Detecting carbon uptake rates in minutes: a pH based approach

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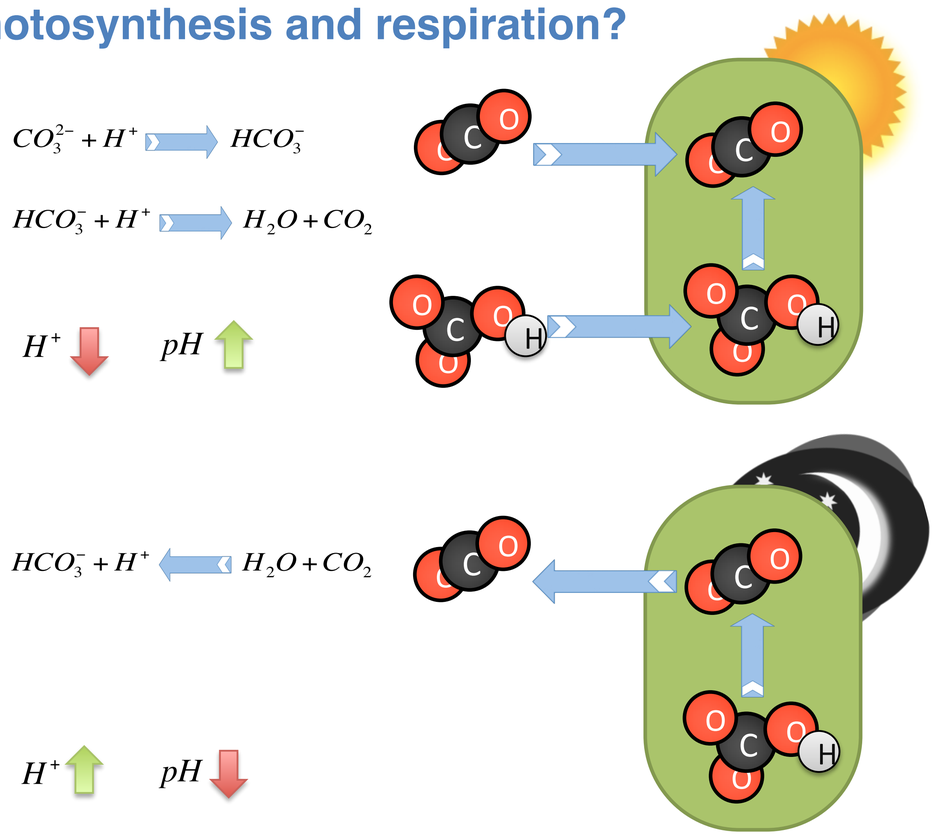
Motivation

Carbon capture and recycling are essential to the reduction of fossil fuel emissions. Algae are ideal platforms for CO_2 removal from air and concentrated carbon sources, such as power plants. The research of improving algae based carbon capture requires quantitative measurement of carbon capture rates for evaluating experimental outcomes and supporting data to life cycle analyses. However, currently available methods are usually low throughput and labor intensive, slowing down the research progresses. Here we introduce a pH based carbon capture rate measurement and based on which a prototype system that can be modified and adopted to a variety of laboratory environments.

What happened in the medium during photosynthesis and respiration?



Why a simple measurement of pH won't work?

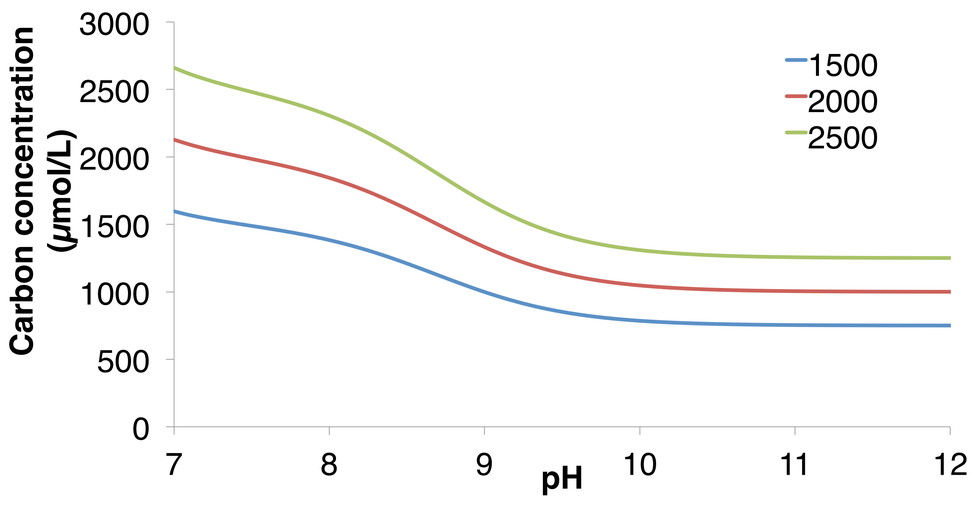
Since carbon uptake and respiration can result in pH change, it is possible to measure carbon uptake by measuring pH, but it's not that simple.

Complications

Alkalinity – the relationship between pH and carbon concentration is regulated by temperature (regulates reaction constants) and alkalinity. When carbon is removed by photosynthesis, the pH in the medium increases, while the level of pH change is depend on the level of alkalinity (shown in different colors below).

Carbonate alkalinity (A_C) – A_C contributes to total alkalinity (A_T) and there are other chemicals, such as phosphate, can affect A_T as well. If carbon is the only source of A_T, then the C-pH relation would look like the figure below. In reality, the system is more complex.

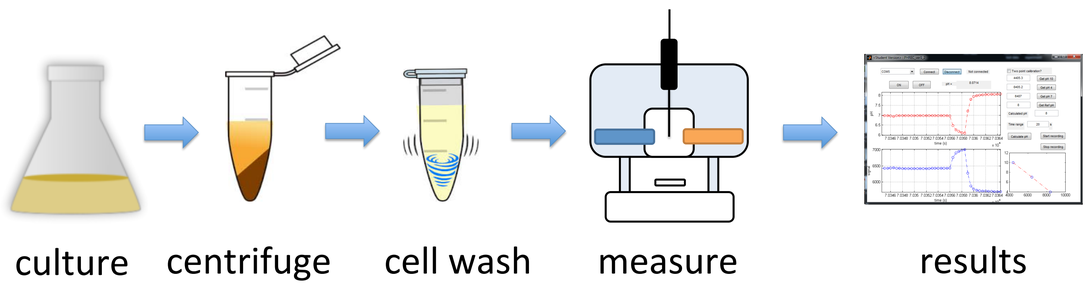
Algae-medium interaction – Over time, the growth of algae changes the chemistry in the medium via absorbing minerals that affects A_T.



How do we determine carbon capture rates using pH?

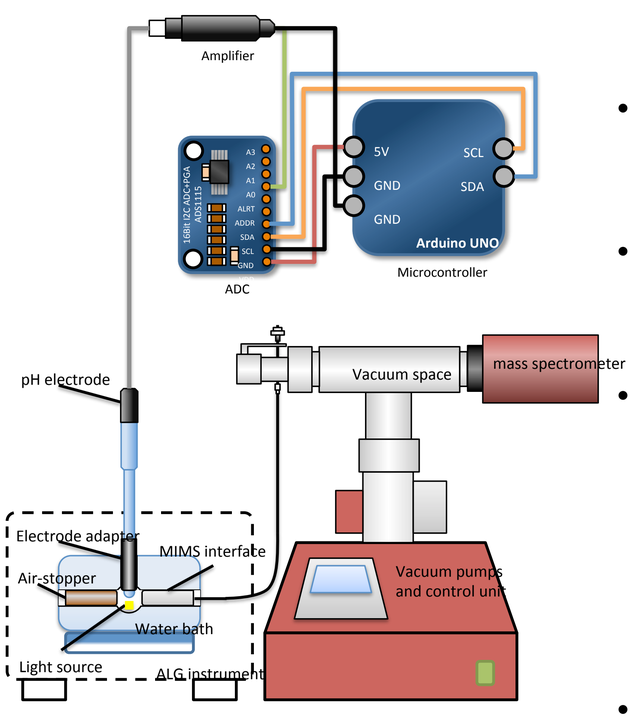
Thanks to the dedicated researchers who worked tirelessly on ocean acidification; now we have all of the equations and coefficients needed for the computations.

Steps



- Cells washed with calibrated buffer solution for consistent baseline and accurate calculation;
- Short detection time to avoid significant chemistry shift during measurement;
- Simple operation & no hazardous materials usage minimize training and experiment time.

What are included in our prototype package?



- Instructions on how to setup your testing systems with off-the-shelf electronic parts;
- Protocols on how to calibrate buffer solution and run the experiment;
- A Matlab based user interface (UI) for data acquisition;
- A Python based data processing UI for simultaneous dissolved gases measurement using an integrated pH – membrane inlet mass spec (MIMS) system;
- All scripts are open-source and all calculations are embedded.

Details of this work can be found at:

Du, Niu, Pardis Gholami, David I. Kline, Christopher L. DuPont, Andrew G. Dickson, Dominick Mendola, Todd Martz, Andrew E. Allen, and B. Greg Mitchell. "Simultaneous quantum yield measurements of carbon uptake and oxygen evolution in microalgal cultures." PloS one 13, no. 6 (2018): e0199125.

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