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The Nature of Matter Curriculum Map

The subject is broken down into bite-sized activities that can be performed in a classroom setting as well as by students at home. Some are quick experiments; others include observations over many weeks. All are unified by explaining how matter interacts with other matter, how phases are changed by external influences, also how all that matter matters to us.

The core of understanding phases of matter is to understand the Particle Theory. This theory and its many versatile applications are explained in this curriculum.

List of Skills & Assessments

- At a Glance
- Teacher Assessment Rubric
- Student Assessment Rubric

Introduction

- Materials List
- Introduction to Experimentation
- Introduction to Experimentation Student Sheet
- Matter Dictionary

Lesson 1: Review of the States of Matter

- Teacher Notes
- Matter Matters: What's the Matter?
- Matter Matters: Matter Around You
- Classify With Class!

Lesson Two: Introduction of Matter - Properties and External Influences

- Teacher Notes
- Let's Get Some Heat!
- Hot Calculations
- The Pressure
- Pressure Worksheet
- Rise and Shine
- Rise and Shine Worksheet
- The Matter Game
- The Matter Game Worksheet
- That's Massive!: Mass, Volume, Density (Why Do Ships Swim?)
- Oily Icing
- Just Hot Gas: External Influence of Temperature on Gaseous Matter
- Just Hot Gas Worksheet
- Press It!: External Influence of Pressure on Density (Compressibility)
- The Swirl of Hot Color: Influence of Temperature on Solid and Liquid Matter
- The Swirl of Hot Color Worksheet
- Some Honey, Honey?: Viscosity Experiments
- Some Honey, Honey?: Viscosity Experiments Worksheets 1 & 2

Lesson Three: Matter Changes in the Classroom – Physical Changes

- Teacher Notes
- Let's Get Changed: Exchanges Between States
- Let's Get Changed: Exchanges Between States Worksheet
- Creating Clouds 1
- Creating Clouds 2

- Creating Clouds 1 and 2 Worksheet
- The Cloud Game
- The Cloud Game Worksheet
- Slightly Sublime
- Slightly Sublime Worksheet
- CO2 Fun
- CO2 Fun Worksheet
- Making a Fire Extinguisher
- Crystal, Crystal on the Wall

Lesson Four: Matter Changes in the Classroom – Chemical Changes

- Teacher Notes
- Chemical Creation of Gases and Heat
- Chemical Creation of Gases and Heat Worksheet
- React-it
- React-it Worksheet
- Black Sugar Snake 1
- Black Sugar Snake 2
- Matter Waste: Environmental Impacts of Reactions

Lesson Five: Mixtures and Solutions

- Teacher Notes
- Mix It, Shake It, Separate It: An Introduction to Miscibility
- Mix It, Shake It, Separate It Worksheet
- Solu-What?: An Introduction of Solute/Solubility/Concentration & Sugar-Gro'
- Solu-What? Worksheet
- Solu-Solubility - a poem

- Dio-mio-Iodine
- Dio-mio-Iodine Solvent – Solubility Worksheet
- They Live in the Jungle
- Do-It-Yourself Precious Gemstones
- Tensing Surfaces: Liquid/Gas Interfaces
- Un-tensing Surfaces
- Bubble-icious
- Mixing Oil and Water: Liquid/Liquid Interfaces
- Muddy Hell: The Science of Soil Erosion: Liquid/Solid Mixtures
- Muddy Hell Worksheet
- A Little Fizz to Freeze: Liquid/Gas Mixtures
- Smoking Mirrors: Gas/Solid Mixtures
- The Needle in the Haystack: How to Separate Mixtures
- The Needle in the Haystack Worksheet

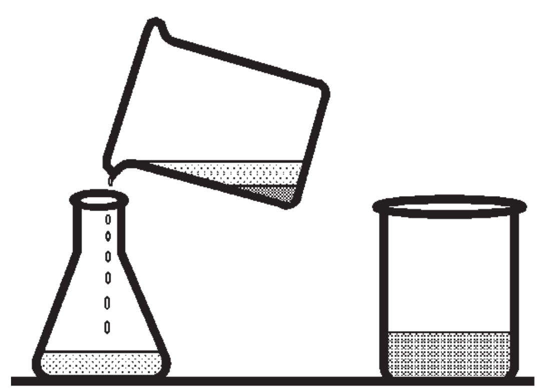
Teacher Notes:

Mixtures and Solutions

In nature, we often find matter not as a single substance, but in mixtures. A simple mixture is the one we walk through and breathe in every day: Air. Air is a mix of varying amounts of over a dozen different gases. The main component of air is nitrogen. Approximately 78% of our air is nitrogen, N_2. This is very advantageous for us since it is an inert gas. It does not generally react at room temperature, is non-flammable, and non-toxic. Slightly less than 21% of our atmosphere is oxygen, O_2. This gas allows us to walk around outside water, and still oxidize carbon (food) in our cells. It is also, together with hydrogen, one of the components of water, H_2O. The third most abundant gas in our atmosphere is Argon, making up less than 1% of the volume of the air. It is a single-atomic gas. The main reaction product of organic oxidation is carbon dioxide gas. The level of CO_2 is currently at about 0.033%. During the times of the dinosaurs, the level was much higher, and scientists calculated that the weather was tropical all around the globe, with no icecaps.

Other simple mixtures are sea water. A multitude of salts, like the table salt sodium chloride, NaCl, dissolve in water. This is a mixture of a solid and a liquid. In this case, the solid dissolves in the liquid. This just means that the atoms of the solid can fit in between the liquid molecules. The solid does not vanish, we just cannot see it anymore. The sand at the bottom of the sea creates mud. This is a mixture of a solid and a liquid where the solid does not dissolve in the water. We can also mix liquids, for example, water and alcohol. Some liquids do not mix. The two liquids are "immiscible." Oil and water is such an example. Solid mixtures are, for example, steels or amalgams. They combine different atoms (mainly metals) into a uniform product that we call an alloy. Other examples of solid mixtures are rocks and sand. Rocks are also crystallized liquid. The center of our earth is hot enough to melt even stones. Due to the motion of tectonic plates, some stones get pressed towards the center of the earth, while other material emerges elsewhere. Most of the matter from this melted mixture hardens (crystallizes), forming solid mixtures. Rocks as well as metals often contain many different types of matter frozen in place together. Sands are ground stones. A simple method to separate rocks by shape and size is to sieve them. Other methods such as sedimentation make use of material density.

In this section, students will learn to determine whether materials in every day life are single phase materials, or whether they are mixtures. They will be able to explain what mixtures are, and determine the contents of materials. The mixtures analyzed include milk, sew water, smoke, fog, pop, tar sand, paper, clay, and gold. The students will distinguish between different colloidal states of mixture (microscopically separated components) and solutions (atomically mixed) mixtures. They will classify substances found at home as pure substances, solutions or mechanical mixtures.



Mix it, Shake it, Separate it

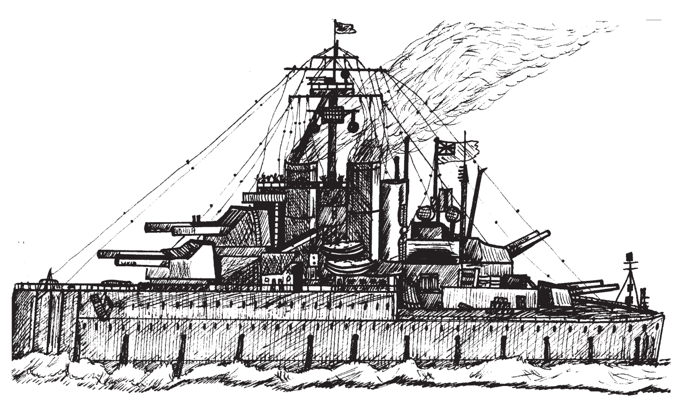
An Introduction to Miscibility

Mixtures of matter are all around us. We can mix gases in gases. Air is a mixture of more than a dozen different gases. We breathe all that mixture in every day. The main gas in the atmosphere is called nitrogen. When we mix liquids and gases, we can have fog (water in air) or a fizzy pop drink (carbon dioxide gas in sugary water). A combination of gas and solids is smoke (air and dust). Clay and mud are mixtures of liquids and solids. The following table contains some examples of mixtures.

Mix ⬇ into ➲	Gas	Liquid	Solid
Gas	Air	Pop, soap bubbles	Hydrogen storage in metal hydrides
Liquid	Fog	Alcohol in water, oil in water (e.g. mayonnaise)	Water in a sponge, ground water, tar sand
Solid	Smoke	Clay, salt water	Steel (mix of different metals)

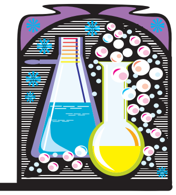
Cool Facts: Gold is never really pure gold. Those juicy gold nuggets might look like gold. They probably are also mainly gold. But they always contain trace amounts of silver, copper, and/or platinum. This is a mixture of one solid in another. It contains several elements. A mixture like this is called an "alloy." Metals are seldom pure. Most metals contain other elements. All these mixtures are alloys. Engineers and scientists produce special alloys. Stainless steel, for example, is iron or nickel alloyed with other elements. It improves the usefulness of steel by making it oxidation resistant. Other alloys become harder or more flexible due to this kind of matter mixing.

In fact, selecting the wrong alloy often results in disaster. In the first half of the last century, many welded ships broke apart in cold waters. The chosen steel alloy became brittle and broke like glass. The most notable were the US Liberty class ships. Some of them even broke in harbor.



Mix it, Shake it Separate it

Worksheet



Objectives:

- Determine the phase and mixture of materials you know.

Equipment:

- Different solids and liquids you find in your kitchen or the classroom.

Procedure:

Take a look at the list exercise below, and fill in the blanks. Find material properties from the internet for samples not available to you. Add more materials that you find in your classroom. One example is given for you. Most of the following mixtures are colloids.

1. Milk is a liquid/liquid mixture of water and oil. The small droplets of oil make the water appear white.

2. Smoke is a ____________________mixture of ______________ and _________________. The soot particles darken the air.

3. Clouds are a _____________________ mixture of ___________________ and _____________ UV light is not stopped by clouds, we can still get sunburn even with a cloudy sky.

4. Pepsi (or Coca Cola) is a _______________________ mixture of ___________________ and _____________________. It is a fizzy drink. The water has been further treated with sugar, sweeteners, artificial flavors, colors and acid. This is the only solution in all these examples.

5. Blood is a _______________________ mixture of __________________ and _______________. The solid cells that make our blood appear red contain iron. When iron oxidizes, it gets dark brown. So does blood in air. It is the same reaction.

6. Tar sands are a _________________ mixture of ____________________ and ___________. Separating the oil from the sand requires vast amounts of energy, and produces a heavy environmental footprint.

7. Find your own examples: ________________ is/are a ___________________ mixture of ___________________ and ______________________.

Solu-what?

An Introduction of Solute, Solubility, and Concentration

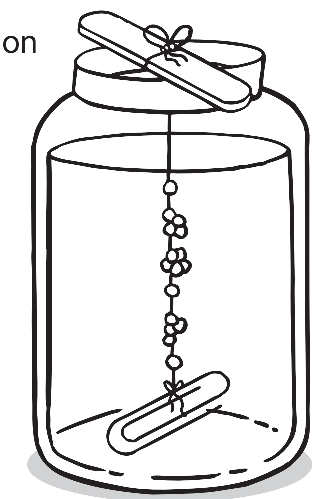
So what's all this "solubility? Some particles can dissolve other particles. The particles of these substances like to be in contact with each other. Air molecules can dissolve water molecules. We call that air humidity. A few carbon atoms can be dissolved in iron. We call that mild steel.

If we dissolve salt or sugar in water, single salt or sugar particles are surrounded by water. In this example, water is the solvent. Sugar/salt is the solute. Water can dissolve only a very specific amount of these particles. How much it can dissolve depends on these factors: Temperature, pressure, particle size and particle shape, and also on how many particles are already in the water. Sea water for example can dissolve less additional salt than tap water or distilled water. Solvents like water evaporates all the time, even at room temperature. The amount of solute (salt/sugar) in the mixture remains constant. There are fewer particles of water left, but the same amount of sugar particles. At some point, the solute (salt/sugar) crystals reappear. This point is called the solubility limit. We can stir harder and longer. The crystals will still not dissolve. The concentration of sugar has become too high. Water evaporation can be used to separate solvent and solute. It can also be used to grow crystals. Let's grow some cool crystals.

Sugar-Gro'

Objectives:

- Over-saturate water with salt or sugar
- Grow crystals from a salt solution and a sugar solution



Equipment:

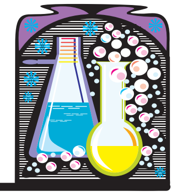
- clear glass beaker or jam glass
- paper clip
- water (the solvent)
- 100 g of table salt (NaCl) or sugar (the solute)
- thread
- chopstick or popsicle stick
- heat source (for example hot plate)

Procedure:

1. Fill the glass container ¾ full with water.
2. Dissolve the solids (sugar or salt) in the water with sufficient stirring.
3. Heat up the water until it boils. Add one tablespoon of sugar (or salt) each minute while heating. Stir constantly. Keep on adding solids until you can see that they do not dissolve any more.
4. Remove the glass from the heater. Place it where it can stand undisturbed for one week.
5. Suspend a thread from a chopstick spanning the top of the glass. The thread can reach the bottom. Let the solution dry for one week. Keep the lid open.
6. The water will evaporate. At some point, there will be insufficient water. The sugar or salt can no longer be dissolved. The solute will start crystallizing. The thread has a rough irregular surface. It acts as a nucleation site. Most of the crystals will grow there. There will also be a crystal film on the glass.

Solu-what?

Worksheet



Explanation: Did you notice that more salt/sugar could be dissolved in hot water? That is true for most mixtures of liquids and solids. Some exceptions exist.
You could not dissolve any more salt/sugar in your liquid at some point? In this case, the solution is called "saturated." We cool such a saturated solution in this experiment. The dissolved salt/sugar cannot stay in solution. It will crystallize. It forms the solid white crystals we can see.

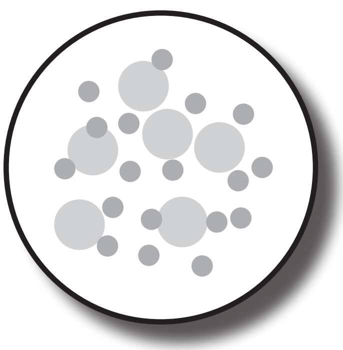
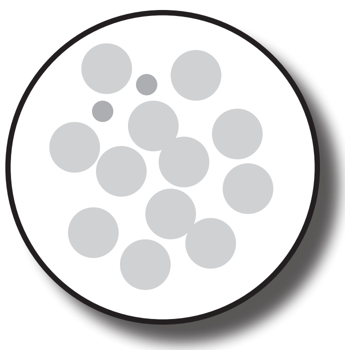
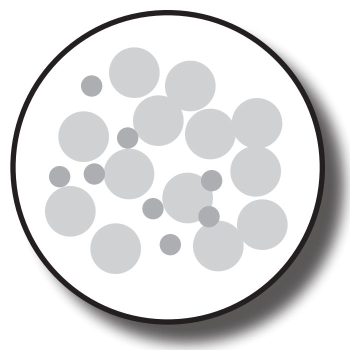
Take a look at the images below. The large particles are salt ions (sodium and chlorine). The small particles are water molecules.

Write under the image which one you think is :

1. Tap water
2. Water with less salt than can be dissolved
3. Water with salt crystallizing

1) Salt Molecule

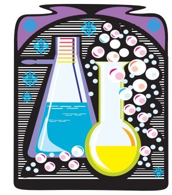
2) Water Molecule

A	B	C
		

Cool Facts: When is a mixture a solution, when is it a colloid?

If you cannot distinguish between the phases by eye or microscope, the mixture is likely a solution. The dissolved material exists as single molecules. All molecules in a pinch of salt will dissolve in fresh tap water, but these molecules can also clump together into chunks. The mixture is then called a colloid. Milk is a colloid. The fat particles clump together. They make milk appear milky.

Solu-Solubility – A Poem



For solubility:
In Water, the source of life –
Alkali metals, ammonium salts,
Can always be depended on.
Whatever they may be.

Acetates and nitrates here:
The solution is so clear,
They each and all are dear -
And soluble in water,
That is what we like to hear.

The halogens now:
The bromides, chlorides, iodides
Are soluble. We read!
Save silver, mercury's low
And, of course, the halides of lead

And what about the sulfates:
They are soluble, it is said.
Except barium, mercury, strontium
That's not all:
And calcium and lead.

Some remain intact:
Sulfides and hydroxides
They do not dissolve at all
But barium, calcium, strontium,
Are partially soluble

And finally to tough ones:
The carbonates and phosphates
Insoluble – you must be pleased to hear
Or else, all our marble structures
Would surely wash away – and we would live in fear.

Extension (Creative Writing): If students are performing solubility experiments, such as the ones in this book, they can expand these poems themselves, based on the findings.

Dio-mio-Iodine:

Introducing the Concepts of Solvent and Solubility

This is a demo experiment, not for student use, and must be performed in a fume hood with the proper safety equipment.

Objective:

- Show solubility of iodine in different materials.

Equipment:

- CCl_4 (carbon tetrachloride, Dry Cleaner solvent)
- water
- ether
- graduated cylinder
- iodine crystals

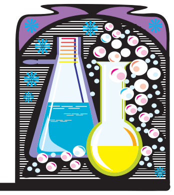
Procedure:

1. In a fume-hood, carefully pour CCl_4, then water, then ether into the graduated cylinder.
2. Take care not to mix the materials, but to layer them.
3. Drop several crystals of iodine through the layers.
4. Prevent any movement of the cylinder.
5. Wait and observe the color in each layer.

Explanations: The solute in this case is iodine. The different liquids are the solvent. Some are more likely to dissolve the iodine ions than others. This is indicated by the color observed. CCl_4 will be purple, it dissolves the iodine better than the other liquids. You might observe that the liquid at the bottom, CCl_4, has an unfair advantage. It has more time to dissolve the iodine. Do experiments in separate cylinders. Each cylinder then only contains one solvent. Drop in the same amount of iodine into each. The result will be the same. Some of the smaller crystals can show some fast movements when they are at the interface between two different liquids. Note: CCl_4 can also be replaced with other organic solvents such as toluene or cyclohexane. All of these are toxic chemicals. The effect of dissolving iodine (purple color) can also simply be mentioned, and the experiment be carried out with only two phases: water and ether. You can also experiment with further mixtures such as water and oil.

Cool Facts: CCl_4 is commonly used as a coolant in fridges. It is also the most common dry cleaning solvent used extensively since the 1940's.

Dio-mio-Iodine



Solvent – Solubility Worksheet

In the graphics below, draw and color the different layers you observe before and after the iodine.

3 solvents before entering iodine	3 solvents after entering iodine

Based on these results, finish the following sentences.

1. Iodine crystals sink to the bottom of the cylinder, because they are ____________________ than all three liquids. (denser, less dense)

2. Iodine has _________________ solubility in CCl_4 (or toluene). (higher, medium, low) That is indicated by the liquid becoming very darkly colored in the color of iodine ions.

3. Iodine has _________________ solubility in ether. (high, medium, low) That is indicated by the liquid becoming brown, a weak version of the iodine ion coloration.

4. Iodine has _________________ solubility water. (high, medium, low) That is indicated by the liquid remaining almost colorless.

Thus we can say that ….

5. … iodine molecules ______________________ (like, somewhat like, do not like) to be surrounded by CCl_4 molecules.

6. … iodine molecules ______________________ (like, somewhat like, do not like) to be surrounded by ether molecules.

7.… iodine molecules ______________________ (like, somewhat like, do not like) to be surrounded by water molecules.

We learned that not all particles are alike. Their differences can cause different behaviors in solubility.

They Live in the jungle

Let's grow a crystal jungle. We will utilize the fact that solvents can dissolve certain salts. These salts later re-form into crystals.

Objectives:

- Grow a crystal jungle.
- Observe the growth rate and crystal shape of different materials.

Equipment:

- sodium silicate solution (water glass)
- distilled water
- crystals of hydrated forms
- small jars or vials, covered or uncovered. If they have a tight lid, the gardens can be transported
- washed fine white sand
- various metal salts

The list below contains only some examples. Many other metals salts (mainly nitrates, chlorides and sulfates) work too. You can experiment with them. Observe safety protocols. Many of these chemicals are dangerous for humans on contact.

Metal Salt	Color	Metal Salt	Color
aluminum(III) chloride ($AlCl_3$)	white	copper(II) chloride ($CuCl_2$)	light blue-green
aluminum(III) nitrate $Al(NO_3)_3$	white	copper(II) sulfate ($CuSO_4$)	light blue
aluminum potassium sulfate $AlK(SO_4)_2 \cdot 12H_2O$	grayish	iron(III) chloride ($FeCl_3$)	yellow
chromium(III) chloride ($CrCl_3$)	dark green	iron(II) sulfate ($FeSO_4$)	grayish white
chromium(III) nitrate $Cr(NO_3)_3$	dark green	nickel(II) chloride ($NiCl_2$)	light green
cobalt(II) chloride ($CoCl_2$)	dark blue	nickel(II) sulfate ($NiSO_4$)	green
cobalt(II) nitrate $Co(NO_3)_2$	dark blue	tin chloride ($SnCl_4$)	white

Procedure:

1. Clean the glass thoroughly.
2. Enter the washed sand until the bottom is covered. This will provide a pleasing look. The sand is not involved in the reaction.
3. Pour sodium silicate into your container. Can be diluted with three parts distilled water.
4. Choose any of the salts you like. Handle all compounds with care.

They Live in the Jungle

5. Drop the crystals of the salts into the solution. Create your own patterns.
6. The reaction starts immediately. It will be mostly finished within minutes. However, allow it to continue one week without disturbing the container. The color of each column is determined by the salt crystal cation.
7. Once the garden has grown, you can either allow the solution to evaporate in a well ventilated place leaving a dry crystal garden. Or you can put a cap on the vial, and store it indefinitely.

Explanations:

Crystal salts are added to the sodium silicate solution. Colorful plant-like extensions grow from the surface of each crystal. From the standpoint of the particle theory, salts are a combination of two different types of particle. One is a cation. This can be a positively charged metal ion. The other is a negatively charged anion like chlorine. As both ions dissolve, the metal ions combine with silicate ions. They form membranes of insoluble silicates around the crystals. The inside of the membranes contains lower water concentrations and higher salt concentrations. That is why water passes inward by osmosis. This causes breaks in the membrane. Consequently, more membrane surface is formed. More metal ions dissolve in the water and expand the growing stalagmites.

Cool Facts: Table salt crystals were worth their weight in gold! That was during the time of the Roman Empire (ca. 2000 years ago).

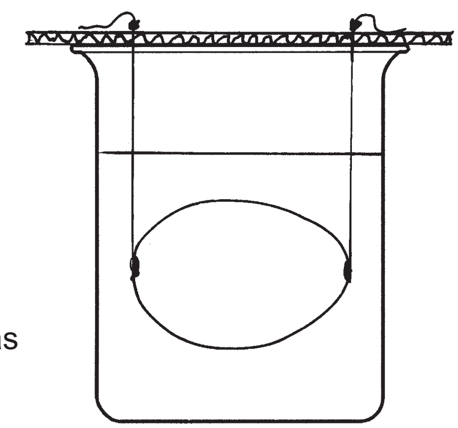
If you keep the garden lid closed, the solution will become milky after many months. About one year later, the white material will precipitate. It will fall onto your crystal tree branches, looking like snow.

Draw three different crystal trees from your own crystal jungle. Imagine the line below as the bottom of your vial.

Salt 1:	**Salt 2:**	**Salt 3:**

Do-It-Yourself Precious Gemstones

Ever heard of malachite? Or, more to the point: copper carbonate hydroxide (the same thing, different name)? In any case, here's an experiment where you can make the precious greenish gem yourself. All you need is an empty egg shell and some chemicals. There goes "ye' good olde" painted Easter egg and out comes a "Gemstone" egg!



Objective:

- Create malachite from calcium carbonate

Equipment:

- Calcium-carbonate containing material (e.g. a blown-out egg shell, shellfish shell, some stones like lime or marble)
- Copper sulfate solution ($CuSO_4$). This can be purchased as blue vitriol which is fully hydrated blue $CuSO_4$ x 5 H_2O.
- Glass or vial large enough to fit around the egg shell (Beaker suggested, a jam jar is also great, but never ever use it for food again afterwards)
- Metal wire or woolen thread
- Chopstick (alternatively a skewer, or cardboard piece – these will be put over your beaker and will hold the egg with the help of the thread)
- Acetone or nail polish remover for cleaning the egg shells (optional)
- Tweezers and clinging foils as a lid

Procedure:

1. Take an egg. Any bird's egg (or clam shell) will do. Punch small holes on both sides. Blow it out. You can use the contents to make scrambled eggs, or use it in a cake.

2. Then, make a little holder for the egg shell using a wire system. You can suspend it from the edges of the container rim. Or punch two holes in a cardboard and knot it around those holes. Test your setup in the empty glass. See that your holder will hold the egg shell. Also take care that the shell does not touch any of the edges, or the bottom.

3. Now wash the shell thoroughly without breaking it. Use acetone (nail polish remover) without touching it. Do this in a well ventilated place. This will remove all fats and lipids that were on the egg, including your fingerprints. If this is not done, there will be areas on the egg that will be protected against gemstone creation. You can also use this method to paint something on the egg with a marker. It will create a relief in your product later.

4. Now, let's make the blue stuff. If you have $CuSO_4$ as a crystalline powder, dissolve it in water. If you use more powder, you will have a higher concentration. The color of your product will change. As a guideline, you can use approximately 10-20g of vitriol in 250 ml water, but you can experiment! Don't fill your container more than ¾ full. The egg volume still has to fit in. Place the container where it can stand undisturbed for months. Put a saucer under it that can contain any liquid that might leak for safety purposes.

5. Carefully enter the egg into the solution using tweezers. If the holes you punched into the eggs are small, it will take a long time to fill its inside with solution. Be patient. The egg is very buoyant when empty. It must be fully immersed.

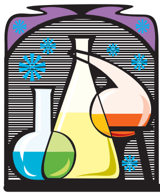
6. In order to reduce the loss of liquid water due to evaporation, put a lid of clinging foil on your glass. You can add water, if too much evaporates. Take care not to drip. And don't perturb the gem growth by moving the glass. Take a look at the egg first once a day, later once a week. Note the changes on the surface. You can raise it out of the solution, too, to check its color, but the growth will be disturbed then. Sometimes, white spiky crystals are formed on the surface, too. That depends on how warm, sunny and dry the storage space is, and how often it is perturbed.

Explanations: The solution helps in the removal of the calcium ions (Ca_{2+}) from the surface of the shell. The calcium ions are then replaced by the copper ions (Cu_{2+}).

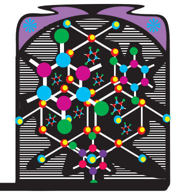
Ion? Like in the Starship Enterprise? Correct. Ion just means this is an atom which misses (or has too many) electrons. In this case, both copper and calcium are cations. Cations are positively charged. If you can't remember that, dig this: "Cation" has a "t", which looks like a plus. t = +. Positive charge. Metal ions are usually cations.

A thin film of azurite is formed on the egg shell within hours. Azurite's chemical structure looks like this: $Cu_3(CO_3)_2(OH)_2$. Within a matter of days, this blue stuff is then converted into green stuff. This is malachite, $Cu_2CO_3(OH)_2$.

Cool Fact: Calcium is present in egg shells and bones. **Wait a minute, I also have calcium in my teeth!** Correct. We remove material from our teeth when we drink pop or fruit juices. That can weaken our teeth. In fact, pop often contains acids as additives. The best drink to sustain good, healthy teeth is tap water. Water also contains minerals which are good for teeth and bones. For example, calcium!



Do-It-Yourself Precious Gemstones



Cool Facts: Blue azurite was ground and used to paint blue skies in oil paintings. There, like in our egg, it undergoes the slow transformation to malachite. This can take many decades. But the images might have been painted in the 1800s. That is why the paintings using this pigment all have a greenly tinted sky now.

Copper? Isn't that, like, worth a lot? Indeed. We require fuels to extract metals and transport them. Due to the continuing price hike in oil prices and the economic growth in Asia, metal prices are on the rise. More and more humans live on this planet. All want more goods. Less and less oil is actually available. This trend will probably accelerate over the next decades.In North America, there are strong economic arguments for removing the penny altogether from circulation. This would free tons of valuable copper.

Extensions (Geology, Igneous Stones): If you use feldspar or quartz instead, what happens? Nothing. These stones are not as easily attacked by acidic solutions, and do not exchange their ions with copper. Eggs, limestone, marble, and carbonate-containing stones will bubble and fizzle when concentrated acid is poured on them. They emit carbon dioxide gas. This is a nice introduction to rock formation, and the chemical differences in the rocks that are found all around us.

Use the space below to write notes about your egg's color, crystal, shape, temperature and water level

Day 1: ____________________

Day 2: ____________________

Day 3: ____________________

Day 4: ____________________

Day 5: ____________________

Week 2: ____________________

Week 4: ____________________

Week 6: ____________________

Week 8: ____________________

Tensing Surfaces

Liquid/Gas Interfaces

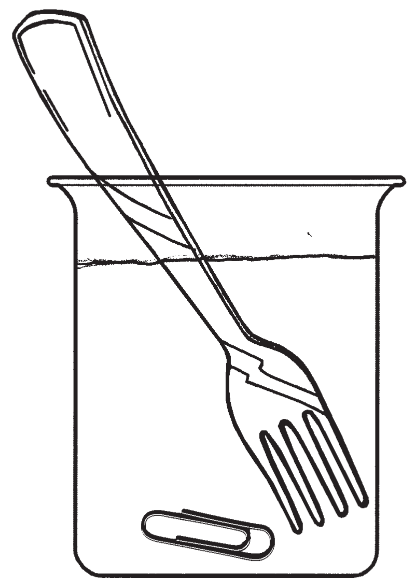
Whenever there are interfaces between materials, there are surfaces. Each particle of a substance likes to be surrounded by particles of the same substance. But on a surface the particles are only partially surrounded by their own kind. Every system consequently tries to reduce its surface. This creates surface tension. Some of these surfaces are clearly defined. The most common surface is the one we all stand on: earth. Another common surface is the one between water and air. The surface tension can be observed by the eye. It can even be changed with chemicals.

Objective:

- Change the surface tension of water.

Equipment:

- empty glass
- soap
- water
- paper clip
- fork



Procedure:

1. Fill the glass with water to 1cm below the rim.
2. Drop a paper clip into the water. Observe how it drops through the interface. It will sink.
3. Use a fork. Carefully lower one paper clip onto the surface. It will float. This is tricky and may take a little while.
4. Add a drop of soap. The surface tension will be lowered. Soap makes water and air "like" each other more. The paper clip will sink.

Cool Facts: Can you fill more water into a container than it will fit? Yes! The surface tension will allow for slightly more liquid to be stored in the container. The water bulges above the rim.

Fill in the following text by completing the words :

Every matter surface has surface t _ _ _ _ _ _. In the case of a water-air surface, this tension is h _ _ _. The surface tension between m _ _ _ _ _ y and air is even higher. This toxic liquid metal does not like to be around air. The surface tension can be l _ _ _ _ _ _ when soap is added. Some animals use the surface tension of water as a walk-able surface. They are called water _ _ _ _ _ _ _ _ s. They _ _ _ k when the surface tension vanishes.

Un-tensing Surfaces

Objective:

- Record the change in surface tension of different liquids

Equipment:

- paper
- liquid soap
- ballpoint pen
- other liquids (e.g. juice, ethanol, glue, oil)
- water
- chemical dropper or pipette (optional)

Procedure:

1. Copy this page.
2. Put a single drop of liquid on the paper in the box below. You can use a pencil or chemical dropper to transfer the drop.
3. Draw the drop diameter with a pen.
4. Add soap to the liquid.
5. Put a single drop of liquid soap in another box.
6. Measure and compare the diameters.
7. Draw conclusions.

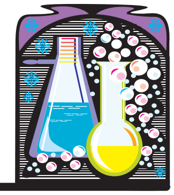
Water droplet	Water & soap droplet	Other liquid (______) droplet	Other liquid (________) plus soap droplet
Diameter (in or mm): ____________	Diameter (in or mm): ____________	Diameter (in or mm): ____________	Diameter (in or mm): ____________

Conclusion:

1. The diameter of the water droplet is ______________ (smaller, larger, the same) as the diameter of the water droplet with soap.
2. The surface tension of pure water is __________ (lowered, increased, staying the same) when you add soap.
3. The diameter of the liquid droplet is ______________ (smaller, larger, the same) as the diameter of the liquid droplet with soap.

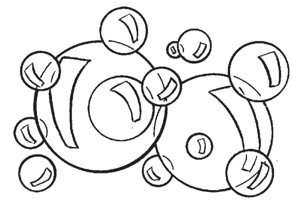
Bubble-icious:

Soap Bubbles Follow Precise Mathematical Equations!



Objectives:

- Produce soap bubbles
- Record their shape and interaction



Equipment:

- dish washing detergent
- a straw
- water
- pipe cleaners (bent into a ring; these can make large bubbles)
- cups for solutions and plates (optional) for making the bubbles on

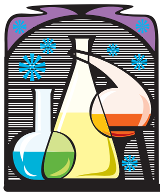
Procedure:

1. One day before bubble making, mix one part dish detergent with 10 parts soft water.
2. Spread on a flat surface (for example a table or plate).
3. Blow bubbles on the table or plate using a straw.
4. Create bubbles inside bubbles. Observe the change in volume when blowing up the inner bubble. Both bubbles will increase since the inner volume pushes away the outer.
5. Combine bubbles by pulling together several bubbles of similar size. Draw the wall patterns that you create in the boxes below. Try to create bubbles of equal sizes. Draw a top view image of the bubbles and their interfaces.
6. Shape pipe cleaners to a ring. A triangle. In heart shape. Does that influence the bubble shape?

1 bubble	2 bubbles	3 bubbles	4 bubbles
5 bubbles	6 bubbles	7 bubbles	8 bubbles

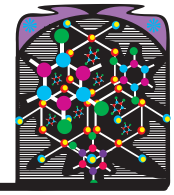
My bubbles started having one central bubble with __________ walls once I combined more than ___________ bubbles to one structure.

Cool Facts: The reason that soap bubbles burst is two-fold. One reason is they dry out and the second reason is they lose liquid. In an experiment, try inserting a wet versus a dry straw. Catch bubbles with a wet versus a dry hand. They burst when they come in contact with dry materials. This has nothing to do with sharpness of the materials!



Mixing Oil and Water

Liquid/Liquid Interfaces



Some liquids can be mixed. Their particles like to be in contact with each other. Alcohol and water is such a case. Other liquids do not mix. These particles do not want to be surrounded by each other. Oil and water for example. Washing in pure water barely cleans oily dirt from clothes. The oil sticks to the fabric. However, oil and water can be mixed with a trick. We can use soap. Soap particles have two sides. One side likes contact with water, the other with oil. Oil droplets are surrounded by a "skin" of soap. The other side of the soap particle is in contact with water. In this way, the soap pulls the oil from the clothes. Our clothes are thus cleaned.

Objectives:

- Observe miscibility of oil and water.
- Observe the effect of soap on this liquid/liquid interface.

Materials:

- soap
- vegetable oil (for example, sunflower oil)
- water
- beaker or transparent cylinder or jam jar with a lid (10-50ml)

Procedure:

1. Pour water into the jar.
2. Add a thin layer of oil (less than 1cm).
3. Mix them vigorously (with a finger or by closing the lid and shaking).
4. Let the mix settle for a minute. Observe changes.
5. Add soap to the mix, at least half as much as oil.
6. Repeat the mixing.
7. Wait and observe. If materials still separate, add more soap.

Fill in the text below:

When mixing oil and water, they ____________ (separate, stay mixed). The oil is ___________ (below, on top of) the water. Water has a ____________ (lower, higher) density than oil. Water and oil particles ____________ (like, don't like) to be in contact with each other.

If we add soap to a mixture of oil and water, the mixture _____________ (separates, stays mixed). Soap particles __________ (like, don't like) to be in contact with water. They _________ (like, don't like) to be in contact with oil. Soap particles ___________ (separate from, squeeze between) oil and water particles.

Muddy Hell! The Science of Soil Erosion

Liquid/Solid Mixtures

Separating solids and liquids is relatively straightforward. We can sieve the solids out. This happens in nature, too. Imagine the roots of trees as gigantic sieves. They "sieve out" the solid particles like earth and allow the water to pass. That is why the rich, healthy soil accumulates in our forests. Once the forests have been removed, the trees are dead or gone. The sieve is no longer in place. Water and soil will swim away together. This is called erosion.

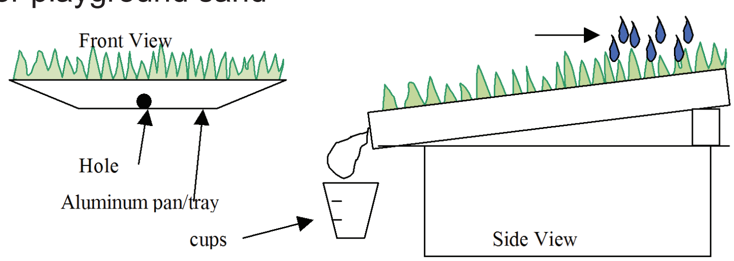
Humans have started to deforest our planet on a large scale. Often, forest is burned to make space for cattle farms. The soil is no longer held in place by vegetation. It gets washed away. What remains are dead rock surfaces. We can simulate this in the classroom.

Objectives:

- How does vegetation stabilize soil?
- What are some different run-off processes?
- How does forestry and land use affect water quality and flood timing?

Equipment:

- graduated cylinder or measuring cup (1L)
- 30 small cups with exact ml measurement units (3x numbered 1-10)
- large aluminum roasting tray (one per soil sample)
- different soil samples: sod (collect leftovers from edging the lawns and let it grow together for 2 weeks), soil with roots (can be freshly collected on the day), beach or playground sand
- timer



Procedure:

1. Designate a timer, a cup provider, a cup holder, and a cup taker in your group.
2. Set the soil into the aluminum tray. Incline it. Start the "rainstorm" by slowly pouring water onto the high end of the soil. Hold an empty cup under the hole which is at the lower end.
3. The timer starts to time at the beginning of the rainstorm. She/He calls "Switch" every 10 seconds. The cup holder collects the water coming out of the tray. The cups are switched every 10 seconds. The cup provider makes sure the holder has a fresh cup ready. The cup taker takes the cups and stores them safely. If only a couple of drips every 10 seconds come out of the tray, stop the experiment.
4. Fill in the table. Then plot the time in 10 second intervals along the bottom axis of a graph, and the volume in ml along the y-axis.

Worksheet

Time (seconds)	Sod Volume (ml)	Fresh soil with roots Volume (ml)	Beach sand Volume (ml)
10			
20			
30			
40			
50			
60			
70			
80			
90			
100			
110			
120			
130			
140			
150			
160			
170			
180			
190			
200			

A Little Fizz to Freeze

Liquid/Gas Mixture

Objectives:

- Cool a bottle of carbonated drink. It should remain liquid even below the freezing point of water.
- Open it and see the whole bottle freezing shut at once.

Equipment:

- small transparent plastic bottle of unopened fizzy (carbonated) drink; remove the label for better viewing
- bowl full of ice
- water
- salt
- thermometer

Procedure:

1. Add water and ice into the bowl. The ice should be half covered in water.
2. Add several spoons of salt to the ice mixture.
3. Measure the temperature, it should be at least -4°C (30^{0}F) cold.
4. Bury the drink bottle in the ice mixture.
5. Wait about 20 to 30 minutes. If the drink freezes, you have waited too long. Restart with a fresh bottle.
6. The same can be done in a freezer. Figure out how long the drink needs to start freezing. Take the bottle out one minute before that happens.
7. Open the bottle and observe. Can get messy.
8. The contents of the bottle should turn to slush in front of your eyes.

Explanations: Before opening the bottle of carbonated liquid, it contains high quantities of carbon dioxide (CO_2). The gas is dissolved in the liquid. This reduces the freezing point. That is the same effect that salt has on ice. That is why the salt-water mixture is below the freezing point of water. The drink does not freeze even at -3°C (31^{0}F). When opening the bottle, the dissolved carbon-dioxide is released. This increases the freezing point of the liquid. It also creates lots of little bubbles. The liquid is now colder than its freezing point. It starts freezing. The freeze process would still take a long time, but many small bubbles are also created. They act as crystallization nuclei.

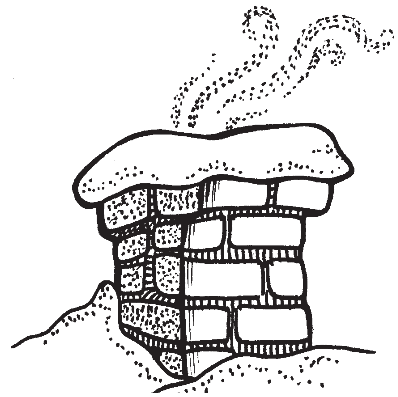
Cool Facts: Freezing a material creates heat. Liquids have to be sufficiently cold to still be below freezing point after crystallization. Otherwise, the liquid remains in its liquid phase, even after opening the bottle. The heating effect of crystallization can be clearly felt in the case of chemical handwarmers.

Smoking Mirrors

Gas/Solid Mixtures

Objectives:

- Understand how air cleaners work.



Equipment:

- Bunsen burner or candle
- ceramic plate

Description:

Turn the Bunsen burner to a yellow (low temperature) flame or use a candle. This flame is not fully burning the fuel gas and produces soot. Soot is mainly carbon. This also happens in each of our cars. These particles are dangerous when inhaled. That's why we have to scrub the exhausts of factories and why we have to install soot traps and catalysts into our car exhaust streams. Hold the ceramic plate above the flame. It cools the hot air stream from the flame. The carbon particles adsorb (get stuck) on its surface. It separates gas and solid.

Here is space for you to draw and label the experiment.

Drawing:

Notes:____

Extensions (Chemistry, Engineering): Novel alternative energy systems do not need gasoline. They can run on a gas called hydrogen. One such system is a fuel cell. Hydrogen fuel storage is difficult. Hydrogen molecules are very small, but they can be stored within a metal. The metal acts as foam for the hydrogen and forms solid metal hydrides. When temperature and pressure are changed, the hydrogen is released again as gas.

The Needle in the Haystack

How to Separate Mixtures

Many substances only mix physically. They do not react chemically to a new material. These mixtures can be separated. Let's perform some physical separations.

Objectives:

- Physically separate different solids.

Equipment:

- water
- glass marbles
- magnets
- beakers
- salt
- nails
- tweezers
- heat source
- sieve
- flour
- toothbrush
- coffee filters
- sugar
- bath salts
- food coloring
- chalk
- magnifying glass
- tea leaves

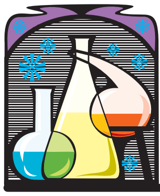
Description:

You have the following mixtures of solids:

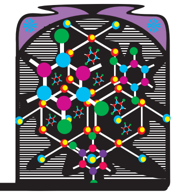
1. tea leaves and sugar
2. salt and flour
3. chalk powder and bath salts
4. salt, glass marbles, nails and tea leaves
5. sand, styrofoam granules and soap

How can you separate these mixtures?

Cool Facts: Many liquid colors that we see are mixtures of other colors. Green food coloring is often a mixture of blue and yellow. Colors and other chemicals in a solution can be separated. One such separation technique is chromatography. It is easy to do this yourself. Mix less than a teaspoon of salt with four cups of water. Make a color dot on the lower end of a coffee filter. Hang the bottom edge of the filter into your salt water. Do not disturb the filter. Wait and observe the result.



The Needle in the Haystack



How to Separate Mixtures

Materials can be separated based on their physical properties. Many powders and dry leaves float on water. Salt and sugar dissolve in water. They crystallize into solids once the water evaporates. Glass marbles sink in water. They have a higher density. Most metals are magnetic. They are pulled out of a mix with a magnet. Some materials are flammable. Glass decorations hidden in a candle can be revealed by burning the wax. Also, differently sized grains are separated by differently sized sieves. Experiment with different materials. Find out about their properties. Write down your findings here. The first one is already done for you.

Material	Your Findings
salt	Can be sieved. Dissolves in water. Does not float. Is not magnetic.
dry tea leaves	
sugar	
chalk powder	
glass marbles	
needles	
flour	
food coloring	

Cool Facts: Some matter can be separated by freezing. Gases with different boiling and freezing points are separated by cooling them. The gases with the highest boiling points will precipitate first.

Answer Key

Mix it, Shake it - Separate it. Worksheet (Page 3)

1. liquid/liquid: water and oil.
2. solid/gaseous: soot and air.
3. liquid/gaseous: water and air.
4. gaseous/liquid: CO_2 and water.
5. solid/liquid: cells and water.
6. liquid/solid: oil and sand
7. Answers will vary

Solu-what? Worksheet (Page 5)
Water molecules are drawn here much smaller than salt molecules. Their electron shells are much closer to the core. Also, in reality, there is significantly more water present. Even many solid crystals may contain water in their atomic structure.
a. 1), b. 3), c. 2)
One exception for lower solubility at higher temperatures is cerium sulfate in water. Also, strictly speaking, the "shape" of the molecule determines its polarity (charge imbalance). Water is polar, the electrons agglomerate on one side of the water molecule. This generates a weak dipole. Fats are usually unpolar. This effect determines their miscibility. Unpolar and polar molecules do not mix, as can be seen in oil/water experiments (e.g. p.17).

Solu-Solubility - A Poem (Page 6)
This poem, an adaptation from Ref 35, includes the proper names for many chemicals and relates them to their solubility properties. For higher grades, poems could, for example, use the crystal gardens (page 6) as inspiration.

Dio-mio-Iodine Solvent – Solubility Worksheet (Page 8)
1. denser 2. high 3. medium 4. low 5. like,
6. somewhat like 7. do not like

Tensing Surfaces (Page 14)
tension, high, mercury, lowered, skippers, sink

Un-tensing Surfaces (Page 16)
1. smaller, lowered 2. Depends on liquid chosen. Usually surfactant increase wetting and diameter.

Bubble-icious (Page 17)
No influence of pipe cleaner shape.
Physical Explanation: Bubbles are always spherical. A sphere has the smallest ratio of surface to volume. Similar-sized bubbles will share straight (planar) walls.

Mixing Oil and Water (Page 18)
separate, on top of, higher, don't like, stays mixed, like, like, squeeze between

Muddy Hell! the Science of Soil Erosion (Page 19)

Vegetation stabilizes the soil by spreading a network of roots. These hold together stones, finer sand and organic sod. This is similar to a sieve. Without a sieve, the solids would just flow away. In a sieve, everything is held in place.
With more roots and organic stuff present, water falling on the surface is held in place longer. The soil acts like a sponge. with playground/beach sand, the water flows off much faster. Also, more sand particles are washed away with the water.

Excessive logging, especially commercial cut-and-burn practices, kill all plant life capable of holding soil in place. The results are increased erosion, especially of the once-fertile sods. This necessitates new cuts to get to fresh fertile soil. Remaining soils often barely hold plant life.

The Needle in the Haystack (Page 90)

Material	Your Findings
salt	Can be sieved. Dissolves in water. Does not float. Is not magnetic.
dry tea leaves	Can be sieved. Will float until wet.
sugar	Can be sieved. Dissolves in water. Does not float. Is not magnetic.
chalk powder	Too fine for standard sieves. Floats for some time. Does not dissolve in water.
glass marbles	Sink in water and do not dissolve. Can be sieved easily.
nails	Are magnetic.
flour	Too fine for most kitchen sieves, unless wholemeal. Does not dissolve in water. However, water gets absorbed in it. The mixture is then called dough.
food color	Dissolves in water. Can be separated further into base colors by chromatography.
sand	Has a higher density than water. Sinks to the bottom. Sand can have different grain sizes than other materials and can be sieved out.
styrofoam granules	Have low density. Float on water.
soap	Dissolves in water. Can be recovered through evaporation of water.