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## 'Green chemistry' comes to UO classroom

Two University of Oregon chemistry professors have developed a new approach to teaching organic chemistry that is both environmentally sound and educationally innovative.

"Organic chemistry has traditionally been taught using a number of very toxic and reactive solvents, reagents and other compounds," says Ken Doxsee, one of the developers of the "green chemistry" course.

"This was an increasingly untenable approach as environmental and safety awareness increased and the cost of handling waste materials rose sharply," adds Jim Hutchison, who initiated the project and collaborated with Doxsee to develop the green organic chemistry laboratory course.

In 1998-99, Hutchison and Doxsee offered a pilot version of the green lab to a limited number of students as an alternative to the UO's normal organic lab sequence. This two-term sequence allowed the professors to refine and test their new green laboratory experiments. This year, the green lab is being offered as a regular class—its 30 available slots quickly filled during registration week.

The key challenge of devising a new approach to teaching organic chemistry was finding environmentally friendly laboratory experiments and exercises. Hutchison and Doxsee found

ways to substitute milder chemicals for the more corrosive or volatile chemicals used in reactions.

"Bromine, for example, is extremely corrosive," Hutchison says. "But when it is incorporated into a compound that makes a solid, it is easy and safe to handle. So we've made that substitution." Doxsee adds that another example of a green approach is the substitution of a solution of hydrogen chloride for chlorine gas in a reaction.

"Although hydrogen chloride solutions still require care in handling, they present significantly fewer hazards than chlorine. Even better, the reaction can be run in ethanol instead of the more commonly used—and more hazardous—conventional organic solvents," he says. "By rethinking and reworking our laboratory exercises we can avoid the more harmful chemicals while still providing students with the important lessons of chemistry. They also learn additional important lessons about the environmental aspects and implications of chemistry."

For several experiments, Hutchison and Doxsee took chemical syntheses reported in the pages of recent leading scientific journals—including *Science* magazine and the *Journal of the American Chemical Society*—then modified them so that students could complete them within

the time constraints of a laboratory class.

"Our students were the first ever to conduct this synthesis. They were really at the cutting edge," Hutchison says. "It is only now that we practitioners of chemistry have advanced far enough in our understanding that a green chemistry course could exist. This is truly revolutionary."

Green chemistry has another significant advantage for students. For the last decade or so, chemistry departments across the nation have widely adopted the so-called "microscale" approach to reducing laboratory waste. The microscale technique simply reduces the quantities of all compounds used in an experiment, shrinking them by, for example, 90 percent. Smaller quantities result in proportionately less waste.

"But this approach really shortchanges students," Hutchison says.

"Microscale requires them to use minuscule amounts of chemicals with unusual specialized apparatus."

In other words, it has little to do with the kind of chemistry the students may eventually be asked to do as they take jobs in industry or academia.

"With green chemistry, we are able to teach students real chemistry techniques using real apparatus on a realistic scale," Doxsee notes.