‘Shells on Acid’ Demonstration

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You will need:

- **White vinegar**
- **An oyster (or other mollusk) shell** (or “dustless chalk” if you can get ahold of a shell); anything made of calcium carbonate
- **A clear glass**

Note: you can reuse these materials. Just rinse the shell, and pour the vinegar back into the bottle when you’re done (discard when it becomes cloudy).

Background:

This demonstration illustrates why calcifiers (organisms that build their shells and external skeletons from calcium carbonate, or $CaCO_3$) are so vulnerable to ocean acidification. When dissolved hydrogen ions (H^+; the ions that give acid its ‘kick’) react with calcium carbonate, they break this mineral down into soluble calcium (Ca^{2+}) and carbonate ions (CO_3^{2-})—in other words, they cause it to dissolve. The bubbles that start forming as soon as the shell is immersed in vinegar (which contains acetic acid) are a product of this dissolution reaction. They are actually CO_2, which is formed when the newly released carbonate ions react with additional hydrogen ions in the vinegar; details about this reaction can be found at www.ask.com/science/reaction-between-chalk-vinegar-d4a507fa59ec8d6e#full-answer.

It’s important to point out to your audience that what they see happening in the glass is *not* happening in the marine environment. We’ll never see an oyster bed bubbling away like the shell in this demonstration! Vinegar is quite acidic, and its pH is much lower than that of seawater (you may refer to the pH scale slide to point out the relative positions of these two solutions). The 5-unit difference in their respective pH values means that the concentration of H^+ in vinegar is ~100,000 times (or 5 orders of magnitude) higher than the concentration of H^+ in seawater. Consequently, the dissolution reaction in this demo is occurring at a dramatically faster rate than it would in seawater, even at the extremely low pH levels scientists have observed in Puget Sound (pH~7.5), where the impacts of acidification have been particularly severe. In today’s oceans, the problem faced by calcifiers is really one of *bioenergetics*. Simply put, as seawater pH declines, calcifiers are having to work harder and harder to obtain dissolved carbonate ions from seawater for their shells and hard parts. The more energy they have to spend to build and maintain their shells, the less energy they have for other essential life functions like growth, locomotion, reproduction, fighting off pathogens, and feeding. Scientists have already documented examples of stunted growth, delayed development, and impaired swimming among sea urchins, molluscs, crabs and pteropod species from high CO_2 environments. Juveniles seem to be especially vulnerable to environmental stress, and it is often at the juvenile stage where the impacts of ocean acidification are first observed. The scientific references below provide an in-depth explanation of this bioenergetic effect.

For a nice overview of how declining pH is making life harder for Pacific Northwest shellfish and the people that depend upon them for their livelihoods, watch these short videos featuring Oregon State University scientist George Waldbusser:

- http://ceoas.oregonstate.edu/profile/waldbusser/
- https://https://www.youtube.com/watch?v=qPhgyB8o_U4.

The Seattle Times *Sea Change* series on ocean acidification is another well-written source of information and graphics about how ocean acidification is harming oysters and other calcifiers (corals, crabs and pteropods).

[Depending on your audience, you may want to introduce the concept of "saturation state", since that is how ocean acidification's effect on calcifiers is often explained. In seawater, calcium carbonate can either exist as a solid (as in shell material) or dissolved into its component calcium (Ca^{2+}) and carbonate (CO_3^{2-}) ions. Which form is favored depends on the saturation state of seawater, which is determined by the pH. At pH 8.1, seawater is 'saturated' with respect to calcium carbonate, and it is relatively easy for calcifiers to obtain dissolved carbonate ions from seawater and crystalize them into their calcium carbonate for their shells. However, as seawater pH declines, its saturation state with respect to calcium carbonate also declines, and the dissolved form starts to be favored over the solid form. When the saturation state drops below "1", scientists say that seawater is 'undersaturated' or 'corrosive' to calcium carbonate. In many parts of the ocean, including Puget Sound and along the U.S. west coast, ocean acidification is already making seawater corrosive to calcifiers at certain times of the year. As ocean acidification worsens, seawater will be corrosive to calcifiers in more places, more of the time. The demonstration 'Crossing Thresholds' touches on this issue.]

Set up:

Fill a clear glass ~2/3 full with vinegar. Submerge your shell or piece of chalk in the vinegar. Pass it around the room so people can observe the bubbles of CO_2 that form on the surface of the shell or piece of chalk.

Scientific references:

1. Barton, A., B. Hales, G. G. Waldbusser, C. Langdon, and R. A. Feely. 2012. The *Pacific oyster,* Crassostrea gigas*, shows negative correlation to naturally elevated carbon dioxide levels: Implications for near-term ocean acidification effects.* Limnology and Oceanography, 57(3): 698-710.

2. Waldbusser, G. G., E. L. Brunner, B. A. Haley, B. Hales, C. J. Langdon, and F. G. Prahl. 2013. *A developmental and energetic basis linking larval oyster shell formation to acidification sensitivity*. Geophysical Research Letters, 40: 1-6.