



Chemistry

Changing Matter: Chocolate from beans

Humans have been enjoying cocoa for millennia. Today, cocoa beans are physically and chemically changed into the buttery-smooth, melt-in-your-mouth chocolate we love so much.

In this lesson you will investigate the following:

- How is chemical change different from physical change?
- When does chemical change occur?
- Which white powder is in the jar?

This lesson will help solidify your understanding of chemical and physical changes!



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

Introduction: Matter changes (P1)



Who doesn't like chocolate? It's one of the oldest foods in the world, made from the beans of the cocoa plant. But it's not always been an everyday sweet treat. Hundreds of years ago the Aztecs used it in their religious ceremonies and even as money – 100 cocoa beans would buy you a slave.

Chocolate today doesn't have quite that value, although it is a huge industry. The long process of turning cocoa beans into a bar of delicious chocolate involves a complex sequence of chemical and physical changes – the main focus of this week's lesson.

After early explorers brought cocoa back to Europe it was, for many years, made into a drink. But in the 1820s a Dutch father and son experimented with cocoa's chemistry. Casparus van Houten – whose name you can still see on some chocolate bars – designed a process where he ground up the cocoa beans, made them into a paste and pressed them under great pressure until the fatty yellow cocoa butter oozed out. Then he added salts to the cocoa powder that was left to make it more soluble.

Then in 1847 the British chocolate maker J.S. Fry added a little cocoa butter back to the cocoa powder, along with sugar, and invented the world's first commercial chocolate bar. And that's pretty much the chocolate that you love today!

Read the full *Cosmos* magazine article [here](#).



Question 1

Describe: We enjoy chocolate in different ways – sometimes solid, sometimes liquid. If you heat chocolate – the heat of your body is enough – it melts.

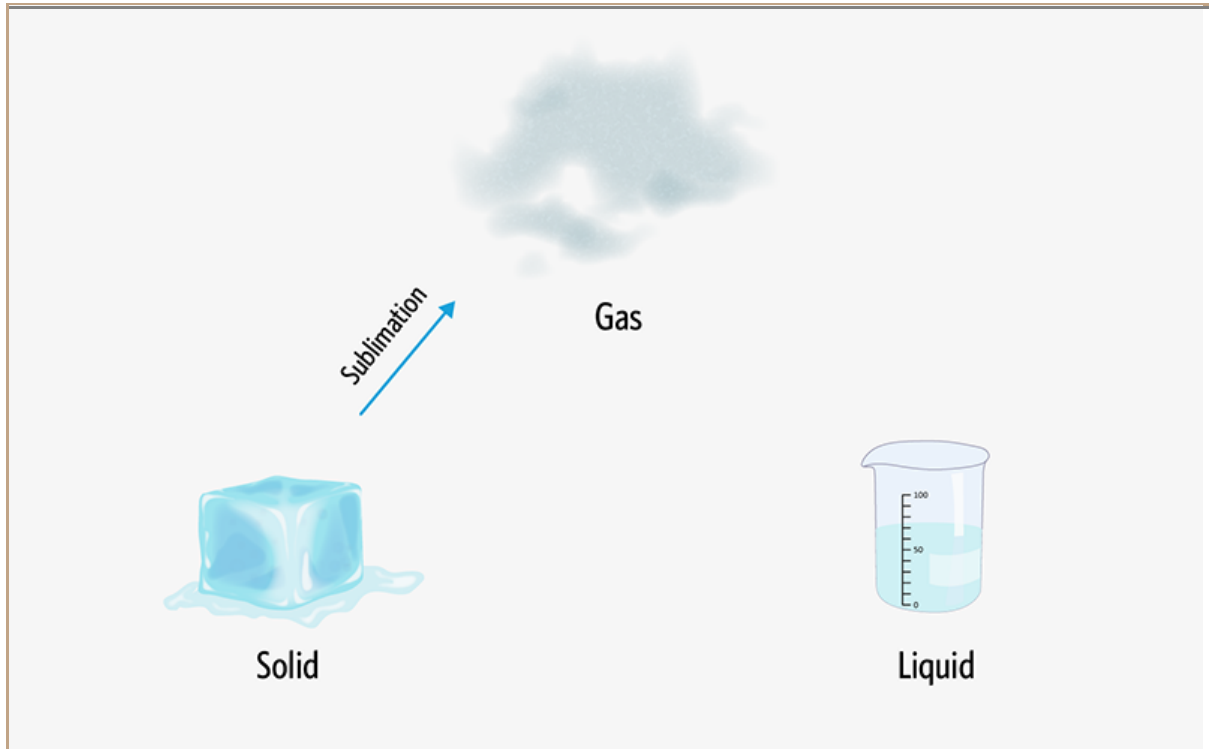
Review your knowledge of these sorts of state transitions by completing the diagram below.

Add arrows for each transition:

- Use **red** arrows to indicate heat energy is released and **blue** arrows to indicate heat energy is absorbed,
- Label each arrow with one of the following terms:

solidification | vaporisation | melting | deposition | condensation

One of the arrows and labels is already done for you.



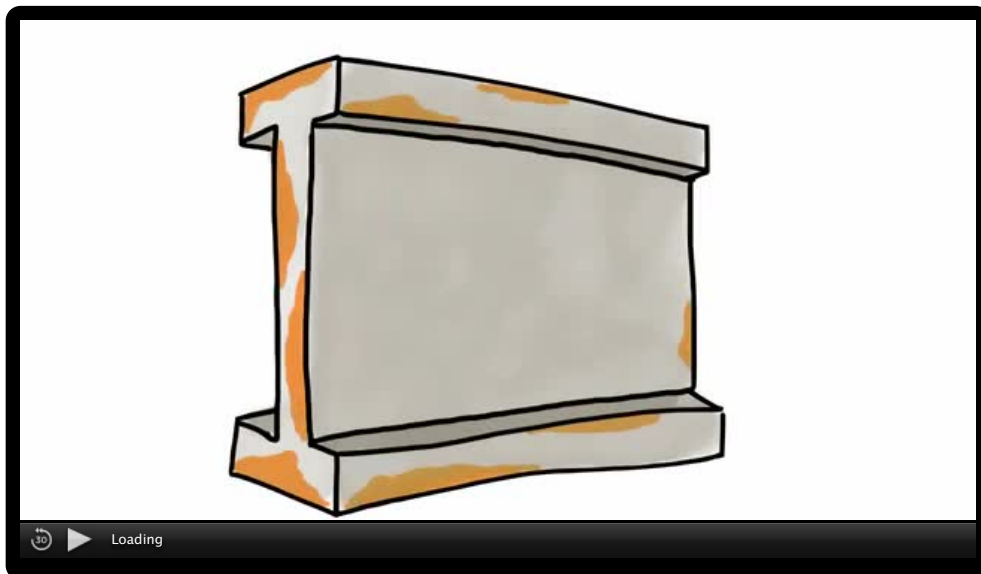
Gather: Matter changes (P1)

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Matter changes

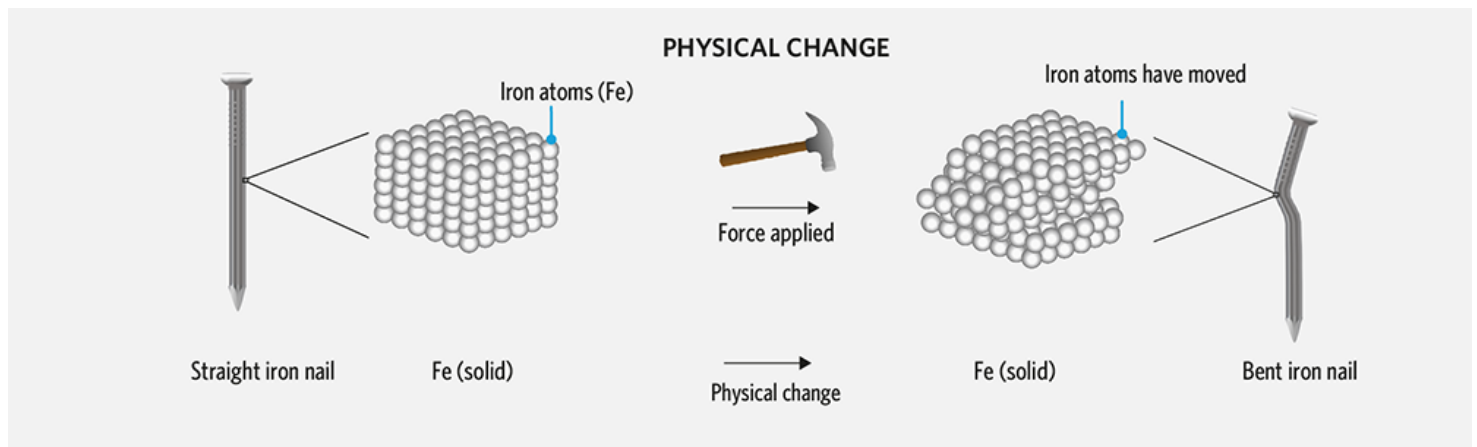
Matter is constantly changing: matches burn, biscuits crumble, cars rust and butter melts. Chemists divide these changes into two types – physical and chemical.



Physical change

During physical changes the particles that make up matter – atoms or molecules – shift to new positions or change their speed. If they gain energy the particles move more quickly and if they lose energy they move more slowly.

Bending a nail with a hammer is an example of a physical change.



The iron (Fe) atoms in the nail slide over one another to new positions as the nail is hammered (this is what it means to say that the iron is *malleable*).

There are the same number of particles before and after the change, and those particles were Fe atoms before the change, and are still Fe atoms after it.







The main characteristics of physical change are:

- the positions and/or energy of the particles change so that:
 - the matter changes shape, or
 - the matter is broken into smaller pieces or pieces of the matter form into larger pieces, or
 - the matter compresses or expands, or
 - the matter mixes with other matter, or
 - the matter's state (solid, liquid or gas) changes
- the types of particle do not change
- the change can often be reversed quite easily, but there are exceptions like shattering a vase or breaking an egg.

 **Question 1**

Identify: We are all familiar with many types of physical change in our daily lives – some examples are pictured below. Match the following terms to the pictures.

melting | tearing | dissolving | expanding | evaporating | splitting

 <input type="text"/>	 <input type="text"/>	 <input type="text"/>
 <input type="text"/>	 <input type="text"/>	 <input type="text"/>

 **Question 2**

Think: Select one of the pictures in the sketchpad above and describe why it is an example of physical change.

Hint: what is happening to the particles in the matter?



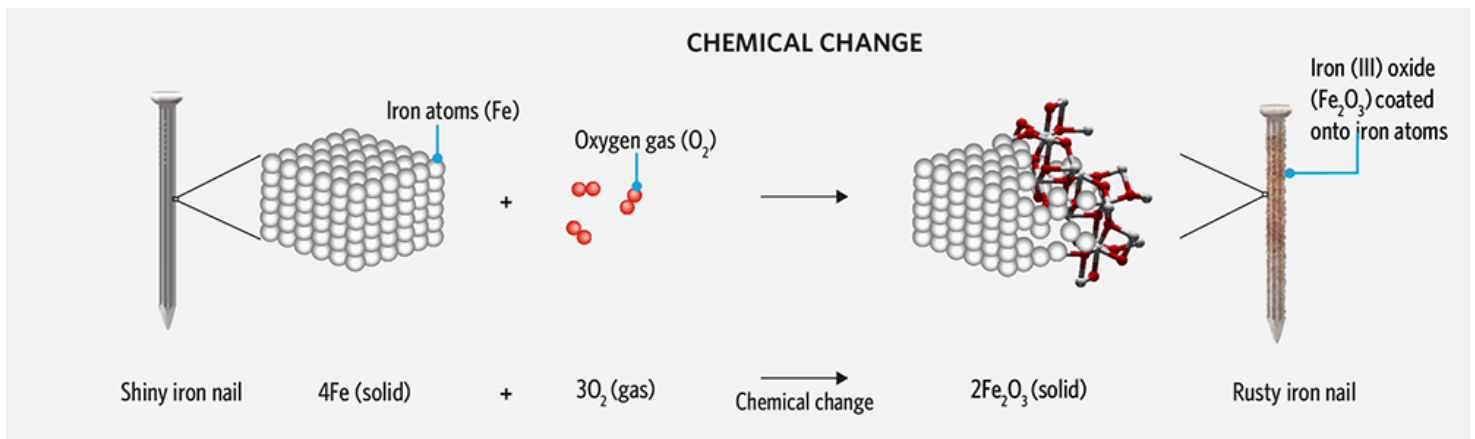
Did you know?

Traditional incandescent light bulbs produce light due to a physical change. As electrical energy passes through a wire, called the *filament*, the atoms in the metal vibrate so much that they release some of the energy as light and heat. When the electricity is switched off the filament cools down and returns to its original condition. These physical changes are repeated every time the light is turned on and off.

Chemical change

During chemical changes, chemical bonds in the matter are broken and new bonds are formed. The total number of atoms always stays the same, but the number and type of molecules may change.

An example of a chemical change is the reaction of iron with oxygen to produce rust. The reaction for one type of rust is illustrated below.



See how an entirely new substance is formed?

And the number of particles changes too – from seven (four iron atoms and three oxygen molecules) to two (two Fe_2O_3 units).

The main characteristics of chemical change are:

- some or all of the substances present at the beginning of the change are not present at the end, and new substances are formed
- the new substances have different chemical properties from the original substances – they often have different physical properties too
- the change usually cannot be easily reversed.

Examples of chemical change include *corrosion*, such as the rusting of iron nails, and *combustion*, such as the burning of fuel in a fire. One type of chemical change that you may not know is *thermal decomposition*, where one substance is broken down into at

least two other substances by heat energy.

Watch the example of thermal decomposition, of sugar, in the video below.



Question 3

Observe: You now know that in chemical changes some substances disappear and new ones are formed. What changes can you see in the video that suggest new substances are forming?



Chemical reactions leave "footprints" that generally make it easy to recognise that chemical change has taken place.

The evidence to look out for includes:

- changes in colour,
- changes in temperature,
- formation or disappearance of a solid,
- production of a new gas, including fizzing, and
- release of a new odour.

Question 4

Identify: Type Xs into the table below to indicate observable evidence that the reactions shown in the video involve chemical change.

Reactants of chemical reaction	Change in colour	New gas formed	Formation or disappearance of a solid
Cola and chlorine			
Caesium and water plus a pH indicator			
Copper and iron sulfate			
Mercury thiocyanate and heat			



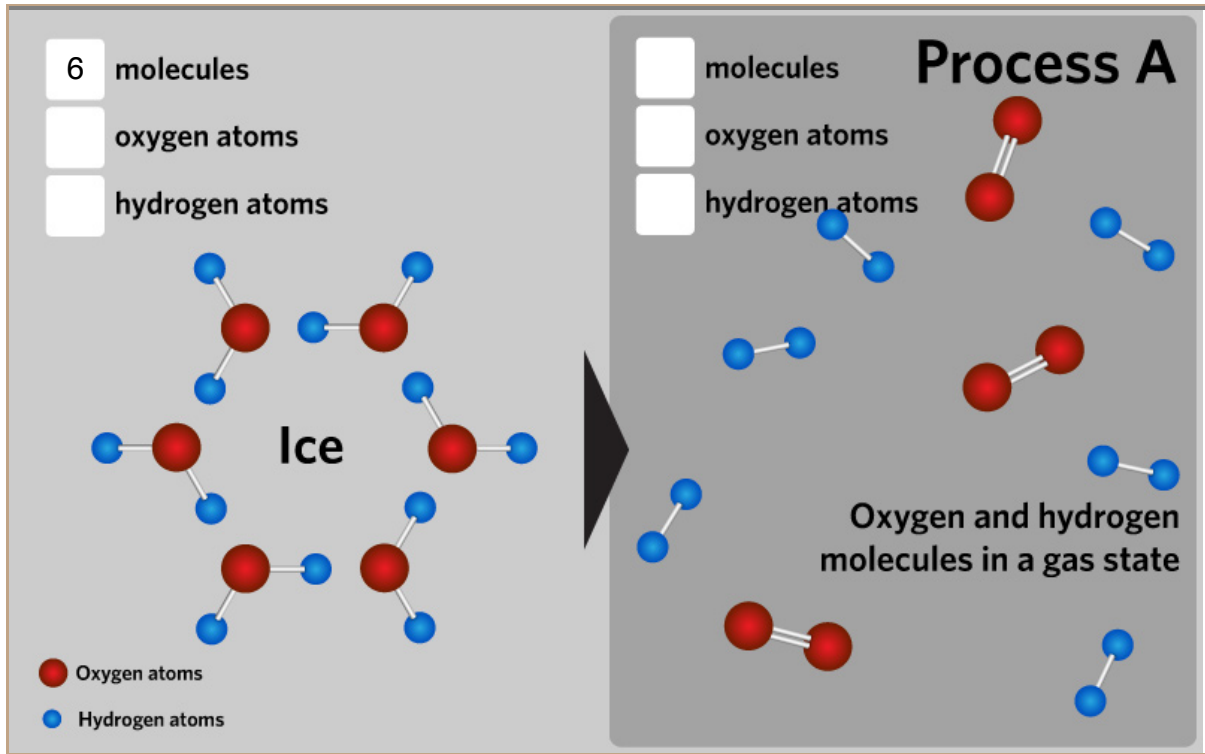
Did you know?

Foods have recommended storage conditions and expiry dates because slow chemical processes occur within them. After the expiry date a significant portion of the ingredients may have undergone chemical change by reacting with the air or other ingredients in the food.

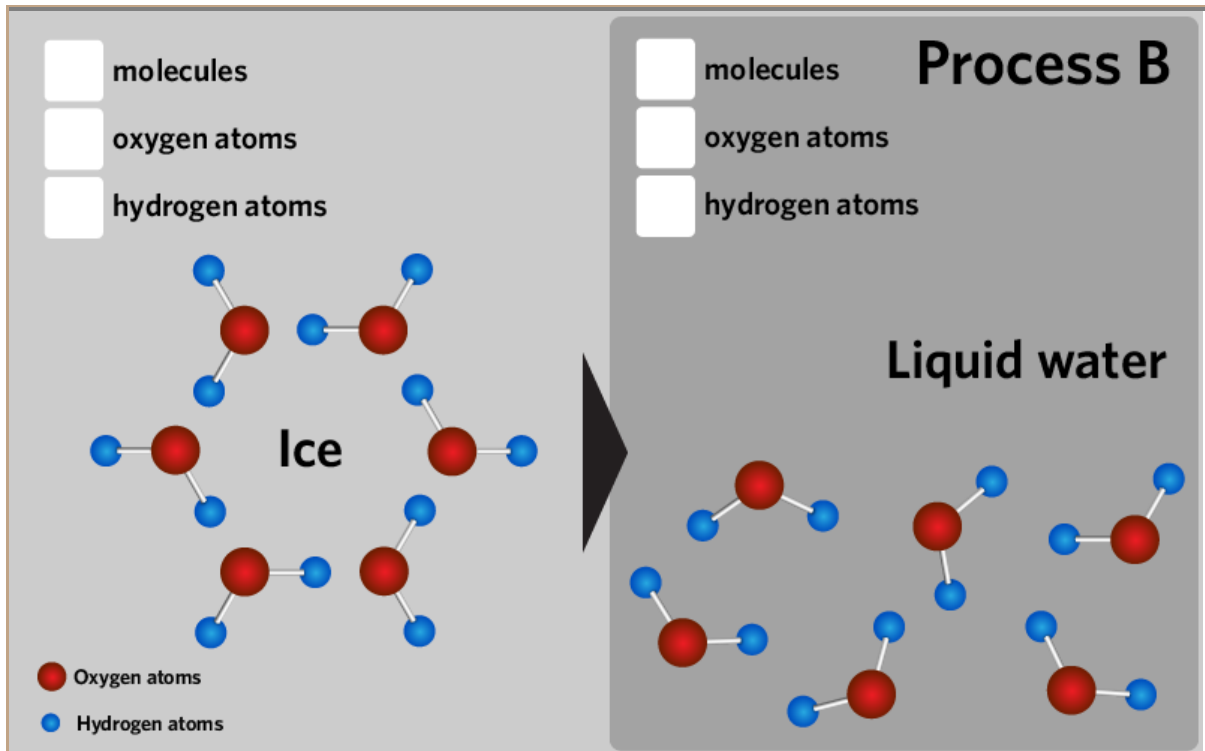
Comparing physical and chemical changes

 Question 5

Calculate: The diagrams below illustrate two processes that involve changes to the same starting material – ice. Count the number of molecules, oxygen atoms and hydrogen atoms that are present before and after each change and enter each number into the sketchpad.



 Question 6



 Question 7

Think: Decide which of the following sentences is *false*.

- Process B occurs when ice cubes are left out in a warm room.
- The number of oxygen atoms stays the same in both processes.
- New types of molecules are created by Process B.
- Process B is an example of a physical change.

 Question 8

Classify: By comparing the number and type of molecules present before and after the change, determine whether Process A is a chemical or physical change. Give reasons for your answer.

Process: Matter changes (P1)



Beans to chocolate

There's a lot of work between a cocoa pod on a tree and the chocolate you buy at the shop. Now we look at some of the changes in that long process, as well as some further changes you can make with the finished chocolate. But first a quick test on chemical and physical changes...

Question 1

Distinguish: Type Xs into the table columns below to classify each of the changes listed as physical or chemical.

Description of change	Physical change	Chemical change
Boiling water		
Breaking a glass		
Burning wood		
Cooking an egg		
Crushing a can		
Dissolving coffee in water		
Exploding fireworks		
Metabolising food in the body		
Milk going sour		
Mixing baking soda and vinegar to produce carbon dioxide gas and a salt		
Mixing sand and water		
Rusting of iron		
Shredding paper		

The art of making chocolate

The *Cosmos* magazine article "Unwrapping the secrets of chocolate", referred to in the introduction, describes the first stages in the complex process that transforms the beans of the cocoa tree (*Theobroma cacao*) into chocolate.

The video on the right shows this process in action.












Question 2

Classify: Watch the video and then:

1. number the steps in order, and
2. classify each step as a physical or chemical change by circling the appropriate label.

The first step has been completed for you.

 <p>order:..... physical chemical</p>	 <p>order:..... physical chemical</p>	 <p>order:..... physical chemical</p>
 <p>order:..... physical chemical</p>	 <p>order: 1..... physical chemical</p>	 <p>order:..... physical chemical</p>
 <p>order:..... physical chemical</p>	 <p>order:..... physical chemical</p>	 <p>order:..... physical chemical</p>

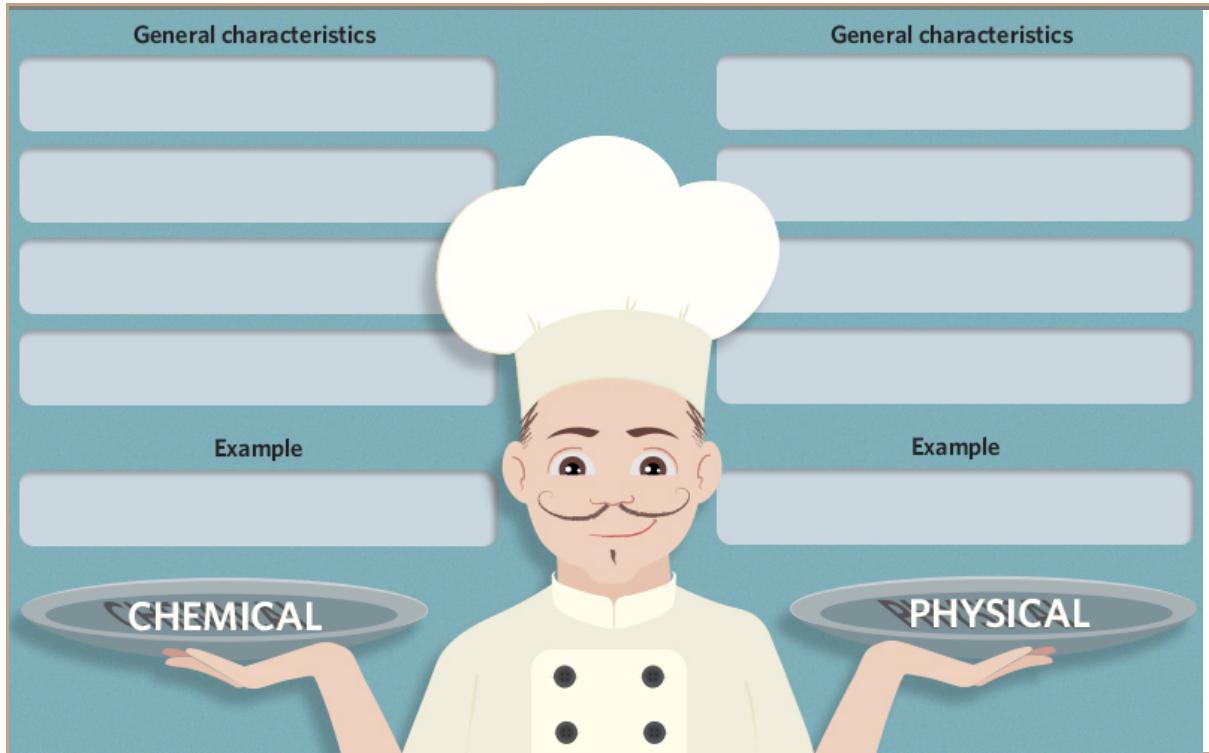
 **Question 3**

Summarise: Listed below are seven general characteristics of physical and chemical changes, and one example of each.

Type each item into its appropriate category on the correct tray in the sketchpad.

new atomic bonds | often easy to reverse | no new substance | rotting
same atoms | usually hard to reverse | flatten | new substance | same molecules

Hint: one item goes on both trays.



The sketchpad features a central chef character with a white toque and a mustache, wearing a light green chef's coat. He holds two silver trays: the left one is labeled 'CHEMICAL' and the right one is labeled 'PHYSICAL'. Behind him are two identical columns of input fields. Each column has four rounded rectangular boxes for 'General characteristics' and one for 'Example', all set against a teal background.

Did you know?

Did you notice that the scientific name for the cocoa tree, *Theobroma cacao*, has "cacao", not "cocoa". "Cacao" is the Spanish name for the plant and closer to the original Mesoamerican name. The English "cocoa" probably started as a mistake, but it caught on and stayed!



Question 4

Research: Do you love eating chocolate chip cookies? Did you realise that baking biscuits is really just a chemistry experiment at home? Prove it for yourself...

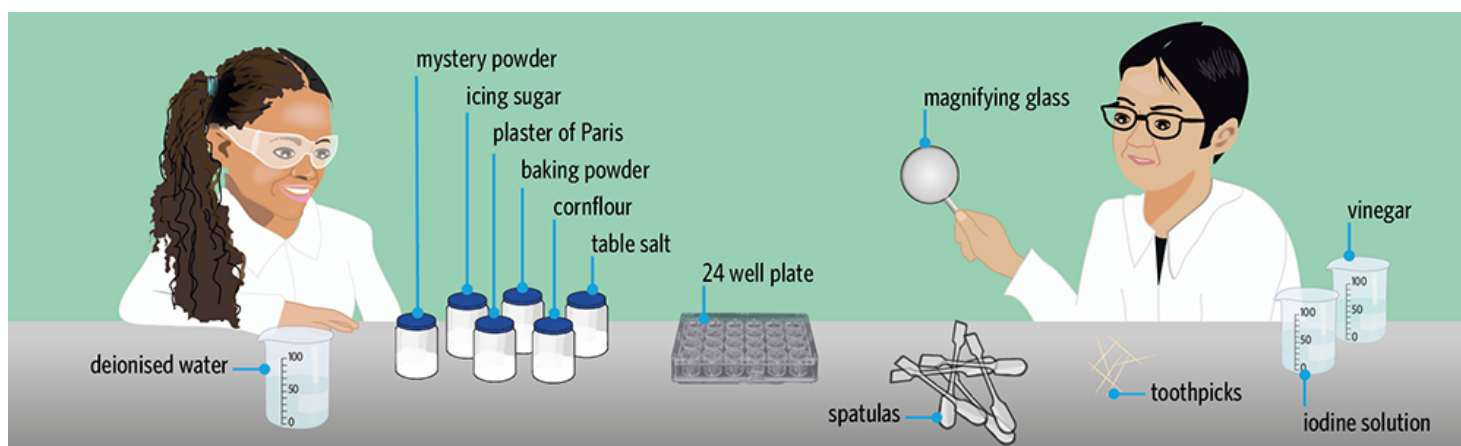
1. Locate two or three examples of your favourite chocolate chip cookie recipe on the internet or from a recipe book.
2. Photograph, scan, or copy and paste the methods into the project space below. You may notice that there are many similarities between the methods.
3. Annotate the recipes to indicate which steps involve chemical and physical changes.

Question 5

Create: After comparing the recipes from the last question, design your own! Create a method using what you have learnt about physical and chemical changes during this lesson. You may need to conduct some additional research of the types of ingredients and how they affect the final product. [Here is an excellent website to inspire you.](#)

Apply: Matter changes (P2)

Experiment: Puzzling powders

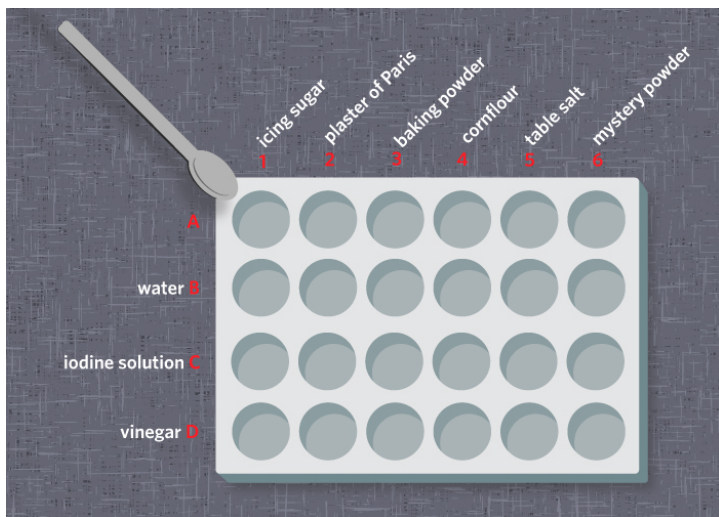


Background

Last week, while your teacher was cleaning out the supply cupboard, they came across an unlabelled jar of white powder. Your teacher knows that the following substances should have been stored in the cupboard: icing sugar, plaster of Paris, baking powder, cornflour and table salt. You have therefore been tasked with helping to identify the powder so that your teacher can confidently relabel the powder and use it in future.

Aims

To investigate the chemical and physical changes occurring when a number of white powders are mixed with water, iodine solution and vinegar and to use your results to deduce the identity of a mystery white powder.



Materials

- 5 white powders: icing sugar, plaster of Paris, baking powder, cornflour and table salt
- 1 mystery white powder
- 24-well plate marked with the letters A, B, C and D and the numbers 1-6
- Magnifying glass or hand lens
- 6 small spatulas, one for each white powder
- Deionised water
- Iodine solution
- Vinegar
- 24 toothpicks, one for each test

Procedure

1. Using a small spatula, add the same small quantity of icing sugar to each of the four wells in Column 1 (add enough to just cover the bottom of the well). Then add the same quantity of plaster of Paris to each of the wells in Column 2 and continue with the remaining powders, ending with the mystery white powder in Column 6.
2. At Station A:
 - a. Use the magnifying glass to closely observe each of the 6 dry white powders in Row A of your 24-well plate.
 - b. Record your detailed observations in the Results section below. You should include a detailed description of the colour and texture (crystalline, finely powdered, etc.). *Hint: a powder might appear white at first but on closer inspection it may in fact be more accurately described as yellowish-white.*
3. At Station B:
 - a. Using a dropper, add 20 drops of water to each of the 6 wells in Row B of your 24-well plate.
 - b. Using a clean toothpick for each well, stir gently and record your detailed observations in the Results section below.
4. Repeat Step 3 for the iodine solution at Station C and the vinegar at Station D, using Rows C and D of your plate and recording your observations in each case.

Results

Question 1

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, videos or other representations.

Discussion

 **Question 2**

Justify: Explain why you needed to add a similar quantity of white powder to each well.

 **Question 3**

Justify: Explain why you used a different toothpick for each test.

 **Question 4**

Analyse: Which of the white powders changed chemically when mixed with water?

 **Question 5**

Analyse: Which white powder neither physically changed nor chemically changed when mixed with vinegar?

 **Question 6**

Generalise: What evidence did you observe that a chemical change occurred when the white powders were mixed with iodine solution?

 **Question 7**

Deduce: Identify the mystery powder you were given. Use your results to support your answer.

Conclusion

 **Question 8**

Conclude: Write a concluding statement that addresses the aims of the experiment.

Career: Matter changes (P2)



Brought to you by Edith Cowan University

Just like Willy Wonka, Joseph Atallah runs a chocolate factory. However, unlike Willy Wonka, Joseph doesn't need Oompa Loompas to make chocolate – he relies on science.

When Joseph was at school he had no idea what he wanted to do, but he had a science teacher who saw that he was talented at chemistry. Joseph enjoyed chemistry and found that he could easily picture chemical reactions in his mind. He went on to get a Bachelor of Science degree followed by a Graduate Diploma in Food Science.

Joseph is now the chocolatier for Kimberley Chocolates in Sydney. Ironically, he wasn't a fan of milk chocolate – that is until he started making his own. He strives to create the perfect chocolate, which requires the right combination of smoothness, melt-in-the-mouth feel, and flavour.

Joseph says that chocolate is something that he, like many other people, is seduced by. The cocoa beans used to make chocolate contain hundreds of chemicals, including those that can influence our mood for the better. One, phenylethylamine, triggers the release of dopamine in our brains. The feeling of "falling in love" has been attributed to this chemical.

Understandably, Joseph enjoys his job and looks forward to arriving at work in the morning. The only thing he doesn't like is the mess. Outside of work he loves to kayak on Sydney Harbour and to cook – because of course he has to eat something other than chocolate! Although, when asked if it's possible to ever eat too much chocolate, he replies "never."



Question 1

Describe: Food scientists apply the results of a wide range of sciences – including chemistry, physics, microbiology and engineering – to the practical task of improving how the foods we eat are produced and preserved. Food chemists also use their understanding of chemical changes to develop better foods, as illustrated by Joseph and his search for the perfect chocolate.

Think of two food products that you enjoy eating and propose how an understanding of science might be relevant to developing and marketing these products.



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