Vitamin C
Author(s): Geoff Coates
Date Created: 1999
Subject: Chemistry
Grade Level: High School
Standards: *New York State- Chemistry* (*www.emsc.nysed.gov/ciai/*) Standard 1- Analysis, Inquiry and Design Standard 4- Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity. Standard 7- Interdisciplinary Problem Solving
Schedule: Two 40-minute class periods
CCMR Lending Library Connected Activities:

Objectives:	**Vocabulary:**
Learn about the process of titration and how chemical reactions can be used to measure or indicate concentration.	Vitamin, Acid Titration, End Point Concentration, Indicator
Students Will: • Test the level of Vitamin C in a variety of fruit juices • Record data for Vitamin C solution and different fruit juices • Conduct a quantitative analysis of the fruit drinks • Gain an understanding of the Chemical Equilibrium Calculations and answer follow up questions on Vitamin C properties • Summarize the results from their analysis	**Materials:** **For Class:** ___ Felt Titration (black, yellow white, & purple felt pieces) **For Each Solution/ Juice Station:** ___ 10 ml Graduated Cylinders (2) ___ Plastic Beakers or Cups (2) ___ Medicine Dropper (1) ___ Indophenol Solution ___ Vitamin C Solution ___ Fruit Juice ***(You should provide others)*** **Teacher Needs to Provide:** ___ White paper (8 ½ x 11) ___ Safety Goggles ___ Pencil
Safety	Safety goggles should be worn when handling Indophenol solution. Also, be sure students know not to drink any of the solutions they're working with.

Science Content:

Vitamin C is very important to human health. While research continues on all the ways that vitamin C contributes to our bodies, it is known that it helps in the formation of connective tissue, bone, teeth, and blood vessel walls, and assists the body in assimilating other important substances, such as iron and some amino acids.

Serious deficiencies of vitamin C harm the entire body. Scurvy is the name of the disease caused by such deficiency, and sailors on long voyages often suffered from scurvy. Then it was discovered that eating citrus fruits would prevent the disease. Large sailing expeditions began bringing crates of limes on long voyages, accounting for the origin of the old nickname for British sailors—"Limeys." When the limes were no longer available, sailors were able to augment their vitamin C intake by eating large quantities of potatoes. Scientists recognized that limes (and to a lesser extent potatoes) contained a substance that prevented scurvy, and they named this substance "vitamin C."

Many years later, in 1937, Dr. Albert Szent-Gyorgyi won a Nobel Prize for isolating vitamin C. He began his research to find out why bananas and apples turn brown when exposed to air, while other foods, such as citrus fruits, do not. He discovered that vitamin C, the anti-scurvy vitamin, was responsible for keeping fruits from turning brown. That is why putting lemon juice on apples and bananas after they are peeled or sliced helps them keep their natural color.

Although vitamin C is found in many plants, and is synthesized by many animals, humans do not create their own, and must consume it in foods. Plants manufacture vitamin C during the process of photosynthesis. The more light a plant gets, the more photosynthetic activity, and the more vitamin C produced. More light also results in darker-colored leaves, and it's generally true that the darker the leaf, the more vitamin C the plant contains.

Among fruits high in vitamin C are all citrus fruits, strawberries, and pineapples. Citrus *peels* contain five to seven times *more* vitamin C than does the juice. Vegetables with particularly high vitamin C content include sweet peppers, cabbage, brussels sprouts, broccoli, and spinach.

Opinions differ regarding the recommended daily requirement for vitamin C in human nutrition. It has been established that 10 mg of vitamin C per day will prevent scurvy. In the United States, the recommended daily allowance (RDA) of vitamin C is 60 mg per day, but it is 30 mg in Norway and Canada, and 70 mg in West Germany. The famous scientist Linus Pauling advocates that people take as much as 3,000 mg per day. One cup of fresh orange juice provides about 125 mg of vitamin C.

Because vitamin C is a water-soluble vitamin (as is vitamin B) it is easily leached out of fruits and vegetables in boiling water. It is also sensitive to heat and light and can be lost through exposure to air, certain metals, and some enzymes, but it is not lost by freezing. Because it is water soluble, when vitamin C reaches an excessive level in the body it is excreted in the urine. There are also fat-soluble vitamins, such as vitamins A, D, E, and K, which tend not to leach out in boiling water. These vitamins can accumulate in the fatty tissues of our bodies if taken in excessive amounts. In some cases, the storage and concentration of these fat-soluble vitamins in the body can be a health hazard.

Preparation:

1. Photocopy print materials (*Activity Sheets 1-7*).
2. Prepare Indophenol solution by combining 200 mg di-chloror indophenol and one gallon of water.
3. Prepare Vitamin C solution by combining two grams of Vitamin C (Ascorbic Acid) with 1 ½ cups of water.
4. Distribute materials evenly to each student pair.

Classroom Procedure:

Engage (Time: 15 mins)

Show students the Felt Titration activity (see Appendix A). Meanwhile discuss chemistry terminology, including "end point" and "chemical titration". Answer any questions students may have regarding the information you just discussed.

Explore (Time: 45 mins)

Divide students into groups of two. Activity Sheets 1-5 as well as all other materials should be distributed to each student and student pair, respectively. Allow students to complete the Activity Sheets and answer all the questions pertaining to these activities with their partners. Assist as necessary.

Explain (Time: 20 mins)

Have students present the results of their experiments to the rest of the class. Discuss the answers to the lab questions as a class.

Acknowledgments:

Samantha Glazier, Graduate Student, Chemistry and Chemical Biology

Assessment:

The following rubric can be used to assess students during each part of the activity. The term "expectations" here refers to the content, process and attitudinal goals for this activity. Evidence for understanding may be in the form of oral as well as written communication, both with the teacher as well as observed communication with other students. Specifics are listed in the table below.

1= exceeds expectations
2= meets expectations consistently
3= meets expectations occasionally
4= not meeting expectations

	Engage	Explore	Explain
1	Shows leadership in the discussion and an in depth understanding of chemical reactions and titration.	Completes work accurately while providing an explanation for what is observed. Works very will with partner.	Provides and in-depth explanation of findings. Fills out worksheet clearly.
2	Participates in the demo and shows an understanding of chemical reactions and titration.	Completes work accurately and works cooperatively with partner.	Provides clear explanation of findings. Fills out worksheet clearly.
3	Contributes to the discussion, but shows little understanding of reactions or titration.	Works cooperatively with partner, but makes some mistakes with the procedure.	Provides a limited explanation of findings. Fills out some of the worksheet.
4	Does not participate in discussion. Shows no understanding of reactions or titration.	Has trouble working with partner. Does little to complete the procedure.	Is not clear in explanation of findings. Does not fill out worksheet.

Appendix A: Felt Titration

Titration of Vitamin C with Indophenol

Have students gather around and lay out the black, circular piece of felt. Explain that this is to represent their beaker. Now, place several (more than four) purple squares of felt in the “beaker”. Explain that these represent molecules of indophenol. Tell them that a real beaker of indophenol solution is a purple/blue liquid in real life. Now show them one of the containers with yellow and white squares; explain that this represents one drop of vitamin C solution, where yellow is molecules of vitamin C and white represents water molecules. When combined, indophenol and vitamin C react, which is shown by a color change of purple and yellow (respectively) to white (or clear, in real-life). This can be represented in the felt by having students stack the yellow and purple pieces and cover them with an extra white piece of felt.

Explain that the process of adding a reactant one drop at a time is called titration and that the process of yellow and purple reacting to form white is a way of showing neutralization. Therefore, by knowing the number of vitamin C molecules in each drop and the number of drops necessary to neutralize the indophenol, it is possible to calculate the original number of indophenol molecules.

After the initial “drop” is added, have students observe the situation. There should now be only purple and white squares of felt showing. Ask them what the real-life solution would now look like; their response of course should be a paler shade of purple. Repeat the process of adding a “drop” of vitamin C solution to your “beaker” until the only color felt remaining is white. Explain that you have now reached the end point of the reaction and ask students what this would look like in real life.

Titration of a Juice Containing Vitamin C with Indophenol

Repeat the above process, again starting with “indophenol” in the “beaker”. Explain that unlike the previous example, the number of indophenol molecules is known, but the amount of vitamin C contained in the juice is not. Add a “drop” of juice (it should contain both green squares of juice and yellow squares of vitamin C). Again, have students neutralize the reacted indophenol by covering the stacks with a white piece of felt. Ask them what this would look like in real life. Continue adding drops of juice until all of the indophenol is neutralized and again ask what this would look like. Explain that because there is still juice present, that even though all of the indophenol has reacted, the solution will not be clear. This is why a control beaker is necessary.

Supplemental Information:

The Dark Side of Linus Pauling's Legacy
By: Stephen Barrett, M.D.

Linus Pauling, Ph.D., was the only person ever to win two unshared Nobel prizes. He received these awards for chemistry in 1954 and for peace in 1962. His recent death has stimulated many tributes to his scientific accomplishments. His impact on the health marketplace, however, was anything but laudable.

Pauling is largely responsible for the widespread misbelief that high doses of vitamin C are effective against colds and other illnesses. In 1968, he postulated that people's needs for vitamins and other nutrients vary markedly and that to maintain good health, many people need amounts of nutrients much greater than the Recommended Dietary Allowances (RDAs). And he speculated that mega doses of certain vitamins and minerals might well be the treatment of choice for some forms of mental illness. He termed this approach "orthomolecular," meaning "right molecule." After that, he steadily expanded the list of illnesses he believed could be influenced by "orthomolecular" therapy and the number of nutrients suitable for such use. No responsible medical or nutrition scientists share these views.

Vitamin C and the Common Cold

In 1970, Pauling announced in Vitamin C and the Common Cold that taking 1,000 mg of vitamin C daily will reduce the incidence of colds by 45% for most people but that some people need much larger amounts. (The RDA for vitamin C is 60 mg.) The 1976 revision of the book, retitled Vitamin C, the Common Cold
and the Flu, suggested even higher dosages. A third book, Vitamin C and Cancer (1979) claims that high doses of vitamin C may be effective against cancer. Yet another book, How to Feel Better and Live Longer (1986), stated that mega doses of vitamins "can improve your general health . . . to increase your enjoyment of life and can help in controlling heart disease, cancer, and other diseases and in slowing down the process of aging." Pauling himself reportedly took at least 12,000 mg daily and raised the amount to 40,000 mg if symptoms of a cold appeared. In 1993, after undergoing radiation therapy for prostate cancer, Pauling said that vitamin C had delayed the cancer's onset for twenty years. This was not a testable claim. He died of the disease in August 1994 at the age of 93.

Scientific fact is established when the same experiment is carried out over and over again with the same results. To test the effect of vitamin C on colds, it is necessary to compare groups which get the vitamin to similar groups which get a placebo (a dummy pill which looks like the real thing). Since the common cold is a very variable illness, proper tests must involve hundreds of people for significantly long periods of time. At least 16 well-designed, double-blind studies have shown that supplementation with vitamin C does not prevent colds and at best may slightly reduce the symptoms of a cold. Slight symptom reduction may occur as the result of an antihistamine-like effect, but whether this has practical value is a matter of dispute. Pauling's views are based on the same studies considered by other scientists, but his analyses are flawed.

The largest clinical trials, involving thousands of volunteers, were directed by Dr. Terence Anderson, professor of epidemiology at the University of Toronto. Taken together, his studies suggest that extra vitamin C may slightly reduce the severity of colds, but it is not necessary to take the high doses suggested by Pauling to achieve this result. Nor is there anything to be gained by taking vitamin C supplements year-round in the hope of preventing colds.

Another important study was reported in 1975 by scientists at the National Institutes of Health who compared vitamin C pills with a placebo before and during colds. Although the experiment was supposed to be double-blind, half the subjects were able to guess which pill they were getting. When the results were tabulated with all subjects lumped together, the vitamin group reported fewer colds per person over a nine-month period. But among the half who hadn't guessed which pill they had been taking, no difference in the incidence or severity was found. This illustrates how people who think they are doing something effective (such as taking a vitamin) can report a favorable result even when none exists.

Vitamin C and Cancer

In 1976, Pauling and Dr. Ewan Cameron, a Scottish physician, reported that a majority of one hundred "terminal" cancer patients treated with 10,000 mg of vitamin C daily survived three to four times longer than similar patients who did not receive vitamin C supplements. However, Dr. William DeWys, chief of clinical investigations at the National Cancer Institute, found that the study was poorly designed because the patient groups were not comparable. The vitamin C patients were Cameron's, while the other patients were under the care of other physicians. Cameron's patients were started on vitamin C when he labeled them "untreatable" by other methods, and their subsequent survival was compared to the survival of the "control" patients after they were labeled untreatable by their doctors. DeWys reasoned that if the two groups were comparable, the lengths of time from entry into the hospital to being labeled untreatable should be equivalent in both groups. However, he found that Cameron's patients were labeled untreatable much earlier in the course of their disease -- which means that they entered the hospital before they were as sick as the other doctors' patients and would naturally be expected to live longer.

Nevertheless, to test whether Pauling might be correct, the Mayo Clinic conducted three double-blind studies involving a total of 367 patients with advanced cancer. The studies, reported in 1979, 1983, and 1985, found that patients given 10,000 mg of vitamin C daily did no better than those given a placebo. Pauling criticized the first study, claiming that chemotherapeutic agents might have suppressed the patients' immune systems so that vitamin C couldn't work. But his 1976 report on Cameron's work states clearly that: "All patients are treated initially in a perfectly conventional way, by operation, use of radiotherapy, and the administration of hormones and cytotoxic substances." And during a subsequent talk at the University of Arizona, he stated that vitamin C therapy could be

used along with all conventional modalities. The participants in the 1983 study had not undergone conventional treatment, but Pauling dismissed its results anyway.

Science aside, it is clear that Pauling was politically aligned with the promoters of unscientific nutrition practices. He said his initial interest in vitamin C was aroused by a letter from biochemist Irwin Stone, with whom he subsequently maintained a close working relationship. Although Stone was often referred to as "Dr. Stone," his only credentials were a certificate showing completion of a two-year chemistry program, an honorary chiropractic degree from the Los Angeles College of Chiropractic, and a "Ph.D." from Donsbach University, a non-accredited correspondence school.

In a little-publicized chapter in Vitamin C and the Common Cold, Pauling attacked the health-food industry for misleading its customers. Pointing out that "synthetic" vitamin C is identical with "natural" vitamin C, he warned that higher-priced "natural" products are a "waste of money." And he added that "the words 'organically grown' are essentially meaningless -- just part of the jargon used by health-food promoters in making their excess profits, often from elderly people with low incomes." But Vitamin C, the Common Cold and the Flu, issued six years later, contained none of these criticisms. This omission was not accidental. In response to a letter, Pauling informed me that, after his first book came out, he was "strongly attacked by people who were also attacking the health-food people." His critics were so "biased," he decided, that he would no longer help them attack the health-food industry while another part of their attack was directed at him.

The Linus Pauling Institute of Medicine, founded in 1973, is dedicated to "orthomolecular medicine." The institute's largest corporate donor has been Hoffmann-La Roche, the pharmaceutical giant that produces most of the world's vitamin C. Many of the institute's fundraising brochures have contained questionable information. They have falsely claimed, for example, that no significant progress has been made in cancer treatment in the past twenty years. This viewpoint, which is frequently expressed by promoters of unproven cancer therapies, is simply untrue.

Other Questionable Activities

A dispute between Pauling and Arthur Robinson, Ph.D., gives additional evidence of Pauling's defense of vitamin C mega dosage was less than honest. Robinson, a former student and long-time associate of Pauling, helped found the institute and became its first president. According to an investigative report by James Lowell, Ph.D., in Nutrition

Forum newsletter, Robinson's own research led him to conclude in 1978 that the high doses (5-10 grams per day) of vitamin C being recommended by Pauling might actually promote some types of cancer in mice. Robinson told Lowell, for example, that animals fed quantities equivalent to Pauling's recommendations contracted skin cancer almost twice as frequently as the control group and that only doses of vitamin C that were nearly lethal had any protective effect. Shortly after reporting this to Pauling, Robinson was asked to resign from the institute, his experimental animals were killed, his scientific data were impounded, and some of the previous research results were destroyed.

Pauling also declared publicly that Robinson's research was "amateurish" and inadequate. Robinson responded by suing the Institute and its trustees. In 1983, the suit was settled out of court for $575,000. In an interview quoted in Nature, Pauling said that the settlement "represented no more than compensation for loss of office and the cost of Robinson's legal fees." However, the court-approved agreement states that $425,000 of the settlement was for slander and libel.

During the mid-1970s, Pauling helped lead the health-food industry's campaign for a federal law that weakened FDA protection of consumers against misleading nutrition claims. In 1977 and 1979, Pauling received awards and presented his views on vitamin C at the annual conventions of the National Nutritional Foods Association (the major trade association of health-food retailers, distributors and producers). In 1981, he accepted an award from the National Health Federation (NHF) for "services rendered in behalf of health freedom" and gave his daughter a life membership in this organization. NHF promotes the gamut of quackery. Many of its leaders have been in legal difficulty and some have even received prison sentences for various "health" activities. Pauling also spoke at a Parker School for Professional Success Seminar, a meeting where chiropractors were taught highly questionable methods of building their practices. An ad for the meeting invited chiropractors to pose with Pauling for a photograph (which presumably could be used for publicity when the chiropractors returned home).

In 1981, after learning that Pauling had donated money to NHF (for his daughter's life membership), I asked whether he knew about NHF's shady background and the fact that it was the leading antifluoridation force in the United States. I also asked whether he cared that the money might be used to help fight fluoridation. In a series of letters, he replied that he: (1) strongly supported fluoridation, (2) was aware of NHF's opposition, (3) had tried to pressure the organization to change its views, (4) had spoken out for it often and over many years, and (5) thought other issues were more important. He also sent me a profluoridation statement he had issued in 1967. His claim that he had spoken out for fluoridation surprised me. Although I have read thousands of documents related to Pauling's views and activities, I had never any indication that he had publicly supported fluoridation.

In 1983, Pauling and Irwin Stone testified at a hearing on behalf of Oscar Falconi, a vitamin promoter charged by the Postal Service with making false claims for several products. Pauling supported Falconi's contentions that vitamin C was useful not only in preventing cancer, but also in curing drug addicts and destroying both viruses and bacteria. Pauling also testified in 1984 before the California Board of Medical Quality Assurance in defense of Michael Gerber, M.D., who was accused of improperly administering to patients. One was a 56-year-old woman with treatable cancer who -- the Board concluded -- had died as a result of Gerber's neglect while he treated her with herbs, enzymes, coffee enemas, and chelation therapy. The other patients were three-year-old twin boys with ear infections for which Gerber had prescribed 70,000 or more units of vitamin A daily and coffee enemas twice daily for several weeks. Gerber lost his license to practice medicine as a result of the hearings.

A flyer distributed in 1991 by the Linus Pauling Institute recommended daily doses of 6,000 to 18,000 mg of vitamin C, 400 to 1,600 IU of vitamin E, and 25,000 IU of vitamin A, plus various other vitamins and minerals. These dosages have no proven benefit and can cause troublesome side effects.

Although Pauling's megavitamin claims lacked the evidence needed for acceptance by the scientific community, they have been accepted by large numbers of people who lack the scientific expertise to evaluate them. Thanks largely to Pauling's prestige, annual vitamin C sales in the United States have been in the hundreds of millions of dollars for many years. The physical damage to people he led astray cannot be measured.

Linus Pauling, Ph.D.
Nobel Prizes in Chemistry and Peace

BIOGRAPHY
b. February 28, 1901
d. August 19, 1994

Linus Pauling was born in Portland, Oregon, where his parents encouraged his scientific interests from the beginning. When Linus's father died, his mother found it difficult to support the large family. Linus was an able student and won scholarships to Oregon State University at Corvallis, but he had to work long hours as a laborer to support himself while he earned his Bachelor of Science degree. He went on to earn a PhD in chemistry at the California Institute of Technology, the institution where he taught and carried out his research for the next 33 years.

The young scientist first made his mark in the world of chemistry with his use of X-rays to examine the molecular structure of crystals. This work led him to a more thorough investigation of the nature of the chemical bond. Pauling revolutionized chemistry in the 1920s with his application of quantum physics to the study of chemistry. He used the new theory of wave mechanics to explain molecular structures which had baffled chemists for years. Pauling's resonance theory proposed that some molecules "resonate" between different structures, rather than holding a single fixed structure. This insight made possible the creation of many of the drugs, dyes, plastics and synthetic fibers we take for granted today. Pauling publicized his findings in a series of papers culminating in an essential work of modern chemistry: The Nature of the Chemical Bond and the Structure of Molecules and Crystals.

Dr. Pauling next turned his attention to the study of organic substances, particularly proteins. By 1942, Pauling and his colleagues had succeeded in producing synthetic antibodies, a major breakthrough. In 1945 Pauling was co-chairman of a project which developed a substitute for blood plasma. In 1949, he performed a groundbreaking study of sickle cell anemia, a disease which disproportionately affects men and women of African descent. In 1951, Pauling and Robert B. Corey described the atomic structure of proteins for the first time. This work had enormous implications for the struggle against disease.

The detonation of the first atomic weapons in 1945 posed an ethical dilemma for Pauling. The more he studied the effects of radiation, the more he became convinced that a nuclear war, or even the continued atmospheric testing of these weapons, could do irreparable damage to the environment and the human population. Because the government was attempting to conceal the dangers of nuclear testing from the public, Pauling believed it was his duty to speak out, but in the first years of the cold war, many Americans considered such dissent treasonous. Pauling could not remain silent. In books, interviews and press conferences, he educated the public about the hazards of radiation and campaigned for peace, disarmament and the end of nuclear testing. These activities cost him friends, funding for his research, and the job he had held at Cal Tech for 33 years.

The State Department revoked Pauling's passport but, when he won the Nobel Prize for Chemistry in 1954 and was unable to leave the U.S. to accept it, the pressure of world opinion forced the Department to relent. Pauling continued his peace activism and, in 1957, drafted a petition calling for an end to the atmospheric testing of nuclear weapons. By the time Pauling delivered his petition to the U.N., he had collected the signatures of 11.021 scientists from all over the world. This campaign led to a Nobel Peace Prize for Pauling in 1962, and to the first Nuclear Test Ban Treaty.

Linus Pauling remained active in anti-war movements, but he won even greater fame for his studies of the role of nutrition in fighting disease. His 1970 book Vitamin C and the Common Cold recommended mega doses of vitamin C to ward off colds and lessen their symptoms. Millions of people now follow this advice. Pauling's theory of "orthomolecular" substances and his views concerning the potential role of vitamin C in fighting cancer have not won wide acceptance in the medical community, but many researchers have followed where he led in studying the role of vitamins and other nutrients in preserving health and fighting disease.

In 1973, Dr. Pauling founded the Linus Pauling Institute of Science and Medicine. From this base, he continued his researches and worked to educate the public about the dangers of smoking and the benefits of vitamins. He received numerous, including the Presidential Medal for Merit and the National Medal of Science. He published books for the general reader on a variety of subjects from one of his first No More War to one of his last How to Live Longer and Feel Better. Linus Pauling died on August 19th, 1994, at the age of 93.

Appendix A: Felt Titration

Titration of Vitamin C with Indophenol

Have students gather around and lay out the black, circular piece of felt. Explain that this is to represent their beaker. Now, place several (more than four) purple squares of felt in the "beaker". Explain that these represent molecules of indophenol. Tell them that a real beaker of indophenol solution is a purple/blue liquid in real life. Now show them one of the containers with yellow and white squares; explain that this represents one drop of vitamin C solution, where yellow is molecules of vitamin C and white represents water molecules. When combined, indophenol and vitamin C react, which is shown by a color change of purple and yellow (respectively) to white (or clear, in real-life). This can be represented in the felt by having students stack the yellow and purple pieces and cover them with an extra white piece of felt.

Explain that the process of adding a reactant one drop at a time is called titration and that the process of yellow and purple reacting to form white is a way of showing neutralization. Therefore, by knowing the number of vitamin C molecules in each drop and the number of drops necessary to neutralize the indophenol, it is possible to calculate the original number of indophenol molecules.

After the initial "drop" is added, have students observe the situation. There should now be only purple and white squares of felt showing. Ask them what the real-life solution would now look like; their response of course should be a paler shade of purple. Repeat the process of adding a "drop" of vitamin C solution to your "beaker" until the only color felt remaining is white. Explain that you have now reached the end point of the reaction and ask students what this would look like in real life.

Titration of a Juice Containing Vitamin C with Indophenol

Repeat the above process, again starting with "indophenol" in the "beaker". Explain that unlike the previous example, the number of indophenol molecules is known, but the amount of vitamin C contained in the juice is not. Add a "drop" of juice (it should contain both green squares of juice and yellow squares of vitamin C). Again, have students neutralize the reacted indophenol by covering the stacks with a white piece of felt. Ask them what this would look like in real life. Continue adding drops of juice until all of the indophenol is neutralized and again ask what this would look like. Explain that because there is still juice present, that even though all of the indophenol has reacted, the solution will not be clear. This is why a control beaker is necessary.