Development of fast-release solid catchers for rare isotopes

DOE-NP SBIR/STTR Exchange Meeting

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Abstract

Porous solid catchers of rare isotopes produced at high energies via in-flight reactions can play an important role in high power heavy ion accelerator facilities such as RIKEN, FRIB, and RISP. Such catchers can be complementary to helium gas catchers especially for parasitic harvesting of rare isotopes in the in-flight separators at such facilities. Materials for solid catchers are being developed by Innosense, LLC, under the DOE ONP SBIR program. A new method for characterizing the release curves of such catchers is being developed at Argonne under this SBIR program. The method will utilize a very efficient and sensitive commercial residual gas analyzer for rapid measurements following implantation of heavy ion beams of stable isotopes.

Carbon Aerogels-Hot Catchers for Exotic Isotopes and/or Molecular Species

Agency: Department of Energy
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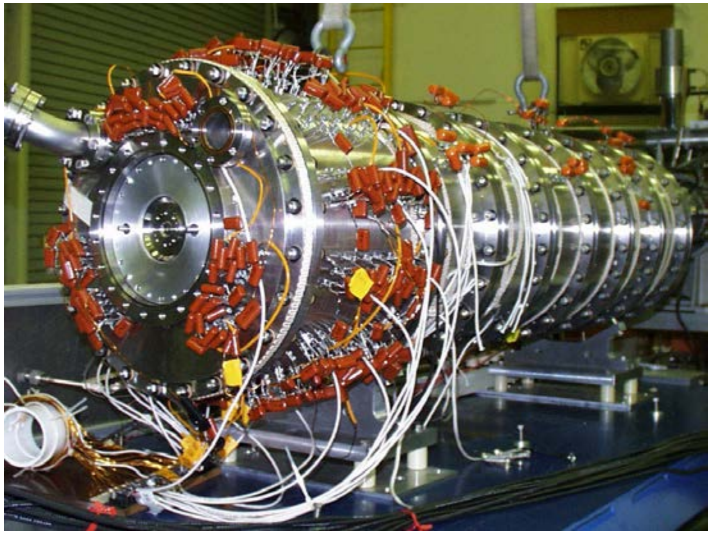
Solid catchers for in-flight heavy ion reaction products

- Solid catchers can play an important role for stopped and reaccelerated beams and for isotope harvesting
- Solid catchers can be used in parasitic or primary user modes
- A key role for solid catchers is for high intensity stopped or reaccelerated beam research
  - Porous catchers using atomic layer deposition (ALD) of W on aerogels have been produced: aimed at catching, e.g. ^{11}Li
  - Carbon isotopes can be stopped in oxide catchers to extract RIBs as CO molecules
  - Similarly, oxygen isotopes stopped in carbon catchers can be extraction as CO molecules
  - Ideas for conversion to CO pioneered at LBL and Louvain la Neuve
  - E.g. ^{15}O from ^{16}O beam can give secondary beams of ~10^{11}/s

Role of solid catchers vs. gas catchers

- Rare isotopes can be stopped in helium gas and extracted quickly and efficiently as ions
- Advantage of gas catchers
  - Almost universal: works well even with refractory and reactive elements
  - CycStopper developed at NSCL to increase stopping power for light isotopes
- Advantages of solid catchers
  - Can be much thicker which is very important for light beams such as ^{11}Li which have a large energy spread after slowing down.
  - Do not have the intensity limit of gas catchers (~1E9/s ions stopping in the gas)
  - More compact than gas catchers, especially compared to the CycStopper

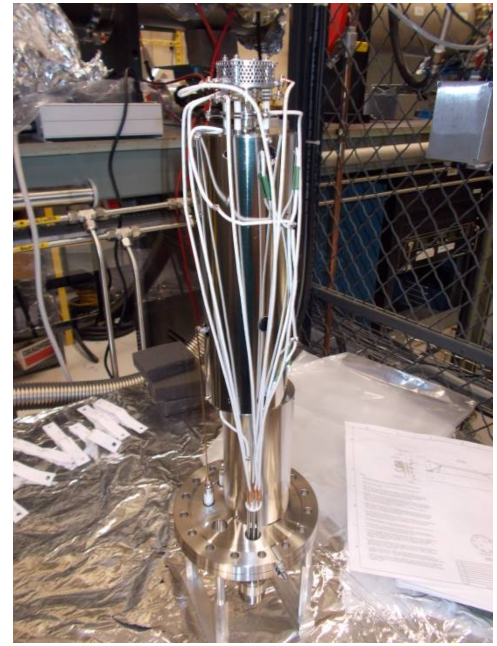


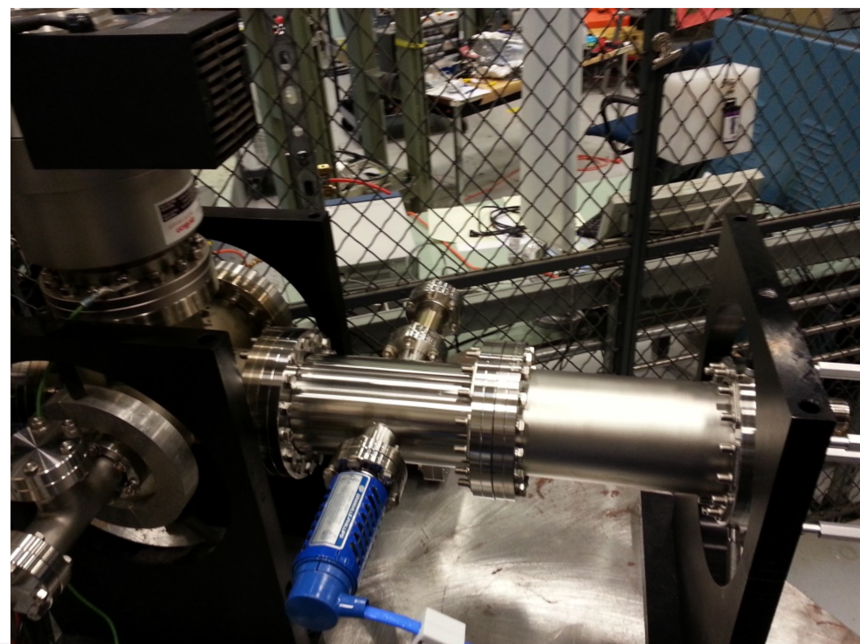
Fast release solid catchers

RGA-method being developed for release and efficiency measurements using stable beams

- Release measurements on-line with radioactive isotopes are not practical because it requires too much beam time
- Reinhard Kirchner developed at GSI a method using implanted stable beams as tracers
  - Method was very useful and productive, but requires access to a full fledged ISOL facility (none currently operating in the U.S.)
- RGA method uses stable beams implanted in the solid catcher materials and detects released atoms vs. time following beam shut-off
  - Primary isotopes of low natural abundance can be used, e.g. ^{13}C, ^{18}O, or ^{22}Ne
  - Primary beam currents can be low power, ~1E10/s (less than 1 watt)
  - RGA sensitivity is 1000-2000 counts per sec at a partial pressure of 1E-14 mbar (3E5 atoms/liter) with Extrel high efficiency RGA
  - 1E-10 mbar-L/s = 3E9 atoms/s
  - With pumping speed of 100 L/s, partial pressure will be 1E-12 mbar (~1E5 counts/sec)
  - Can test off-line by "doping" oxide catcher with ^{13}C stable isotope

EXTREL MAX 500H RGA

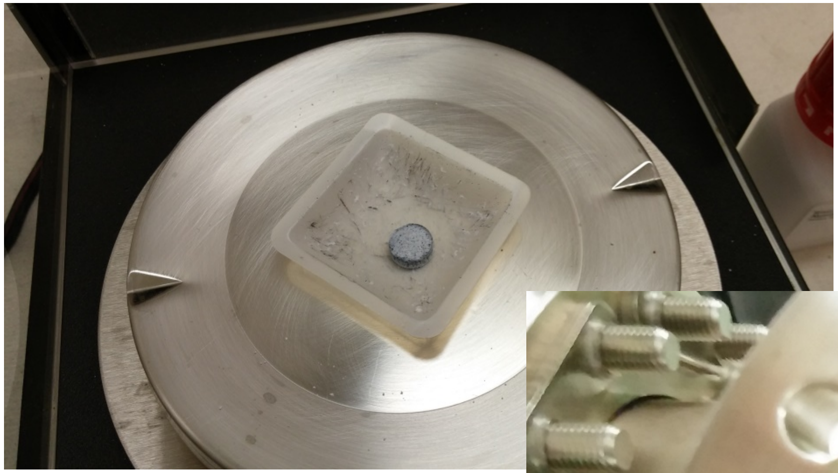


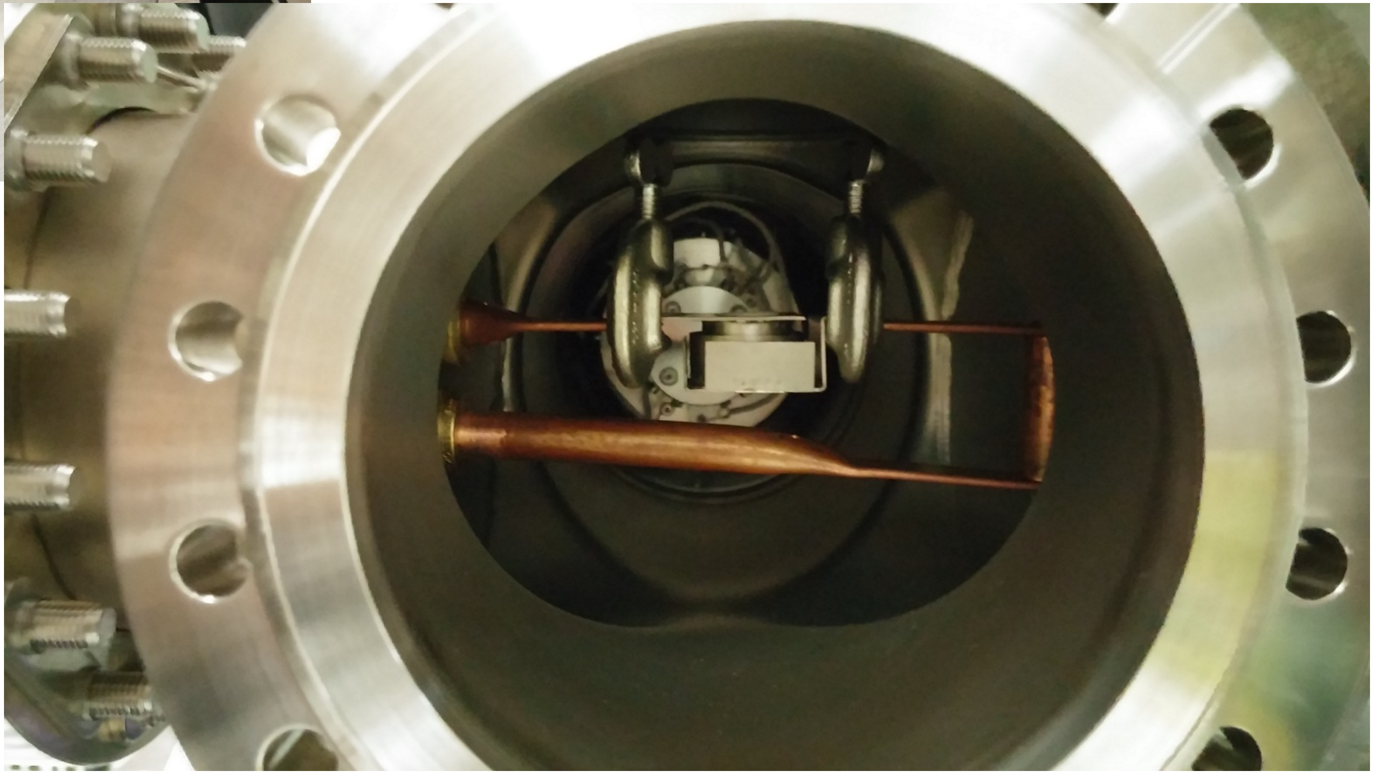


Extrel
Core Mass Spectrometers

Fast release solid catchers

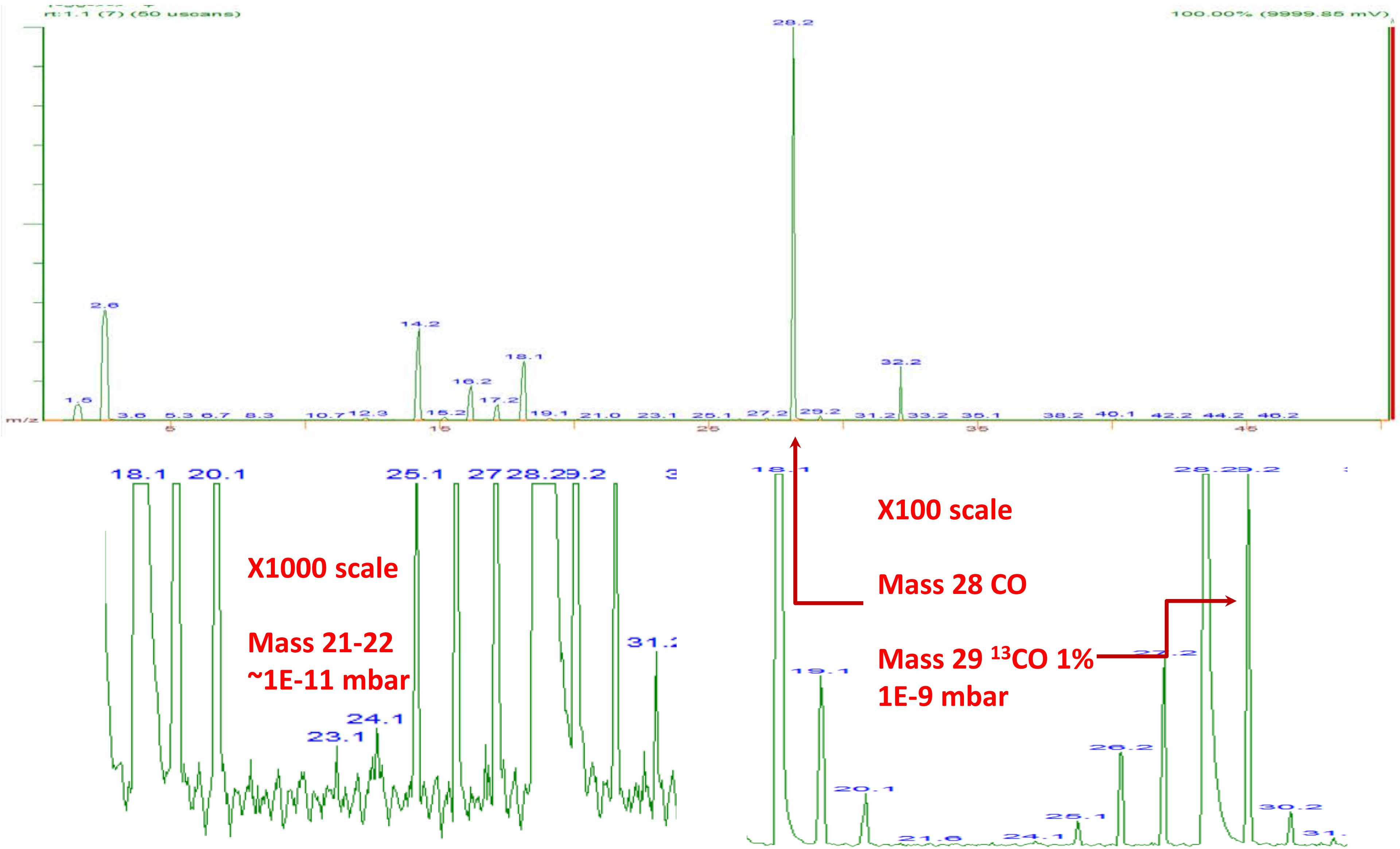
Picture of ^{13}C/alumina nanopowder sample and sample mounted in 1500 C heater in vacuum chamber





^{13}C doped alumina nanopowder sample is loaded and being outgassed. Present vacuum 1E-7 mbar.

RGA spectra with outgassed ^{13}C/alumina sample



Calibration

- An absolute efficiency calibration will be done using a general-purpose calibrated leak
  - The leak will be based on differential pumping between a low pressure (~1E-3 mb and high vacuum) through a commercially available silica capillary tube (ID 25 microns, length 5 cm up to 50 cm).

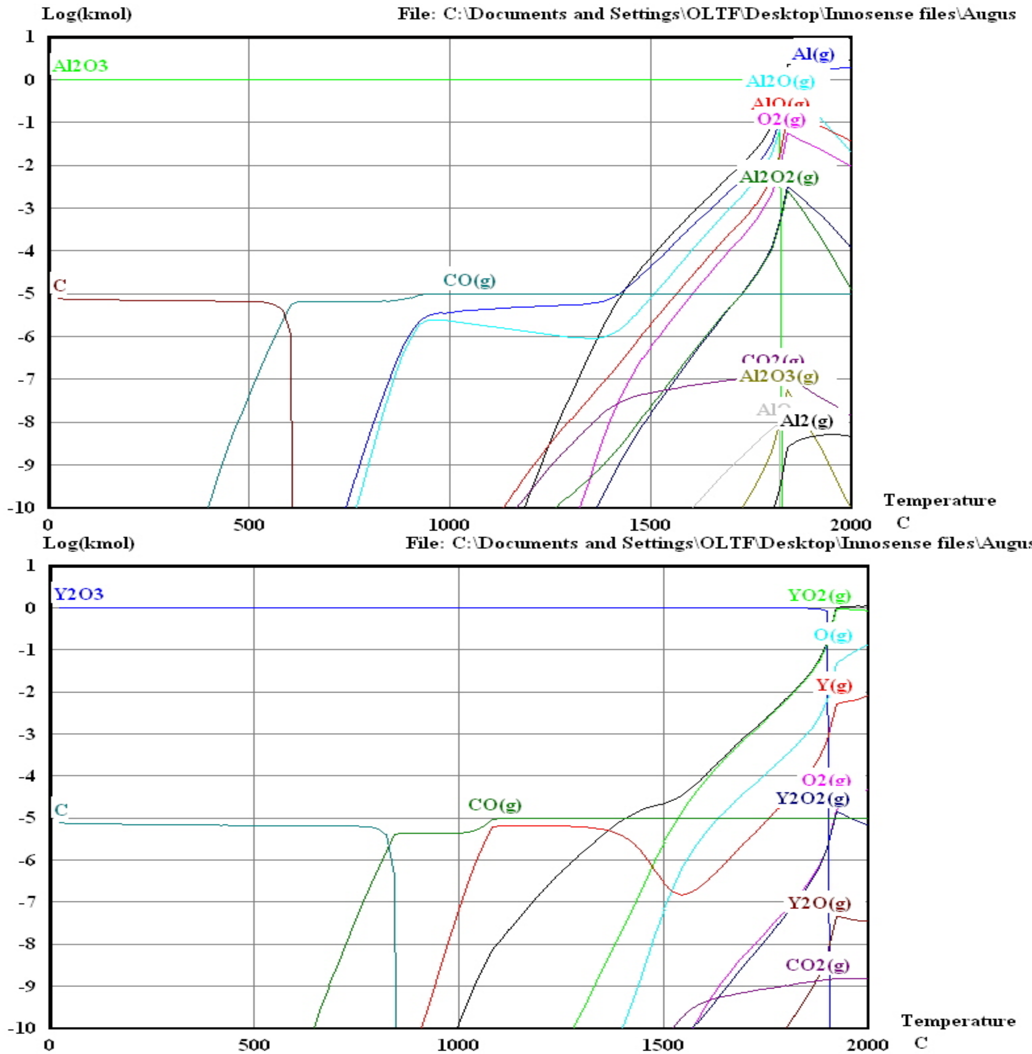
Next steps

- Near term (2014)
  - Move off-line RGA system to get higher power – 1500 C
  - Determine ^{13}CO conversion efficiency and release time for alumina, yttria stabilized zirconia, and hafnia oxides vs. T and stability vs total time at high T
  - Similar tests of C catchers using trace doping with ^{18}O-enriched oxides
  - Develop absolute calibration technique for CO and noble gases in the UHV regime (partial pressures <~1E-12 mbar)
- Longer term (limited by accelerator beam time priority)
  - On-line tests of various catchers w/ ^{6}Li, ^{18}O, and ^{22}Ne (2015)
  - Evaluation w/ stable and radioactive beams at NSCL (2016)

Predicted conversion of carbon to CO in oxide catchers - Trace C in oxide solid at low pressure (Simulations with HSC Chemistry by Dan Stracener/ORNL)

Yttria (lower) is more stable than alumina (upper) so complete conversion is at ~200 C higher T

Can be evaluated off-line using ^{13}C doping of porous oxides



Summary

- Solid catchers can play an important role for stopped and reaccelerated beams at FRIB and other advanced facilities for selected rare isotopes for intensities greater than gas catcher limits
- Innosense, LLC and ANL have developed a variety of porous solid catcher materials
  - W coated aerogels using Atomic Layer Deposition
  - Carbon-based aerogels
  - Nano-porosity refractory oxides
- A new method for direct measurements of release curves and efficiencies is being developed
  - The method is an evolution of one developed at the GSI ISOL facility by R. Kirchner
  - The new aspect is to use a very sensitive commercial RGA in place of a complete ISOL facility
  - A method for absolute efficiency is being developed based on a general purpose calibrated leak using commercially available silica capillary tubing
- Simulations of release temperatures and molecular species evolution are being carried out using the program HSC Chemistry