### “The Candle Experiment” – an Opening Exercise for General (or introductory) chemistry

I … bring before you, in the course of these lectures, the Chemical History of a Candle. There is not a law under which any part of this universe is governed which does not come into play and is touched upon in these phenomena. … There is no more open door by which you can enter into the study of natural philosophy than by considering the physical phenomena of a candle.
 Michael Faraday - *The Chemical History of a Candle* - 1860

<http://home.att.net/~a.caimi/faraday.html>

This exercise is intended as an ice-breaker for a first or second class meeting. It also serves as an introduction to physical & chemical properties and application of the macro/micro/symbolic representations of chemical phenomena. Finally, it provides a framework to mention many of the topics to be covered in a general chem first semester course.

Students become absorbed in the depth of exploration to be found in a simple and familiar object. Because they are generating the observations without specific directions or a check-list, they must think for themselves about which observations are important or unimportant, and what they can agree on.

After brief introduction of the concepts of macroscopic observations & measurements; microscopic modeling of molecular events; and symbolic (equations & pictures) representing those events, unlit candles are passed out to the class such that there is about one per four students. Depending on the layout of the classroom it may be more or less easy to have students form groups. In our table-based classroom, I usually ask the first and third rows to turn around to face the second and fourth.

Students are asked to write down as many observations as possible about the candle and also to note the possible measurements they would make with other equipment (thermometer, balance, etc.). While the groups are making their observations, the instructor can wander the classroom and monitor group interactions; ask leading questions, etc. After a few minutes I pass out a few matchbooks without additional instructions. Some groups use them immediately; some include the matches in their observations; and some are still gathering observations (or talking to each other).

Eventually all the groups are working with lit candles. Here, the level of observation and experimenting/playing can vary widely. Usually someone in each group knows that the flame requires oxygen; often that carbon dioxide is produced by burning. I ask the groups (individually) what they have seen and try to get them to consider one or more leading questions:

* whether it is the wick itself or the candle wax that burns
* whether the decreasing size of the candle is the result of drips, evaporation, or burning of the wax
* what might happen in an enclosed container
* whether the mass of the candle is changing (and how)

Someone in the group usually has a textbook or at least a syllabus; the table of contents or topics list can be used as a guide to see how many topics can relate to a candle. That helps students to connect the course material to their everyday lives (hopefully an affective improvement) and also provides the candle exercise as a referent hook for when we get to those topics.

After several more minutes for group discussion, I return to the front of the room and ask for group observations. This leads to additional discussion within and between groups; and I steer the discussion toward categorizing their comments as chemical vs. physical changes and macro/micro/symbolic representations. Very often there will be some prior-knowledge ideas: “We need oxygen” – respond with “how do you know” (or, “what experiment could prove that”) etc. It allows discussion of conservation of mass, atomic theory, and the early development of chemistry as natural philosophers tried to determine whether fire was a substance.

Because I use the exercise as an icebreaker and as an affective booster, I avoid graded evaluation or too much writing for this activity. As an assessment, you could ask students for a 2-minute reflection paper on one of these topics:

* What was something you learned today about candles? Or, what was something you helped someone else learn?
* List three or more topics in the upcoming course material that could relate to candles, and why the candle might be a good example for each.
* Explain what happens as a candle burns from the perspective of an oxygen atom in the air (or a carbon atom in the candle wax, etc.)
* Early scientists worked with candles to explore the idea of whether fire was a substance or not. In a few sentences, how would you answer their question?
* How did your group decide what observations to report?

This exercise’s goals are

* 1. Introduce students to the group discussion/reporting type activity (class process)
	2. Illustrate the importance of chemistry to the everyday world (affective)
	3. Provide connections of class topics as preview or “hook” back to familiar
	4. Introduce/exemplify idea of physical & chemical properties/ changes
	5. Introduce/exemplify the macro-micro-symbolic thinking.
* Assessment of goals:
	1. Assessed by observation of groups during discussion and at report-out
	2. Assessed by questioning during report-out
	3. Continuing presentation during semester; report-out content
	4. Assessed by Q&A during report-out, if not volunteered.
	5. Assessed in future class activities, quiz & homework

Student engagement is improved in this exercise for the following reasons:

* it examines a familiar object with the chemist’s viewpoint;
* it introduces the peer-group interaction model,
* there is a referent for several future topics
	+ balancing reactions & limiting reactants
	+ heat, energy, and fossil fuels,
	+ light/photon concepts,
	+ activation energy and rates,
	+ organic molecules.