Lesson Fourteen: Chemistry: Using Chemistry

Aims

By the end of this lesson you should:

- understand that many of the changes that happen in everyday life are due to chemical reactions
- know some of the useful products and processes that depend upon chemical reactions
- know that chemical reactions can sometimes be harmful to us, or a nuisance
- understand how rusting occurs and how it can be prevented

Context

This lesson draws together some of the ways in which Chemistry impacts upon everyday life.

Oxford Home Schooling

Introduction

This is the last Chemistry lesson of the course, so we shall use it to survey some of the ways in which chemistry is relevant to everyday life. Chemical reactions:

- cause several changes that help us;
- are used to make many of the products that we use in everyday life;
- can sometimes be harmful or a nuisance to us.

We shall look at some examples of each of these in turn.

Helpful Chemical Changes

What do cooking food, using superglue and curing stomach ache have in common? They all involve chemical reactions!

Curing Stomach Ache

As we learned in Lesson One of the Year 8 course, our stomachs contain **hydrochloric acid** (HCl). It does a useful job there killing many pathogenic bacteria in food which might otherwise kill us. However hydrochloric acid is a strong acid, and if the acidity gets too great it can start attacking the lining of the stomach. This gives us stomach ache.

The solution is to **neutralise** the acid using a **base**. Many indigestion tablets and liquids contain the base **magnesium oxide**. (Others contain calcium or magnesium hydroxide or carbonate instead.) This reacts with the acid as follows:

hydrochloric acid + magnesium oxide ----> magnesium chloride + water

$$2HCl + MgO \longrightarrow MgCl_2 + H_2O$$

Magnesium chloride is neutral and harmless: problem solved!

Activity 1	Having asked permission, investigate your medicine cabinet looking for cures for stomach ache such as Gaviscon and Rennies. Can you identify the ingredient which neutralizes acids in each case?

Superglue

Superglue, as you probably know, sets in less than a minute: much faster than other glues. This is because its setting depends upon a chemical reaction, not the evaporation of a solvent.

The liquid in the tube consists of small molecules. The moment these are exposed to water (including water vapour in the air) they join together in chains to form large molecules that form the set solid.

This joining together is called **polymerisation**, and is similar to the chemical reaction that a plant uses to turn glucose into starch in leaves. As you will find out later on, it is also used to make plastics.

http://commons.wikimedia.org/wiki/File:Super_Glue_tube.jpgReproduced under:
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The chemical name for superglue is "cyanoacrylate"

Cooking

Cooking also causes chemical reactions – in the food that is being cooked. The new molecules made by the cooking process are usually smaller than the ones in the raw food and:

- are more tasty, as "taste" is the reaction of certain sorts of small molecule with the taste buds in our tongues;
- are easier to digest by the enzymes in our digestive system.

So cooking is really "applied chemistry". What about that?!

http://commons.wikimedia.org/wiki/File:Wok_Cooking.jpg

Photosynthesis and Respiration

Of course, we must not forget that photosynthesis and respiration are vital chemical reactions, without which life on earth would be impossible:

- **photosynthesis** (Lesson Seven) converts carbon dioxide and water into glucose using light energy. This gives life its supply of energy;
- **respiration** (Year 8, Lesson Four) breaks the glucose back down, releasing this energy for use by cells.

http://commons.wikimedia.org/wiki/File:Souzao_leaf.JPG

Activity 2	See if you can write out the word and symbol equations for both respiration and photosynthesis from memory. We met respiration in Year 8, Lesson Four, and photosynthesis in Year 9, Lesson Seven.

Making useful Products

Fermentation by Yeast

Two useful products are made by a chemical reaction inside **yeast**: **ethanol** (alcohol) and **carbon dioxide**. These are used in the making of alcoholic drinks and bread respectively.

Yeast is a single-celled fungus (see Year 7 Lesson One) that is able to respire both **aerobically** (using oxygen) and **anaerobically** (without oxygen). When it respires anaerobically the following chemical reaction, called **fermentation**, takes place:

glucose ----> ethanol + carbon dioxide

$C_6H_{12}O_6$ ---> $2C_2H_5OH$ + $2CO_2$

1. Yeast is used when making **beer** and **wine** to produce the ethanol (alcohol) that they contain. It is also used to produce the alcohol solution which undergoes **fractional distillation** (see Year 7, Lesson Ten) to make **spirits** such as whisky. In all cases, the yeast is given sugar from which it can make the glucose for the reaction.

http://commons.wikimedia.org/wiki/File:Florence_-_Large_wine_bottles.jpg
Bottles of wine

2. When making **bread** in the traditional way, yeast and sugar are added to the **dough** made from flour and water. The dough is kept in a warm place to encourage the yeast to grow and respire. As the yeast produces carbon dioxide, it blows small bubbles in the dough, causing it to **rise**. The risen dough is then baked, which kills the yeast and evaporates off the ethanol.

http://commons.wikimedia.org/wiki/File:Navy_baking_bread.jpg

Baking bread

Activity 3	1. Having asked permission, investigate your home's drinks cupboard. Any alcoholic drinks will have the percentage of alcohol they contained marked on them. What are the highest and lowest concentrations marked? 2. See if you can discover a recipe for home-baked bread in the kitchen. How does the recipe help the growing yeast do its job? If you draw a blank, put "bread recipe" into Google instead.

Making Metals

As we saw in Lesson Two, most metals are extracted from their **ores** by chemical reactions. For example iron, the most-used metal, is extracted from its ore called **haematite** in a **blast furnace**. The reactions involved are quite complicated, but overall this is what happens:

iron oxide + carbon → iron + carbon dioxide

$$2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$$

The carbon is in the form of **coke**, which is made by heating mined coal in the absence of air so that it doesn't burn.

The outside of a blast furnace in Germany

Chemical reactions that are a nuisance

Food going off

If you leave fresh food in a cupboard or on a table, before long it starts to go off. What has this got to do with Chemistry?

Food only goes off because it has **bacteria** and **fungi** growing on or in it. They digest the food and feed on it, decomposing it in the process. It follows that if we can slow up the chemical reactions going on inside these **decomposers** we can slow up or stop food spoiling.

Some ways of slowing up these chemical reactions are:

- *Cooling* them down in a fridge or freezer: all chemical reactions go slower at lower temperature.
- *Drying* the food out: the chemical reactions involved only go on in solution in water.
- Making the food *acid* by pickling it: the reactions are made to work by special molecules called **enzymes**, which only function properly at a neutral pH.

http://commons.wikimedia.org/wiki/File:Koelkast_open.jpg
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A refrigerator preserves food by cooling it so that the chemical reactions inside decomposer organisms go slower

Activity 4	Investigate your kitchen. How many different methods for preserving food can you find there? See if you can work out how each stops or slows up the chemical reactions inside decomposer organisms.

Corrosion

One of the problems of using metals is that they often **corrode** ("rot away"). This happens when a metal reacts with oxygen or water to form a compound (often an oxide), and the metal is lost.

The corrosion of **iron**, our most-used metal, is called **rusting**. This is so important that it deserves a whole section to itself.

http://commons.wikimedia.org/wiki/File:Heavily_corroded_end_post_.jpg

Metal attacked by corrosion

Rusting

What is rust?

Unprotected iron rapidly loses its shiny metallic appearance, especially if it exposed to damp conditions as well as air. Soon afterwards it goes red/brown as it is covered with a layer of **rust**.

Rust is a mixture of iron oxide (Fe_2O_3) and iron hydroxide. It is formed by the reaction of iron with oxygen from the air and water. Part of the reaction is this:

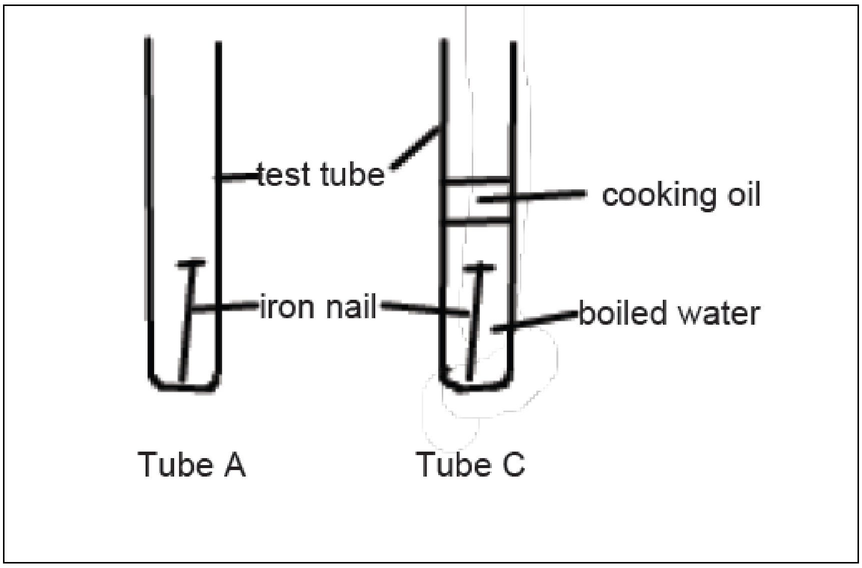
iron + oxygen ----> iron oxide

$$4Fe + 3O_2 \longrightarrow 2Fe_2O_3$$

Investigating the conditions needed for rusting

Everyday experience suggests that exposure to water speeds rusting up. But what conditions exactly are needed for it to occur? The following investigation tries to find out. If possible, try this investigation out for yourself at home (see Activity 5 below).

Several test tubes are set up, each with an iron nail treated differently:



Test	Treatment	Conditions
A	Nail half-covered with water. This is the control tube.	Air and water
B	Solid calcium chloride1. Stopper in tube	No water
C	Nail covered with freshly-boiled water. Layer of cooking oil on top of water2	No air
D	Nail half-covered with water. Left on radiator	Air and warm water
E	Nail half-covered with water. Left in fridge	Air and cold water
F	Nail half covered in salt solution	Air, water and salt

Notes:

1. Calcium chloride removes water vapour from the air, making it dry.
2. Boiling drives dissolved air out of the water, and the cooking oil prevents any more dissolving in it.

The expected results are:

- the nails in B and C do not rust, showing the *both* air *and* water are needed for iron to rust;

- the nail in A rusts. This is the **control** tube, which the other tubes should be compared with;

- the nail in D rusts faster and E slower than the control, because chemical reactions go faster as the temperature increases;

- the nail in F rusts faster than the control. Salt acts as a **catalyst** – something that speeds a chemical reaction up without being changed by the reaction itself.

Activity 5

1. Try out the above investigation for yourself. You could use jam jars instead of test tubes. For tube C, instead of calcium chloride, use a packet of silica gel included in the box with electronic equipment when you buy it to keep the air dry, and put a lid on the jam jar.

2. The nails will take a few days to rust. While you are waiting, try to answer the following:

   a. If the nail in tube A rusts, but that in tube B doesn't, what does this tell you?
   b. If the nail in tube D rusts faster than that in tube E, what does this tell you?
   c. If the nail in tube A fails to rust, what does this tell you?

3. Salt is spread on the roads in cold weather to stop them freezing. Why is this a problem?

4. What investigation, discussed in Lesson Two. Suggests that it is only the oxygen in the air which causes rusting?

http://commons.wikimedia.org/wiki/File:Road_gritter,_Belfast_-_geograph.org.uk_-_1651057.jpg

A gritter lorry spreading salt on winter roads. Unfortunately this makes cars rust faster.

Preventing Rusting

Because iron is the most-used metal in the modern world, and because it rusts easily, rust-prevention is very important. Three main methods are used to prevent iron rusting:

1. Mixing the iron with about 10% of the metal **chromium** during its manufacture to make **stainless steel**. This is used to make kitchen knives, for example, which do not rust even

though they are frequently exposed to water. However stainless steel is much more expensive than normal iron, so it cannot be used in large structures like bridges

2. Put a **barrier** between the iron and the air/water surrounding it. This can be achieved by *painting* it (e.g. on car bodies), or *greasing* it (e.g. on bicycle chains), or by adding a layer of *plastic* (e.g. on some fences).

http://commons.wikimedia.org/wiki/File:Forth_Bridge.JPG

The Forth Rail Bridge in Scotland. A team of painters are permanently employed re-painting this steel bridge to stop it rusting.

3. Add lumps, or a coating, of the more reactive metal zinc. This is called **sacrificial protection**. Because it is more reactive, the zinc corrodes instead of the iron. This is used, for example, on the underwater parts of steel bridges and as a coating on some iron nails and wheelbarrows.

http://commons.wikimedia.org/wiki/File:Anodes-on-jacket.jpg

Long small bars of zinc attached to a steel bridge for sacrificial protection

Activity 6	See if you can explain the following; (a) If a bike chain is left for a long time without being oiled or greased it goes rusty. (b) If the paint on a car is chipped, the car body underneath quite soon develops rust.

Keywords

Hydrochloric acid	**Ore**
Neutralise	**Haematite**
Base	**Ore**
Magnesium oxide	**Haematite**
Polymerisation	**Blast furnace**
Photosynthesis	**Coke**
Respiration	**Decomposers**
Yeast	**Enzymes**
Dough	**Corrode**
Ethanol	**Rust**
Carbon dioxide	**Control**
Rises	**Catalyst**
Fermentation	**Chromium**
Anaerobic respiration	**Stainless steel**
Spirits	**Barrier protection**
Fractional distillation	**Zinc**
	Sacrificial protection

Self-Assessment Activities

Say whether the following statements are true or false. If false, correct them or explain why they are false:

1. Fermentation by yeast is a form of aerobic respiration.
2. Rusting is a form of corrosion.
3. Food poisoning is caused by decomposers.
4. Rust is a mixture of iron oxide and iron hydroxide.
5. Copper can be used for the sacrificial protection of iron.
6. Magnesium chloride is used in antacid tablets to treat stomach ache.
7. Superglue sets as the result of a polymerisation reaction.
8. Iron can be made by heating iron oxide with carbon.
9. Food can be preserved by making it more acid.
10. Salt slows up rusting.

Suggested Answers to Activities

Activity 2

The *word* equation for respiration is:

glucose + oxygen ---------------------> carbon dioxide + water (energy released)

The *symbol* equation for respiration is:

$C_6H_{12}O_6 + 6O_2$ -----------------------> $6CO_2 + 6H_2O$ (energy released)

The *word* equation for photosynthesis is:

carbon dioxide + water ------------------> glucose + oxygen (light energy; chlorophyll)

The *symbol* equation for photosynthesis is:

$6CO_2 + 6H_2O$ -------------------> $C_6H_{12}O_6 + 6O_2$ (light energy; chlorophyll)

Activity 5

2. (a) Water is needed for rusting.
   (b) The rate of rusting increases as the temperature rises.
   (c) That something else, not provided, is also need for rusting.

3. It will speed up the rusting of cars, which are largely made of steel (which is mainly iron).

4. The second one in Activity 2 of Lesson Two.

Activity 6

(a) The grease layer wears thin, and water and air reach the iron of the chain.

(b) The paint prevents water and air reaching the steel of the car body, but the scratch exposes the steel to them.