Experiment
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TEACHER INFORMATION

Acids and Bases

1. Editable Microsoft Word versions of the student pages and pre-configured TI-Nspire files can be found on the CD that accompanies this book. See *Appendix A* for more information.

2. To prepare the 0.1 M NaOH solution, use 4.0 g of solid NaOH pellets per 1 L of solution. **HAZARD ALERT:** Corrosive solid; skin burns are possible; much heat evolves when added to water; very dangerous to eyes; wear face and eye protection when using this substance. Wear gloves. Hazard Code: B—Hazardous.

   To prepare the 0.1 M HCl solution, use 8.6 mL of concentrated acid per 1 L of solution. **HAZARD ALERT:** Highly toxic by ingestion or inhalation; severely corrosive to skin and eyes. Hazard Code: A—Extremely hazardous.

   The hazard information reference is: Flinn Scientific, Inc., *Chemical & Biological Catalog Reference Manual, 2000*, (800) 452-1261, www.flinnsci.com. See *Appendix F* for more information.

3. Try to make a 1% solution of the materials to test. It is not too critical to be exact. Add ~10 grams of material for each liter of solution.

4. Have the students help design the list of materials to use. Try to use the same number of chemicals in each of the three classes of materials—biological organisms or tissues, biological chemicals, and non-biological chemicals.

   Good organisms or tissues to use might include blended liver, plant leaves, potato roots, yeast, fruit juices (from real fruit—not those <10% varieties!) or Euglena (if you culture them). Try to avoid oily materials—they will be difficult to clean off the probe.

   Good chemicals include starch, enzymes, gelatin, vitamin Bs or C, casein, egg white, or other simple, non-oily biochemicals.

   Good non-biological materials include a mix of buffers with non-buffers. Buffers might include soda water, Alka-Seltzer, phosphate buffer, Tums, etc. An interesting combination is aspirin and Bufferin. Good non-buffers include table salt and nitrogen fertilizer. It is fun to include rocks—try marble (calcium carbonate—a buffer in acid) and quartz.

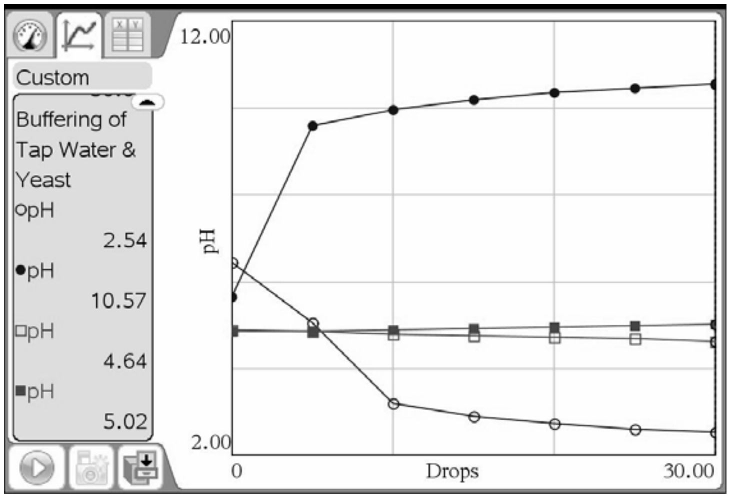
5. It is not necessary to calibrate your pH sensors, the stored calibration will work fine for this experiment.

6. Vernier Software & Technology sells a pH buffer package for preparing buffer solutions with pH values of 4, 7, and 10 (order code PHB). Simply add the capsule contents to 100 mL of distilled water. You can also prepare pH buffers using the following recipes:

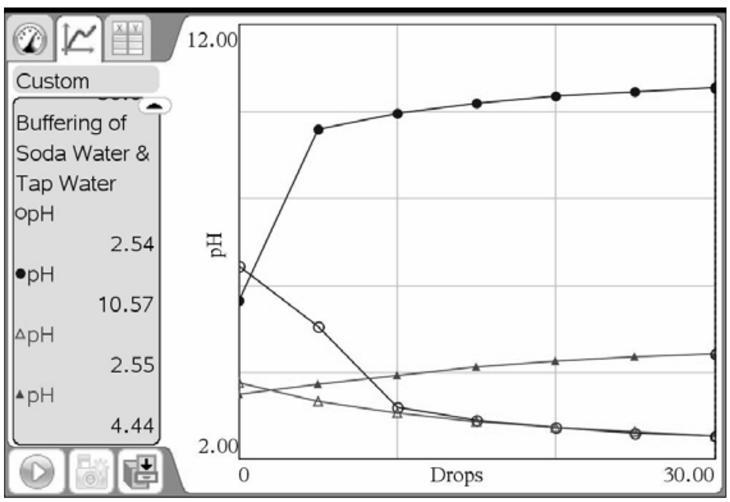
   - pH 4.00: Add 2.0 mL of 0.1 M HCl to 1 L of 0.1 M potassium hydrogen phthalate.
   - pH 7.00: Add 582 mL of 0.1 M NaOH to 1 L of 0.1 M potassium dihydrogen phosphate.
   - pH 10.00: Add 214 mL of 0.1 M NaOH to 1 L of 0.05 M sodium bicarbonate.

SAMPLE RESULTS

Table 1										
Material Tested	Add	pH, after adding this many drops								Total buffer range
		0	5	10	15	20	25	30	ΔpH	
Tap water	Acid	6.46	5.07	3.20	2.92	2.74	2.61	2.54	-3.92	8.82
	Base	5.67	9.59	9.97	10.21	10.37	10.46	10.57	4.90	
Aspirin	Acid	2.71	2.65	2.62	2.58	2.55	2.51	2.48	-0.23	0.38
	Base	2.76	2.76	2.79	2.82	2.85	2.88	2.91	0.15	
Vitamin B2	Acid	4.72	4.25	3.48	2.95	2.74	2.63	2.54	-2.18	5.89
	Base	6.56	8.64	9.45	9.85	10.08	10.19	10.27	3.71	
Vitamin C	Acid	2.84	2.71	2.65	2.59	2.56	2.52	2.48	-0.36	0.49
	Base	2.52	2.53	2.55	2.56	2.58	2.61	2.65	0.13	
Soda water	Acid	3.76	3.34	3.08	2.87	2.74	2.63	2.55	-1.21	2.13
	Base	3.52	3.73	3.94	4.14	4.26	4.36	4.44	0.92	
Cornstarch	acid	4.87	3.30	3.02	2.87	2.76	2.67	2.60	-2.27	7.29
	base	5.84	9.54	10.21	10.47	10.64	10.78	10.86	5.02	
Salt water	acid	4.13	3.06	2.75	2.63	2.53	2.46	2.40	-1.73	8.49
	base	4.72	10.35	10.85	11.07	11.23	11.37	11.48	6.76	
Yeast	acid	4.91	4.87	4.81	4.77	4.72	4.68	4.64	-0.27	0.43
	base	4.86	4.86	4.89	4.92	4.95	4.99	5.02	0.16	



Data for tap water (acid - ○ and base - ●) and Yeast (acid - □ and base - ■). Notice that Tap water has virtually no buffering while yeast shows significant buffering.



Data for tap water (acid - ○ and base - ●) and soda water (acid - △ and base - ▲).

Classification of Materials		
Organisms or tissues	Biological chemicals	Non-biological chemicals
Yeast	Aspirin Starch Vitamin B2 Vitamin C	Soda Water Tap Water Salt Water

Table 2		
Material	Initial pH	Rank
Aspirin	2.71	most acidic
Vitamin C	2.84	2
Soda Water	3.76	3
Salt Water	4.13	4
Vitamin B2	4.72	5
Cornstarch	4.87	6
Yeast	4.91	7
Tap Water	6.46	least acidic

Table 3		
Material	Total Buffer Range	Rank
Tap Water	8.82	Greatest change
Salt Water	8.49	2
Cornstarch	7.29	3
Vitamin B2	5.89	4
Soda Water	2.13	5
Vitamin C	0.49	6
Yeast	0.43	7
Aspirin	0.38	Least change

ANSWERS TO QUESTIONS

1. The values should be the same, since the same solution is in each beaker.
2. The actual results may vary. Possible reasons include:
   - The beakers were not cleaned equally well by the cooperative groups.
   - The probes differed slightly in their response.
3. The effect HCl had on each solution was to decrease its pH. Not all materials responded equally, and several did not respond much at all. These were better buffers.
4. The effect NaOH had on each solution was to increase its pH. Not all materials responded equally, and several did not respond much at all. These were better buffers.
5. Tap water acted as a control. The similarities and differences among the graphs can be noted more easily when each is compared to a single substance, such as water.
6. Non-biological chemicals, such as water and salt, reacted most dramatically to the addition of acid or base. Biologically complex materials and non-biological buffers resisted pH changes most. The non-biological materials were most divergent in their behavior. This is especially true if any of the graphs have a different scaling than the others.

   The order in which material reacted most dramatically to the addition of acid or base is: tap water, salt water, cornstarch, vitamin B2, soda water, vitamin C, yeast and aspirin. The ranking by complexity is similar—water (tap and salt) is the simplest material, followed by a carbohydrate. The soda water has a natural buffer, the bicarbonate ion. Yeast is cellular material, thus more complex than any of the above. Finally, aspirin is a simple chemical with great buffering capacity.

   As a general rule, simple chemicals may or may not be good buffers, depending upon their make-up. Complex biological materials are almost always better buffers than simple ones, since there are usually a greater number of chemicals in cellular matter that serve as buffers.
7. Answers may vary. See Table 1 for sample values. Of these data, aspirin is the best buffer and water is the poorest buffer.