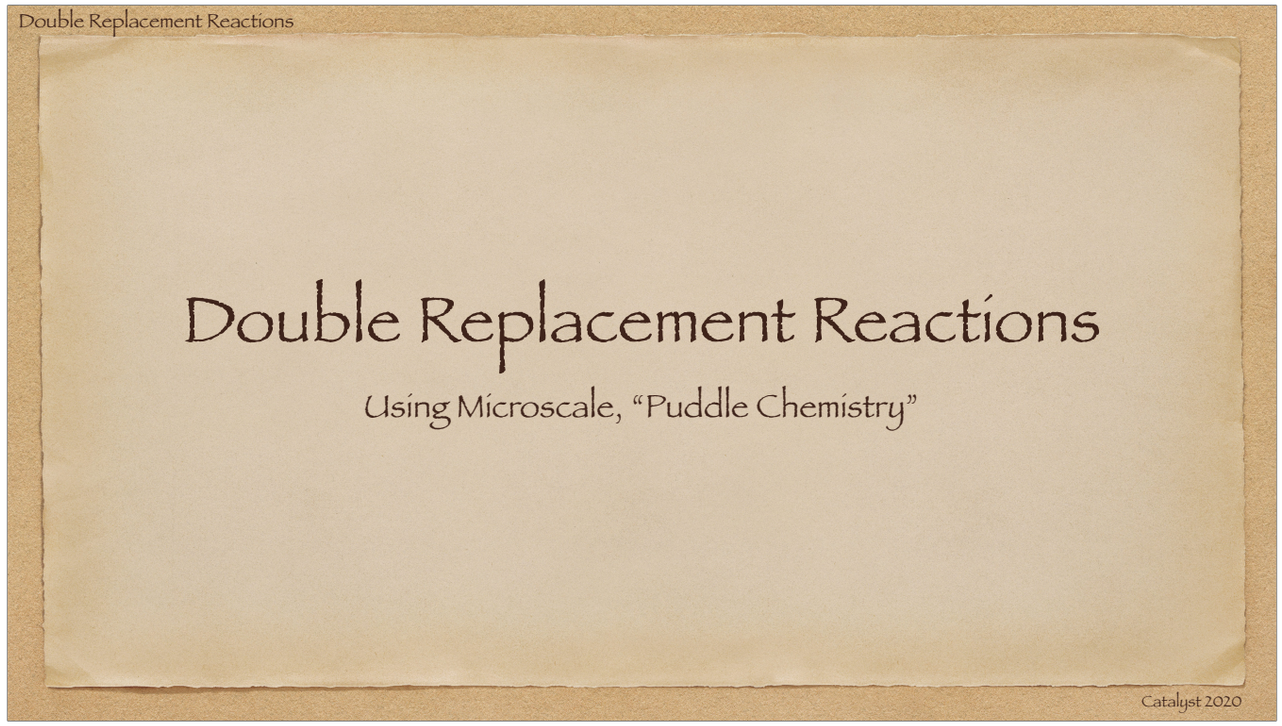
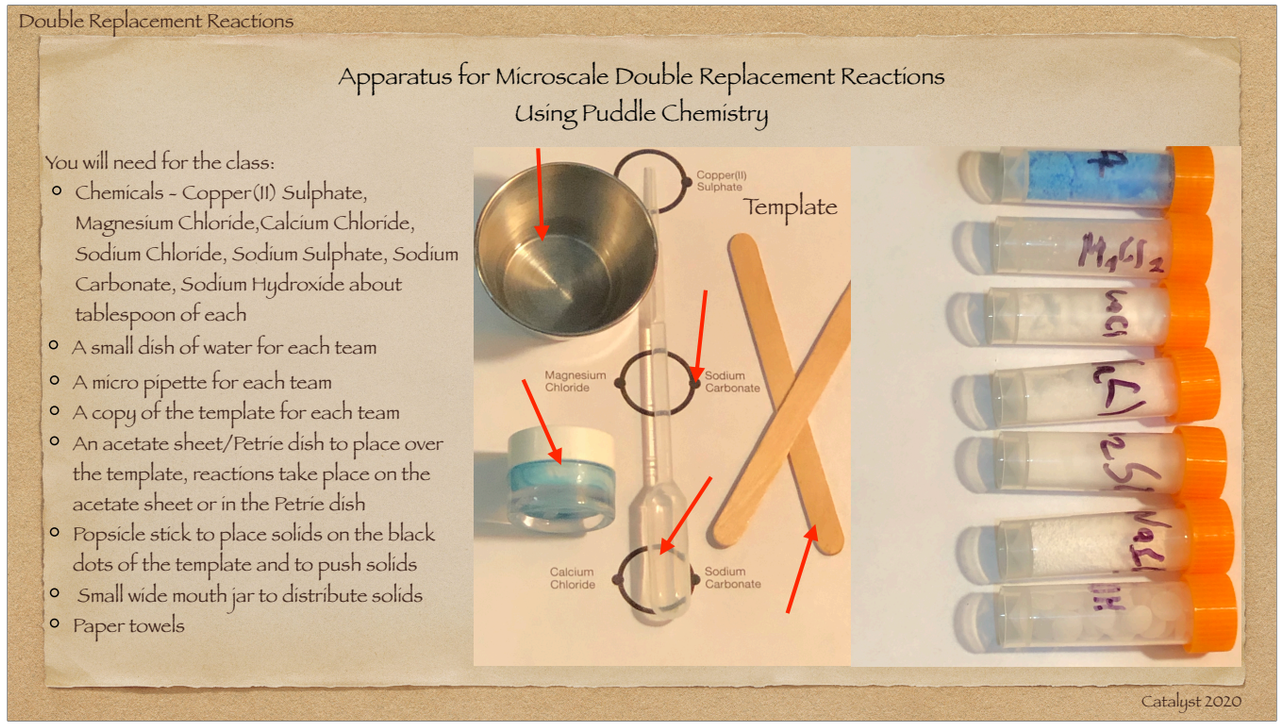
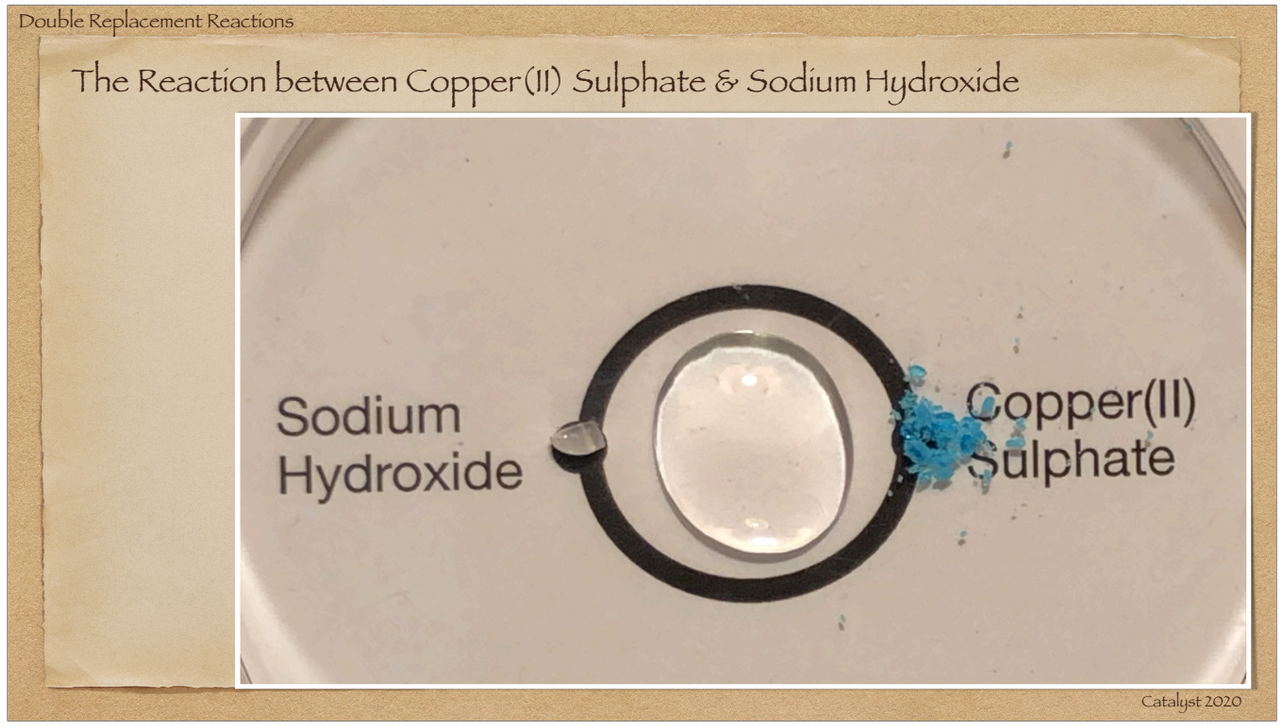


Thank you for joining this session on Double Replacement Reactions! Never fear if you have no idea what that term means. Hopefully in this session you will learn what Double Replacement Reactions are, if you don't know already. What we are going to do is look at how you might introduce chemical reactions using Double Replacement reactions. We are going to use micro scale chemistry in particular "Puddle Chemistry" because we do not wish to squander precious resources and to contribute to environmental pollution more than necessary. The presentation that I am using will be made available to you. Which includes my presenter notes. Also my style is to ask questions when I present or teach. However, because we are limited in time I will ask my questions but there will not be time for you to interact and respond. So my questions will be rhetorical

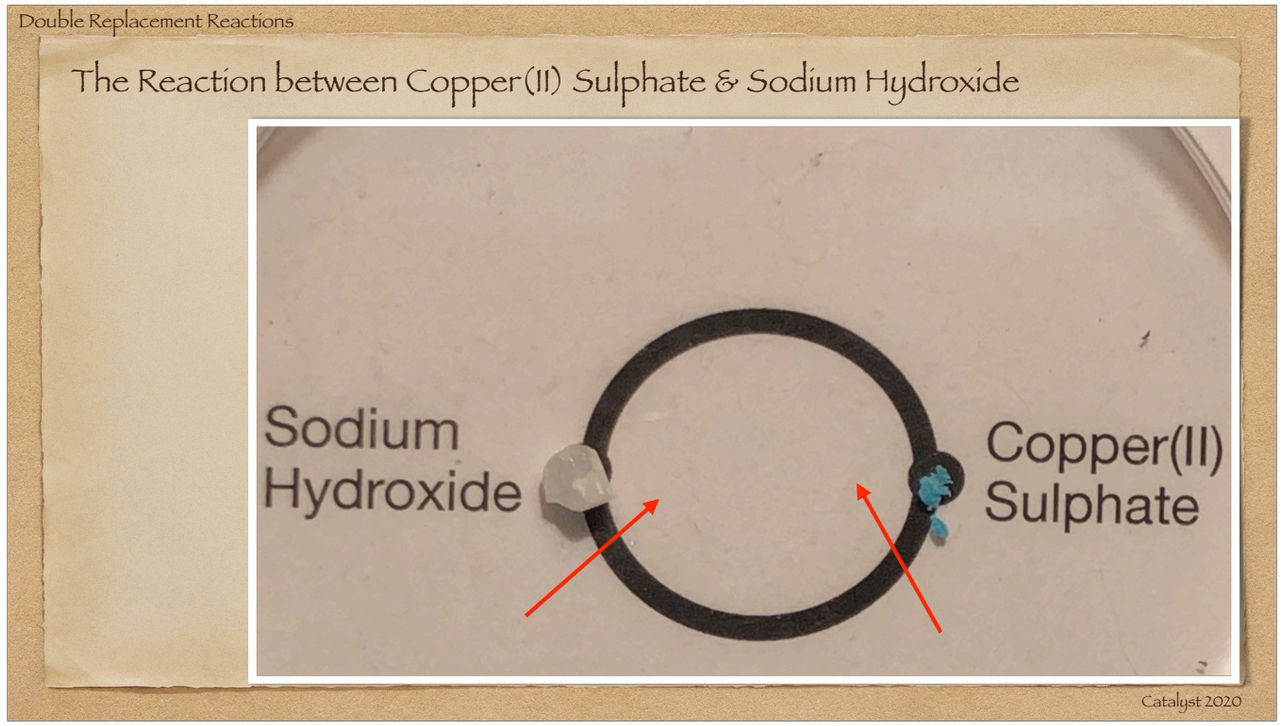


To do Puddle Chemistry you need very little but since this a new approach to doing Chemistry you may find some of the stuff needed is not in your school. You need some chemicals they are listed here, a table spoon of each is more than sufficient to do a class. The little vials you see in the photo is more than enough to do the two classes I had. If you need to, these chemicals may be available locally Copper(II) Sulphate is often sold as Bluestone at hardware and lumber stores as is Magnesium Chloride and Calcium Chloride these are sold as Pet Safe Ice Melt in lumber and hardware stores. Sodium Carbonate commonly called washing soda, salt and Sodium Hydroxide commonly called Lye or oven cleaner are sold in grocery stores. Sodium Sulphate or Glauber's Salt is the hardest to purchase locally but if you have a dying or tie dye industry, Sodium Sulphate acts as a mordant, help dyes stick to cloth. You may be able to scrounge a teaspoon or two of Sodium Sulphate

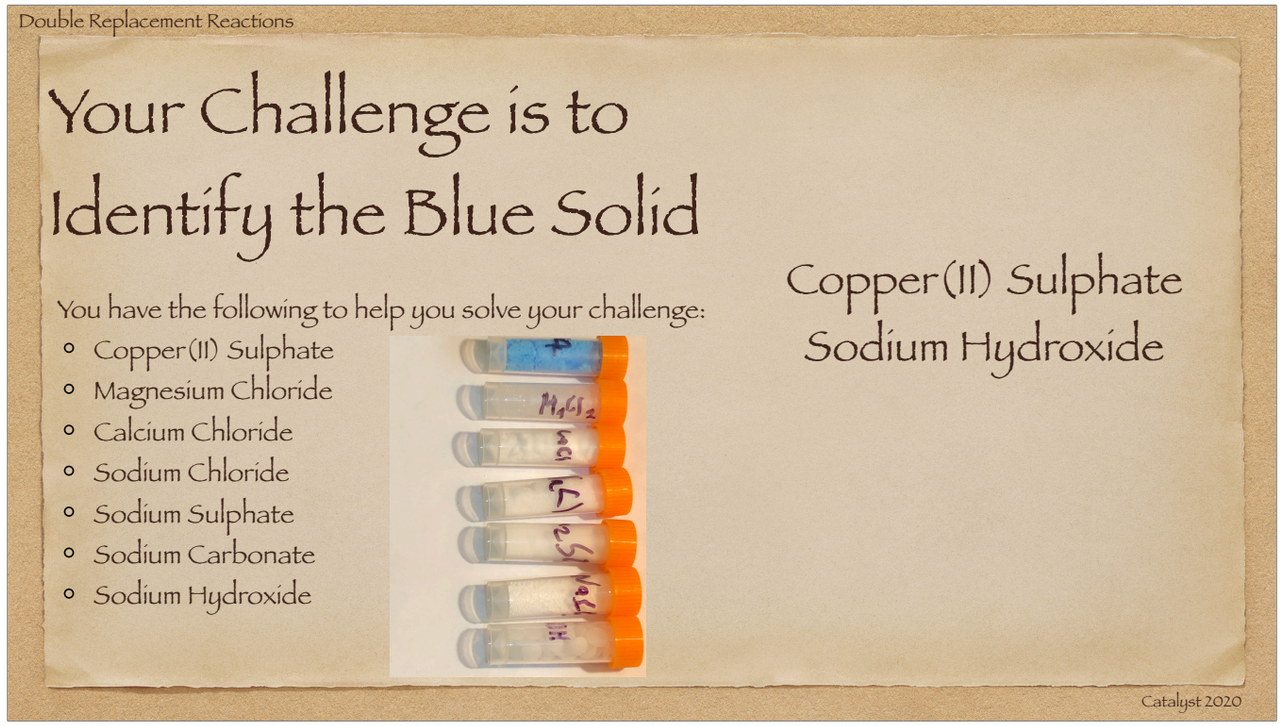
You need a beaker or dish to hold water and a micro pipette to dispense the water. The template you can make in your word processor, the circles can be 1-3 cm in diameter. I think mine are about 2 cm. You make one for each combination a team is going to do. You need to cover the template with an acetate sheet or a transparent envelope that holds the sheet. To clean up you use a paper towel to absorb the puddles and put in the trash. I used Petrie dishes for videoing just because it was more convenient. Popsicle sticks are used to transfer solids to the little dots on the template. There are two approaches; you can use popsicle sticks to push the solids into the puddles or you can just add water to the puddle till it reaches the solid, I will illustrate both. Since everything is small use a small wide mouth jar to distribute solids to the teams. Paper towels are used to clean up. The amount of solid used for each experiment barely covers the round portion of the popsicle stick. Bigger is not better!



So today we are going to investigate what happens when copper(II) sulphate and sodium hydroxide are mixed. Because we are meeting virtually I have prepared videos of the reactions. I chose this reaction for a couple of reasons the main is that copper sulphate or Bluestone is available from Lumber or Hardware stores. Sodium hydroxide or lye is also available from these stores or grocery stores as lye or oven cleaner. Make sure when purchasing from these stores that you read the label to ensure you are getting copper sulphate and sodium hydroxide. Here is the reaction big on the screen but micro scale in reality. Oops sorry I was so busy looking to see what was happening to the Copper(II) Sulphate that I forgot to push the Sodium Hydroxide into the water! Describe what you saw happening! The sodium hydroxide seemed to vigorously enter the water and a blue opaque substance formed in the middle of the puddle. What state is the blue coloured substance in? solid What is your evidence for that? It is opaque. In order for the blue solid to form there what must have happened to to the Copper(II) Sulphate and the Sodium Hydroxide? They must have diffused through the water and met in the middle. Your challenge is to identify the blue solid. Some questions that arise: Did the Copper(II) Sulphate and Sodium Hydroxide diffuse at the same rate? Which do think moved faster? Evidence? How might we modify the experiment to get a better idea of which is the fastest? Add both the Copper(II) Sulphate and Sodium Hydroxide to the water at the same time



Ok in this video I am going to add water to make a puddle large enough to touch both solids at the same time. I have put arrows where I want you to focus. Describe what you saw happening by the red arrow on the left. Sodium hydroxide seems to vigorously enter the water. Describe what you saw happening by the red arrow on your right. Faint blue colour diffuses out from the Copper(II) Sulphate Based on this experiment what can you tell me about the diffusion rates of Copper(II) Sulphate and Sodium Hydroxide. The Sodium Hydroxide moves much faster than the Copper(II) Sulphate. So when these two mix a blue solid is formed your challenge is to identify the blue solid!



Since you are teachers you may know the identity of the blue solid. That is good! Your challenge is to gather the observations using the listed chemicals that would justify your answer. So in class I would demonstrate what happens or show the video, online I'd show the video when copper sulphate and sodium hydroxide are put at either end of a puddle of water. Ok so now you know what the challenge is and what you are given to solve the challenge I'd like you to take a couple of minutes to think how you might go about finding a solution to the challenge. In class and if we had time today I would put the students or you in teams/Zoom rooms and give you about 15 min to think and discuss. In this situation I will give you a few minutes to think. Ok time for thinking is done, I realize the time was not sufficient but I have little time to show you everything. Get the teams to share what thoughts they had? Presented with a problem one approach is to look at the substances you have been given and consider what do they all have in common? Their names all have two components just like your name, a first or given name and a second or surname. So if we consider that commonality, about their names, Copper(II) Sulphate and Sodium Hydroxide what combination of names could we come up with? Copper Sodium, Copper Hydroxide, Hydroxide Sulphate or Sulphate Hydroxide and Copper(II) Sulphate and Sodium Hydroxide so the Blue Solid could be any of these combinations, the reverse or something else. PLEASE NOTE not all chemicals have two names but the chemicals we have today do have two names.

Your Challenge is to Identify the Blue Solid

The following are possible name combinations for the Blue Solid:

- ~~Copper(II) Sulphate~~
- Copper(II) Hydroxide
- Copper(II) Sodium
- Sulphate Hydroxide
- ~~Sodium Sulphate~~
- ~~Sodium Hydroxide~~

Here are the possible combinations of the names. Can we eliminate any of them from what we know already? Yes the Sodium Hydroxide was not blue and also Sodium Sulphate was not blue so they are not likely the blue solid. And the Copper(II) Sulphate is not likely to be the blue solid because the blue solid formed a long way from the copper(II) sulphate but it is blue. So we are left with only 3 likely candidates. I say likely because our reasoning on the copper(II) sulphate is not as good as the others we eliminated. So we know need to figure out experiments to eliminate candidates.

What Experiments can be done to eliminate possibilities?

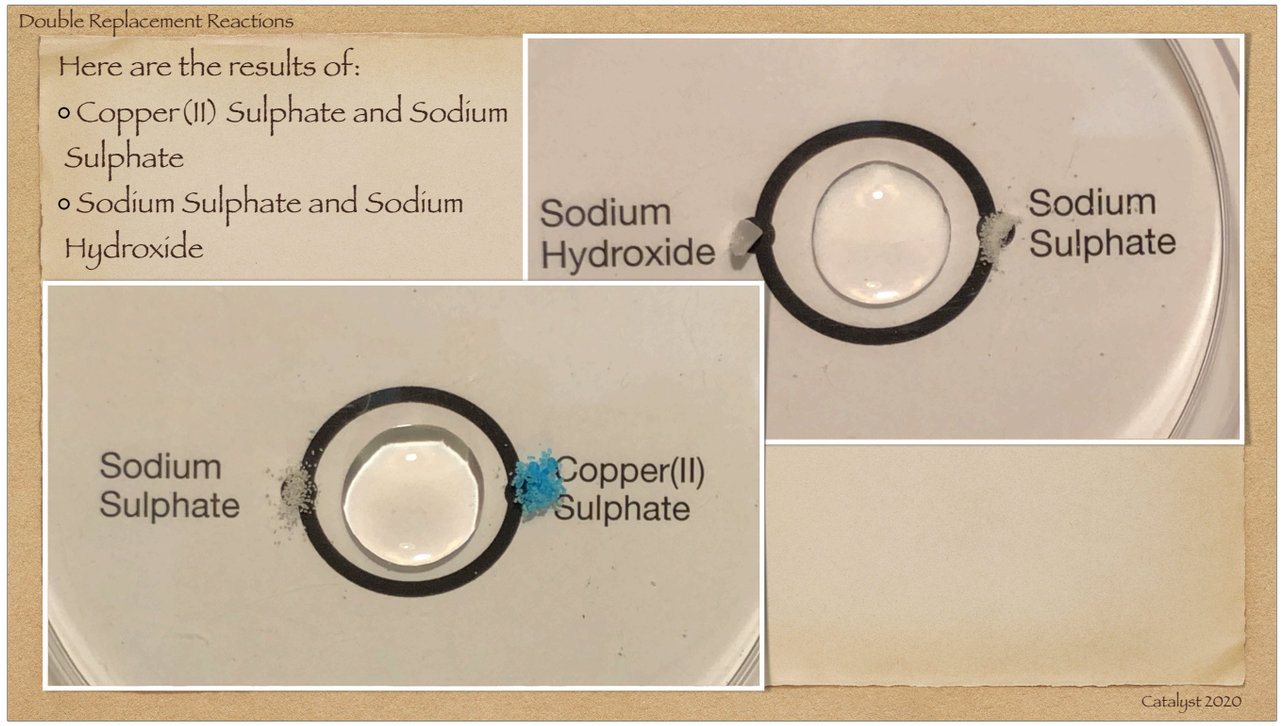
You have the following to help you solve your challenge:

- Copper(II) Sulphate
- Magnesium Chloride
- Calcium Chloride
- Sodium Chloride
- Sodium Carbonate
- Sodium Sulphate
- Sodium Hydroxide

The following are possible name combinations for the Blue Gel:

- ~~Copper(II) Sulphate~~
- Copper(II) Hydroxide
- Copper(II) Sodium
- Sulphate Hydroxide
- ~~Sodium Sulphate~~
- ~~Sodium Hydroxide~~

Here you have all the chemicals we have to work with and the possibilities we want to eliminate. So at this point I would challenge my teams to think about what experiments that could be done to try and eliminate some of these possibilities? So if online I'd send the teams to their online rooms and give them say 15 min to discuss and think. In this situation please give some thought to this problem. For example how could we test that Sulphate Hydroxide is the Blue solid? How Copper(II) Sodium?



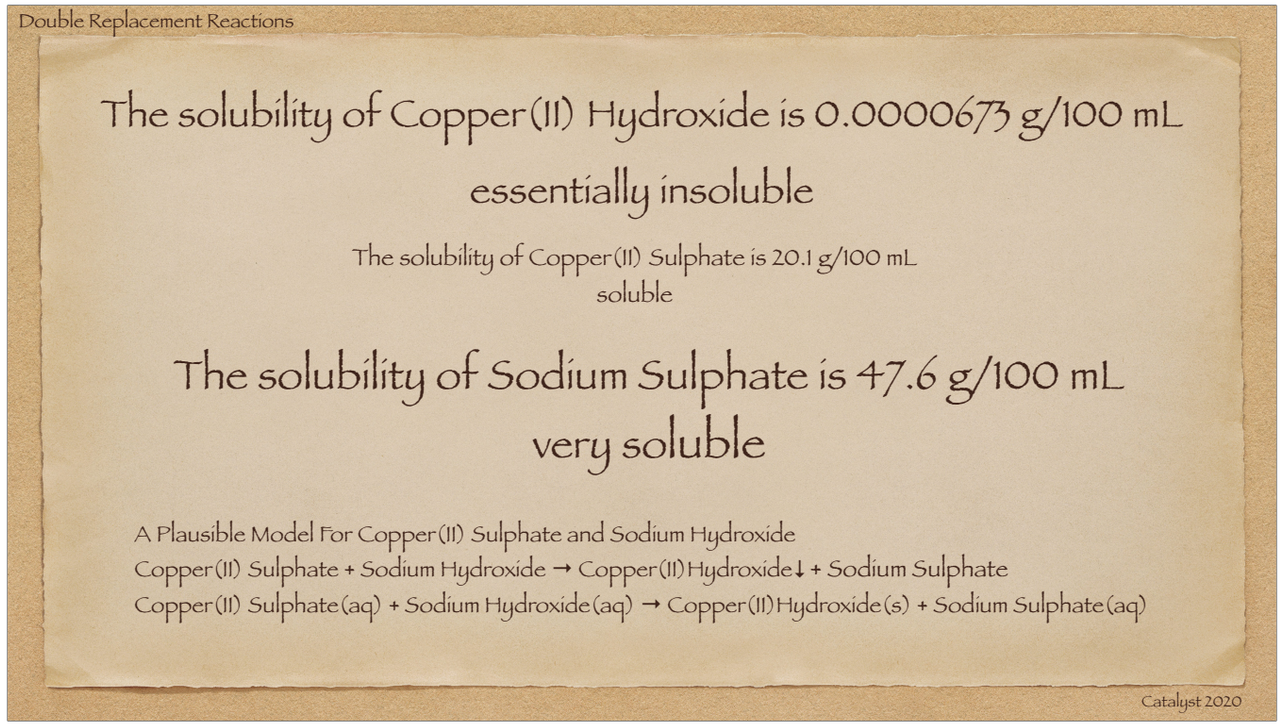
Here are the videos of Copper(II) Sulphate and Sodium Sulphate and Sodium Sulphate and Sodium Hydroxide? In these videos I will demonstrate the technique of pushing the solid into the puddle to start the reaction. I ran the videos for 3 min

Your Challenge is to Identify the Blue Solid

The following are possible name combinations for the Blue Solid:

- ~~Copper(II) Sulphate~~
- Copper(II) Hydroxide
- ~~Copper(II) Sodium~~
- ~~Sulphate Hydroxide~~
- ~~Sodium Sulphate~~
- ~~Sodium Hydroxide~~

Based on the two experiments we just did which possibilities can we eliminate? We have only one possibility left but are we really sure the Blue Solid is Copper(II) Hydroxide? No but what evidence suggests it is? We eliminated all the other choices and copper(II) Sulphate was blue and Sodium Sulphate was colourless. What else could we do that might convince us that Copper(II) Hydroxide was the blue solid? get more evidence What kind of evidence? solubility because the blue solid came out of the water i.e. it didn't dissolve in ti



To get more evidence I looked up the solubility of Copper(II) Hydroxide it is 0.0000673 g/100mL of water at 18oC. What does this mean? essentially insoluble So Copper(II) Hydroxide will essentially not dissolve in water. Copper(II) Sulphate in comparison is 20.1 g/100 mL of water. What does that mean? whereas Copper(II) Sulphate lots of it dissolves in water So if Copper(II) Hydroxide was formed in the water from the Copper(II) Sulphate diffusing from one end and Sodium Hydroxide diffusing from the other what would happen to it? It would precipitate out, in other words it would fall out of the water as a Blue Solid. So a plausible model for the reaction of Copper(II) Sulphate and Sodium Hydroxide is that the two reactants diffuse together through the puddle meet and form Copper(II) Hydroxide which drops out of solution so our model could look like this! So it appears like the Hydroxide is taking the place of or replacing the Sulphate. If we follow that process might the Sulphate do? It might replace the Hydroxide. What would be the resulting substance? Sodium Sulphate But I didn't see any white solid form and I know Sodium Sulphate is colourless or white? If Sodium Sulphate forms why don't we see it? it remains in solution. How can we check to see if Sodium Sulphate would stay in solution? look up solubility So based on our experiments and the solubility data our model for the reaction would look like this. The model we have developed is called a word equation for the reaction. Here is another model word equation for the reaction.
Another way of tackling the Challenge of Identifying the Blue Solid would be to take all the chemicals and experiment with all the possible combinations of two of them. To determine all possible combinations we can use a table, the table would look like this -

Possible Experimental Combinations

Possible Combos	Copper(II) Sulphate	Magnesium Chloride	Calcium Chloride	Sodium Chloride	Sodium Carbonate	Sodium Sulphate	Sodium Hydroxide
Copper(II) Sulphate							
Magnesium Chloride							
Calcium Chloride							
Sodium Chloride							
Sodium Carbonate							
Sodium Sulphate							
Sodium Hydroxide							

NOTE: I have set up the table so that each chemical is listed in a cell both on the vertical and horizontal axes. And in the same order. So what do each of the empty cells represent? A combination of two chemicals. I think there are 49 empty cells that is a lot of chemical combinations to test. Can we logically eliminate any? yes

Double Replacement Reactions

Possible Experimental Combinations

Possible Combos	Copper(II) Sulphate	Magnesium Chloride	Calcium Chloride	Sodium Chloride	Sodium Carbonate	Sodium Sulphate	Sodium Hydroxide
Copper(II) Sulphate	X						
Magnesium Chloride		X					
Calcium Chloride			X				
Sodium Chloride				X			
Sodium Carbonate					X		
Sodium Sulphate						X	
Sodium Hydroxide							X

Catalyst 2020

For example let us focus on the first empty column, can we eliminate this combination? Yes because combine the two just gives you more of the same thing. Following this principle what others could we eliminate? Ok were down to 42 experiments. Ok think about what other combinations we could eliminate but keep you thoughts to your self! NOTE: in Zoom you can make this interactive by getting the participants to mark up the table. But in this case I don’t have the time to do those those things. But you can when you are working with your students.

Double Replacement Reactions

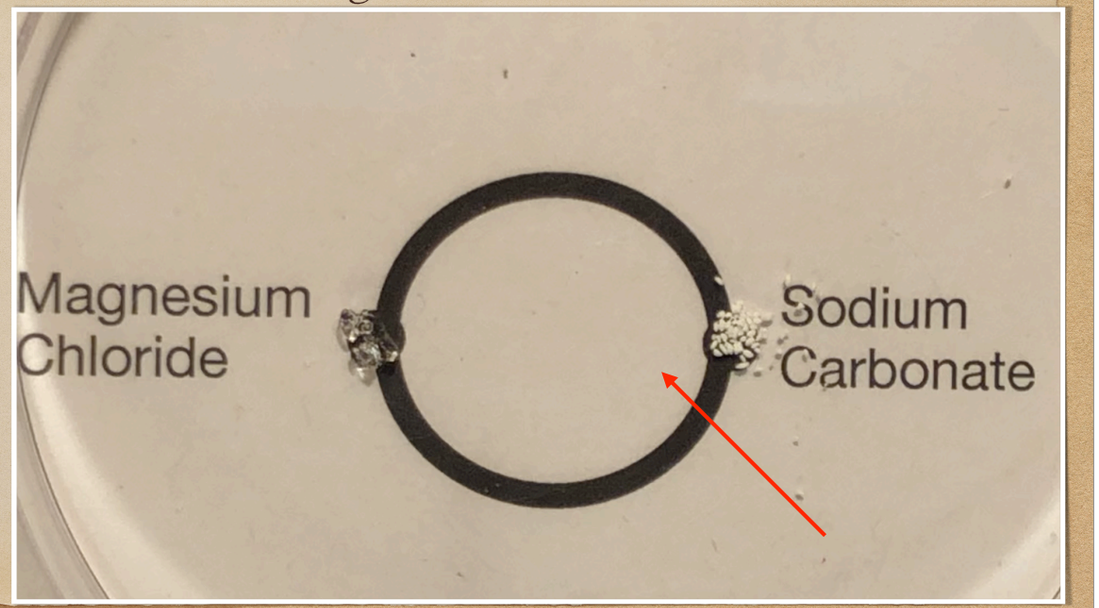
Possible Experimental Combinations

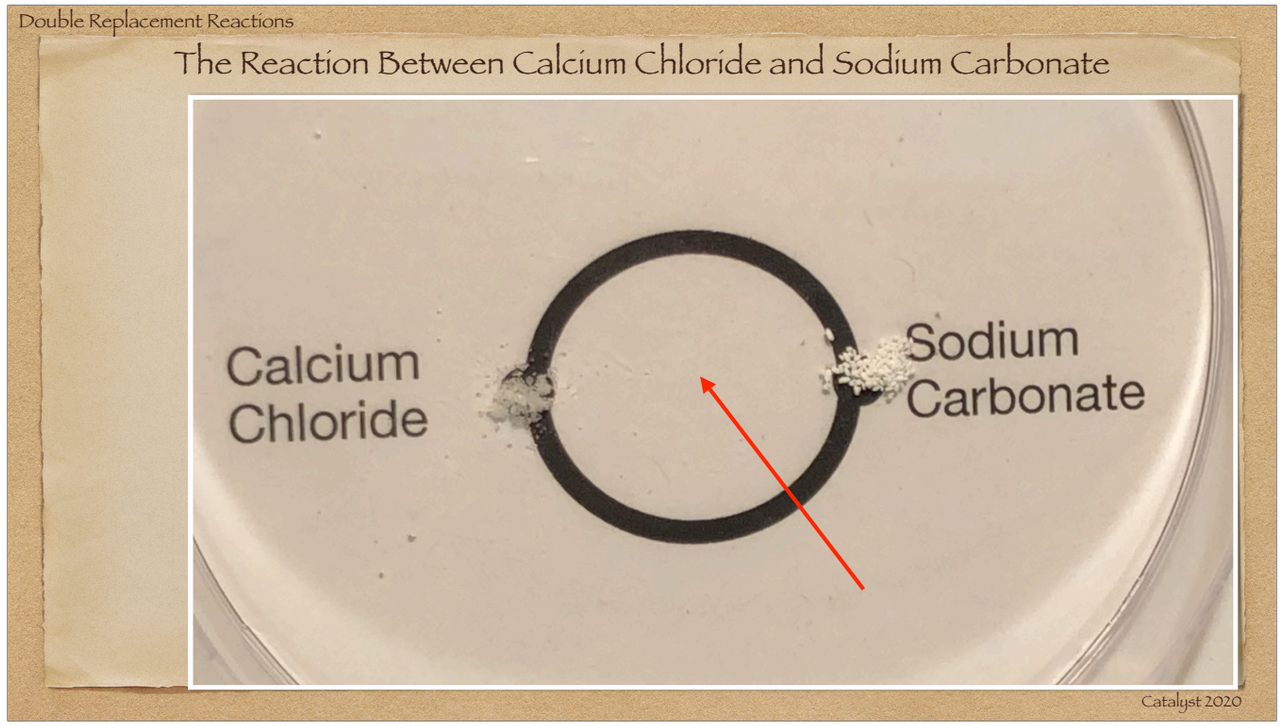
Possible Combos	Copper(II) Sulphate	Magnesium Chloride	Calcium Chloride	Sodium Chloride	Sodium Carbonate	Sodium Sulphate	Sodium Hydroxide
Copper(II) Sulphate	X	X	X	X	X	X	X
Magnesium Chloride	✓	X	X	X	X	X	X
Calacium Chloride	✓	✓	X	X	X	X	X
Sodium Chloride	✓	✓	✓	X	X	X	X
Sodium Carbonate	✓	✓	✓	✓	X	X	X
Sodium Sulphate	✓	✓	✓	✓	✓	X	X
Sodium Hydroxide	✓	✓	✓	✓	✓	✓	X

Catalyst 2020

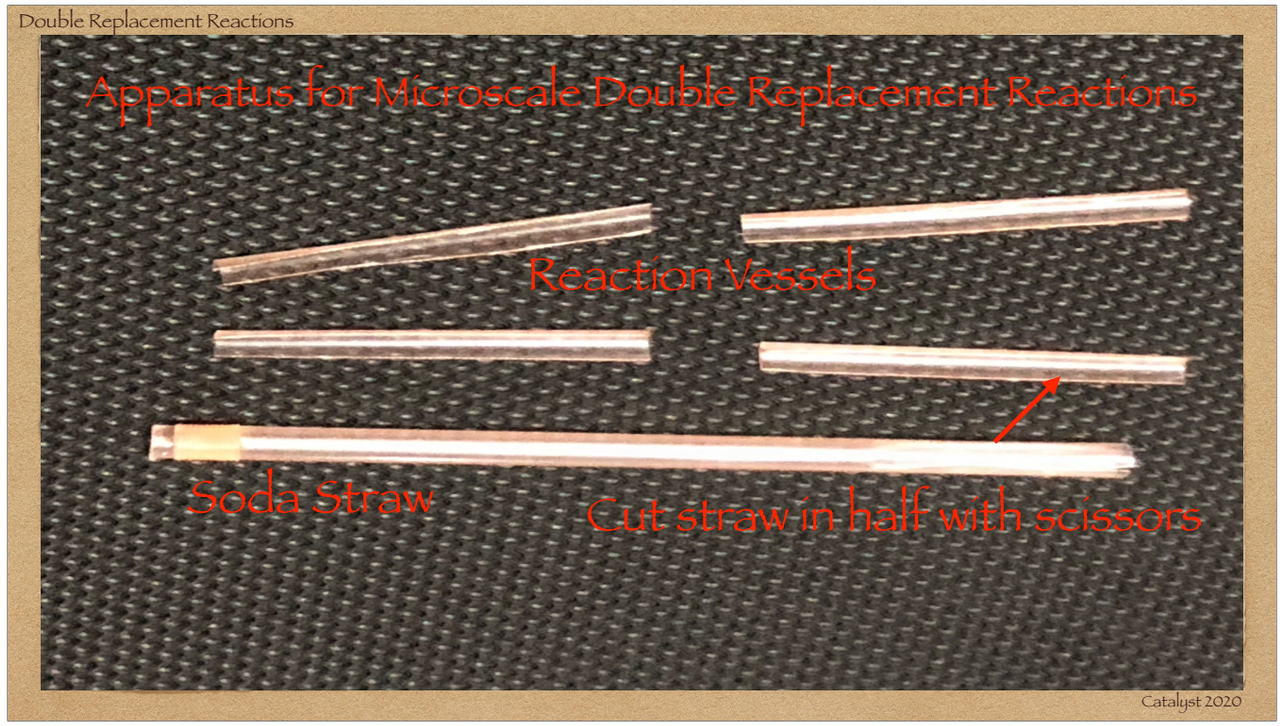
Preceding down the first column of empty cells is the combination of Magnesium Chloride and Copper(II) Sulphate one we should try? This one? This one etc. Now let us move down the next empty column, is the Magnesium Chloride and Copper(II) Sulphate combination one we have to do? This one? This one? etc. Now let us move down the next empty column. Now if anyone one can see the pattern please shout it out. So how many combinations do we have try? 21 So at this point you put your class into teams and divide up the task. Another way of doing it would be to have the students predict all the double replacement reactions, write out the word equations and then use solubility tables to identify reactions that we can observe happening, a precipitate forms. The following substances have very low solubility Copper(II) Carbonate, Copper(II) Hydroxide, Calcium Carbonate, Calcium Sulphate, Magnesium Carbonate, Magnesium Sulphate, Calcium Hydroxide and Magnesium Hydroxide. If you do all the combinations make sure each team has some that form a precipitate and some that don't. My preference is that the students should see reactions that form a precipitate and some that don't, the double replacement reaction may occur in those that we don't see a precipitate but we won't have any observations that suggest the switch occurs.

The Reaction Between Magnesium Chloride and Sodium Carbonate





With the combinations of chemicals you can set up ratios and eventually a scale of relative speeds of diffusion of the Magnesium and the Carbonate and Calcium and the carbonate and then for Calcium and Magnesium. The results are very interesting, the expectation is the bigger ion would diffuse more slowly and Calcium is moving more slowly than Magnesium. But what role does the rate of dissolving play? Is there a relationship between diffusion and Molar Mass? And how many molecules of water are being drag along? What role does charge density play? Are questions for further experiments. Please note clean up up is a wipe with a paper towel. On the next slide I show another way of doing the Micro Scale



Here is another way to do Micro Scale, soda straws cut in half longitudinally 4-5 cm in length. Pieces of straw will be our reaction vessels. At this point I have not been able to make these work reliably enough but the soda straw reaction vessel makes measuring distances so much easier. So I am looking for something like a half a soda straw that is cheap and does not roll.

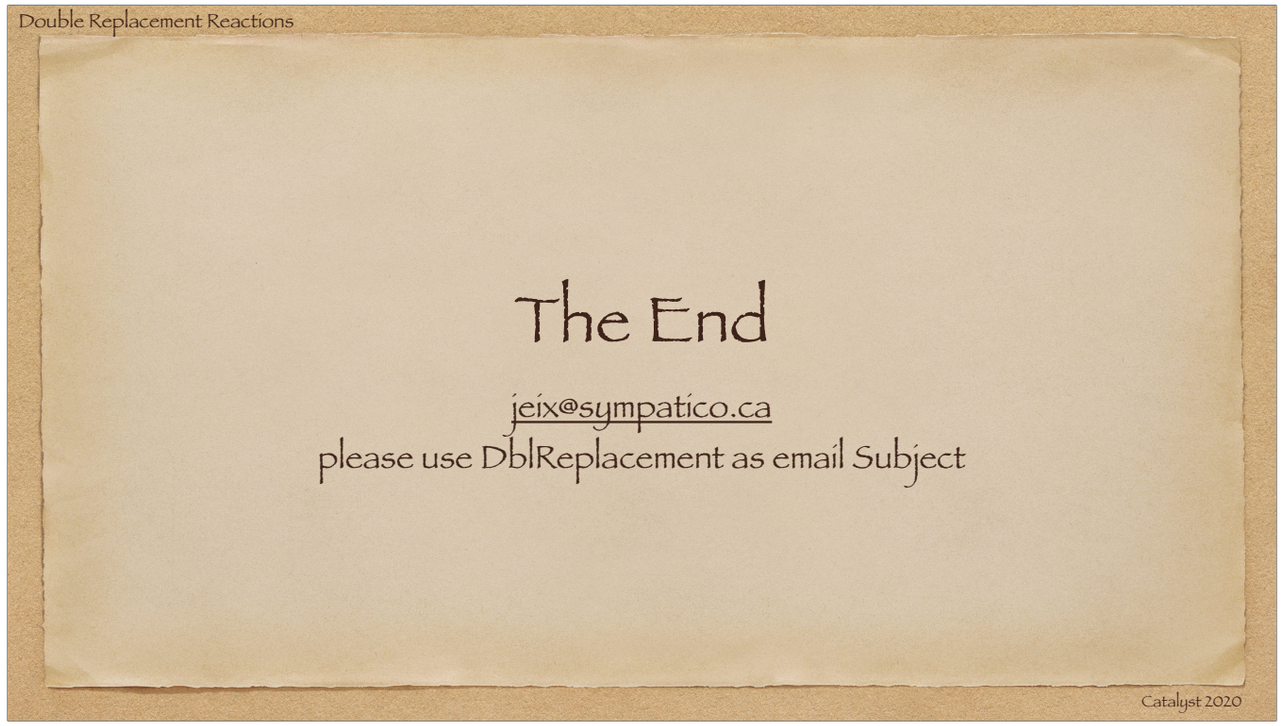
Hints or Things that Frustrated Me

- Bigger is not better when using the chemicals
- To do puddle chemistry the table has to be level
- Always place solids before adding water
- The amount of solid covers less than the curved part of the popsicle stick
- Use the Popsicle stick to gather the solid into one spot
- Solids can be pushed into the puddle or the puddle expanded into the solids
- Working with Sodium Hydroxide is frustrating, the pellets that come in the lab reagent bottles have to be cut to make small pieces I used one pellet for all my Sodium Hydroxide experiments. I haven't had time to play with Oven Cleaner it might be easier to work with
- The reaction time is less than 3 min, this is a plus
- Have students use their cell phones to video Puddle or Soda Straw Chemistry

My frustrations are mainly with the apparatus, working small is a problem with hands that shake. Currently plastic straws are still available but they are being banned. A substitute for them is the long stem of a plastic pipette. The reason I used straws is of course cost. You can also do what I have suggested so far in spot plates however what you can't do in spot plates is the extension that I am going to suggest and that is students will notice that the precipitate doesn't form in the middle of the straw and then they will notice that the position is different for different substances. So using the straw or puddle you can measure the distance between the chemical and where the precipitate starts. A ratio of the distances gives a relative speed of the participants say the Copper(II) and the Hydroxide. There is enough data to set up relative ratios for the the various components and students could set up a scale of speeds from slowest to fastest just think of the math applications STEM

Hints or Things that Frustrated Me

- Cutting the straws, the best I found was these scissors, they have a serrated edge -
- Placing the solids on the Petrie Dish or in the half straw - static electricity and tipsy straw results in solid all over the place, Magnesium Chloride, Calcium Chloride, Sodium Hydroxide deliquesce, that is they absorb water from the atmosphere, so they will stick to the straw, add them first pick up the half straw and use it as a scoop to get the other solid
- If I have wetted your appetite about micro scale Chemistry follow Bob Worley on Twitter, he is the guru when it comes to making chemistry small, and safe for the students and the environment



I hope you enjoyed a look or relook at Double replacement Reactions. I hope you will consider making Micro Scale Chemistry part of your teaching bag of tricks and I highly recommend you follow Bob Worley on Twitter for more ideas on making Chemistry Small and Safe. Please NOTE: this presentation including my presenter notes will be made available to you. If you have feedback or questions of me here is my email. Please use DblReplacement as the subject of your email so I don’t delete it as spam