Welcome to the Cafe Thorium, where Chemist Ken Buesseler serves up a brew of fresh espresso and solid science.

BY TOM GIDWITZ

RV Thomas G. Thompson is home to in the Arabian Sea, riding the swells, its bow smacked by waves. It is August 1995, and the ship is in the midst of the southwest monsoon, the summer cycle of blasting winds that brings searing heat from the Arabian Peninsula and turns the sky hazy with desert dust. Scientists and crew members labor on the ship's fantail, sampling the bath-hot seawater and casting instruments into the depths.

But across the ship wafts the sound of rock and roll and the scent of strong coffee, drifting from a white cargo container chained to the deck. Taped to the container's door is a picture of a strange atom: its electrons are lemon yellow, and its nucleus is a lightning-struck coffee cup. This is the Cafe Thorium, open for business on the Arabian Sea.

At the Cafe Thorium, passers-by can linger for a cappuccino or cafelatte, but refreshment is not the Cafe's prime pursuit. Along with an espresso machine, grinder, and six-pound bag of beans, the Cafe boasts bottles of acid, beakers, a generator, computers, an oven, a radiation detector, twelve hundred pounds of lead radiation shielding, and a sleep-deprived scientist for whom caffeine is an essential fuel.

The scientist is marine chemist Ken Buesseler, and the Cafe Thorium is his seagoing lab. Every so often Buesseler leaves his workbench and goes to the rail, where for hours crew members have been slowly lowering a custom-made pump, straining thousands of liters of seawater.

Buesseler is a radiochemist, and with this pump he's fishing for clocks. Buesseler's clocks are radioactive isotopes that he collects on the pump's filters. Buesseler can tell time with these clocks, because they continuously decay at a known rate into other elements or into isotopes, which are different forms of the same element. By comparing the amount of these radionuclides to their progenitors, or by measuring the amount remaining of a specific radionuclide that has drifted into the depths, Buesseler and other marine radiochemists can measure how fast substances, particles, and parcels of water move from place to place, and how quickly biological and chemical processes are taking place in the sea.

Buesseler and his assistants have taken the Cafe Thorium to the equatorial Pacific, the North Atlantic, the waters around Bermuda, and the Gulf of Maine. Along the way he's refined a research tool that brings the chemistry of wide ocean regions into clearer focus.
Radioactive elements continuously emit particles and rays, and decay into isotopes or separate elements with lighter atomic weights. Their life spans are measured in half-lives—the amount of time required for the isotope to lose exactly one-half of its radioactivity. Illustration shows the decay chain of Uranium 238, along with each isotope’s respective half-life.

and gathered data that are instrumental in the study of climate change.

He’s also the world’s first radiochemist with a cyberspace clothing emporium and an international fan club. At the Cafe Thorium’s World Wide Web site, side by side with the latest bulletins about seawater colloids and particle sinking flux, Bueseler offers Cafe Thorium T-shirts to the world’s radionuclide devotees. Recently, employees of a South African mineral company signed on to the site and ordered T-shirts to strut at the world’s largest thorium mine, proving that the Cafe Thorium is not only a place of first-class research, but a way of life and a state of mind.

“I LIKE TO DO INTERDISCIPLINARY work, and you can apply tracers to almost any area of oceanography,” Bueseler said recently while sipping a tasty cup of dark roast Sumatran in his office in Clark Laboratory, the Cafe Thorium’s WHOI branch. “You can focus on physical oceanography problems, like how fast the Black Sea mixes. You can touch on biological problems, like how much carbon is fixed with photosynthesis and exported through the grazing cycle. You can solve geological problems, like how fast sediment is accumulating.”

For the past seven years Bueseler and his assistants have been taking part in JGOFS, the Joint Global Ocean Flux Study, a program involving hundreds of scientists from over thirty nations. JGOFS’s intent is to understand, at a global level, how carbon and other biologically active elements in the ocean interact with the atmosphere, ocean margins, and seafloor, and how carbon dioxide, taken up by the sea, will modulate the ever-increasing amount of greenhouse gases produced by burning fossil fuels.

Oceanic carbon rides on a merry-go-round of biological and chemical activity. Carbon is constantly eaten, digested, excreted, and reconsumed. It enters the sea from rivers and rains down in smokestack soot. It is absorbed from atmospheric carbon dioxide by phytoplankton and is released into the air and water when organisms die and dissolve.

Bueseler and his crew have been measuring an important sliver of the global carbon cycle: how much carbon is leaving the upper 100 meters of the ocean and raining to the seafloor in particle form. Bueseler quantifies this falling carbon indirectly—by measuring the radionuclide thorium 234.

Everything on Earth is slightly radioactive, thanks to the presence of natural and manmade radionuclides in the air, sea, and continental rocks. Cosmonucleides such as carbon 14, tritium, and aluminum 26 are formed when cosmic rays, high-energy particles from outer space, bombard the atmosphere. Primitive radionuclides survive from the time the elements were formed, and include uranium 238 and uranium 235. Manmade radionuclides are the by-products of atomic weapons, nuclear powerplants, crashing satellites, and accidents. All of these radionuclides are in constant transformation. Their nuclei spontaneously decay, emitting particles and rays.

Thorium 234 is produced by the decay of uranium 238. The mechanics of this decay dictate that the ratio of thorium 234 to uranium 238 should be constant throughout the ocean.

This one-to-one ratio, however, does not always occur. Thorium 234 has an amazing affinity for particles of any type: It sticks to fecal pellets, plankton, bacteria, dead fish, dust—in short to any available surface. Most of this material is carbon; it stays in the upper ocean and is continuously recycled, but some of it accumulates into particles large enough to sink. As these bits fall to the seafloor, they carry hitchhiking thorium 234. They “scavenge” thorium from the surface ocean, and create a thorium 234 “deficit” relative to uranium 238. By measuring the size of the deficit determined from thorium 234 and the carbon-to-thorium ratio on particles, Bueseler can trace how quickly carbon is leaving the upper layers of the sea.

The quest seems obscure, but for modelers hoping to predict the ocean’s response to climate change, the numbers are essential.

“If you want to answer the big question as to how the ocean functions as a global system, the sinking flux is a question that you have to get right,” says J. R. Toggweiler, who is creating a combined biological and physical model of the equatorial Pacific at the National Oceanic and Atmospheric Administration’s Geophysical Fluid Dynamics Lab in Princeton, New Jersey. “Until you have information like the stuff Ken provides, you’re really just whistling in the dark.” Previous models for the region that relied on other properties “were just wrong.”

Thorium’s potential as a tracer for carbon particles was first shown by Kirk Cochran of the State University of New York, WHOI’s Mike Bacon, and Ken Bruland of the University of California, Santa Cruz. “We showed the tantalizing possibilities,” Bruland says, but then were “overwhelmed” by the effort needed to amass enough useful data. “We got twenty to thirty data points, and we considered that a miracle. Ken developed novel shipboard sampling approaches so that he can get the thou-
sands of data points that you need to put it to use as a real tool."

Despite Buesseler’s technical breakthroughs, thorium surveys are still a grueling effort, because he can only afford to send one member of his team to sea at a time. In 1992, Buesseler made 300 measurements to map the rate of falling carbon particles over 8.25 million square miles of the equatorial Pacific. On five JGOFS Arabian Sea cruises in 1995, Buesseler and his assistants Lary Ball, John Andrews, and Claudia Benitez-Nelson collected and processed over 1,200 seawater samples.

“Spending months getting the field data like this is phenomenally labor intensive,” Bruland says, “and he’s doing a phenomenally difficult task.”

THERE’S A PICTURE OF BUSSERLER taken at the end of his last voyage, when he cranked up the stereo and brought his coffee gear out on deck, and in his beard and beach thongs, he looks like a guy before a rock concert sharing java from his van. But when it comes to science, Buesseler is far from laid-back. Since coming to WHOI as a graduate student in 1983, the Minnesota native has measured Chernobyl fall-out in the Black Sea, tracked plutonium in lakes and groundwater, and gauged how growing coral absorbs radioactive lead.

Buesseler sets exacting standards for himself and expects other scientists to do the same. In the late 1980s, he discovered that sediment traps, a widely-used method of measuring falling particles in the open ocean, were inaccurate. The traps were large open-ended cones with collecting jars underneath; they are supposed to act like rain gauges, accurately collecting material sinking from above.

But Buesseler’s particle counts often disagreed with the traps’ totals by factors of three or more. Currents in the sea’s upper layers swept material away from some traps; swimming organisms sometimes entered others.

“I tend to be very concerned about the techniques and methods. In oceanography, your interpretation is only as good as your measurement technique.” He felt the sediment traps’ inaccuracies were causing a chain reaction of wrong assumptions and incorrect models. In 1991 he reported his findings in a short paper in Nature. The results were immediate and loud.

“There were people who had based their whole careers on these traps. There was a lot of resentment. E-mail was just getting started, and I’d get a nasty gram condemning my Nature paper, saying that basically I was out on a witch hunt to trash all the sediment trap work.”

Funding agencies were reluctant to give money to controversial projects, and for a time trap studies came to a halt. When the balance of evidence supported Buesseler’s findings, some of the traps’ most ardent defenders left the field.

“People often collect data that tell them what they want to believe,” Buesseler says. “But the more interesting science is when you find a sample that should be telling you one thing, and it tells you the opposite. When things don’t agree, you learn more than if the data tell you what you already know.”

Buesseler is fully prepared for a time when his own ideas are discredited. “All my work might be proved wrong some day,” he says as he sips his cup of java, “and that’s just the advance of science.”

THORIUM FUN

Like many elements dissolved in the ocean, thorium 234 is ubiquitous but extremely hard to find. Thorium 234’s concentration in seawater is on the order of one part per million of one part per million of one part per million.

Detecting a thorium atom, Buesseler says, “is like finding a single dollar in a pile that you made by putting $1,000 in a stack, every second since the Big Bang. [4.5 x 109 years x 365 days x 24 hours x 60 min x 60 sec x $1,000 dollars = 140,000,000,000,000,000,000] That’s a big pile!”

For more fun thorium facts, visit the Cafe Thorium World Wide Web site: go to www.whoi.edu, click on “WWW Servers at WHOI,” then click on “Cafe Thorium.”

The Cafe Thorium aboard R/V Thomas G. Thompson—Buesseler brews a cup of espresso for thirsty shipmates. WHOI chemist Ed Peltzer waits to the right of Buesseler.