

**Title:** Separate This (Mixtures and Solutions)

**Grade Level:** 3-5

**Benchmarks:**

**SCI IV.1.E.1** Classify common objects and substances according to observable attributes/properties.

**SCI IV.2.E.2** Prepare mixtures and separate them into their component parts.

**SCI I.1.E.2** Develop solutions to problems through reasoning, observation, and investigations.

**Objectives:**

Upon completion of this lesson a student will be able to:

1. Identify and provide examples of mixtures and solutions.
2. Design a separation scheme for simple mixtures of up to 3 substances.
3. Explain what happens to substances when a mixture or solution is formed (i.e. that substances do not change or “disappear”).

**Misconceptions:**

Students believe that when something dissolves that a chemical reaction takes place (Cahk & Ayas, 2005). This lesson will address this misconception by having students separate the salt from a solution, showing them that the salt was not changed.

**Differentiation:**

These activities provide students with the opportunity to manipulate objects, record or draw pictures of their observations, and explain their results to accommodate a variety of learning styles. Additionally, careful grouping of students will allow the teacher to provide additional assistance for some student either through support from their group members or through small group questioning.

**Materials and Setup:**

Engage: These materials should be on a tray that can be distributed at the beginning of the lesson. Each group of 3 students will get a tray that contains:

- 1 x 250 mL beaker (can also use a plastic cup – Walmart)
- enough marbles to overfill the beaker in a plastic Ziploc™ bag (Walmart)
- enough sand in a plastic cup to overfill the beaker/cup filled with marbles (play sand – Walmart)
- enough water in a plastic cup to overfill cup filled with marbles and sand

Collect the mixtures, cover with plastic wrap and put group names on them to be saved for the next day. Return excess sand to storage. Cups can be dried/cleaned and kept for future use.

Each student will need paper or their lab book to record their observations.

Explore: These materials should be on a tray that can be distributed at the beginning of the lesson. Each group of 3 students will get a tray that contains:

- The mixture from the previous day (make sure that you put plastic wrap over it so the water doesn't evaporate over night)
- Funnel (Walmart)
- Sieve/strainer (Walmart)
- Cone coffee filter (Walmart)
- Plastic spoon (Walmart)
- 3 plastic cups (Walmart)
- 15 cm x 15 cm piece of cheese cloth (Walmart)

After separating the mixture the sand should be combined in a bucket. This can be dried and saved for future use. The marbles should also be collected in a bucket and saved for future use. Spoons, plastic cups, funnels, strainers should be cleaned and put away for future use. The cheese cloth and used coffee filters should be thrown in the garbage.

**Elaborate:** These materials should be on a tray that can be distributed at the beginning of the lesson. Each group of 3 students will get a tray that contains:

- 1 condiment cup half filled with sand (cups from Gordon Food Service)
- 1 condiment cup half filled with salt (Walmart)
- 1 condiment cup half filled with iron filings (filing from Flinn – 500g \$3.45)
- 1 condiment cup half filled with the three component mixture
- funnel
- 2 cone coffee filters (Walmart)
- cheese cloth (Walmart)
- 4 straw scoops (cut a straw in half and cut the end so it can be used as a scoop) (Walmart)
- toothpicks for mixing (Walmart)
- 3 empty condiment cups or small plastic cups for mixing, filtering, etc.
- a magnet in a baggie (remind students not to remove magnet from baggie!) (cow magnets work well \$11.75 each, but ceramic disc magnets should also work (\$5.25 for 6) from Flinn)
- dropper bottle with water (bottle from Flinn package of 12 - \$7.80)
- optional – 2 aluminum muffin tins (Walmart)
- optional – a spot plate for solubility tests (could use plastic or Dixie cups) (Flinn - \$7.80 for 12)

Optional – have a hot plate or a candle at the front of the room for evaporating the water. The other option is to leave the salt water solution sitting overnight for the water to evaporate. The second option may require a few days.

Any extra sand, salt, filing, or mixture can be stored for future use. Cups and straw scoops can be reused. The funnels, magnets, dropper bottles, and spot plates should be collected and stored. Toothpicks and coffee filters should be thrown in the garbage. Any wet sand or iron should be collected. The iron can be removed using a magnet and dried for future use. The sand can be added to the wet sand from the explore activity and stored for future use.

### **Safety:**

If safety goggles are available it would be good for students to wear them to make sure they do not get any sand or iron filings in their eyes. Students should be warned to be careful not to get the sand and iron filings in their eyes and to wash their hands thoroughly when they are done. Students should be reminded not to taste any of the materials. When dealing with water there is always a chance of spills. Make sure any spills are cleaned up immediately to avoid slipping.

### **Requisite Knowledge/skills for students:**

Students should have already learned about physical properties of matter and physical changes.

### **Procedure:**

Engage: (45-50 minutes depending on discussion and detail of observations)

The engage activity will introduce students to the concept of mixtures, provide them with an opportunity to make observations, and introduce them to the idea of Conservation of Matter.

1. Put students into groups of 3 and ask them to fill a 250 mL beaker with marbles. Have the students weigh their beakers (if a scale is available). Ask them if the beaker is full. Can you add any more to this beaker? Get students to explain why they think they can or cannot put any more in the beaker.

(Students will probably say something like if you try to add any more marbles they will fall out.) At this point you could get students to draw a picture of and describe their observations.

2. Give each group a cup of sand. Have them weigh the cup of sand (if you have a scale). Ask them if they can add some sand to their beakers. Get students to explain their answers. (You should expect students to say that the sand will fit in the holes between the marbles.) Get students to add sand and determine how much sand was added to the beaker. Ask students where the sand went. Did it disappear? How do they know? At this point you could get students to draw a picture of and describe their observations.
3. Provide each group of students with a cup of water and repeat step 2.
4. Get students to explain what happened to the marbles, sand, and water when they were added to the beaker. Students should come to the conclusions that the substances did not change or disappear when they were mixed together.

#### Explore: (45-50 minutes)

The explore activity will build on the engage activity as students try and develop ways to separate the mixture they have made.

Provide each group with their mixture from the previous day and the separation equipment listed in the Materials and Setup section (the term mixture will be introduced formally in the Explain section). Have students plan and test a separation scheme. Students should record their scheme in their lab notebooks. You may want to provide them with a flowchart template like the one on the attached worksheet (pg. 9) to help them organize their separation plan. During this time the teacher should be circulating among the groups and monitoring their progress. Students should be recording their observations for each step in their separation scheme in their lab notebooks. The teacher should ask students why they choose a particular method and encourage students to link the methods to the physical properties of the mixture components. If a group is stuck the teacher may want to ask something like how would you separate a mixture of just sand and marbles? Why don't you try that and see where that gets you?

#### Explain: (45-50 minutes)

The explain activity builds on the explore activity by having students present their separation schemes and introducing the term mixtures.

1. Have groups of students present their separation schemes discussing all their trials, what was successful and what was not.
2. If students do not bring it up during their presentations, ask them if the marbles, sand, and water they got at end were the same as the marbles, sand, and water they started with. How do they know? Maybe some students weighed their separated components! Make sure students can explain why they used a particular method. Encourage them to link the method to the physical properties of the components they were trying to separate. Overall you want to get students to realize that the substances could be separated because their physical properties did not change when they were mixed together.
3. Introduce the concept of a mixture. A mixture is formed when two or more substances are combined, but those substances are not changed. The components of a mixture (such as the marbles, sand, and water) can be separated based on their physical properties using a variety of techniques. Note: students should have already talked about physical properties but you may want to ask them what physical properties are to make sure they remember/understand.
4. Introduce the proper terms for the techniques sifting for separating two solids (separating the marbles from the sand based on size of particles) and filtration for separating a solid and a liquid (separating the sand from water using the coffee filter). There are other separation techniques that can be used. See if

the students can think of any. For example, evaporation or distillation is a way to separate solutions such as salt water. This concept will be investigated further in the Elaborate section. List all of the student answers on the board.

Elaborate (Apply, Extend): (2 x 50 minute periods)

Up to this point students have looked at heterogeneous mixtures (mixtures where the various components are visible to naked eye). Solutions are homogeneous mixtures (mixtures where you cannot see the various components with the naked eye).

1. Take either salt or sugar and mix a small amount with water to dissolve it. Ask the students if this is a mixture. Why or why not? Ask students what evidence they have to support their answer. You may want to ask them where the salt or sugar went – did it disappear? (Some students will probably conclude that it did because they can not see it any more. Some students may conclude no because if they dissolve sugar in water the water tastes sweet so the sugar must still be there, or because they have seen water evaporate leaving a solid behind). It is important that students do not think that the sugar water is a new substance.

Ask students how they could test their answer? (If students weighed things in the Engage activity some may remember and suggest this as a method.) Ask students if they can separate the salt/sugar and the water? How might you do this? You want students to come to the idea of evaporating the water through heating to get rid of the water and leave the solid behind. It is important that students do not think the water disappears when it evaporates. You may need to remind them about changes of state.

Overall, you want students to realize that the salt/sugar did not disappear, but is now mixed with the water forming a new kind of mixture. You can use the analogy water fitting in the spaces between the sand grains to explain why you can no longer see the salt/sugar. You may have to remind students that a mixture is something that you can separate back into its individual components.

You can introduce this new type of mixture as a solution. A solution is formed when you form a mixture but you cannot see all the individual components any longer. Ask students to give some examples of solutions. (They will probably come up mostly with water solutions such as Koolaid<sup>TM</sup>, tea, the ocean, etc.) There are also other types of solutions such as air (a mixture of oxygen and nitrogen gases) and brass (a mixture of copper and zinc metals). When we mix another substance with water and it forms a solution we say that substance is soluble in water or dissolves in water.

2. Tell students that they are analytical chemists and they need to separate mixture of salt, sand, and iron filings, but first they need to know something about the physical properties of salt, sand, and iron filings. (Provide each student with a copy of the activity Separate This! pp. 8-10). Provide each group of 3 students with a tray that has the materials listed in the Materials and Setup section.
3. While the students are working through the activity they should be recording their observations and separation scheme on the activity sheet. The teacher needs to check on each group, making sure that all students are participating, and asking questions to ensure students understand the process. Some questions you might ask are – what technique are you using to separate sand and salt? Could you use sifting? Why or why not? If students are having difficulty you may need to prompt them using some of the same questions. Encourage students to use proper science terms when they are recording their results and designing their separation schemes. While you are checking on groups and asking questions make notes on the Grading Sheet for Separate This! (pg. 6).
4. Bring students back together for whole group discussion/presentation of separation schemes. Overall students should recognize that the iron can be separated due to its magnetic properties, that the salt can be dissolved in the water and separated from the other solids via filtration, and that the salt can be recovered by evaporation of the water. The order of the steps may vary from group to group.

### Evaluate:

A variety of assessments will be used throughout the activities in this lesson.

**Engage:** During the engage activity the teacher will assess group understanding by asking the class questions (pp. 2 & 3). Additionally, individual understanding will be assessed as students will draw pictures of and describe their observations at the various stages in forming a mixture. Sample student observations can be shown below. Through this activity students should come to the understanding that the substances did not change when they were mixed together. This is in alignment with learning objectives 1 and 3.



**Explore:** The explore activity will provide an opportunity to assess students' understanding of the concept of a mixture and students' problem solving skills through a performance assessment. In developing a method for separation students will demonstrate: (1) their understanding of the different physical properties of marbles, sand, and water; (2) their understanding of mixtures and that the physical properties of substances do not change in mixtures; and (3) their problem solving skills. This is in alignment with learning objective 2. This will be an opportunity for the teacher to spend a little more time with the groups who are struggling with this concept.

**Explain:** During the Explain activity the teacher will more formally assess students' understanding of mixtures during the group presentations of their separation schemes. Student presentations will allow the teacher to more closely examine each group's reasoning. This will also allow for students to assess their own understanding as they talk about what worked, what did not, and why. This is in alignment with all 3 learning objectives. Student presentations will be graded using the following rubric.

	<b>Excellent</b>	<b>Good</b>	<b>Poor</b>
<b>Overall</b>	Easy to follow All group members participated equally Easy to hear (5)	Could follow Group members participated but not equally Could hear (3-4)	Difficult to follow Not all group members participated Difficult to hear (1-2)
<b>Scheme</b>	Scheme was successful (5)		Scheme was not successful (3)
<b>Explanation</b>	Clearly explained what worked, what did not, and why (5)	Explained what worked and what did not but not why (3-4)	Did not clearly explain what worked, what did not, or why (1-2)
<b>Questions</b>	Was able to answer all questions using data to support answers (5)	Able to answer most questions and used data to support some answers (3-4)	Had difficulty answering questions (1-2)

**Elaborate:** The elaborate activity will involve an informal assessment of student understanding of mixtures through questioning about a solution. Students often think that when a solid dissolves it "disappears" or reacts chemically. Questioning about a salt/sugar solution should lead students to the idea that this is a mixture because you can recover the solid by evaporating the water.

The majority of this activity, however, is a performance assessment that will require students to test the physical properties of three components and then use those properties to separate a mixture of sand, salt, and iron filings. Students will complete the **Separate This!** activity worksheet. The answer key for this worksheet has been attached (pp. 11 & 12). Student answers may differ slightly depending on their scheme. This activity is in alignment with all 3 learning objectives. During this activity the teacher will be checking on each group and asking students questions to assess their understanding of mixtures and the separation

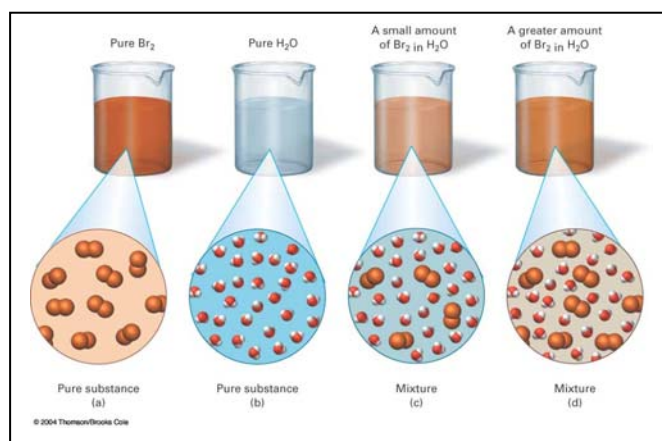
process. In addition to the activity sheet, the teacher should assess students by making notes for each student as they check on each group during the activity. The following grading sheet will be used and the teacher will make notes for each student under these categories as they monitor groups during the activity.

### Grading Sheet for Separate This! Activity

Student	Participation	Understanding
	5 = actively involved 3-4 = somewhat involved 0-2 = not involved or very little participation	9-10 = were able to develop and explain successful scheme on their own and were able to answer questions 7-8 = developed successful scheme with little help but could not explain all or answer all questions 4-6 = developed successful scheme with some help but difficulty with questions/explanation 0-3 = could not explain scheme or answer questions, or much assistance was required for successful scheme

### Scientific Background for the Teacher:

Pure substances are substances that are made up of only one type of particle and can be either elements (composed of atoms) or compounds (composed of molecules or ions). Pure substances have unique physical properties (for example: melting point, boiling point, density, etc.). A mixture is a substance that is composed of two or more pure substances. Particulate level diagrams of a mixture and a pure substance are shown in the adjacent figure.



Cracolice & Peters, Introductory Chemistry: An Active Learning Approach 2<sup>nd</sup> Edition, pg. 25

There are two basic types of mixtures. Heterogeneous mixtures have more than one visible phase/component. For example, pepper, granite, oil and water, and the marbles/sand/water mixtures are all heterogeneous.

Homogeneous mixtures, on the other hand, have a uniform appearance, or only have one visible phase. For example, tea, koolaid, ocean water, and the air we breathe are all homogeneous mixtures. Homogeneous mixtures we are most familiar with are water solutions. When something mixes with water to form a homogeneous mixture we say it is soluble in water or it dissolves in water. At the particulate level what happens is that the water molecules surround the particles being dissolved as in the diagrams above. As we cannot see individual particles with our eyes, the mixture appears to be one phase. A good analogy is the sand fitting in between the marbles in the beaker.

As the components of mixtures have different physical properties they can be separated using a variety of techniques. These include filtration, sifting, evaporation, and distillation.

- Filtration is a method for separating heterogeneous mixtures of solids and liquids. The filter allows the liquid to pass through but traps the solid.
- Sifting is a way to separate two solids based on size. A common example is the sifters children use in the sand box to remove rocks. The sand grains pass through the small holes but the rocks are too big.
- Evaporation can be used to separate homogeneous mixtures like salt and water. As water has a much lower boiling point than salt (sodium chloride), you can remove the water and leave the salt behind by either heating to boil off the water or letting the solution sit long enough for the water to evaporate. This occurs because at any time some water molecules have enough energy to overcome the intermolecular

forces and escape into the vapor state. These molecules are then free to spread through the air. Molecules continue to escape until all the liquid water molecules have escaped into the vapor state.

- Distillation is similar to evaporation in that it is used to separate homogenous mixtures of two liquids with different boiling points or solids dissolved in a liquid. This technique is used in industry to separate out the fractions of crude oil into useful materials such as gasoline, kerosene, and tar. As the solution is heated, the particles of liquid with the lower boiling point will enter the vapor state first. This vapor then comes in contact with a cooling column which condense the vapor into a liquid so that the pure liquid can be collected.

**References:**

Cracolice, M. & Peters, E. (2004). *Introductory chemistry: An active learning approach* (2<sup>nd</sup> ed.). Belmont, CA: Brooks/Cole.

Cahk, M. & Ayas, A. (2005). A cross-age study on the understanding of chemical solutions and their components. *International Education Journal*, 6(1), 30-41.

## SEPARATE THIS

Mixtures of 2 or more substances can be separated based on their physical properties. Separation of mixtures plays a very important role in our society. For example, the crude oil that is pumped out of the ground is separated into natural gas for heating and cooking, gasoline to power our cars, kerosene for oil lamps, lubricating oil and waxes, and asphalt for paving our roads.

We want to design a method for separating a mixture of salt, sand, and iron filings. First, we need investigate the physical properties of salt, sand, and iron filings.

### Physical Properties

1. Look carefully at each substance and describe in detail what each looks like in the table below.

#### Physical Appearance

Substance	Appearance
Salt	
Sand	
Iron Filings	

2. Water solubility. To test the solubility of a substance in water, fill a section of the spot plate  $\frac{3}{4}$  full of water. Add a very small amount of one substance to the water and mix. What do you expect to see if something is soluble? If something is not soluble? Test the solubility of all three substances; record your observations and results in the table below.

#### Water Solubility

Substance	Observations	Soluble (yes or no)
Sand		
Salt		
Iron Filings		

3. Magnetic properties. To test the magnetic properties, place a small amount of one of the substances in the plastic weighing boat. Put the magnet in a baggie and then touch the substance with the baggie containing the magnet. Test the magnetic properties of all three substances; record your observations and results in the table below.

#### Magnetic Properties

Substance	Observations	Attracted to Magnet (yes or no)
Sand		
Salt		
Iron Filings		

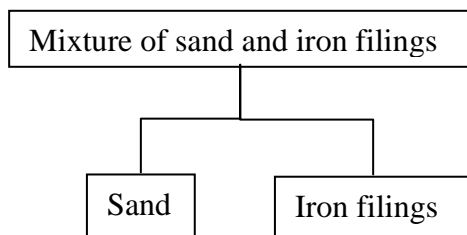


## Separating a Mixture

You are the analytical chemist for Separate Inc. and your boss has given you the task of designing a method to separate a mixture of sand, salt, and iron filings. Using your knowledge about the physical properties of these substances and your knowledge of separation techniques (sifting, filtering, distillation/evaporation) you must design and test your separation method.

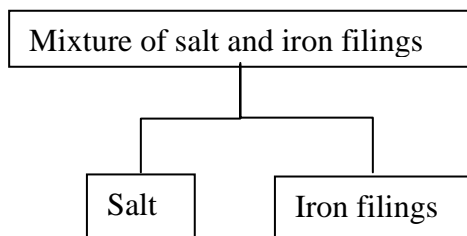
It may help if you first think about how you would separate a mixture of sand and iron filings, salt and iron filings, and sand and salt. You should test each separation, note your observations and results, and indicate any modifications that need to be made.

### Separation of Two Components



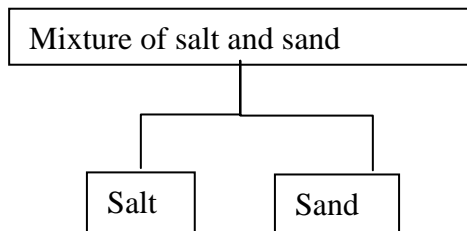
Separation method:

Observations and Results of separation	Modifications to separation



Separation method:

Observations and Results of separation	Modifications to separation



Separation method:

Observations and Results of separation	Modifications to separation

### **Separation of Sand, Salt, and Iron Filings**

Use your results from separating two components to design a separation scheme for a mixture of all three. In the space below write a step-by-step plan for separating your mixture. You may use a flow chart as in the previous section. In the Observations and Results section record your observations for each step of the separation and indicate which components were separated.

**Separation Plan:**

**Observations and Results:**

## SEPARATE THIS! ANSWER KEY

### Physical Properties

1. Look carefully at each substance and describe in detail what each looks like in the table below.

#### Physical Appearance (3 points for complete observations)

Substance	Appearance
Salt	small colourless crystals (particles), hard, all the same colour, larger than grains of sand, solid, all crystals look the same
Sand	very small grains, various colours (white, black, tan, colourless), smaller in size than salt, solid
Iron Filings	small black/grey particles, long and thin particles, all particles look the same, solid

2. Water solubility

#### Water Solubility (3 points for complete observations and correct solubility determination)

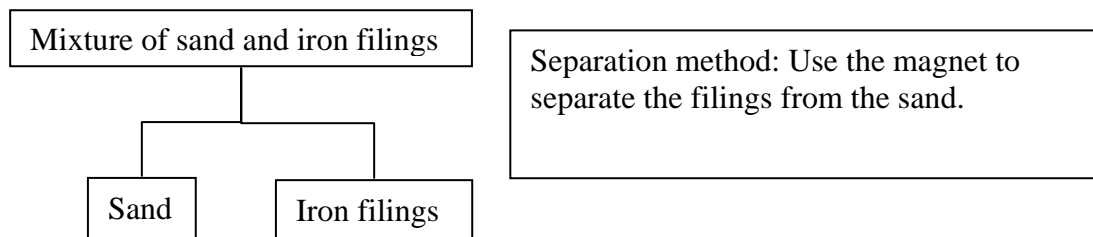
Substance	Observations	Soluble (yes or no)
Sand	Sand settled at the bottom and water stayed on top. You could still see both the sand and the water	NO
Salt	Salt mixed with the water. You could no longer see the salt. The salt appeared to disappear.	YES
Iron Filings	The iron filings did not mix with the water, you could still see both the filings and the water	NO

3. Magnetic properties.

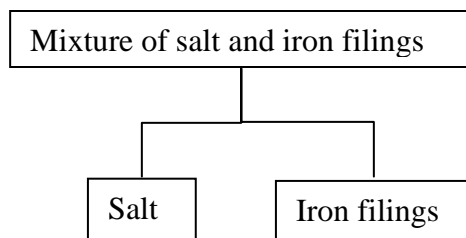
#### Magnetic Properties (3 points for complete observations and correct magnetic determination)

Substance	Observations	Attracted to Magnet (yes or no)
Sand	The magnet did not attract the sand. The sand did not stick to the magnet.	NO
Salt	The magnet did not attract the salt. The salt did not stick to the magnet.	NO
Iron Filings	The magnet attracted the iron filings. The iron filings stuck to the magnet.	YES

**Separation of Two Components (5 points each for reasonable separation method, observations and any necessary modifications)**

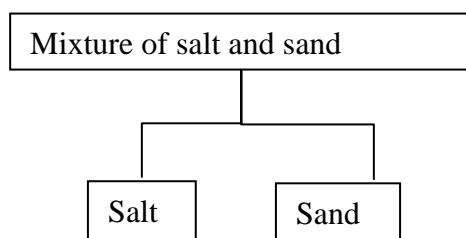


Observations and Results of separation	Modifications to separation
The magnet attracted the iron filings and left the sand in the container. Holding the magnet over a clean cup and removing the magnet from the baggie made the filings fall into the clean cup	No modifications needed.



Separation method: Use the magnet to separate the filings from the sand.

Observations and Results of separation	Modifications to separation
The magnet attracted the iron filings and left the salt in the container. Holding the magnet over a clean cup and removing the magnet from the baggie made the filings fall into the clean cup	No modifications needed.

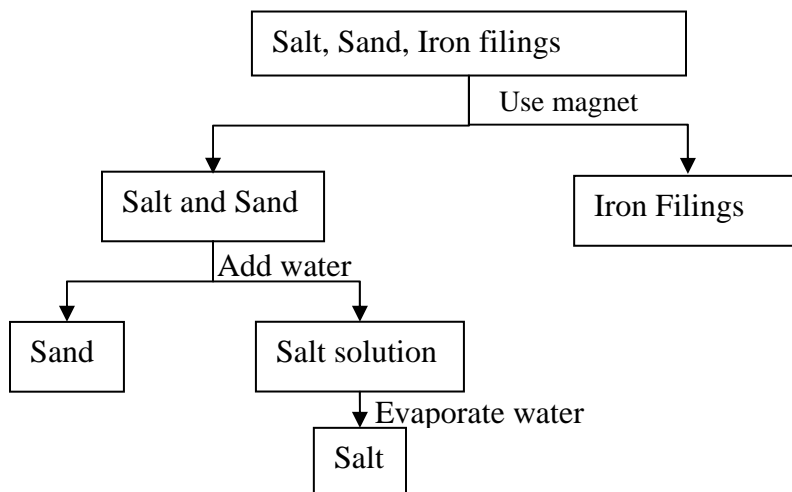


Separation method: Add water and dissolve the salt. Then filter out the sand.

Observations and Results of separation	Modifications to separation
The salt dissolved in the water and the sand remained on the bottom. Pouring the mixture through a filter removed the sand.	The water has to be removed to isolate the salt. Try heating the water.

**Separation of Sand, Salt, and Iron Filings (10 points for reasonable separation scheme and complete summary of observations and results)**

**Separation Plan:**



**Observations and Results:** The magnet removed the iron filings and left the salt and sand behind. Adding water dissolved the salt and the sand was left at the bottom. We could tell because the amount of solid present got smaller when the water was added. The sand was removed by pouring the mixture through a filter. The salt was separated from the water by evaporating the water by heating it.