SMALLab Chemistry Titration Lesson Plan – Teacher Guide

Section	Notes	Teacher
Day 1: Intro		This lesson has three distinct parts. It can spread across 2 or 3 days depending on how many students you have and how quickly you move through it. It is easiest to describe in a 3 day sequence covering several main concepts.
Day 1 Goals	The concepts	Concepts – 1. Chemical structure of acids & bases and their behavior in water. 2. Dissociation and ionization 3. Reactions involving hydroxide and hydronium ions and the measurement of pH 4. Titration with indicators
	Intro "Identifying the elements of the scenario"	On the first day, introduce students to the scenario by asking them to observe and describe what they see. This is the beginning of the inquiry process, where students use their observations to construct a working model of the system together. During this process, make sure that your students touch on these key points. 1. They can identify the molecules and molecule types (that is, acid or base) 2. Identify what makes molecules similar or different (the structure of acids and bases). 3. They notice that different colors are associated with each molecule category and with the indicator molecule. 4. They understand that the center image represents water in a virtual flask.
	II. "Playing with molecules in the space"	Once they have taken inventory of the display, invite them to take turns adding molecules into the space. They should be able to select a single molecule and observe what happens when they "drop" the molecule into the space with the wand. The velocity with which students toss the molecules in will affect how the molecules move. Have them observe and try to explain the phenomena that are occurring. You can help them with this process by using the pointer/clicker to pause, play, and reset the scenario so that students can develop an understanding of how the molecules interact with the water and one another. During this process, make sure students make sense of these key elements: 1. The ionization process – that once acids or bases are placed into water, they dissociate into ions.

		(*Possible probes*: How can they tell something is an ion? What are the charges of the different ions that are formed? How do the products in this dissociation reaction correspond to the molecule of acid that is added to the solution e.g., H_2SO_4 produces two H_3O^+ ions and one SO_4^{2-} ion, while KOH produces one K^+ ion and one OH^- ion? What is the role of water in the dissociation of acids and bases, i.e., the polarity of the water molecule?) 2. The similarities and differences between the reactions that occur when either acids or bases are added to water. (*Possible probes:* Do all acid molecules placed in the water result in an equal amount of oppositely charged particles? What are the particles formed as a result of each of these reactions? What are the differences between the ionization of acids and bases?) 3. Make sure they understand what pH means (hydrogen ion concentration) and how the addition of acids or bases to the solution changes its pH. (*Possible probes:* What does it mean for a solution to be neutral? What pH value is neutral? If acid is added, how does the pH change? Bases?)
Day 2	Build on Concepts of first lesson	Concepts – 1. Water formation-what happens when hydronium and hydroxide ions collide? 2. Neutralization- how can you know that a solution is neutral? Can hydronium and hydroxide ions be present in a neutral solution? Other ions? 3. Identify ions as cations or anions. 4. Relate formulas on the molecules to formulas in acid-base equations.
		On the second day, we will discuss what happens when multiple molecules are placed in the water. During this process, make sure students make sense of these key points: 1. They recognize and anticipate reactions between hydronium and hydroxide molecules – specifically, the formation of water molecules. Make sure they try adding in different combinations of molecules and pay attention to which ions "react" or disappear when they collide in the water.

	$2\ H_2O \rightleftharpoons OH^- + H_3O^+$	2. They should see that ions remain intact in the solution unless an OH^- molecule encounters an H_3O^+ molecule (i.e., hydroxide encounters hydronium). Have them explain what they think happens when these ions collide and disappear. You might opt to have them write the formula for this reaction. $2\ H_2O \rightleftharpoons OH^- + H_3O^+$ The formula should help them realize that two molecules of water are being produced for every OH^- and H_3O^+ that react. (PLEASE note in the experiment in this article the teacher did not have the participants in the *SMALLab* condition write the equations.) 3. They can link this to neutralization – the condition in which the concentration of hydronium and hydroxide ions is balanced. When this happens the solution has a pH of 7.0. Students can work on neutralizing the pH, given some number of base or acid molecules in the water. To help them practice this idea, you can put in some number of base molecules and ask them to place acid molecules into the space until the pH is neutral. Challenge them to do this with the most or the least added molecules.
Day 2 (or 3)	III. Have students develop simple games around the concepts of neutralization reactions	By the time they arrive to this stage, they should be able to solve simple problems that require the understandings from the previous class. You can use this day to help students solidify previous knowledge by having them construct games based on neutralization concepts. For example: 1. Have students compete as the "acid" team and "base" team. Give them 15-30 seconds to put in as many molecules as possible. Whichever team has the most molecules in the space wins. The winners will be students who identify a strategy for choosing the molecule that produces the most hydronium or hydroxide ions when thrown into the water. 2. Have one team of students add some number of bases into the water while the other team is not looking. Based on the information available to them, they have to determine the fewest number of moves necessary in order to neutralize the solution. 3. Given a mixture of acid and base molecules in the flask,

		pause the scenario and have students work in teams to determine the number of water molecules that were formed, write these on paper of small whiteboards and discuss as a whole class. Compare the number of water molecules formed with the number of acid and base molecules added to the solution.
Day 3	IV. Final components- indicator molecule	If you wish to continue to a titration activity, proceed with this section. Concepts – 1. Understand the role of the indicator. 2. Understand how structure of the indicator molecule relates to the structure of acids and bases. 3. Examine the behavior of an indicator molecule in water (it does not dissociate), and what happens to it when it comes into contact with acid or base molecules.
		The use of the indicator molecule takes the concept of neutralization one step further. Only one indicator molecule should ever be added to the solution. Students should go through the process of making sense of its chemical structure and how it reacts in solution. During this process, make sure they touch on these key points: 1. Examine its formula. (HIn) Is it similar or different from the other molecules? In what ways? They should notice that it has an H, just like the acids. 2. Add a single indicator molecule to the water. What do you observe? Students should see that the pH remains the same, and that the indicator has not ionized. 3. Have students add one or more acid molecules and wait until each of the ions formed collide with the indicator molecule to see if the indicator reacts with it. Record observations. Reset the scenario, and have them repeat the process – this time, adding a single indicator and one or more molecules of a base to the scenario. **Students should see that when the HIn collides with an OH^- that formed when a molecule of base dissociated, it turns pink and has the symbol In^- on it (there is music playing to draw students' attention to this). This indicates that there is free OH^- in the solution, which may mean that all the hydronium ions in the solution have reacted with hydroxides to form water. Check to see if this is true. If so, the Indicator molecule will remain ionized (pink) in spite of what it collides with. If not, it will change back to HIn as soon as it collides with a free H_3O^+.
		Students should work together to develop an explanation for the usefulness of this process on a macroscopic level (as they see it in the laboratory setting where they are adding drops of base to an acid of unknown concentration). If they have done a titration

		lab before interacting with this scenario they should be able to map what is happening in the scenario onto what happened in class when they counted the drops of some base they were adding to a flask containing acid and an indicator. What the indicator "indicates" is whether all the acid added to the solution has been neutralized by the base that has been added to the solution. This process, "titration," is used in the laboratory to determine the relative strength of an acid, by adding a base of known strength to it until it is neutral (until it just turns pink). The ultimate goal of the indicator is to identify the point at which all the free hydroniums in solution have reacted with the hydroxides that have been added when molecules of base dissociate.
	End game	Play a game again if time. See which team can neutralize the pH level in the fewest moves.

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