

# Delta College

## *Small-Scale Chemistry*



### *Case Study*



**Delta College is a Michigan Community College that offers two-year associate degrees, student transfer, and certificate programs. Delta College is located at University Center, Michigan, in Bay County and lies midway between the cities of Saginaw (69,512), Bay City (38,936), and Midland (37,819).**

### **SMALL-SCALE CHEMISTRY**

Maintaining a pollution free environment and handling chemical wastes are subjects of increasing concern to educators, universities, and school systems. The best way to alleviate this concern is to eliminate chemical wastes at the source by using pollution prevention practices. The chemistry department at Delta College has significantly reduced the amount of chemical waste it generates by introducing small-scale chemistry experiments into its laboratory courses.



### **WHAT IS POLLUTION PREVENTION?**

Pollution Prevention is defined as the elimination or minimization of waste generation or environmentally sound on-site and off-site recycling. Pollution prevention activities include

process changes, technology changes, input material substitutions, product changes, and good operating practices. Only after pollution prevention has been applied or considered should alternative waste treatment, release, or disposal technologies be used.

### **WHAT IS SMALL-SCALE CHEMISTRY?**

Small-scale chemistry is simply the process of conducting chemical experiments on a much smaller scale. Instead of using large amounts of chemicals, the same experiments are conducted with minute quantities. This great reduction in scale requires modified techniques, equipment, and instruction. Small-scale chemistry builds pollution prevention, waste minimization, and

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July 2000 • #9824



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student safety at the design stage rather than controlling it at the disposal stage. Drops of chemicals in specially designed containers replace liters of hazardous waste in breakable glassware. The innovative use of high tech plastic ware designed for genetics research also reduces cost while maintaining safety and sophistication. Small-scale chemistry inherently manifests characteristics of the “Green Chemistry” movement by incorporating the principles and methodology of source reduction. Green chemistry promotes the use of innovative chemical technologies that reduce or eliminate the use or generation of hazardous substances in the design, manufacture, and use of chemical products.

The chemistry department at Delta College recently instituted the use of small-scale experiments into their laboratory courses. This innovative approach has proven to be a highly creative and effective teaching tool, while reducing the exposure of students to potentially toxic chemicals and virtually eliminating the chances of fire or explosions. The cost and quantity of chemicals used are also greatly reduced. Small-scale chemistry lab results have also been found to be more accurate than the traditional method of macro-scale chemistry.

These new experiments expose the students to more instrumentation and emphasize important technical skills.



Most of the student responses to these small-scale laboratory experiments have been positive. They appear to enjoy these laboratory classes more than the traditional laboratory experiments. Students are not concerned with breaking glassware and measuring out large quantities of reagents. Instead, there is more time for understanding the concepts and basic principles of these experiments. There is also a closer tie to their organic chemistry lectures. Although the initial cost of the equipment is significant, costs are quickly recovered from reduced chemical use. Also, benefits that are hard to measure, such as improved student education and reduced environmental impacts, are realized by using small-scale chemistry techniques. Figures on the savings are presented below.

Small-scale chemistry is an important teaching approach if we are to train our future scientists and engineers in the responsible use of chemicals.

### **BENEFITS OF SMALL-SCALE CHEMISTRY**

- + *Reduces the use of chemicals, promotes waste reduction at the source.*
- + *Reduces the amount of waste produced.*
- + *Makes recycling easier (less material to recycle).*
- + *Reduces the students' exposure to hazardous chemicals.*

- + *Virtually eliminates fire or explosive hazards.*
- + *Vastly improves laboratory safety.*
- + *Improves laboratory air quality.*
- + *Reduces the amount of spills and accidents.*
- + *Sharply reduces laboratory costs.*
- + *Requires less experiment time.*
- + *Teaches excellent laboratory techniques.*
- + *Lowers glass breakage cost.*
- + *Saves storage space.*
- + *Improves students' laboratory skills.*
- + *Provides a clean and productive environment*
- + *Adheres to the principles of "Green Chemistry."*
- + *Teaches students awareness of chemicals and their impact on the environment.*
- + *Makes the laboratory more user friendly to people with physical disabilities.*

**The bottom line:** It is a cost-effective and safe pollution prevention program that any teaching institution can adopt.

## DELTA COLLEGE CASE STUDY

The data listed below is for a single semester at Delta, 5 classes with 25 students per class. Each student conducted one double-replacement reaction experiment which involved testing a set of 8 cations and a set of 12 anions, 96 separate reactions in all. The traditional, or macro-scale version, uses 96 test tubes, with 10-30 ml of each cation and anion combined. In comparison, the small-scale version of this lab experiment uses only 1-2 drops of each cation and anion.

### Volume of Chemical Solutions Required for All Experiments

<u>Macro/Traditional</u>	<u>Micro/Small-Scale</u>
180L (Liters)	20L

**Performing the experiment with small-scale chemistry reduces the required quantity of chemical solution by more than 99%.**

### Volume of Waste Generated by Type (all waste must be treated and/or disposed of properly)

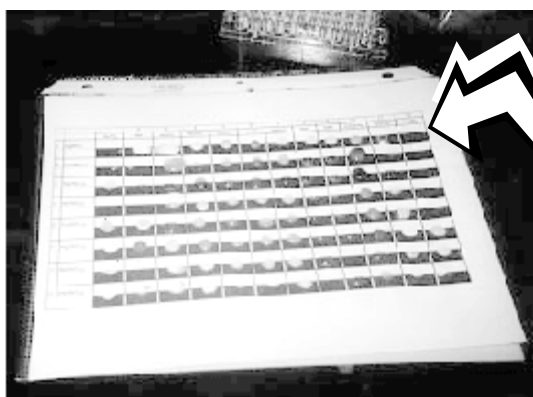
Type of Waste Generated	Waste Under Standard Lab Practice (Macro) (Liters)	Waste Under Micro-Chemistry (Micro) (Liters)
Heavy Metals	45	0.36
Poisons	60	0.50
Basic Waste	22	0.19
Eutrophication	180	0.44
Chemicals (total)	300-350	1-2

**Small-scale chemistry reduces waste up to 99.6%.**

**Cost and Time Comparison**

	Macro	vs.	Micro
Labor and preparation time	10 hours		4 hours
Chemical raw materials and preparation costs for 5 labs	\$1,550		\$171.58
Cost of only 1 lab exercise being run	\$310		\$171.58
Cost of 52 lab exercises being run	\$15,500		\$171.58

**Small-scale chemistry saves up to 60% of time.**



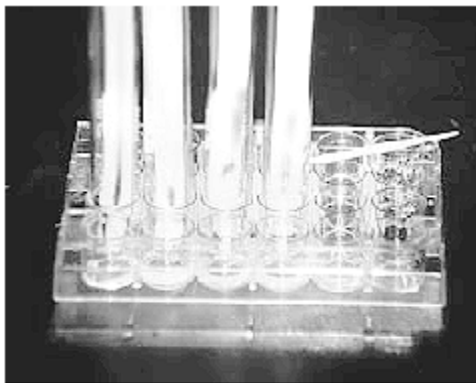
Delta College's double replacement reaction experiments are easy and safe with small-scale chemistry. The reaction sheet shown in this picture replaces 96 test tubes filled with 10-30 mL (milliliters) of chemicals with 2-3 drops of each chemical on a plastic grid sheet.



This is a complete lab set-up ready for transport to a Delta College off-campus non-lab site. Small-scale chemistry doesn't require an extensive laboratory to do these exercises; most can be accomplished in any setting, even a typical classroom or lecture hall.



Delta has found that reactions that would be considered too dangerous as traditionally performed can be safely operated using small-scale. This set-up is used to split water into its two component elements – hydrogen and oxygen. The kicker is that at the end of the experiment the students safely put these elements back together with a BANG! It's fun, safe, and a real learning opportunity!



This is a paper chromatography set-up that allows direct comparison of up to 12 different factors, including different dyes, solvents, or mixtures. All are run side by side at the same time. Small-scale has so many advantages!

Since Delta implemented small-scale chemistry, they have been able to use the money saved in laboratories to purchase equipment like balances, pH meters, and hot plates that were not previously in the budget.

## Delta College Small-Scale Chemistry Participant Comments

*A fun way to do real chemistry!*

*I cannot believe how many reactions I was able to do so fast!*

*Great workshop; one of the most useful ones that I have ever been to!*

*The simplicity, large number of reactions, and colors possible in one small lab are great!*

*A really wonderful way to do electrolysis (splitting water) on a limited school budget.*

*Great program! ... Getting new ideas was extremely helpful.*

*I gained a lot of useful information.*

*These labs are very effective in my limited class time of 40 minutes. Thanks!*

## ECONOMIC BENEFITS OF SMALL-SCALE CHEMISTRY FROM OTHER UNIVERSITIES AROUND THE COUNTRY

### Small-Scale Inorganic Chemistry

- ✦ *Colorado State University teaches general inorganic chemistry to approximately 3,000 students annually. The associated cost, prior to implementing small-scale chemistry, was over \$50,000 per year for consumable chemicals and waste disposal. Utilizing small-scale approaches, the total cost is now less than \$5,000; and the associated waste generation and disposal costs have been effectively reduced to zero.*

### Small-Scale Organic Chemistry

- ✦ *Waste disposal from Columbia University chemistry programs utilizing the traditional macro-scale chemistry technique was \$17,000 per term compared to \$200 per term for the small-scale chemistry program.*
- ✦ *Cost comparison for 100 students at the University of Wisconsin for one laboratory experiment using the Wittig Reaction was \$545 for macro-chemistry versus \$13 for small-scale chemistry.*
- ✦ *Converting a single introductory chemistry course to small-scale has helped the University of Arizona eliminate 3,600 gallons of hazardous waste and save over \$12,000 in disposal costs.*

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