# Water, Climate Change and You

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Grade Level – High School Chemistry

**Introduction**

Water plays a crucial role on our planet. Its physical properties make it uniquely suitable for life on our planet. Global Climate Change (GCC) threatens to change how we live on Earth, and learning about water provides students a window into a scientist's eyes. It also provides an opportunity for students to make the connection between chemistry, biology and climatology. This activity focuses on the physical properties of water for the high school physical science or chemistry student.

**Background and Introductory Lessons**

As a pre-cursor to the lesson, students are asked what they know about water and its importance to biological systems. Students are then presented with several inquiry activities, and asked to explain their observations (see *Investigation #1 – Water* in Middle School Lessons). The physical properties of water are then explained to clarify observations. The lesson then moves to radioactivity, radioactive isotopes and their practical uses. This information is provided as a vehicle to discuss temperature proxies, specifically, how we know about past climate(s) through ice core data.

The socio-political aspects of Climate Change are avoided in order to have students look at hard science and scientific data and evidence that have been gathered. The main idea of the activity is to provide an opportunity for students to question the properties of water, and then ponder how science and technology combine to help us answer "big" questions, in this case climate change.

Success of the lesson is measured in several different ways. First, class discussions reveal that many students had already learned some information regarding the physical properties of water and the uses of radioactivity. In most cases, this knowledge was superficial, and warranted a more in depth investigation. Although many students will know what to expect from the experiments, the molecular models used to explain the observations are typically met with surprise. At the beginning of each day during this multi-day lesson, formative assessments can provide insight on the level of depth students were remembering. Students were also required to keep a laboratory notebook, and this record served as an assessment of their learning. Last, a written test was prepared to assess students background knowledge before the lesson, and then again after the lesson to assess what they learned.

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**Science Lesson to Incorporate Experimental and Descriptive Inquiry**

A) Concepts addressed by the lesson

This lesson addressed the physical properties of water, and how those properties make water unique and essential to life on our planet. This lesson also addressed radioactive isotopes, and how they are used in scientific research. Climate change was addressed as radioactive isotopes help us understand past climate through historical records (ice core data).

B) Nevada State Standards

**N.12.A.1** Students know tables, charts, illustrations and graphs can be used in making arguments and claims in oral and written presentations.

**N.12.A.3** Students know repeated experimentation allows for statistical analyses and unbiased conclusions.

**N.12.A.5** Students know models and modeling can be used to identify and predict cause-effect relationships.

**N.12.B.1** Students know science, technology, and society influenced one another in both positive and negative ways.

**N.12.B.2** Students know consumption patterns, conservation efforts, and cultural or social practices in countries have varying environmental impacts.

**P.12.A.1** Students know different molecular arrangements and motions account for the different physical properties of solids liquids, and gases.

**P.12.A.4** Students know atoms bond with one another by transferring or sharing electrons.

**P.12.A.8** Students know most elements have two or more isotopes, some of which have practical applications.

**P.12.C.3** Students know nuclear reactions convert a relatively small amount of material into a large amount of energy.

**P.12.C.4** Students know characteristics, applications and impacts of radioactivity.

C) Basic Procedures

Attached is the lesson plan outline in the experimental inquiry format (Cantrell, 2010). The lesson started with a couple of activities that asked students to look at the physical properties of water. The following day a KWL was used to see if students could explain their observations. In this lesson, I substituted the meanings for K and W (traditionally "what we know" and "what we want to know") with S and T ("what we're SURE we know" and "what we THINK we know"). The investigation continues by having students perform another inquiry activity, documenting data and graphing results. This information is then extended with a second theme (radioactivity) within the lesson. After a teacher led lecture, students performed activities including Bohr models of different isotopes. Climate Change was then tied in by showing students how technology (the ability to measure radioactive isotopes) enables scientists to collect information about the earth's past climate. Prior to the post-

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lesson assessment, students completed concept maps summarizing major concepts learned throughout the lesson.

**Addressing Standards and Teaching Techniques**

Because water is uniquely important to our lives, and because it is an easy substance to investigate in the lab, its physical properties are an ideal way to demonstrate the Nature of Science Standards. First, students were asked make simple observations of the behavior of water when putting drops on a penny, and then getting an aluminum foil "boat" loaded with pennies to float. Some students were asked to use the "heads" side and others the "tails" side of the penny, and all students repeated their water drop experiment three times. Statistical analysis (mean, standard deviation) was then determined so "heads" and "tails" could be compared. N.12.A.3 Second students were presented with the molecular structure of water, and asked to explain why the molecule behaves the way it does. The teacher then facilitated the discussion of polarity, and scaffolded what students know (opposites attract) with what they observed, but couldn't explain in chemical terms. (The polarity of water and hydrogen bonding explain the high surface tension of water, and thus its ability to form spheres or rounded shapes on flat surfaces.)

Students then performed an experiment where they observed the effect of adding salt to a water/ice mixture, and then boiling the mixture. These observations led to several questions, including, "why does our water boil at 96°C instead of 100?", and, "how does the water get down to -7°C?" An explanation of vapor pressure and colligative properties answered these questions, and succeeded in provoking more thought in students. Students were then asked to graph their own data, and compare it to that of another group. This activity showed the students that scientific experiments require record-keeping, collaboration, and repeated experimentation (N.12.A.1-3). The graphing a temperature curve of ice melting and water boiling - with and without salt – also enabled students to draw a conclusion from their own data. This demonstrated that the presence of salt affects the melting and boiling temperatures of water (a colligative property).

A teacher-led lesson was then presented regarding radioactive isotopes, radioactivity, and then practical uses of radioactivity. Later, students were shown graphs from the IPCC's 4$^{th}$ report on climate change (2007) to demonstrate how radioactive isotopes can be used to measure paleoclimate. Global temperature from various direct measurements was shown, as well as that from several proxies including tree ring and oxygen-18 isotopic ratios from ice cores. After presenting several of these graphs, students were asked why and how they can believe in these complex data sets. N.12.A.5 Explanation included the fact that current predictions of climate change are based on thousands of observations, and dozens of models based on collaboration of hundreds of scientists worldwide. All of these are integral to Strand A. During the discussion, a student fortuitously asked, "How do we know that this really happens? I mean, do we really know that nuclear fission occurs in the sun?" This question led directly into "how we know what

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we know" and are "we" (society) ready to understand it argument. (N.12.B.1) The answer, of course, lies in the mountains of scientific data that have been accumulated over the past millennia, and that lots of people have contributed to the body of knowledge. This holds true for all scientific disciplines, whether it is nuclear fission or climate change.

**Differentiated Instruction**

Because much of this lesson is based on inquiry, it is accessible to many types of learners at different levels. The hands-on nature of the water drop exercise provides both visual and kinesthetic learners an opportunity to observe waters unique physical properties. Although students may not at first relate to the molecular model of hydrogen bonds, they can certainly see its effects when using a pipette to place drops on a penny, or when trying to float an aluminum "boat" loaded with pennies. These processes enable different types of learners to assimilate more information than if it were simply presented on paper or during a lecture.

Having students graph the time vs. temperature data provided learners to compare simple data sets, and view content while comparing them. This also enabled them to make a product that helped come to their own conclusion about the effect of salt on plain water. Several different students benefitted with this model. A few "slower" learners benefitted from the easily observable exercises. I believe these students had a much better chance of internalizing information due to the sensorial nature of the experience and then associating this with the conceptual explanation. Additionally, higher-level learners were more open to new information because they had the opportunity to get out of their seats and participate in an activity. The visual cues involved in the experiments enabled them to attain a higher level of understanding – one that is more likely to stick in their minds.

Additionally, students made Bohr models of atoms using play-doh. Students that had difficulty were only asked to make a simple atom, and perhaps tell me how they would make a different isotope. More advanced students were asked to make multiple models, showing different isotopes and ion formation. This helped students of all levels understand the primary concepts, but also pushed the higher level students beyond a simple level.

**Assessment Strategies**

A) <u>Assessment Methods</u>

Both formative and summative assessments were used in this lesson. Formative assessments took the form of question and answer during discussion. These discussions were both teacher-led and student-led. A KWL (TSL) was used to spark conversation, and to give an idea of the level of understanding after the opening exercise, but before further investigation. Other formative assessments were short written assignments that students performed upon entering the class. Usually 2-5 minutes to complete the task in the form of a "quick-write". The information was reviewed before continuing the lesson.

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Students were also required to collect time versus temperature data and graph their results. This served as a major assessment as it demonstrates a range of process skills, addressing many of the science standards including the Nature of Science standard.

Last, a summative assessment (a written test) can be designed and given (pre- and) post-lesson to evaluate the overall understanding of the concepts presented in the lesson. Using this tool will allow the teacher to determine how much was learned during the unit.

B) Student Production

These can include the statistical analysis of the water drop experiments, data collection for the colligative properties experiment, and the graphs that students generated from their data, etc. Students can also diagram on paper the Bohr models they made out of play-doh, and later of the models they do as a period opener. Teachers may also choose to have students do something more expansive like posters or presentations.

C) Use of Formative Assessments

I often start off a lesson by asking students what they know about a particular subject.
In this lesson, the class participated in a TSL (KWL) where students were encouraged to say anything they thought was relevant to the topic – after doing the opening activities. This discussion will often reveal that many students have little knowledge of surface tension or hydrogen bonding, and most had no exposure to colligative properties or radioactive isotopes. Very few students will have learned the practical applications of radioactive isotopes. This information drives the lesson, and helps the teacher determine how fast the lesson should go and to what level of depth for each particular class. In some cases teachers may spend more time discussing the polar nature of the water molecule and how it dictates hydrogen bonding, surface tension and other unique properties such as the high melting and boiling points in order to advance them to the larger topics.
Using Bohr models to help explain the concept will help students to understand key concepts of radioactive isotopes and these models can be effective even with younger students and general science students. The play-doh activity (using play-doh to model atomic structure) can be done as a quick lesson and may be more effective than just having the students draw Bohr model diagrams.

**Background and Expectations**

D) Preparation

Most General Chemistry teachers do a unit on physical properties of water at the beginning of the new semester in the fall. Others teach the properties of water as an adjunct lesson to solutions instead of a self-standing unit. Teachers should be very familiar with these properties and have additional activities that can relate the properties of water in an inquiry-style lab or activity.

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Since some teachers never teach about radioactive isotopes due to time constraints including this unit on radioactive isotopes as part of this lesson and tying it into a discussion of climate change can be a very effective way of including an often omitted topic that is uniquely relevant. The practical use of radioactive isotopes is also a Nevada State Standard that often gets ignored. Preparing for this lesson and determining practical and relevant way of presenting it can be a very good way for teachers to include one more aspect of climate change science to the curriculum

E) Different Student Responses

Because these activities require student participation and engagement, students are more likely to learn than if they are spoon fed information from a lecture. Students involved in asking questions to explain their observations, rather than being told the "answers" and then asked to observe them are more likely to own the knowledge and retain it longer due to accepting responsibility for their learning.

Additionally, the inclusion of practical uses of radioactive isotopes, and particularly their use as temperature proxies as evidence for climate change, will engage many students who might otherwise tune out. Relating chemistry to current real-world issues will lead to more interest in the lesson.

F) Changed Approach and its Effect on Student Performance

In this unit using elements of inquiry-based learning, teachers can expect students to be more engaged than in more traditional skill and drill and lecture/lab methods. In particular the sensorial activities help students perform better and learn the material to a depth that exceeds lecture-practice systems. Inquiry methods and teaching to depth undoubtedly improves student understanding, not to mention interest level. Students exposed to information that tied together chemistry with real issues in the practical uses section, and this will improve their performance beyond the chemistry classroom.

G) Inquiries and Comments

Inquiries and comments regarding this lesson can be directed to John Batcabe, Wooster High School, 1331 E. Plumb Lane, Reno, Nevada 89502, 775- 333-5100, or by e-mail: John Batcabe <JBatcabe@washoeschools.net>

References

Bloom, AJ (2010) Global Climate Change, Convergence of Disciplines Sinauer Sunderland, MA. Ch. 1-4 p. 1-102.

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Cherry L and Braasch G (2008) How We Know What We Know About Our Changing Climate Dawn Publications, Nevada City, CA

Keeling CD, Piper SC, Bacastow RB, Wahlen M, Whorf TP, Heimann M, and Meijer HA, Exchanges of atmospheric CO2 and 13CO2 with the terrestrial biosphere and oceans from 1978 to 2000. I. Global aspects, SIO Reference Series, No. 01-06, Scripps Institution of Oceanography, San Diego, 88 pages, 2001 Accessed at http://scrippsco2.ucsd.edu/data/in_situ_co2/monthly_mlo.csv Aug. 2, 2010.

Mann ME, Bradley RS, Hughes MK (1999). "Northern hemisphere temperatures during the past millennium: Inferences, uncertainties, and limitations" (PDF). *Geophys. Res. Lett.* **26** (6): 759–762. Accessed at https://www.ncdc.noaa.gov/paleo/pubs/millennium-camera.pdf Accessed Nov. 18, 2010.

IPCC, Fourth Assessment Report "The Physical Science Basis" (2007) http://www.ipcc.ch/ipccreports/ar4-wg1.htm. Accessed Nov 14, 2011.

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# Independent Investigation Guidelines

**Step 1: Create a Question**

- ➢ What do you want to find out?
- ➢ Does your question relate to the topic?
- ➢ Can you develop an experiment to answer your question?
- ➢ Does your question make sense? Is it confusing?

**Step 2: Hypothesis**

- ➢ What do you think will happen?
- ➢ BE SPECIFIC!
- ➢ Use complete sentences.

**Step 3: Procedure**

- ➢ What steps will you follow to find an answer?
  - ✓ BE SPECIFIC! Label your steps using 1, 2, 3, etc.
  - ✓ Would someone else be able to follow your directions?
- ➢ How will you collect your data?
- ➢ How will you ensure reliable results?
- ➢ What safety issues need to be addressed?

**Step 4: Experiment & Data**

- ➢ Be sure to display your data in an organized manner. Use a table or chart to help you show your results. Don't forget to label!
- ➢ Include enough data to prove or disprove your hypothesis.

**Step 5: Analysis/Conclusion**

- ➢ What happened during your experiment?
- ➢ Did your results support your hypothesis?
- ➢ Write a summary of what you learned during your experiment and address your results.
- ➢ Explain any unexpected results.
- ➢ Are your results reliable?
- ➢ Did you use complete sentences?

Independent Investigation Name ___________________________

## Question
What do you want to find out?

## Hypothesis
What do you think will happen?

## Procedure
Design your experiment! Write the steps for your experiment in the space below.

## Safety Rules
What safety rules do you need to follow during your experiment?

## Data

Create a table, chart, or graph to record your data.

## Conclusion/Analysis

What did you find out? Did your results support your hypothesis? Are your results reliable?