Chemistry

Mixtures: Chemical warfare

When scientists investigate samples of chemicals collected in the environment, there is often more than one substance present in the sample and the pieces must be sorted out before an effective analysis can even begin.

In this lesson you will investigate the following:

▪ How is a pure substance different from a mixture?
▪ What are some methods for separating and purifying the different substances in mixtures?
▪ Is black ink really black?

After this lesson you’re not going to feel as mixed up about mixtures!

This is a print version of an interactive online lesson. To sign up for the real thing or for curriculum details about the lesson go to www.cosmosforschools.com
It’s not often that scientists have to go to the front line of a war zone, but that’s what happened recently in Syria.

The government there, which is fighting in a civil war, had used poisonous gas against the rebels. The United Nations voted to stop the rebels, but before it could demand that Syria give up its chemical weapons the United Nations had to prove what was in them. That’s where the scientists came in.

Travelling in very dangerous areas where they could be shot at any time, the chemists moved through the war zone collecting various samples from where the gas had been used. Fortunately they did so safely and got the samples back to the lab.

The next job was to analyse the samples to see exactly what gas had been used.

They used a two-step technique called gas chromatography–mass spectrometry (GC-MS). The first step separates the sample into its components. The second step identifies the components by identifying signature chemical properties.

The scientists proved that the poisonous gas sarin had been used and so the United Nations was able to use that as proof to force Syria to destroy its chemical weapons.
List: Have you ever noticed that you are surrounded by pure substances and mixtures? List three things from around your home or school that you think might be pure substances and another three things that you think might be mixtures.

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<thead>
<tr>
<th>Pure substances</th>
<th>Mixtures</th>
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Classifying matter

Already today, your body has processed matter in the form of solids, liquids and gases: your breakfast, a drink and the air around you.

As described in the Introduction, scientists use their understanding of how matter is classified to investigate the presence of pollutants such as the deadly toxin, sarin.

All matter is made up of extremely tiny particles. These particles can be atoms of one type of element or two or more different elements that are chemically combined into a compound.

For example, gold is a pure substance composed of only gold atoms while distilled water is a pure substance composed of hydrogen and oxygen atoms chemically bonded together to form water molecules.

A mixture is a combination of two or more pure substances that can be physically separated.

For example, a soft drink is a mixture of water, sugar, carbon dioxide gas and other chemicals. Air is also a mixture, composed of nitrogen, oxygen, argon and other gases including carbon dioxide.

Question 1

Recall: Only elements are pure substances.

- True
- False
We can group mixtures further by classifying them into those that are **heterogeneous** and those that are **homogeneous**.

**Question 3**

**Summarise:** Based on information in the media clip, define the terms "homogeneous mixture" and "heterogeneous mixture" in the project space below. Give two examples of each type of mixture. You may wish to upload images of your examples in addition to naming them.
In liquid form, homogeneous mixtures are generally called solutions.

You may recall from a previous *Cosmos* lesson *Solutions: Bringing things together (029)*, that a *solution* is a homogeneous mixture in which one or more substances (the *solute*) are dissolved into another substance (the *solvent*).

Solutions are made up of elements or compounds mixed together at the molecular level.

Apple juice is a solution. The juice looks (and tastes) the same whether it comes from the top, middle, or bottom of the glass.

**Question 4**

**Discuss:** Do you agree or disagree with the statement “*All solutions are mixtures, but not all mixtures are solutions*”? Give a reason for your choice.
Question 5

Review: You have encountered lots of terms already in this lesson, including: pure substance; mixture; homogeneous mixture; heterogeneous mixture; atom; element; compound; solute; solvent; and solute.

Revisit these terms and then construct a detailed mind map that shows your understanding of how these terms are related.
Gas masks contain sophisticated filters to separate out toxic particles from the air to protect the wearer. Combustion engines, such as those in cars and buses, also contain filters. These filters separate out tiny carbon particles from the exhaust. Credits: Reuters / Mohamed Abdullah and iStock.

Separating mixtures

It is often important for human and environmental health that the components of a mixture are separated away from each other. As reported in the Introduction, scientists investigated mixtures suspected of containing microscopic particles of a lethal substance called sarin.

The combustion engines in cars and buses have been designed to separate out very tiny carbon particles and prevent them from polluting the atmosphere. A similar, more sophisticated, separation system can be found in the gas masks worn by the scientists in Syria.

Mixtures can be separated into their different pure substance components based on the physical properties of the components. Pure substances have unique physical properties such as different density, state of matter, melting point, boiling point and solubility. Scientists need an understanding of these different physical properties to be able to distinguish one type of particle from another.

Techniques used to separate mixtures rely on these differences in the physical properties of the components.
Filtration

Filtration can be used to separate insoluble solids from a liquid using a filter. The holes in a filter are usually too small to see, but solid pieces become trapped whereas the soluble components pass through.

Example: When a mixture of sand and water is poured through a filter paper in a funnel, the sand particles remain as a solid residue in the filter paper, while the water is collected in the beaker below as a liquid filtrate.

Filtration separates on the basis of differences in size and solubility in a solvent.

Evaporation
Evaporation is used to recover solid substances that are dissolved to form a solution by evaporating away the solvent.

Example: Salt can be collected from a salt water mixture by evaporation. The liquid water evaporates to leave the crystallised solid solute behind since water but has a much lower boiling temperature than salt.

Evaporation separates on the basis of differences in melting and boiling temperatures.

**Question 1**

**Explain:** Outline what happens to the particles in a liquid during the process of evaporation.

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**Simple distillation**

Simple distillation is an extension of evaporation. It is used to recover a liquid pure substance from a solution. The solution is heated to evaporate the solvent into gaseous form (a vapour) and then cooled to condense it back into liquid, which is then collected in a separate container.

Example: A mixture of salt and water is heated to just over 100°C in a special distillation flask. Since water has a much lower boiling temperature than salt, steam rises up and passes into a cooling tube which condenses the steam back into liquid water so it can be collected as distillate. The salt is left behind.

Simple distillation separates on the basis of differences in boiling temperatures.
Question 2

Sort: The following processes occur during the distillation of pure water from salty sea water. Sequence them into the correct order.

Condensing, Evaporating, Heating, Cooling
Flotation can be used to recover a solid or a liquid from another liquid depending on which components sink or float.

Example: If sawdust and sand are stirred into water, the sawdust floats and the sand sinks, because the sawdust is less dense than the water and the sand is more dense than the water.

Another example of this is if oil and water are stirred together. The oil will float on top of the water as it is less dense than the water.

Flotation separates on the basis of differences in density. A less dense component will float to the top of a liquid where it can be skimmed or poured off and a more dense component will sink to the bottom.

**Question 3**

**Categorise:** Identify the separation technique represented by the following images.

<table>
<thead>
<tr>
<th>Image</th>
<th>Separation technique represented</th>
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<tbody>
<tr>
<td><img src="https://via.placeholder.com/150" alt="Image" /></td>
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**Question 4**

**Analyse:** Identify the separation techniques you would likely need to use to separate a mixture of Styrofoam beads, sand and magnesium sulfate solution given the information in the table below. Explain your choices.

<table>
<thead>
<tr>
<th></th>
<th>Step 1: Styrofoam beads</th>
<th>Step 2: Sand</th>
<th>Step 3: Magnesium sulfate</th>
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<tbody>
<tr>
<td>Water soluble</td>
<td>no</td>
<td>no</td>
<td>yes</td>
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<tr>
<td>State of matter at 25°C</td>
<td>solid</td>
<td>solid</td>
<td>solid</td>
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<td>Less dense than water</td>
<td>yes</td>
<td>no</td>
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**Separation technique required – including explanation**

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Experiment: Separation of a mixture by simple paper chromatography

Background

The *Cosmos* magazine article *Inside Syria – the search for sarin* identifies a sophisticated separation technique known as gas chromatography (GC).

Chromatography is a separation technique based on how the components of a mixture interact with their surroundings.

There are many different types of chromatography but in each case the sample mixture needs to be dissolved, carried along by a solvent and dropped. Some components of the sample mixture interact more strongly with the surroundings and so travel at different speeds from other components in the mixture.

The inks in non-permanent black texta pens are often made from a mixture of different coloured pigments that can all dissolve in water. However, due to their different structures, these pigments are soluble by different amounts and so travel at different speeds.

Water acts as a solvent to dissolve the inks. The water carries the pigments along as it wets the filter paper and then drops them onto the paper at different places to create a uniquely coloured pattern for each texta pen.

*Did you know?*

Did you know that the water wets the paper because of a phenomenon called “capillary action”. It is essentially the same action that a tree uses to soak water up its trunk from its roots and into its branches.

Aim
To separate the mixture of coloured pigments present in black inks using paper chromatography.

Materials
- 1 filter paper disc
- 4 different brands of water-soluble black texta pens (labelled A, B, C, D)
- Pencil
- Plastic dropper
- 10 mL distilled water
- Optional extension – 10 mL salt water solution (10%)

Safety information
Students should wear a lab coat and goggles at all times.

Procedure
1. Using clean hands, fold the filter paper in half, then in half again, to make quarters.
2. Unfold the filter paper onto a clean, dry and flat surface – this will give you 4 fold lines on your paper.
3. Using the black coloured texta pens place a small dot (about 2 mm diameter each) on each of the four fold lines approximately 2 cm from the centre.
4. Write the letter corresponding to each black texta at the edge of the filter paper using the pencil.
5. Very carefully, use the plastic dropper to place one drop of water onto the centre of the filter paper and watch what happens. Record your initial observations in the project space below.
6. Once the water has stopped spreading, add another drop and record your next set of observations.
7. Add further drops of water, one drop at a time, waiting in between each drop for the spreading to stop. Record your final observations.

If you have time, you could repeat the experiment in exactly the same way but using salty water instead of distilled water.

Variables
*Independent variable* – different brand of black texta pen ink.
*Dependent variable* – distance travelled by each pigment in the ink mixture.

Question 1

List: Identify all of the controlled variables in this experiment.

Note: *The independent variable is what is being changed each time, the dependent variable is what you are measuring or testing and the controlled variables are all of the factors that remain constant throughout the experiment.*

Hypothesis
It is possible that different brands of black texta pen inks will contain different mixtures of pigments that travel at different speeds during the separation process.

Results
Question 2

Collect: Use the project space below to present your results. You should construct a table of results which best suits the data but you may also include photos, video or other representations.

Discussion

Question 3

Justify: Explain why you used a pencil to write the letter corresponding to each black texta at the edge of the filter paper (rather than a pen).

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Question 4

Assess: Explain whether or not you think separation of the mixture is taking place to the same extent for each brand of black texta pen. Use your results to support your answer.

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Question 5

Propose: Suggest what you might observe if the experiment was repeated to include a permanent black texta pen. Explain your reasoning.

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Question 6

Evaluate: Identify some limitations to the experimental design that prevent you from collecting more reliable and accurate data.

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Question 7

Evaluate: Suggest changes that you could make if you were to repeat this experiment, which address the limitations you identified.

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Conclusion
Conclude: Write a concluding statement that addresses both the aim of the experiment and the hypothesis.
As the only child of a cleaner and a builder, young Martin Boland never gave much thought to going to university. Martin had his sights set on becoming a fighter pilot in the Royal Australian Air Force.

So he studied chemistry and physics in high school in the hope that they would help get him into the air force. But Martin’s dreams were dashed when he was told he was too tall to fit into the ejector seats of a fighter jet. Nevertheless, inspired by the science officers he had seen on Star Trek, he decided to study chemistry at university.

Martin now calls chemistry “the great love of his life.” He is a lecturer of pharmaceutical and medicinal chemistry at Charles Darwin University in the Northern Territory. He also runs his own research lab, where he tries to figure out how to use native plants as medical treatments and how to make drugs last longer in the unforgiving hot climate of Northern Australia. Martin has even had the opportunity to work with Australia’s only nuclear reactor in Sydney.

But what Martin loves most is talking about science. He relishes every opportunity to share his scientific knowledge with the public and constantly takes part in various science outreach activities.

His background in chemistry also gives him a deep understanding of chemical weapons. Organic chemistry is the basis for most poisons and explosives, such as those used in Syria, Iraq, and Boston, says Martin. He hates to see chemistry being put to use in chemical warfare, and hopes it will one day be a thing of the past.

Outside the lab, Martin is a certified mountain bike and ski instructor, and stand-up comedian. He is also trying to fulfil his childhood dream of joining the air force by applying for the Australian Army Reserves.
Question 1

Research: Chemical agents can cause damage to humans either immediately, like mustard gas in World War I and II, or over a longer term, such as prolonged exposure to arsenic poison. However, for many years, researchers around the world have been working to develop therapeutic uses of such chemicals. Specific forms of both mustard gas and arsenic have useful anti-cancer properties.

Find out about one naturally occurring chemical agent that can also be used as a medical treatment. Examples include: snake venom, cone snail toxin, ricin from castor oil plants and scorpion toxin. Identify the source organism of the chemical, how the chemical is used by the organism (e.g. defence or attack) and in general terms how it might used as a medical treatment.