Precipitation Reactions: Crash Course Chemistry #9
Crash Course: Chemistry
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You're at dinner with your best friend: fine conversation, fine wine, some barbecued beef cheeks. You look outside to admire the full moon, but when you glance back you realize that your friend has turned into a werewolf. Fortunately, the cutlery is made of silver, and you know how to use it!
Or perhaps, you're in the bath one day, and as you reach for the soap you notice a wart on your big toe. Well squeeze a little silver nitrate on that big boy and you'll be ready for sandals season in no time.
Shiny, electrically conductive, and oh-so-useful, silver has been valued since ancient times and has a reputation for purity and warding off evil, whether in the form of werewolves or warts.

(00:34)

=====Precipitation Reactions=====

Silver was also a big driver of settlement in the western United States, including Montana, where I live. And, of course, all that silver got here because of chemistry. Specifically it's here because of countless chemical reactions that took place over the eons called precipitation reactions: when chemicals in a solution react to form a solid. Precipitation reactions are what create geological deposits in the earth as well as rings around your bathtub. They're what we use to make our waste water drinkable and they've been used by folks for thousands of years to get rich. Because precipitation reactions happen to be one of the best ways to produce chemicals of the highest purity. So they're not only the key to how silver was deposited in these mountains hundreds of millions of years ago; they're also the key to getting that silver back out. I can do it, right here on this desk. And all I need to get started is this [holds up table salt]

[Intro Music]

(01:35)

=====Determining Precipitates=====

Precipitation. It's stuff falling out of other stuff: water falling out of the sky, solids falling out of solution. And for us here it all comes down to a little thing called solubility. Water, as we've discussed here before, is pretty dang good at dissolving stuff, ionic compounds in particular. A positively charge ion and a negatively charged ion held together by their charges might form a crystal when they're dry, but add a bit of water and those little polar molecules slide their way between the ions dissolving massive amounts of ionic compounds. But some ionic compounds can overcome even the dissolving power of water and when they form through reactions in solution, they fall out as a solid precipitate. Yes, precipitate is both a noun and verb. Get used to it. When we talk about an ionic compound that's fallen out of solution I say precipitate [pre-sip-uh-tit] to distinguish it from from precipitate [pre-sip-eh-tate] which is more the verb-y sound. And this is purely my preference because that's how my teacher said it when I was being taught.

So the rich silver veins in Montana formed when water stuffed with ionic compounds ran through cracks in paleozoic limestone. Where conditions were right, silver ions in the water reacted with ionic compounds, or salts, in the limestone to make insoluble silver compounds that fell out of solution. And it looks, a little bit, like this [holds up a rock]. It actually looks exactly like this. It's pretty cool because, you can't feel this but, it is extremely heavy, because silver is a pretty heavy element. And it wasn't just the silver salts in solution, all kinds of stuff: gold and potassium and copper salts and, most notably, sodium salts are dissolved as water rushes across the landscape. If these dissolved compounds stay in solution until they get to the ocean, they pretty much stay there forever. The water evaporates, leaving the salts behind in the ocean where over the eons it has built up, leaving the ocean super salty. As we know it today.

And while sodium chloride, what we call salt when not doing chemistry, is the most common salt, there are also tons of other things dissolved in the ocean, including quite a lot of gold. In fact, at today's market value the ocean contains about one hundred million trillion dollars of gold. And that was not a stutter, a hundred million trillion. That's a hundred trillion with six more zeros after it.

So you can see why it might be nice to master some precipitation reactions. There have been chemists that have driven themselves crazy trying to figure out how to economically extract gold from seawater, but thus far none have done it.

This solution here of silver nitrate is similar to that ion rich water that steeped through the Montana limestone millions of years ago. And we can use it right here at this desk to recreate the ancient reactions that deposited silver in veins across our landscape. But instead of the types of salts found in limestone, we can use a very similar and substantially more familiar ion compound: table salt, good old NaCl. Add some drops of sodium chloride, also known as your salt water to the silver nitrate solution and there you see your precipitate. Ooooo...gross.

Now the question that we immediately want to ask is, "What is this white stuff down here?" The key to understanding what just happened here is that both of the compounds are ionic. You remember there are two kinds of ions, right? Cations are positively charged and anions are negatively charged. Just like little bar magnets, they attract. So cations only react with anions to form new compounds. And don't just think that there's one anion and one cation. The sodium ion in sodium chloride will have chloride ions on all four sides, which in turn are surrounded by four sodiums and this pattern repeats many, many, many times until we end up with the salt crystals that we dissolved in the water.

But how do we know which ions are cations and which are anions? Well sodium is positively charged so it's a cation and we know that it's positively charged because sodium is a metal from the left side of the periodic table and those are always cations when they're alone. Silver is also a metal and is also a cation. We know that chlorine is a gas from the right side of the periodic table, so that is an anion. Now what about the nitrate? Also anion. Nitrates, sulfates and phosphates are really common and they're always anions. Whenever you see an N, S, or P followed by a bunch of oxygens, you know you're looking at an anion.

With that in mind, look at the possible products of this reaction. What we're looking for is a product that doesn't dissolve in water, so we know it's not sodium chloride. That was one of our reactants and it dissolves readily in water, hence the oceans. And it isn't silver nitrate, our other reactant, or sodium nitrate because as a rule, nitrates dissolve really easily in water, so we know that's dissolved. So we're left with silver chloride. Just process of elimination. This makes sense because silver also makes insoluble compounds with bromine and iodine, which are in the same column of the periodic table as chlorine. Elements in the same column often behave in similar ways. And you'll notice of course that we don't end up with like a huge, nice chunk of pure silver there; now it's bonded to chlorine. Kinda like table salt, silver chloride is a crystalline solid, unlike salt though it's not very soluble in water. Now getting the silver out of this compound will involve another kind of reaction, a redox reaction, which we'll talk more about next week.

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=====Writing Precipitate Reactions=====

In the meantime, we still have to learn the language of describing this sort of reaction. Because the neat and somewhat unique interactions that are involved in precipitation reactions--dissolved substances producing solids, ions dissociating and rebonding--there are special ways to write and balance them as equations. One way is to include notations in parenthesis that tell you what state the chemicals are in: Aq meaning aqueous, or in solution, and s for solid, meaning that it's your precipitate, this is called the molecular equation.

Another way which tends to give a clearer picture of what actually happens during the reaction is to write everything out as ions. Here you list the compounds that dissolve completely in solution as ions; makes sense because as soon as the salts are dissolved every ion is on it's own, and it doesn't really matter where it originally came from. So the left side shows silver, and nitrate, and sodium, and chloride ions all in one solution. And the right side shows sodium and nitrate still as separate ions in solution with the silver chloride precipitated out as solid.

Now if we don't care about the complete equation, and only want to see the active participants, we can write it in yet a third way. We just leave out the so-called spectator ions: nitrate and sodium, which don't participate directly in the reaction, and end up with a net ionic equation showing just silver and chloride ions reacting to form silver chloride.This is nice, and short, and to the point, which is what chemists love because remember some of them have terrible writing skills and have to dictate their stuff to their mom.

Now as an aside remember when I first brought up the weirdness of using Ag to denote the word silver? Well all that stems from the fact that the Latin world for silver is argentum and the ancients were, as most people are today, obsessed with what silver represented, not just wealth, but also health.
Ancient Indo-Europeans associated silver with purity and goodness. Hippocrates, the ancient Greek doctor, wrote about silver's anti-disease properties. And there's good science behind silver's medical uses. A lot of the metals are toxic to things like fungi and microbes. But unlike say, lead, silver isn't that toxic to humans. Silver nitrate and a compound called silver sulfadiazine, were used to disinfect wounds in World War I, before antibiotics were discovered. Silver sulfadiazine is still used to dress burns. And researchers are now looking at the antimicrobial uses for silver nanoparticles. Some people even take colloidal silver, basically silver particles in a liquid suspension, as a kind of general health booster, but there's not actually any evidence that it boosts health. It can turn you blue though. Now you want that silver even more, don't you.

(08:52)

=====Calculating Molar Mass Equation=====

Now, as we always do, in order to make a reaction practical you have to go through the final step of converting the formula equation into a molar mass equation. If we wanted to get the silver out of solution, how much salt would we need? Specifically, let's say that we want to get one troy ounce of silver. The troy ounce is part of the troy weight system which is used to weigh precious metals. It's derived from the way the Romans measured bronze and silver bars they used for currency two thousand years ago, and we are still stuck with it. But let's be at least a little bit modern about this, a troy ounce equals 31.1 grams. So we want 31.3 grams of silver, the molar mass of silver is 107.868 grams per mole. Do the calculation and we find that 31.1 grams equals 0.288 moles of silver. From the molecular equation we can see that in order for it to balance we'll need one mole of sodium chloride for every mole of silver. So to get 0.288 moles of silver, how much sodium chloride do we need? We've made it easy for you; it's 0.288 moles. So then we convert 0.288 moles of sodium chloride into units of mass and grams. Sodium chloride's molar mass is 58.45 grams per mole. Multiply 58.45 grams per mole by 0.288 and we find we need 16.8 grams of sodium chloride to precipitate out 1 troy ounce of silver out of silver nitrate solution. And look at that you get a nice pile of silver chloride in solution. Yes, it's not pure silver not yet. Just like real miners who dig ores out of the ground that contain just a few percent silver, we need to do some refining. In our case, there's another type of reaction necessary called a redox reaction. Redox is short for reduction-oxidation and that is what we'll be talking about next time.

=====Summary=====

Thank you for watching this episode of Crash Course Chemistry. This week we discussed what defines precipitation reactions and how you can determine what precipitants they form. We also learned how to write precipitate reaction equations and finally we calculated a molar mass equation to figure out how much of a reactant we need to produce a desired amount of precipitant.

=====Credits=====

This episode of Crash Course was written by Kim Krieger and the script was edited by Blake de Pastino and myself. Our chemistry consultant is Dr. Heiko Langner. This episode was filmed and directed and edited by Nicholas Jenkins with sound design by Michael Aranda. Our script supervisor was Caitlin Hofmeister. And our graphics team is Thought Cafe.