of magnesium hydroxide with hydrochloric acid (HCl).
b) How many moles of hydrochloric acid are neutralised by the two tablets of magnesium hydroxide?

However, this simple antacid approach is not without its problems:

- The stomach is supposed to be acidic and this helps it break down food and gives some defence against bacteria and viruses that we might swallow - it is only when this acid escapes from the stomach into the oesophagus that it may lead to problems.

- The stomach will react to the neutralisation by producing more acid so the reduction in acid concentration will only be temporary.

The chemistry behind Gaviscon (1 of 3)

Gaviscon works quite differently from a simple antacid. It contains an ingredient, sodium alginate, which forms a gel that floats to the top of the stomach contents. This acts as a barrier to stop acid refluxing into the oesophagus while leaving the acidity of the stomach relatively unchanged. Hence the phrase ‘keeping the acid where it works, not where it hurts’.

The main ingredients of Gaviscon are:

- sodium alginate;
- sodium bicarbonate (sodium hydrogencarbonate); and
- calcium carbonate.

The alginate raft

The key ingredient of Gaviscon Liquid is sodium alginate, which is derived from seaweed.

Active Ingredients
Sodium alginate Ph Eur 500 mg
sodium bicarbonate Ph Eur 267 mg
calcium carbonate Ph Eur 160 mg per 10 mL dose
methyl and propyl hydroxybenzoates
sodium saccharin.

The active ingredients of Gaviscon (Ph Eur stands for European Pharmacopoeia, a compendium of pharmaceutical ingredients used in Europe).

The structure of sodium alginate is shown in Figure 4.

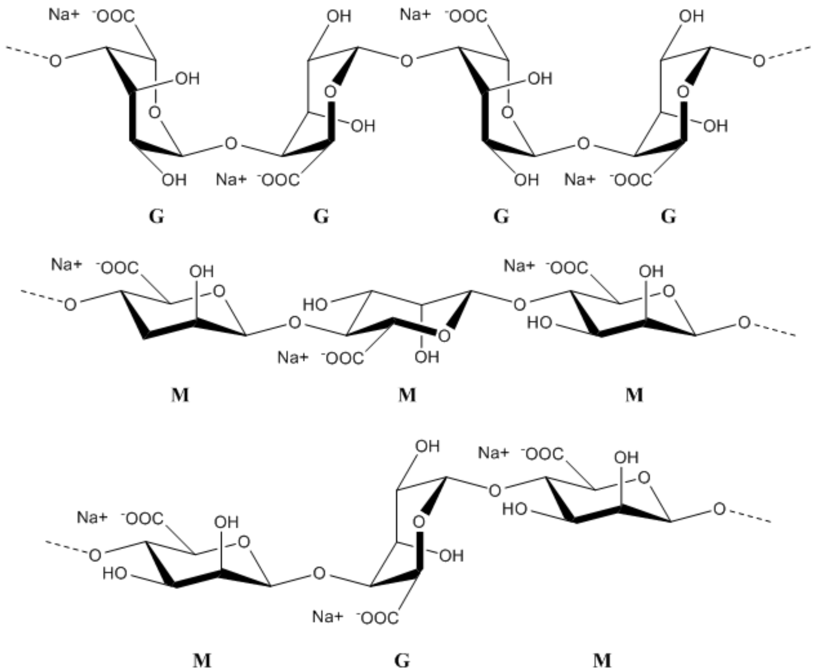


Figure 4: Three sections of sodium alginate polymer molecules showing the two different monomers, ‘G’ and ‘M’.

Question 3
Although it is a large molecule, sodium alginate is quite soluble in water. Explain why you would expect this.

It is a linear polymer made from two sugar-like monomers (which we shall call ‘G’ and ‘M’) each of which has a $-COO^-$ group. For each $-COO^-$ group there is a Na^+ ion to balance the charges.

G stands for (1 → 4) α-L-guluronate and M for (1 → 4) β-D-mannuronate. These are both sugars, so sodium alginate is a polysaccharide.

You will not know (or be expected to know) any of the chemistry of sodium alginate, but you can make some predictions based on what you know about more familiar compounds. In particular, you should be able to spot the sugar monomers (which have a ring of five carbons and one oxygen) in the structures in Figure 4.

The chemistry behind Gaviscon (2 of 3)

You can think of sodium alginate as being $R-COO^-Na^+$, that is the salt of a carboxylic acid like ethanoic acid, CH_3COOH, and expect it to behave similarly.

Ethanoic acid is a weak acid and partially dissociates in water

$$CH_3COOH_{(aq)} \rightleftharpoons CH_3COO^-{}_{(aq)} + H^+{}_{(aq)}$$

This is what happens to the $-COO^-$ groups when sodium alginate is added to acid, as occurs when a dose of Gaviscon reaches the stomach.

Question 4
What will happen to the equilibrium of the dissociation of ethanoic acid if more H^+ ions are added?

Although carboxylic acids, RCOOH, are weak acids, not all the $-COO^-$ groups will accept a proton (H^+ ion) – some will remain as $-COO^-$. This leads to a further important bit of chemistry that allows Gaviscon to work.

After taking Gaviscon, the stomach will contain Ca^{2+} ions from the calcium carbonate which has dissolved in the stomach contents. Two negatively-charged $-COO^-$ groups, one on one alginate chain and one on another can associate with each other because both may be attracted to a positive ion. Because of their double charge, Ca^{2+} ions are better at this than singly charged ions such as Na^+. This has the effect of cross-linking alginate molecules together in a three dimensional network as shown in Figure 5. This is called the alginate 'raft'.

Question 5
This process makes the alginate molecules become less soluble. Explain why.

In fact the cross-linking takes place between regions of the alginate polymer chains consisting of G monomers. This is because of the zig-zag shape of these regions of the chain which allows calcium ions to sit neatly between the polymer chains.

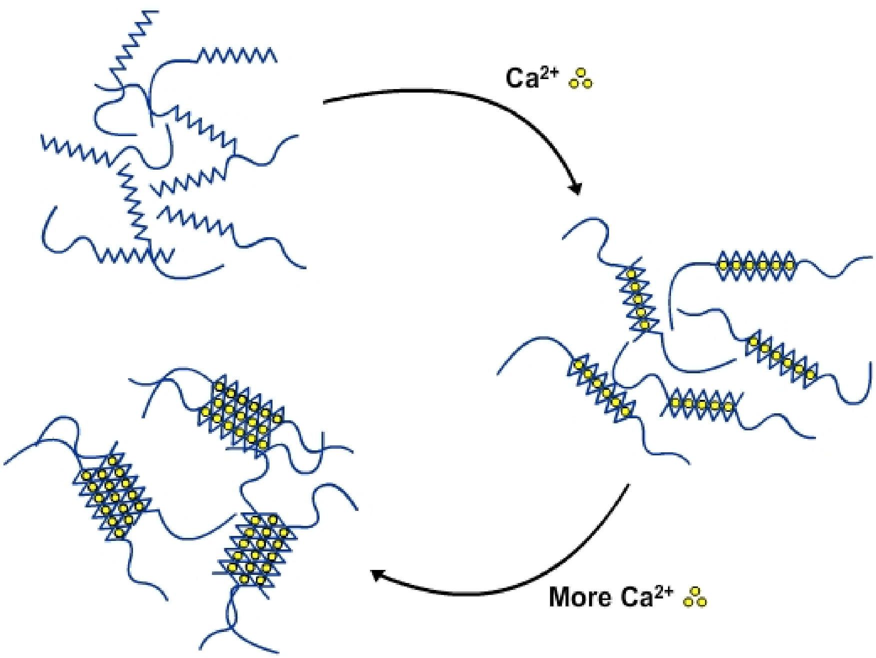


Figure 5: Cross linking of alginate molecules by Ca^{2+} ions forms an 'alginate raft'.

The chemistry behind Gaviscon (3 of 3)

One final piece of chemistry completes the picture.

The reactions of the sodium hydrogencarbonate and calcium carbonate with the stomach acid produce carbon dioxide gas. This becomes trapped within the raft, lifting it to float on top of the stomach contents and forming a barrier that prevents these contents rising into the oesophagus and causing pain.

This is a most efficient bit of chemistry in which all the ingredients (sodium alginate, sodium hydrogencarbonate and calcium carbonate) play a role:

- Soluble sodium alginate reacts with stomach acid to form insoluble alginic acid, a linear polymer.
- Calcium carbonate dissolves in the stomach contents releasing calcium ions, Ca^{2+}.
- This linear polymer is cross linked by calcium ions, originally from the calcium carbonate, to form an alginate raft.
- The sodium hydrogencarbonate and calcium carbonate react with a little of the stomach acid, forming carbon dioxide gas.
- The carbon dioxide lifts the raft so that it floats on top of the stomach contents preventing reflux into the oesophagus.

The alginate raft will not remain in the stomach permanently; it is broken down over time by the mechanical action of stomach contractions.

Question 6
Consider what might happen to the alginate raft if an astronaut in a weightless condition took Gaviscon.

How does Gaviscon affect the pH of the stomach? (1 of 2)

Gaviscon does neutralise a small amount of stomach acid – this is an inevitable side effect of the reactions of calcium carbonate ($CaCO_3$) and sodium hydrogencarbonate ($NaHCO_3$) which react to form the carbon dioxide which lifts the alginate raft.

Question 7
Hydrochloric acid, HCl, is a strong acid.
a) Write an equation for the reaction of calcium carbonate with hydrochloric acid.
b) Write an equation for the reaction of sodium hydrogencarbonate with hydrochloric acid.

However, this is much less than the amount of acid neutralised by a simple antacid such as Milk of Magnesia. According to the ingredients list, one 10 ml dose of Gaviscon Liquid contains 267 mg sodium hydrogencarbonate and 160 mg calcium carbonate.

Question 8
a) Use the equations you have written above to calculate how many moles of hydrochloric acid are neutralised by
(i) the calcium carbonate in a 10 ml dose of Gaviscon.
(ii) the sodium hydrogencarbonate in a 10 ml dose of Gaviscon.

b) So how many moles of hydrochloric acid are neutralised in total by the ingredients in a 10 ml dose of Gaviscon?
c) Compare this with the amount of hydrochloric acid neutralised by the recommended dose of Milk of Magnesia (see your answer to question 2).

How does Gaviscon affect the pH of the stomach? (2 of 2)

'In vivo' versus 'in vitro'

The calculations in questions 2 and 7 ignore the fact that in the stomach of a living person, as soon as some acid is neutralised, the stomach reacts to make more acid in an attempt to restore the original concentration. This is called **'biofeedback'**.

To simplify matters, scientists sometimes think about what would happen if this effect did not occur, ie what would happen if the stomach were simply a glass laboratory beaker. As well as doing calculations, they often do experiments *in vitro* as this is obviously easier than doing them *in vivo*: '*in vivo*' means 'in life' whilst '*in vitro*' literally means 'in glass'. For both calculations and experiments, this can be helpful as a model but scientists must be careful when applying their results to real life situations.

Stomachs obviously vary between individuals both in their size and concentration of acid they contain. However, to enable us to do some calculations we can work on a volume of 1 dm^3 and a concentration of acid of 0.01 mol dm^{-3} (pH = 2).

Question 9
How many moles of hydrochloric acid are contained in a typical stomach described above?

Notice that as the stomach gets *less* acidic, the pH *increases* (not decreases). This is because of the negative sign in the equation

$pH = -\log_{10}[H^+_{(aq)}]$.

The fact that increasing pH represents decreasing acidity occasionally catches out even experienced chemists.

Question 10
The answer to question 8 shows that 6.38 x 10^{-3} moles of hydrochloric acid are neutralised by a 10 ml dose of Gaviscon.
a) How many moles of acid will be left in the stomach?
b) What is the concentration of hydrochloric acid in the stomach after taking the Gaviscon?
c) What is the pH in the stomach now?

This simplified *in vitro* calculation of course ignores the fact that the stomach will react to a drop in acidity by making more acid. Doctors have measured the effect that Gaviscon (and other medicines) have on stomach pH by inserting pH probes into the stomachs of volunteers. They find that the pH does not change as much as our calculation predicts. In fact, there is a 'spike' in the pH which initially rises for a few minutes and then drops again.

How does Gaviscon compare with a simple antacid?

Question 2 shows us that two tablets of Milk of Magnesia contain, 8.62 x 10^{-3} mol $Mg(OH)_2$. Question 8 shows us that our model stomach contains 10 x 10^{-3} mol HCl. The following calculation estimates the effect of two 250 mg tablets of Milk of Magnesia on the acidity of our model stomach. It has several steps and makes a number of assumptions.

How do magnesium hydroxide and hydrochloric acid react together?

Hydrochloric acid and magnesium hydroxide react together as follows:

$$2HCl_{(aq)} + Mg(OH)_{2(s)} \rightarrow MgCl_{2(aq)} + 2H_2O_{(l)}$$

Each mole of HCl reacts with ½ mol $Mg(OH)_2$ which means 10 x 10^{-3} mol HCl will react with 5 x 10^{-3} mol $Mg(OH)_2$. We have 8.62 x 10^{-3} mol $Mg(OH)_2$, so there is enough $Mg(OH)_2$ to react with all the HCl and leave (8.62 x 10^{-3} − 5 x 10^{-3}) = 3.62 x 10^{-3} mol of solid $Mg(OH)_2$ left.

What is the pH of the model stomach after the reaction?

All the acid has been neutralised and there is still solid $Mg(OH)_2$ left. So the solution in the stomach will be alkaline, not acidic.

This means that the concentration of $OH^-_{(aq)}$ will be governed by the solubility of $Mg(OH)_2$, which is 4 x 10^{-4} mol dm^{-3} of $Mg(OH)_2$, ie a concentration of OH^- ions of 8 x 10^{-4} mol dm^{-3}, as each $Mg(OH)_2$ entity that dissolves produces 2 $OH^-_{(aq)}$ ions.

To work out the pH of this solution, we use the relationship that in all aqueous solutions,

$$\mathbf{[H^+_{(aq)}] \times [OH^-_{(aq)}] = 1 \times 10^{-14}\ mol^2\ dm^{-6}}$$

This is called the ionic product of water, K_w , and is an example of the Equilibrium Law.

Remember that square brackets represent concentrations in mol dm^{-3}.

So $[H^+_{(aq)}] \times [8 \times 10^{-4}] = 1 \times 10^{-14}$ mol^2 dm^{-6}

and $[H^+_{(aq)}] = \dfrac{1 \times 10^{-14}}{8 \times 10^{-4}} = 1.25 \times 10^{-11}$ mol dm^{-3}

pH = $-\log_{10}[H^+_{(aq)}] = -\log_{10}[1.25 \times 10^{-12}] = 10.9$

So the pH in our model stomach changes from 2.00 to 2.44 after a dose of Gaviscon and from 2.00 to 10.9 after a dose of Milk of Magnesia.

The calculation makes a number of assumptions which may not be exactly true under the conditions of real a stomach. Nor have we considered the biofeedback effect that generates more acid to replace that used up. However, the difference between the effects of the two medicines is significant.

Incidentally, the excess solid magnesium hydroxide does have a use. It will be present to react with the acid generated in the stomach by biofeedback until all the solid is used up. This gives the tablets a longer-term antacid effect.

Always read the label

Extension - 'How Science Works' material

Once the alginate raft has been produced, it will not remain in the stomach indefinitely.

It is largely broken up mechanically by the action of stomach contractions. However, a pharmaceutical chemist might have to consider other possible chemical reasons for its breakdown before being sure that mechanical destruction was its principal fate.

These might include:

- loss of calcium ions that cross link the alginate molecules to form the raft, by absorption of these ions through the stomach wall, for example; and
- hydrolysis of some of the saccharide bonds that hold the alginate linear polymers together

In fact, neither of these mechanisms is believed to be significant in dispersing the raft in practice.

Experimental work

The alginate raft can be demonstrated simply and effectively as follows. Take a 100 cm^3 conical flask with a narrow neck and fill it to the 100 cm^3 mark with 0.1 mol dm^{-3} hydrochloric acid. The acid will reach almost to the base of the neck of the flask. The body of the flask represents the stomach, the neck of the flask the oesophagus and the acid the stomach contents.

Add to the acid about 10 ml of Gaviscon Liquid. This is quite viscous, but the exact amount is not critical. The Gaviscon initially sinks to the bottom of the flask where a gel forms on contact with the acid. Over a period of a minute or two bubbles of carbon dioxide gas can be seen forming on the surface of the Gaviscon and these carry layers of the gel to the surface of the acid where they form a plug in the neck of the flask.

Question 11

Any gas would work to float the raft to the top of the stomach. Suggest why carbon dioxide is the one used.

After about five minutes a plug of gelatinous foam will have formed which blocks the neck of the flask and which may rise out of its mouth. At this stage the flask may be inverted (over a sink) and the plug will remain in place holding in the contents of the flask, Figure 8.

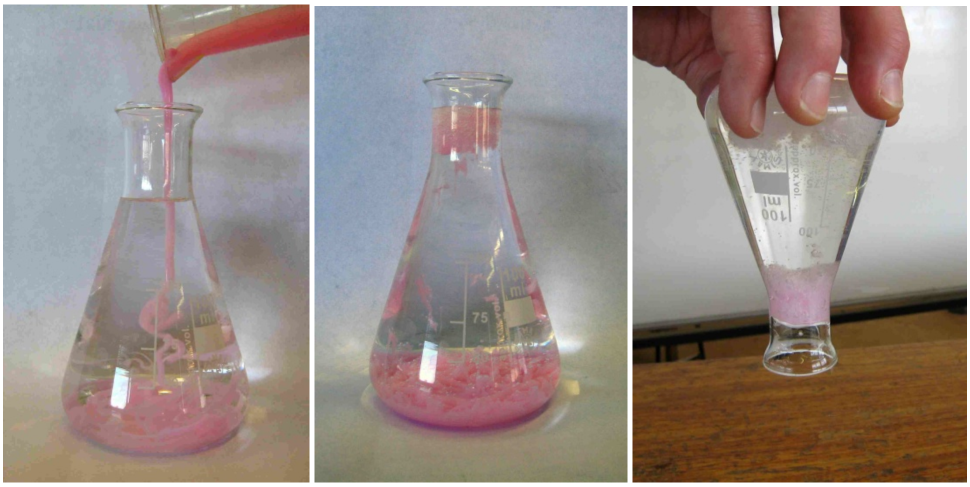


Figure 8: Demonstration of how alginate raft works

Question 12
a) Draw a section of an alginate molecule consisting of just two sugar-like molecules and write an equation for the hydrolysis.
b) Suggest why hydrolysis of the saccharide bonds could be a realistic suggestion.

After the experiments the plug (and the acid) may be washed down the sink with hot water, the plug having been broken up with a test tube brush. With larger quantities, resulting from a class experiment, it may be worth sieving off the gel and disposing of it with the solid waste to avoid the possibility of blocked sinks.

Safety

- Wear eye protection.
- Your school/college should be consulted before carrying out this activity. This activity is covered by model (general) risk assessments widely adopted for use in UK schools such as those provided by CLEAPSS, SSERC, ASE and DfES. Bear in mind, however, that these may need some modification to suit local conditions.

Further information

Gaviscon is sold in the UK by Reckitt Benckiser (www.gaviscon.co.uk) and a slightly different product is sold in the USA by GlaxoSmithKline (www.gaviscon.com). There are other branded products which work in a similar way.

Acknowledgements

The Royal Society of Chemistry wishes to thank Reckitt Benckiser for help in preparing this material.

The Royal Society of Chemistry gratefully acknowledges that this project was initially supported by Reckitt Benckiser in 2007. Reckitt Benckiser conducted a final review in 2013 so please note that certain information may be out of date.

QUESTIONS AND ANSWERS

Question 1
Hydrochloric acid, HCl is a strong acid.
a) Explain the terms 'strong' and 'weak' in relation to acids. Make it clear how these terms differ from 'concentrated' and 'dilute'.
Acids dissociate in water to produce solutions containing $H^+_{(aq)}$ ions, sometimes called protons. Strong acids dissociate completely, for example hydrochloric acid:

$$HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$$

Weak acids dissociate only partially, for example ethanoic acid:

$$CH_3COOH_{(aq)} \rightleftharpoons CH_3COO^-_{(aq)} + H^+_{(aq)}$$

In a 1 mol dm^{-3} solution of ethanoic acid, fewer than half of one percent of the ethanoic acid molecules have dissociated.

Concentration refers only to the number of moles of acid dissolved in the solution and not to its degree of dissociation. So it is perfectly possible to have a concentrated solution of a weak acid and a dilute solution of a strong acid.

In everyday speech, 'strong' and 'weak' are often used to mean the same as 'concentrated' and 'dilute' respectively. In chemistry the terms are quite distinct.

b) What is the concentration of hydrogen ions in stomach acid if it is hydrochloric acid of pH 2?

$$pH = -\log_{10}[H^+_{(aq)}]$$

Remember that square brackets [ ] represent concentration in mol dm^{-3}

$$2 = -\log_{10}[H^+_{(aq)}]$$

$$[H^+_{(aq)}] = \text{inv}\log_{10}(-2)$$

$$[H^+_{(aq)}] = 10^{-2} \text{ mol dm}^{-3}$$

$$[H^+_{(aq)}] = 0.01 \text{ mol dm}^{-3}$$

Question 2
A simple antacid tablet, Milk of Magnesia, has the following active ingredient, 250 mg of magnesium hydroxide ($Mg(OH)_2$), and the label suggests a dose of two tablets.
a) Write an equation for the reaction of magnesium hydroxide with hydrochloric acid (HCl).

$$Mg(OH)_{2(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + 2H_2O_{(l)}$$

b) How many moles of hydrochloric acid are neutralised by the two tablets of magnesium hydroxide?
Two tablets contain 500 mg (0.5 g) $Mg(OH)_2$

M_r $Mg(OH)_2$ = 24 + 2(16 + 1) = 58

So 0.5 g is 0.5 / 58 = 8.62×10^{-3} mol $Mg(OH)_2$

From the equation 1 mol $Mg(OH)_2$ will neutralise 2 mol HCl

So two tablets $Mg(OH)_2$ will neutralise 2 x 8.62×10^{-3} = 0.0172 mol HCl

(This may be written as 17.2×10^{-3} mol dm^{-3} even though this is not standard form. Many of the calculations in this unit are conveniently expressed in the form Y x 10^{-3} or Y millimoles per cubic decimetre)

Question 3
Although it is a large molecule, sodium alginate is quite soluble in water. Explain why you would expect this.
It is an ionic compound as each molecule has a large number of $-COO^-$ groups (and the same number of Na^+ ions). It also has a number of polar groups such as $-OH$ and $-COO^-$ which can form hydrogen bonds with water molecules.

Question 4
What will happen to the equilibrium of the dissociation of ethanoic acid if more H^+ ions are added?
The equilibrium will move to the left as predicted by Le Chatelier's principle. This will produce more undissociated ethanoic acid and fewer CH_3COO^- ions. We say that the ions have been protonated because an H^+ ion is simply a proton (although in aqueous solution it will be hydrated and is sometimes written H_3O^+).

Question 5
This process makes the alginate molecules become less soluble. Explain why.
The alginate molecules will have fewer ionic charges and it is these that help to make them soluble.

Question 6
Consider what might happen to the alginate raft if an astronaut in a weightless condition took Gaviscon.
The raft would not float to the top of the stomach as there is no gravity to make it rise in the stomach whilst heavier stomach contents sink. However, the raft might thicken up the stomach contents to help reduce the reflux.

Question 7
Hydrochloric acid, HCl, is a strong acid.
a) Write an equation for the reaction of calcium carbonate with hydrochloric acid.

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

b) Write an equation for the reaction of sodium hydrogencarbonate with hydrochloric acid.

$$NaHCO_{3(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$$

(These equations could be written ionically.)

Question 8

a) Use the equations you have written above to calculate how many moles of hydrochloric acid are neutralised by

(i) the calcium carbonate in a 10 ml dose of Gaviscon.

10 ml Gaviscon contains 160 mg (0.160 g) $CaCO_3$

M_r $CaCO_3$ = 40 + 12 + (3 x 16) = 100

So 0.160 g is 0.160 / 100 = 1.60 x 10^{-3} mol $CaCO_3$

From the equation 1 mol $CaCO_3$ will neutralise 2 mol HCl

So 160 mg $CaCO_3$ will neutralise 2 x 1.60 x 10^{-3} = 3.20 x 10^{-3} mol HCl

(ii) the sodium hydrogencarbonate in a 10 ml dose of Gaviscon.

10 ml Gaviscon contains 267 mg (0.267 g) $NaHCO_3$

M_r $NaHCO_3$ = 23 + 1 + 12 + (3 x 16) = 84

So 0.267 g is 0.267 / 84 = 3.18 x 10^{-3} mol $NaHCO_3$

From the equation 1 mol $NaHCO_3$ will neutralise 1 mol HCl

So 267 mg $NaHCO_3$ will neutralise 3.18 x 10^{-3} mol HCl

b) So how many moles of hydrochloric acid are neutralised in total by the ingredients in a 10 ml dose of Gaviscon?

3.18 x 10^{-3} mol + 3.20 x 10^{-3} mol = 6.38 x 10^{-3} mol

c) Compare this with the amount of hydrochloric acid neutralised by the recommended dose of Milk of Magnesia (see your answer to question 2)

The recommended dose of Milk of Magnesia neutralises 0.0172 mol, ie 17.2 x 10^{-3} mol hydrochloric acid. This is almost three times as much.

Question 9

How many moles of hydrochloric acid are contained in a typical stomach described above?

The concentration (C) is 0.01 mol dm^{-3} and the volume (V) is 1000 ml.

No. moles = $\frac{C \times V}{1000} = \frac{0.01 \times 1000}{1000}$ = 0.01 mol = 10 x 10^{-3} mol

We have to divide by 1000 to convert 1000 ml to dm^3

Always read the label

Question 10
The answer to question 8 shows that 6.38×10^{-3} moles of hydrochloric acid are neutralised by a 10 ml dose of Gaviscon.
a) How many moles of acid will be left in the stomach?
$10 \times 10^{-3} - 6.38 \times 10^{-3} = 3.62 \times 10^{-3}$ mol HCl

b) What is the concentration of hydrochloric acid in the stomach after taking the Gaviscon?
The stomach now has 3.62×10^{-3} mol HCl dissolved in 1 dm^3, so the concentration of HCl is 3.62×10^{-3} mol dm^{-3}

c) What is the pH in the stomach now?
$pH = -\log_{10}[H^+(aq)]$

$pH = -\log_{10}[3.62 \times 10^{-3}]$

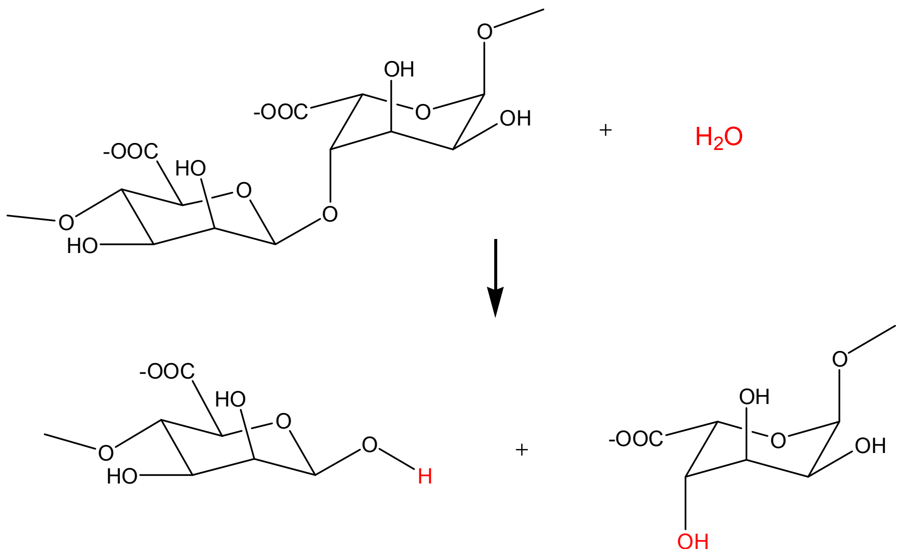
pH = 2.44

This compares with a pH of 2.0 before taking a 10 cm^3 dose of Gaviscon, a relatively small change.

Question 11
Any gas would work to float the raft to the top of the stomach. Suggest why carbon dioxide is the one used.
The gas used must safe and easy to generate. Carbon dioxide is safe (being produced in the body during respiration). It is easily generated by the reaction of carbonates and hydrogencarbonates with the acid that exists naturally in the stomach.

Hydrogen, too, would be easy to generate (by reaction of a metal with stomach acid) but would not be safe (especially for smokers!). Sulfur dioxide, too could be easily be generated (by reaction of sulfite salts with stomach acid, for example) but sulfur dioxide is a toxic gas.

Question 12
a) Draw a section of an alginate molecule consisting of just two sugar-like molecules and write an equation for the hydrolysis.



b) Suggest why hydrolysis of the saccharide bonds could be a realistic suggestion.
Saccharide bonds in starch, a polysaccharide similar to alginate hydrolyse in acidic conditions not dissimilar to those in the stomach.