CO_2 Gas Scrubbing with MEA Solution:

Measuring heat release using isothermal microcalorimetry

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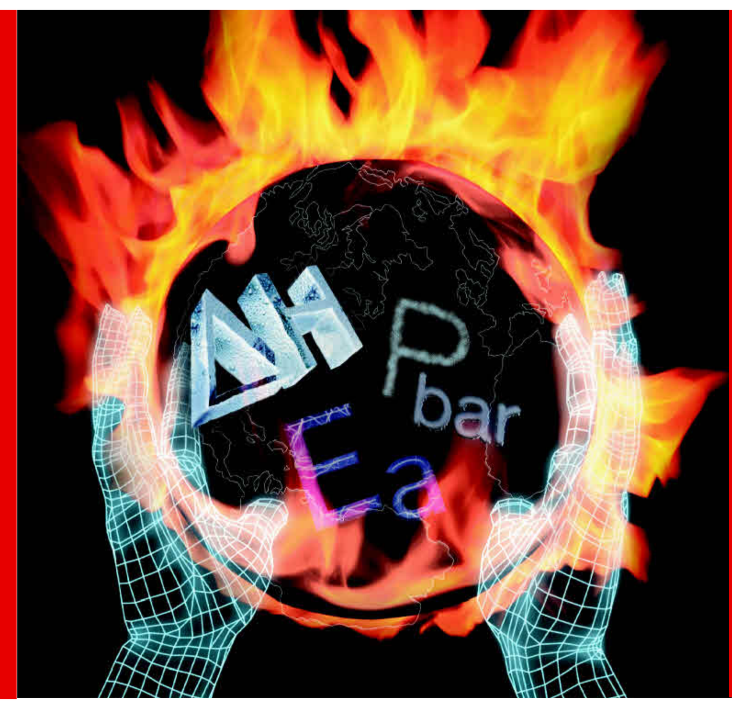

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Application of microcalorimetry to study CO_2 absorption by MEA

Carbon capture is one of the methods used for offsetting high volumes of CO_2 production. There are many types of carbon capture involving different capture processes. The capture process examined here is gas scrubbing, which involves the reversible reaction of carbon dioxide with a solution of an amine and water. The reaction happens in two stages:

1. Dissolution of the gas into the amine solution

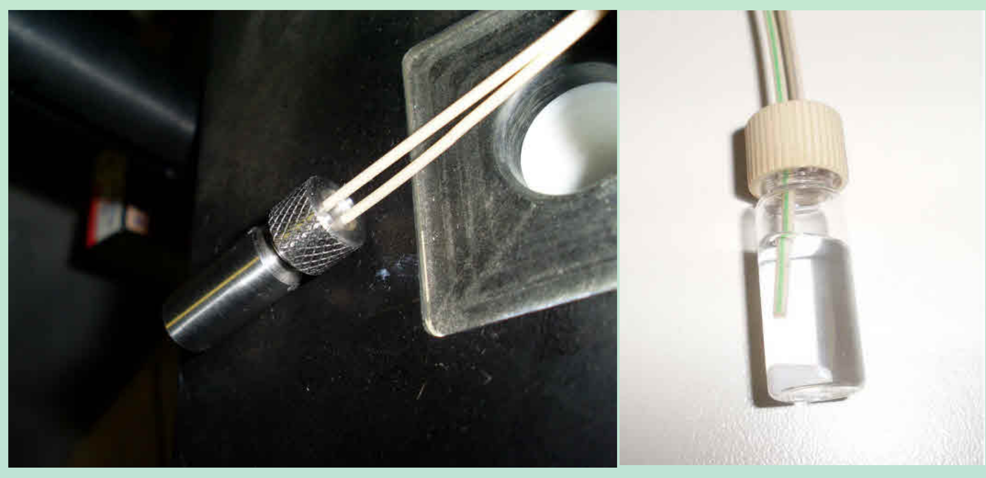
2. The uptake of the gas by the amine

The process of carbon dioxide absorption via amine solution is exothermic. This means that over time, the process will produce heat in the reactants. This heat output can be measured by calorimetry, which allows the volume and rate of gas absorption to be quantified from measurement of heat.

The Micro Reaction Calorimeter from THT can perform isothermal enthalpy measurements on the exothermic reactions that occur when CO_2 gas is absorbed by an amine solution. The versatility of the instrument allows measurement of the heat of reaction at different temperatures, flow rates, volumes of solution and gas pressures. Using the instrument's scanning functionality it is also possible to investigate the reverse reaction of carbon dioxide release from solution, which is endothermic.

The stand-alone µRC instrument and combined with the gas flow option

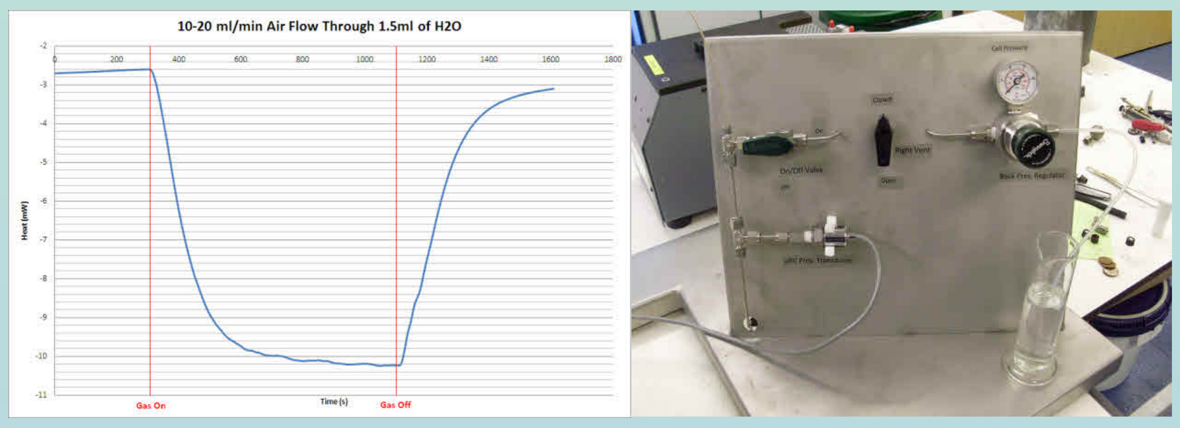
Gas flow tests can be carried out at ambient or elevated pressure using standard glass vials or stainless steel vials with a PEEK tubing attachment for gas delivery to and from the vial. Gas pressure and flow rate are monitored electronically. Static pressurized tests are also possible.



Vials for pressurized (left) and ambient (right) flow tests.

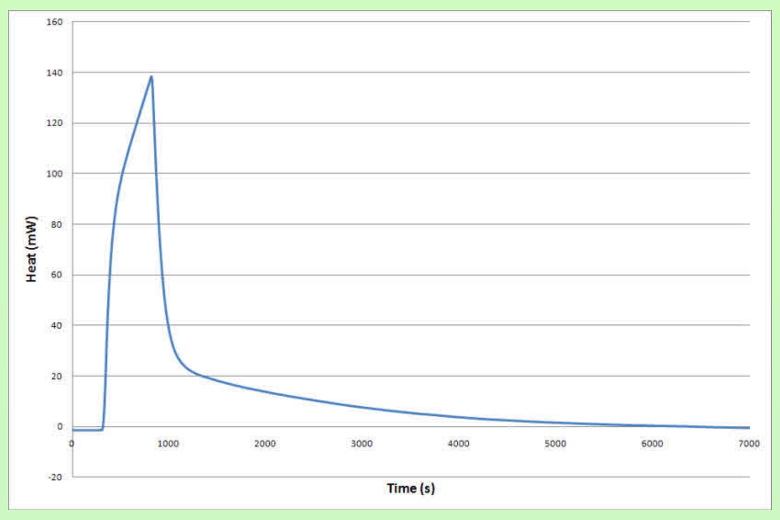
At THT gas flow tests in the µRC were carried out at ambient pressure at two different temperatures. Methylethanolamine (MEA) was used as the amine for capturing CO^{2-} ions. The MEA was added to water in 30% concentration by weight.

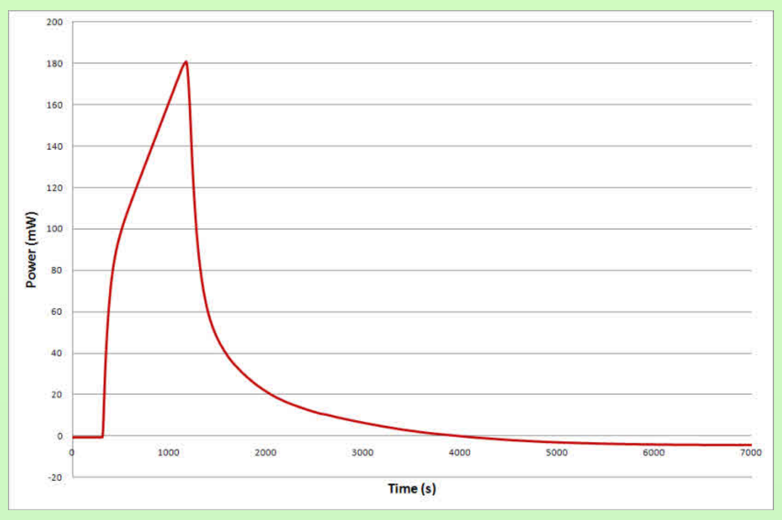
In order to check baseline noise, a flow of air through water was tested at 10ml/min. At this flow rate the baseline was steady at around -10mW.



Baseline flow data (10ml/min), part of the apparatus is shown on the right

Flow rates are kept low to minimize baseline shift due to evaporation of the solution. Reducing gas flow rates also helps minimize the effect of heat transfer to and from the system via the flowing gas. Gas flow is measured by an electronic mass flow meter. The first test was carried out at ambient temperature (25°C). The second test was at elevated temperature (40°C). In each case, gas flow was turned on after 300 seconds.

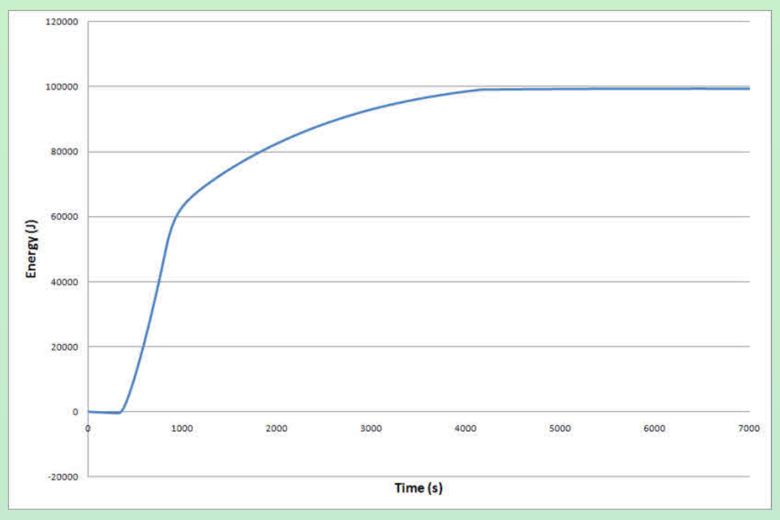


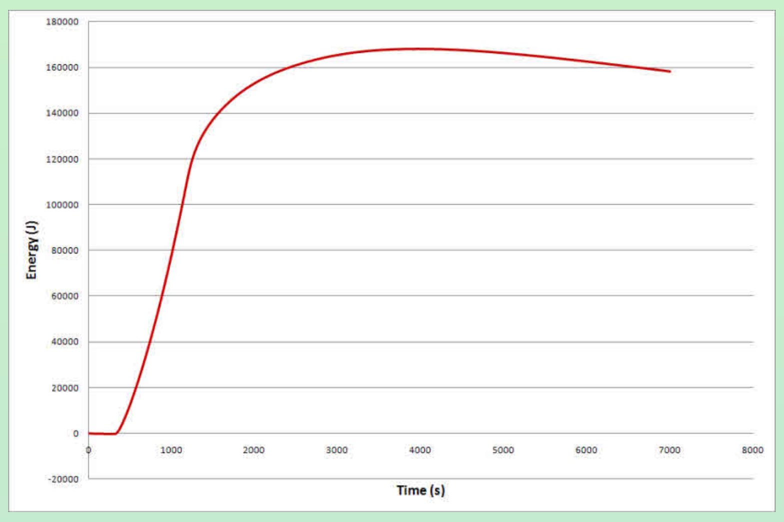


On the left is the CO_2 flow test carried out at 25°C and on the right is a similar test carried out at 40°C.

Correcting for the differences in sample mass (the sample mass at 25°C was approximately half that at 40°C) we obtain heats of reaction of:
58.7 kJ/mol at 25°C and **37.8 kJ/mol** at 40°C.

These results define the amount of capture and uptake as well as the rate of uptake and the stages involved in the reaction. These results demonstrate that increasing the temperature of the system decreases the total heat produced from the reaction. This in turn means a lower loading of CO_2 after the system has fully equilibrated. The rates of gas flow in both tests were approximately equal. The graph shape indicates a two-stage process due to the changing kinetics.

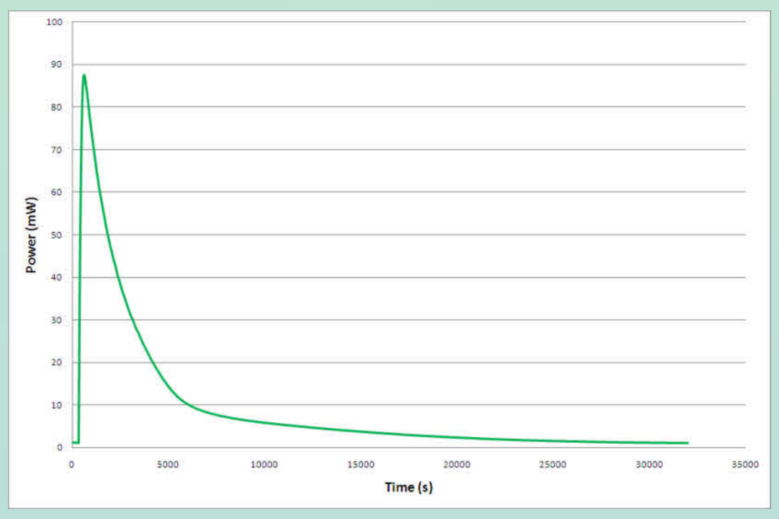


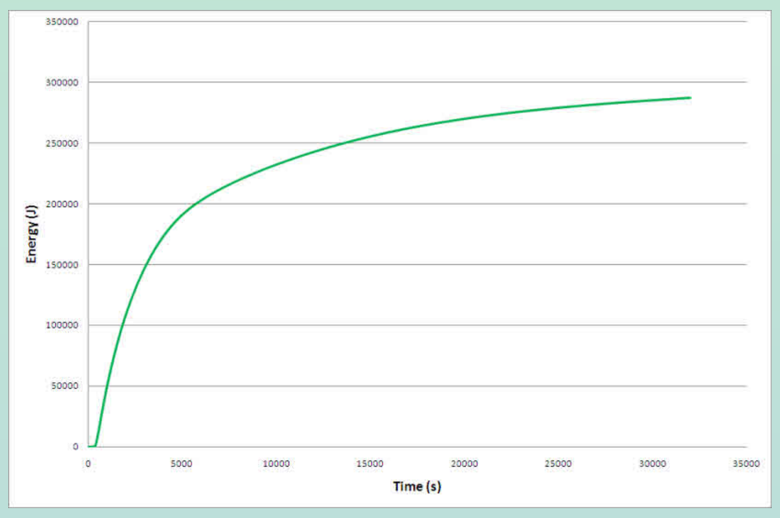


Above are the integrated results of the flow test.
Y-axis units are energy instead of power.

Tests at elevated pressure and under static conditions were also carried out. Stainless steel vials were used for these tests which can hold 150 PSI of pressure. As with a gas flow test, the elevated pressure test may be carried out with or without stirring via PTFE coated magnets driven at up to 300 rpm.

Pressure is measured via a transducer integrate with the instrument. Pressure data is recorded along with thermal data. The test illustrated here was carried out at a static pressure of 60 PSI and a temperature 25°C.

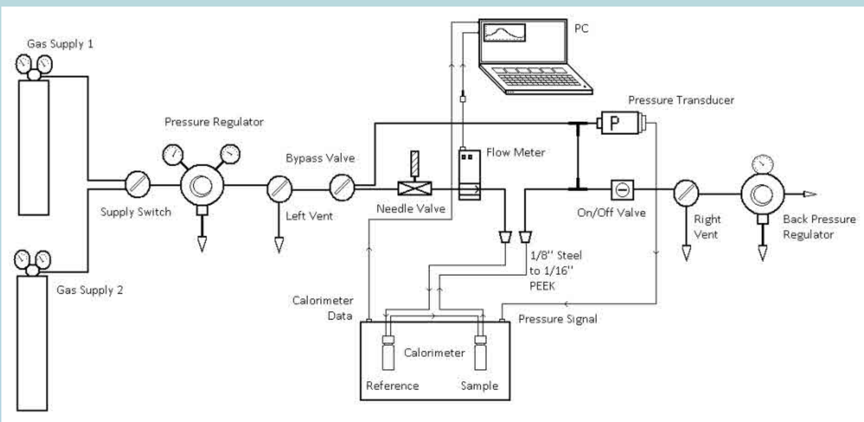




Power versus time is on the left, and energy versus time is on the right.

In terms of reaction kinetics, the heat output is different in shape to that observed in the flow tests. Instead of a two-stage heat release, the power signal shows an exponential decay. The peak heat is obtained very shortly after the moment of pressurization. The equilibrium point also takes longer to reach.

The heat absorbed by the MEA solution in this 4 bar pressure test was **64.2 kJ/mol**. Increasing the pressure of the CO_2 gas increases it's uptake. The optimum absorption rate is obtained using a lower-than-ambient temperature solution at a higher-than-ambient pressure.



Further studies would allow the quantification of the change of solubility with temperature and Pressure (both flowing and static).

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