02 Purification of Substances

Introduction

Most substances are mixtures and need to be separated for two main reasons:

- To obtain chemicals that can be used to make useful substances such as medicines
- To identify substances (This is a purpose of carrying out chromatography.)

This chapter is about methods of separating mixtures.

Chapter Opener (page 13)

1. Begin the chapter by discussing some key questions, such as those below. Precise answers are not needed at this stage.

   What is a pure substance? Why is it important to have pure substances?

   Answer: A pure substance is a single substance not mixed with anything else. Pure substances are important as impurities in, for example, medicines and foods, can be harmful to people.

   What are some methods used to obtain pure substances?

   Answer: Examples include filtration of river water and desalination of sea water by reverse osmosis (as at the Tuas plant).

   What methods are used to purify water in Singapore?

   Answer: For example, desalination process in the Tuas plant.

2. Carry out an 'Inquiry Preview' (Refer to page 1, found in Chapter 1 of this Teacher's Resource file, for ways of carrying out this preview.)

Notes for Teachers

Separating mixtures
The method used to separate a mixture depends on:

- the nature of the mixture (whether solid-solid, solid-liquid or liquid-liquid), and
- differences in the physical properties of the substances in the mixture.

The following table summarises how mixtures can be separated and purified.

Mixture	Physical properties	Method(s)
Solid-solid	One soluble solid, one insoluble solid in a certain solvent	Add a suitable solvent followed by filtration; the insoluble solid is obtained as a residue, the soluble solid is obtained by crystallisation of filtrate.
	Two solids soluble in a particular solvent	Paper chromatography
	One sublimes, one does not	Sublimation
Solid-liquid	Solid insoluble in the liquid	Decanting Filtration
	Solid soluble in liquid (only solid wanted)	Crystallisation
	Solid soluble in liquid (only liquid wanted)	Simple distillation
Liquid-liquid	Immiscible liquids	Using a separating funnel
	Miscible liquids, with widely different boiling points	Fractional distillation

Learning Outcomes

After completing this chapter, you should be able to:

- explain, with illustrative examples, why pure substances are needed
- suggest methods of separation and purification given information about components of mixtures
- describe methods for separation and purification
- interpret chromatograms including comparison with 'known' sample and the use of R_f values
- explain the need to use locating agents in the chromatography of colourless compounds
- deduce from the given melting point and boiling point, the identities of substances and their purity
- explain that the measurement of purity in substances used in everyday life is important

Teaching pointers

2.1 What is a Pure Substance? (page 14)

Stimulation

One way to begin the topic is by asking the class if they have read or heard of any recent reports about harmful substances being detected in foods or commercial products (see the examples on page 13 of the Textbook). If possible, show the class newspaper or magazine clippings of analyses of consumer products such as food, medicines, toys and cosmetics for harmful ingredients. (You might save such clippings as they appear in newspapers and magazines during the year. "The Consumer", the magazine of the Consumers Association of Singapore (CASE) is a useful source of articles.) From the

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examples, discuss the importance of purity, the idea of analysis in chemistry and the difference between a pure substance and a mixture.

Snippets from issues of "The Consumer" are available online:
http://www.case.org.sg/the_consumer.html

1. Mixtures are very common in everyday life. Get students to suggest examples. You may bring along packaged foods and drinks and get students to look at the labels to see that most of the ingredients are mixtures.
2. Discuss the need for pure substances. Ask the class to suggest additional examples where purity is important. See examples in 'Notes for Teachers' on the next page.

(page 14)

Mystery Clue

It is mixed with smaller amounts of other substances (such as magnesium chloride).

Skills Practice (page 15)

Most of these questions relate to work that was already done in Secondary 1 Science.

1. All the sugar crystals are of the same shape and colour.
2. (a) Possible answers include salt, pure water, sugar, alcohol, gold, aluminium and other metals.
   (b) Possible answers include salt water, muddy/sandy water, chlorine and other substances in drinking water, soft drinks (e.g. water, sugar, carbon dioxide, flavourings), milk, packaged foods, brass, bronze and other alloys.
3. Nitrogen, oxygen, carbon dioxide, noble gases (e.g. helium, neon, argon), water vapour
4. Possible answers include the need to prepare a pure product in a reaction and that chemists need pure substances in order to study their properties.

Notes for Teachers

Additional examples where purity is needed

- Chemicals, such as colouring and flavouring, added to food must be pure.
- Drinking water needs to be free of poisonous chemicals (e.g. nitrates and pesticides that may leach from farms into streams and rivers).
- Water used to make soft drinks and canned foods. (Some time ago, a well-known brand of mineral water had to be withdrawn from the market as it contained traces of cancer-causing benzene. Cola drinks were withdrawn in India as the water used to make the drinks was contaminated with pesticides.)
- Aviation fuel. This is regularly tested to make sure it is not contaminated. Unlike a bus, the aircraft would crash if the engine were to stop.
- Palm oil and other vegetable oils. The oils must be free of copper when processed, otherwise they will be oxidised by the air and become rancid.

The danger of impure drugs

Two examples of the dangers of impure drugs are stated below:

1. *Tryptophan* is a substance used by the body to make healthy tissue. Some years ago, a cheap but impure quantity of this substance was sold by a chemical company for use in health food. The impurities caused irreversible harm to the human nervous system and thousands of healthy people were then forced to live out the rest of their lives on wheelchairs.
2. Fake and poor quality anti-malarial drugs are threatening efforts to control the disease in several African countries which could put millions of lives at risk. The counterfeit medicines could harm patients and promote drug resistance among malaria parasites. Refer to: http://www.bbc.co.uk/news/health-16588153

NE: Food safety programme in Singapore

- In Singapore, the Primary Production Unit under the Ministry of National Development ensures that there is a stable and adequate supply of safe, wholesome and quality meat, fish, fruits and vegetables.
- The Department conducts routine random sampling on imports from all sources as well as local productions to ensure that our vegetables and fruits are free from excessive residues of chemicals such as pesticides.
- Chemical contaminants such as pesticides and drug residues in our food supply can be detected and analysed in laboratories.
- For more information, visit the following website http://www.mnd.gov.sg/MNDAPPImages/About%20Us/Eating%20Safely%20-%20Living%20Well.pdf

Teaching pointers

2.2 How are Pure Substances Obtained? (page 15)

1. *Filtration:* To introduce filtration, you may show a tea strainer or a coffee filter and ask the class how they work. Then lead into the way filtration is carried out in the laboratory by demonstrating filtration, including how to fold a piece of filter paper.
2. Introduce the idea that the filter paper has small holes or pores and that only particles smaller than the size of the pores can pass through. Demonstrate filtration of sand and water. Sand particles are larger than the pores and are stopped by the paper. Water particles/molecules are smaller and so pass through the pores.
3. A solution of salt in water cannot be separated by filtration as the salt particles are smaller than the pores and so pass through the paper.
4. Other examples of filtration are:
   - Filtration units in fish tanks
   - Dust filters in air conditioners
   - Oil filters to remove unwanted particles from engine oil
   - Air filters to filter air used to burn fuels in engines
   - The use of filtration in the extraction of sugar from sugar cane. The sugar cane is first crushed to obtain the juice (a solution of sugar). The mixture is then filtered to separate the solid waste from the juice.
5. *Crystallisation:* You may demonstrate the crystallisation of copper(II) sulfate solution. Use copper(II) sulfate crystals that has been sitting on the shelves for some time as they look impure. Carry out crystallisation on these impure crystals to obtain 'clean' pure crystals. Discuss the change of solubility with temperature, the formation of a saturated solution and then the crystals.
6. Ask the class to suggest additional ways of obtaining more crystals from the cold copper(II) sulfate solution. (Possible answers include cooling the solution to a lower temperature in a refrigerator; heating the solution to evaporate more water and then allowing the solution to cool; allowing the solution to stand for several days so that water evaporates.)
7. *Sublimation*: Demonstrate the separation of iodine from sand by the sublimation of iodine. Because iodine vapour is harmful, carry out the demonstration in a well-ventilated laboratory or in a fume cupboard. Also ensure the evaporating basin is full of cold water to condense the iodine vapour.

(page 17)

Mystery Clue

It is mixed with smaller amounts of other substances (such as magnesium chloride).

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8. If 'dry ice' (solid carbon dioxide) is available, you may demonstrate how it readily sublimes. **Warning:** Do not handle dry ice with bare hands. This can cause severe burns due to rapid heat loss as the temperature of dry ice is very low.

   Two common uses of dry ice are:

   - To keep ice cream and similar foods cold
   - To simulate clouds or smoke on stages (by condensing water vapour in the air)

9. Carry out a word analysis on the terms 'anhydrous' and 'desalination.' (See 'Notes for Teachers' on page 15.)

10. *Simple distillation*: Discuss distillation (also referred to as simple distillation to distinguish it from fractional distillation) using seawater as an example. Water is distilled as it has a lower boiling point. Salt is not distilled as its boiling point is very high.

11. Comment on von Liebig and his condenser. You may photocopy the notes on page 20 and distribute to the class.

12. Briefly discuss desalination by means of distillation and reverse osmosis.

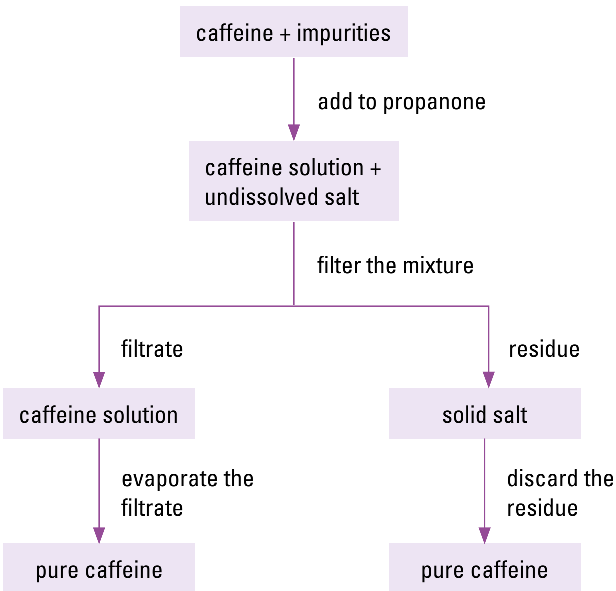
13. About 70% of the world's desalination capacity is dependent on the distilling process and 25% on reverse osmosis. Distillation of seawater is the main process used in the Middle East and North Africa. However, reverse osmosis is the process favoured in the United States and Singapore.

14. *Factional distillation*: In a mixture of ethanol and water, ethanol distils first as it has a lower boiling point than water. While it is distilling, the thermometer shows a constant temperature of 78 °C, which is the boiling point of ethanol. The slower the distillation, the more efficient is the separation. The ethanol obtained is up to 98% pure and will burn in air. You can demonstrate this experiment now or in Chapter 26 when teaching the production of ethanol by fermentation.

Theory Workbook (page 10)

• Exercise 2.2, Question 2: Purifying caffeine

Instead of writing answers as a sequence of steps, the teacher could ask students to devise a flow chart to show the steps. A possible flow chart is shown below.



Practical Workbook (page 37)

• **Experiment 2.1**

This is the first experiment involving the planning of an investigation. Spend some time discussing the tasks that need to be carried out. (Refer to the Lesson Plan for Chapter 2.) For impure salt, use rock salt or ordinary salt mixed with about 10% by weight of sand. Ensure that students are aware of the need to stop heating when there is still a little water left in the evaporating basin. This is to prevent the salt from jumping out of the basin. Supervise the students and ensure that they turn off the Bunsen burner before the salt becomes completely dry.

Suggested learning and teaching sequence

Period 1:
The teacher introduces the experiment and the idea of purification. Groups are formed with two to four students in each. The groups begin to plan the investigation using the list of apparatus and materials provided. The teacher can move from group to group offering guidance and hints.

Preparation before Period 2:
The groups complete their plans, discuss them with the teacher and make any necessary changes.

Period 2 :
In the laboratory, the groups carry out their experiment.

Follow-up activity (optional):
Groups prepare a written report and hand it in after about one week. Teachers should discuss with the class how to write up the report (see Practical Workbook, Section A.10). Teachers should let the class know which of the components should be included.

Chemistry in Society (page 21)

The Seawater Desalination Plant

Singapore is dependent on other countries for water. However, should these countries decide to stop their supply to us, we would have an inadequate supply of drinking water available. With that in mind, the government has built a desalination plant in Tuas, which uses reverse osmosis (*not* distillation) to obtain drinking water from seawater. The production of NEWater from wastewater also uses the process of reverse osmosis.

Exercise

1. Filter paper; filtration

   Similarities: Both involve the use of thin pieces of material with very small holes. Both involve separating solid particles found in water

   Differences: Reverse osmosis requires high-pressure pumps but filtration does not.

   In reverse osmosis, dissolved salt particles do not pass through the membrane, while in filtration, dissolved salt particles can pass through the membrane.

2. Distillation requires boiling to change the seawater to vapour. The boiling process requires oil as fuel. As oil is expensive, this will f the pure water produced more expensive. Also, Singapore does not produce oil and needs to import oil. This results in competition between using oil for the boiling process and using oil for other uses, such as fuels for transport vehicles and to produce chemicals which are required to make many products we use in daily life.

Skills Practice (page 22)

1. The salt particles are small enough to go through the pores in the filter paper.

2. The small amount of impurity is insufficient to saturate the solution and form crystals. This is the basis of the use of the use of crystallisation for separation. However, complete separation will only occur if the impurities are present in *small* amounts.

3. **(a)** Similarities: Both separate a liquid from a mixture. In both, liquids boil and vapours condense after leaving the flask.
(b) Differences: In simple distillation, one liquid is separated from a solid-liquid mixture. In fractional distillation, two or more miscible liquids with widely different boiling points are separated.

4. Solid-solid: Sublimation, paper chromatography, filtration plus crystallisation
Solid-liquid: Decantation, filtration, crystallisation, simple distillation
Liquid-liquid (miscible): Fractional distillation
Liquid-liquid (immiscible): Using a separating funnel

5. Possible answers are:

Filtration: Filtration of water at a water treatment plant.
Crystallisation: Obtaining salt from seawater.
Simple distillation: Preparation of distilled water.
Fractional distillation: Separation of substances in petroleum

6. Neon will distil first as it has the lowest boiling point. Krypton will distil last as it has the highest boiling point.

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Notes for Teachers

Filter beds

At a water treatment plant, water is filtered in large tanks called filter beds. A typical tank is about half the length of an Olympic-sized swimming pool and consists of three layers of materials. The top layer (30–40 cm) is filled with fine anthracite coal powder ranging in grain size from 1–3 mm. The middle layer (30–50 cm) is sand with a 0.5–0.6 mm grain size. The bottom layer (8–15 cm) is coarse sand or small stones ranging in size from 3–20 mm. At the bottom of the filter bed, there may be a porous layer of glazed tile blocks that supports the filter. As the water seeps down through the layers, tiny particle, as small as one micron are left behind.

Learning strategies: Word analysis

Many technical words in science are made of smaller parts joined together. Each part has a meaning. By knowing the meanings of the parts, students may be able to work out the meaning of new, unknown words. Use of this strategy also facilitates memory of the terms. A word analysis table is provided on page 458 of the Textbook to help students carry out word analyses.

IT Link

Picture showing the sublimation of iodine:
http://cwx.prenhall.com/petrucci/medialib/media_portfolio/text_images/FG13_16.JPG

Information on desalination and its use around the world:
http://en.wikipedia.org/wiki/Desalination

Reverse osmosis and NEWwater in Singapore:
http://en.wikipedia.org/wiki/NEWater

Teaching pointers

2.3 What is Chromatography? (page 22)

1. Analyse the term 'chromatography' and get students to work out its meaning. This is: 'chroma- = colour. 'graph' = write. 'chromatography' = writing with colour. Paper chromatography is a method of separating mixtures, especially mixtures of coloured substances. Then demonstrate demonstrate the chromatography process using a pen ink that consists of a mixture of coloured dyes. Write some words on a piece of paper, dry the ink, and then smudge it with water. Some separation of the coloured substances in the ink should occur. This is a primitive sort of chromatography. Alternatively, hold a strip of filter paper in a beaker of diluted blue or black ink. The ink spreads out into two or three different colours. The colours are due to the different coloured dyes present in the ink.
2. For the separation and identification of coloured substances, as shown in Figure 2.26, the assumption is that the dyes are the same if they are of the same colour and have moved the same distance up the paper.
3. Paper chromatography can also be used to separate colourless substances, such as mixtures of amino acids obtained from proteins. To make the spots visible, either in normal light or under ultraviolet light, the chromatogram is sprayed with a 'locating agent' such as ninhydrin.
4. Next, move onto the idea of R_f values. R_f values are useful in identifying substances without having to make comparisons on the same chromatography paper. For example, there are over 20 amino acids and it would not be practical to put all of them along the same starting line to identify an unknown amino acid. It is easier and more sensible to measure the R_f value and then identify the unknown by looking at known R_f values in a reference table.
5. **Note:** Emphasise that in a paper chromatography experiment, paper that is 2 cm long is never used. The example shown in Figure 2.25 is only to show how the R_f value is calculated.

Practical Workbook (page 39)

- **Experiment 2.2**

1. Choose four water-soluble black inks (preferably from different pens).
2. Different solvents are used to separate different kinds of mixtures. In this experiment, water is suitable for separating black inks (provided all the inks are water soluble). Otherwise a more effective solvent is butanol, ethanoic acid, water mixture in the volume ratio of 60 : 15 : 25.
3. As an additional investigation using paper chromatography (or as an alternative to Experiment 2.2), the separation of the colourings in a food can be carried out. Refer to the notes under Additional experiment in 'Notes for Teachers' on the next page.

Skills Practice (page 25)

(a) It is needed because sugars are colourless and cannot be seen on the paper unless coloured with a locating agent.

(b) No sucrose remained as there is no 'spot' for sucrose on the paper.

(c) Sucrose reacts to produce glucose and fructose as their spots have R_f values of about 0.9 and 0.56, which are close to those for these sugars.

Notes for Teachers

NE: Drug abuse

The Central Narcotics Bureau often conducts random checks to detect any misuse of drugs. The ease of the use of paper chromatography makes such random checks possible. Through the use of these tests, many drug abusers, athletes included, have been identified and arrested.

Enrichment: Use of paper chromatography to detect forgeries

- Chromatography can be used to detect forgeries. In 1983, the publisher of a German magazine paid S$8 million for diaries, which were supposed to have been written by Adolf Hitler, the Nazi wartime dictator.
- However, chromatography proved that the diaries were fakes. The ink used in the writing was shown to be a mixture of modern inks and not the document inks normally used between 1941 and 1943, when the diaries were supposed to have been written.
- Also, the paper contained chemicals that help make the paper whiter. The chemicals were identified by chromatography and shown to have been manufactured after 1955. The forger was arrested and sent to prison.

Additional Experiment 1: Separating coloured substances in a sweet

A worksheet for this experiment is given on pages 21 to 22. It can be photocopied and distributed to the class. Comments on this experiment:

- It is more convenient if a concentrated solution of the chocolate bean dye is prepared in advance of the lesson. A concentrated solution will enable the separated colours to be seen more clearly.
- An alternative to using a dye solution is to use a moistened paintbrush to remove some of the dye from a chocolate bean. Paint a spot on the paper. The spot should be larger than 5 mm across. If the colour is faint, dry the paper and paint on another layer of the dye.
- A suggested answer for Question 3 on the worksheet is: "The spots will dissolve in the solvent and be washed away instead of being separated into its components".

Additional Exercise 1: Looking at a student's research project

A worksheet for this activity is given on pages 23 to 24. It can be photocopied and distributed to the class. Here are suggested answers for the worksheet questions:

1. The student was investigating whether or not the coloured ink in a felt-tip marker is really a mixture of colours.
2. The individual colours of the markers are made up of a mixture of different colours.
3. He first cut four strips of filter paper. Then he drew a large dot near the bottom of each strip with ink from black, purple, green and blue felt-tip pens and placed the strips in a glass of water.
4. (a) The black dye separated into yellow, orange and blue. The blue separated into purple and turquoise. The green separated into blue and yellow and the purple separated into purple and red.
   (b) As each ink separated into at least two colours, he accepted his hypothesis.
5. As the solvent moves up the paper, the dyes in the ink travel/move up the paper at different speeds. Hence, the mixture of dyes separates.
6. E.g. If a person did not have a particular colour, such as green, he could make that colour by mixing blue and yellow.
7. Accept all possible answers.

IT Link

Video on the separation of inks using chromatography: http://cwx.prenhall.com/petrucci/medialib/media_portfolio/text_images/002_DEMOPAPER.MOV

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Teaching pointers

2.4 How Do We Check the Purity of Substances? (page 25)

1. Do not demonstrate the effects that impurities have on the melting point of a substance as melting is not formally studied until Chapter 3. Return to this topic when melting is being taught.
2. To show that a solid mixture melts over a range of temperatures, place some butter or margarine (which is a mixture of fats) in hot sunlight. From the gradual melting process, get the class to infer that butter or margarine must be a mixture.

Skills Practice (page 26)

Nitrophenol and butanamide because they melt just above 113 °C.
Note: Impurities lower the melting point of a substance.

Notes for Teachers

Reasons for determining melting points
A melting point is a characteristic physical property of a substance. There are three main reasons that chemists determine melting points of compounds. These are:

1. To *identify* an unknown compound by comparing its melting point with melting points of substances found in the chemical literature.
2. To determine the *purity* of a solid sample. A pure solid will have a narrow melting point range; an impure sample will have a broader melting point range and lower melting point than that given in the literature. (**Note:** The literature is not always correct.) This is often called the "melting point depression".
3. To *characterise new compounds*, so that other chemists will have a published melting point range to compare with.

The effect of impurities on melting point
Most of the solids in the laboratory are in crystalline form. Impurities affect the melting point of a solid by disrupting the forces that hold the solid together. Therefore, less energy is required to melt the part of the solid surrounding the impurity and hence the melting point is lowered. The more impure the solid is, the more the crystal structure is disrupted, and the less the energy needed to separate the particles in the solid.

Solving the Mystery (page 26)

A lake divided — how did a railroad affect the Great Salt Lake?

Infer

Because of its high salt concentration, most people easily float as a result of the higher density of the lake water.

Connect

E.g. Like the Dead Sea in the Middle East, water flows in but not out and the concentration of salt in the water is high.

Further Thought

E.g. Fractional crystallisation is a method of separating substances based on differences in solubility. A mixture of two or more solids is dissolved in a solvent (often water), heated and allowed to cool (as in ordinary crystallisation). The crystals will contain more of the least soluble substance. The crystals may not be 100% pure so the process needs to be repeated using the crystals obtained.

02 Chapter Review

Self-Management

Misconception Analysis (page 27)

1. **False** The filtrate may be a solution; the solid dissolved in the solution also passes through the filter paper.
2. **False** It can also be obtained by reverse osmosis.
3. **True** If two liquids have the same boiling points, they cannot be separated by fractional distillation.
4. **True** In a physical method, substances can be separated without changing into other substances.
5. **False** Mixtures melt and boil over a range of temperatures.

Practice

Structured Questions (page 28)

1. (a) Filtration, which separates the insoluble mud from the water (as in a water purification plant); or, distillation which separates the water from the insoluble mud. (Both answers are acceptable.)
   (b) Filtration, which separates the insoluble chalk; the copper(II) sulfate solution goes through the filter paper as the filtrate.
   (c) Fractional distillation as the substances in crude oil have different boiling points.
   (d) Use a separating funnel as olive oil and water are immiscible and form two layers when mixed.
   (e) Filtration, which separates the solid leaves from the water.
   (f) Crystallisation, which evaporates off the water to leave crystals of sugar.
   (g) Paper chromatography, which can be used to separate a mixture of coloured substances.

2. (a) crush the fruit → filter the crushed fruit to remove solids → heat the filtrate to evaporate most of the water → allow the hot solution to cool; citric acid crystals form → filter off the crystals and dry them
   (b) About –1 °C (a little below the freezing point of pure water, 0 °C)
   (c) Pure water, as citric acid probably has a much higher boiling point than water.

3. (a) Add the mixture of jelly crystals and sand to water and stir. The jelly, but not the sand, dissolves. Filter to remove the sand from the solution. Evaporate the solution to obtain pure jelly crystals.
   (b) Place a drop of concentrated jelly solution near the bottom of the chromatography/filter paper. Place the paper in a suitable solvent (water). As the solvent moves up the paper, coloured dyes in the jelly separate. If only one approved dye is used, there should be just one coloured spot on the chromatogram.

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4. (a) (i) To allow you to see clearly the location of the 'spots' for the metals on the paper.
   (ii) No. Electrode B contains one more metal than Electrode A.
   (b) 0.50
   (c) [Mark a spot for iron on the paper in line with the number '9' on the vertical scale.]

5. (a) Ink would dissolve in the solvent but the lead in pencil will not.
   (b) Orange colour in drink X and brown colour in chocolate B
   (c) No. A has four dyes and B has only one.
   (d) Mix the green colour in lime ice cream with the orange colour in drink Y.
   (e) Artificial dyes might be poisonous.

Free Response Question (page 29)

1. Step 1: Put Glauber's Salt in a beaker with water.
   Step 2: Stir to dissolve the salt.
   Step 3: Filter the solution to remove the sand.
   Step 4: Heat filtrate in an evaporating basin to evaporate as much of the water as possible.
   Step 5: Filter off the crystals and dry with filter paper.

2. Briefly:
   – Mix the impure camphor with ethanol.
   – Stir to dissolve the camphor.
   – None of the impurities dissolve.
   – Filter the mixture.
   – Heat the filtrate to evaporate most of the ethanol solvent.
   – Pure camphor crystallises as the hot saturated solution cools.
   – Filter off the crystals and dry them.

Extension (page 29)

1. Impurities are added to the pure silicon to change its electrical conductivity so that it can be used as a computer chip.

2. (a) Both produce ice when frozen. Both produce pure water when distilled.
   (b) Water is a pure substance while fruit juice is a mixture. Water melts and boils at fixed temperatures while fruit juice melts and boils over a range of temperatures.

3. Some information about Johann Glauber:
   - Born in Germany in 1604
   - Received no formal education
   - Moved to Amsterdam in the Netherlands in 1655 and worked as an alchemist; died there in 1670.
   - First to produce hydrochloric acid
   - Discovered another way to make nitric acid (from the reaction of potassium nitrate and sulfuric acid)
   - First to produce sodium sulfate (from Hungarian spring waters), which is named after him ("Glauber's Salt"). Sodium sulfate was used as a laxative. Today, it is used in the manufacture of paper, glass and detergents.

The following websites contain short biographies on Glauber:
http://en.wikipedia.org/wiki/Johann_Rudolf_Glauber
http://www.todayinsci.com/G/Glauber_Johann/GlauberJohann-Bio.htm

Notes for Teachers

Some information about Johann Glauber:

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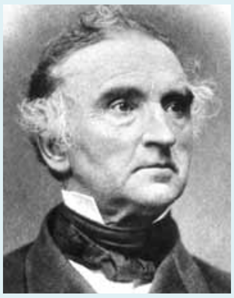
Short biographies on Glauber:
http://en.wikipedia.org/wiki/Johann_Rudolf_Glauber
http://www.todayinsci.com/cgi-bin/indexpage.pl?http://www.todayinsci.com/3/3_10.htm

Chemistry **Bulletin**

Baron Justus von Liebig (1803 – 1873)



Distillation and history: Baron Justus von Liebig (1803–1873)
The condenser used for simple distillation is also called the Liebig condenser, in honour of the 19th Century German chemist. From this, you might think that Liebig invented the condenser. He did not. Nobody knows who did invent it. Liebig developed this water-cooled condenser and made it popular.

Liebig's main work was in Organic Chemistry (see Theme Seven of the Textbook). He isolated several organic chemicals for the first time, including ethanol (alcohol) and trichloromethane (chloroform).

He is also known as the founder of 'Agricultural Chemistry'. He showed that certain elements, such as nitrogen, are essential nutrients for plant growth. He proved that as plants take in these elements from the soil, the soil becomes barren if nutrients are not replaced. This led to the use of natural and artificial fertilisers for the growth of crops.

Von Liebig also invented laboratory instructions and was one of the first chemists to organise a laboratory as we know it today. He also invented baby food as a substitute for mother's milk.

IT Link

Powerpoint slides showing the life and work of Von Liebig, including a photograph of his distillation apparatus and condenser (slide 33):
http://www.chem.uic.edu/marek/trips/JustusvonLiebig72dpi.pdf

Questions

When setting up distillation apparatus, give reasons for each of the following:

1. **The bulb of the thermometer is placed next to the side arm of the condenser.**
   In order to accurately measure the temperature of the gas passing into the condenser. The reading gives the boiling point of the liquid distilled.
2. **Cold water enters the *bottom* of the condenser and leaves from the *top*.**
   So that water fills the condenser. If it entered from the top, the water would flow straight through and would not cool/condense the vapour.
3. **The condenser slopes downwards.**
   So that the distillate/condensate can flow down into the receiving vessel.
4. **If the distillate has a low boiling point, the receiver is placed in a container filled with ice.**
   To be cold enough to get the distillate in the liquid state. Otherwise, the air temperature, being higher than the boiling point of the liquid would cause it to evaporate quickly.

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Additional Teaching Material

Additional Experiment 1: Separating the Colouring in a Sweet

Objective

- To separate the dyes in chocolate beans by chromatography

Apparatus and Materials

- glass rod
- packet of coloured chocolate beans
- toothpick
- 1% sodium chloride solution
- chromatography paper
- deionised or distilled water
- gas jar or large beaker (250 cm^3 or greater)

Key Skills and Processes

- **Practical skills:** following instructions, handling apparatus, observing
- **Thinking skills:** analysing, inferring

Safety Warnings

Coloured substances are added to foods to make them more attractive.

Paper chromatography is a method for separating and analysing small quantities of mixtures. In this activity, you will identify the colours of the dyes used in the sugar coating of chocolate beans.

Procedure

1. Make sure your hands and the bench or table where you are working at are dry.

2. Obtain a rectangular piece of chromatography paper. Make sure it fits into your container without touching the sides.

3. Draw a straight pencil line along one edge of the paper, about 2 cm from the edge. Lightly mark five equally-spaced pencil crosses along the line as shown in Figure (a) on the next page.

4. **(a)** Slightly moisten a brown chocolate bean with deionised or distilled water and rub it directly onto the first cross until an intense coloured spot is formed.
(b) Repeat with chocolate beans of four other colours.

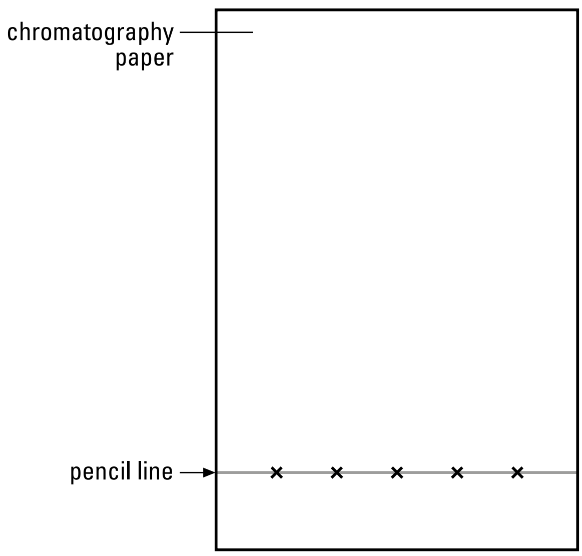

Figure (a)

! Small concentrated spots give better results.

! The spots should be slightly above the level of the solvent.

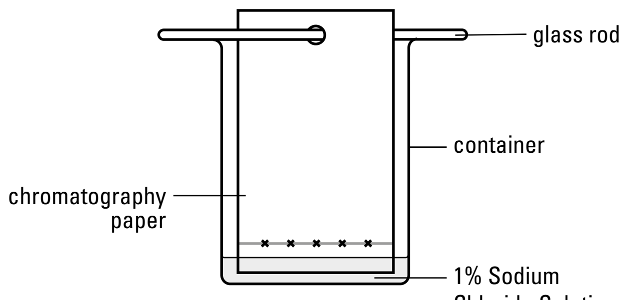

Figure (b)

5. Place 1% sodium chloride solution into the gas jar or beaker to a depth of about 1 cm. Then carefully hang the chromatography paper in the solution as shown in Figure (b) above.
6. Leave the container for 10 to 20 minutes until the dyes have been well separated on the paper.
7. Remove the chromatograph and leave it to dry.
   Examine the chromatogram and compare the pattern on it.

Results

Paste your chromatogram in the space provided.

Questions

1. Which chocolate bean, if any, contains only one dye?

___

2. Which chocolate bean contains the greatest number of dyes? How many does it contain? List the colours of these dyes.

___

___

3. Why must the spots on the chromatography paper be above the level of the solvent?

___

___

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Additional Teaching Material

Additional Exercise 1: Looking at a student research project

Objective

- To analyse and evaluate a student's research on the use of chromatography to separate dyes in a black ink

Strategy

- Doing a case study

The following website contains a report of a student's research project:
http://webcache.googleusercontent.com/search?q=cache:http://youth.net/nsrc/sci/sci023.html

Go to the website and scroll down to Research project Number 10 entitled 'Chromatographic Analysis of Colored Ink'. Use the information to answer the following questions.

1. What problem or question was the student investigating?

____

____

2. What hypothesis did the student make?

____

____

3. Briefly describe, in your own words, the procedure used by the student.

____

____

____

____

4. **(a)** What did his results show?

____

____

(b) Did he accept or reject his hypothesis?

____

____

5. Explain why the inks separate.

____

____

6. The student suggested applications of his results. Briefly describe one of these applications.

7. If you were to investigate the same problem as the student, would you do it differently? Describe how.

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