PRODUCT PROFILE

Evaporators

Evaporation is a fundamental function in any chemistry laboratory, whether it involves removing solvent from a completed organic synthesis or extracting inorganic pollutants from an environmental sample. For these and similar purposes, a chemist needs a solvent evaporator. The process of evaporation, whether in a chemistry lab or anywhere else, is fundamentally about the movement of molecules from liquid to gas. In the laboratory, specific instruments have been developed to handle the requirements of chemical solvents. While each instrument permits a chemist to vary the amount of heat applied to the solvent, there are differences in the use of vacuum and inert gas streams to facilitate the solvent molecular movement.

Heating

To evaporate samples under different conditions, many companies, some of which are shown in Table 1, have introduced various types of evaporators. One common element among all these laboratory devices is heat. Heating is required because a sample will cool as solvent evaporates, thereby slowing evaporation. In addition, evaporation rates increase as temperature increases. However, not all sample materials can survive undue heating, and instrument makers now provide heaters with precise temperature control. Some manufacturers, such as Büchi, Heidolph, and Organomation, use water baths to heat solvents; others, such as Labconco, use blocks of aluminum in most of their systems. Some systems use aluminum particles or even hot air, such as the Caliper 96-well-plate evaporator, to heat samples.

Heating options are important for users to consider because some solvents, such as water, may require temperatures above 100 °C, forcing oil to be used in place of water in water baths. In addition, heating times vary for the different materials and can be a factor if preparation time is important.

While evaporators fall into several categories, two main ones stand out: nitrogen blowdown concentrators and vacuum evaporators.

Nitrogen Blowdown

Nitrogen blowdown or gas blowdown concentrators accelerate evaporation by decreasing the partial vapor pressure of the solvent just above the surface of the liquid. "If you were to put a ruler and measure away from the surface, what you would find is that right up close to the surface it's a 100% saturated environment, like fog if you will, and as you move farther away from the sample the vapor begins to disperse," says Robert Sawyer of Organomation.

Nitrogen blowdown evaporator. (Photo: Caliper.)

A rotary evaporator. (Photo: Brinkmann Instruments.)

Blowdown evaporators use a jet of gas to continually force off the layer of air that is saturated with vapor. By immediately removing molecules that enter the vapor state, the molecules do not have a chance to return to the liquid, which increases the evaporation rate.

Nitrogen blowdown is very useful for small sample volumes, under 50 mL, because with larger samples nitrogen blowdown will take longer and, as a result, semivolatile compounds may be lost.

Several companies have developed nitrogen blowdown desktop units. Caliper (formerly Zymark) produces the TurboVap line of evaporators, which feature a method to force any stray sample down the sidewalls of the sample vessel. The nitrogen is aimed at the vessel wall, creating a gas vortex, which swirls around and pushes the compounds of interest to the bottom of the tube.

Labconco's RapidVap N2 is somewhat of a hybrid design, which uses an orbital shaking motor to create a liquid vortex in the sample container. "All you are doing is getting this liquid to climb up the side of the wall and exposing more surface area," says Bob Applequist of Labconco. Increasing the surface area is usually a method used

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Table 1. Selected Evaporator Manufacturers

Company	Website	Product line
Caliper Life Sciences	www.calipertech.com	The TurboVap line of nitrogen blowdown evaporators uses gas vortexing to force sample back down to the bottom of the sample receptacle. TurboVap LV accommodates 50 1.5–35-mL tubes or Dionex ASE vials, TurboVap II uses Dionex ASE 40-mL tubes and 50- or 200-mL conventional tubes, TurboVap 96 uses 96-well plates, and TurboVap 500 is used for recovery of solvent.
Büchi	www.Büchi.com www.brinkmann.com	Rotavapor and SafetyVAP lines of rotary evaporators. The Rotavapor industrial evaporators handle samples of 6–20 mL and 50 mL. The Rotavapor Collegiate, for 1–3-L samples, is designed for education. SafetyVAP models handle samples of 50–3000 mL and range from analog controls to digital temperature and vacuum controls.
Organomation	www.organomation.com	The N-Evap line of nitrogen evaporators uses 1–50 mL of sample in test tubes 10–29 mm in diameter and is available in 6-, 12-, 24-, 34-, and 45-position models. A new N-Evap model supports 96-well plates. The N-Multivap is available for 64 and 100 positions with water bath and 48 and 96 positions with DryBlock heating. The S-Evap 5-, 8-, or 10-position evaporator is used for 250–500-mL flasks and is suitable for oil and grease analysis. The S-Evap-KD Kuderna-Danish uses 5 or 8 250–1000-mL KD flasks.
Labconco	www.labconco.com	The RapidVap line of vacuum or nitrogen blowdown evaporators can reduce samples to dryness or to an end-point volume. RapidVap vacuum evaporation systems use vortex motion on samples held in interchangeable sample blocks for samples up to 450 mL, or as many as 110 samples. The RapidVap N2 nitrogen blowdown model holds 8 samples of up to 450 mL each, and the Cool-Zone block insulates samples so they can be removed before complete dryness. The RapidVap N2/48 systems use vortex motion and heat (DryBlock) to speed nitrogen blowdown of up to 48 samples.
Yamato	www.yamato-net.co.jp	The RE200 rotary evaporator uses a variable rotary joint, distillation flask extraction. The RE400/500 models include a vacuum controller and autolift, and the RE500 displays settings and rpm.
Hettlab	www.hettlab.ch	The CombiDancer Infrared Vortex Evaporator uses vacuum and vortex shaking to evaporate samples from interchangeable sample racks, allowing different numbers and volumes of samples to be processed.
Heidolph	http://heidolph.neptun.diewerber.de	The VV Micro rotary evaporator evaporates 50–250 mL and features a small footprint. The Laborota series of benchtop rotary evaporators, for samples of 1–3 L, range from analog controls to vacuum and vapor temperature controller and programming options. Large-scale, 20-L rotary evaporators are also available.

in rotary vacuum evaporators, but in this case it is applied to nitrogen evaporation. The RapidVap is also one of the most automated systems, which can slow evaporation and alert users when a given volume of sample and solvent is left instead of requiring the user to stop the evaporation or evaporating to dryness. Most nitrogen blowdown evaporators handle multiple samples, and one of the newest options is units especially designed for 96-well plates offered by Caliper and Organomation.

Vacuum Evaporators

Rotary evaporators, like their nitrogen blowdown counterparts, remove the vapor from the surface of the sample, but they do so using vacuum instead of a stream of nitrogen. Several companies, including Labconco and Hettlab, produce evaporators that use vacuum pumps to remove the vapor phase of the evaporating solvent, but they do not rotate the solvent and sample in a typical glassware rotary assembly. To increase evaporation, they shake the samples and create liquid vortexes. However, most laboratory evaporators that use vacuum use rotating glassware to increase evaporation rates.

Rotating the sample vessel increases the surface area, according to Richard Jezykowski of Brinkmann Instruments, the North American distributor of Büchi rotary evaporators. "The liquid travels up the walls, similar to swirling the wine in a wineglass," he says. The rotation also provides uniform heating and helps prevent flash boiling.

"The specifications and quality of the glassware are key," says Jezykowski. While good glassware is important for both nitrogen and rotary evaporators, it is a safety concern for rotary evaporators because of the vacuum present. If glassware is defective or damaged, there is a risk of implosion, which can send glass and reagents flying. Büchi offers glass with a coating that produces an effect similar to that of automobile safety glass, which reduces the chances that users will be injured from glass shards if the evaporators should implode.

Rotary evaporators are typically for volumes larger than those that nitrogen blowdown evaporation is used for. Heidolph produces a model capable of handling 50–250 mL, the VV Micro, but it offers 3 units for the 1- to 3-L range. Büchi sells several versions of its Rotavapor that handle glassware from 50 mL to 3 L. Both companies offer much larger industrial-scale units that can handle 20 L or more.

While powered rotary evaporators have been around

since 1957, today's versions have been improved with digital electronics and additional safety features. Heidolph's LR4002/4003 uses digital displays, vacuum controller, and vapor temperature controller and is capable of storing common evaporation procedures, according to Monica Veneziano of Heidolph. Büchi also uses vacuum controllers to optimize the evaporation process. In addition, the units are easier to operate than they used to be, with many manufacturers offering easier methods of handling the glassware, such as Yamato's autolift feature or Büchi's Quick-action Jack.

More Vacuum

Rotary evaporators are not the only evaporators to use vacuum to speed up evaporation. Although not discussed in this article, freeze dryers use vacuum, but two companies, Labconco and Hettlab, produce non-freeze-drying vacuum-powered evaporators. Labconco's RapidVap Vacuum and Hettlab's CombiDancer operate like the nitrogen blowdown version of the RapidVap, using orbital motion to move the liquid up a container's sidewalls to increase the surface area for evaporation. Although they may not perform exactly like rotary evaporators, these units serve different needs because multiple samples in various-sized containers can be evaporated, while rotary evaporators can only handle one sample at a time.

Labconco's CentriVap also uses vacuum, but it centrifuges samples before and during vacuum evaporation. "Forcing the sample down into the bottom of the tube is counterproductive," says Applequist, "but by heating the chamber and putting it under deep vacuum it still evaporates." The advantage of centrifugation is that the finished sample is in a pellet in the bottom of the cuvette or tube and not distributed over the sides of the container. Such a result may be important in biotech and medical analysis.

A centrifuge evaporator. (Photo: Labconco.)

Other Evaporators

While rotary and nitrogen blowdown evaporators are common equipment, there are evaporation products available that use different technologies. One example is Kuderna-Danish glassware, offered by many glassware and scientific suppliers (not included in the table). The glassware is closed to the outside environment, and the sample resides in a flask separated by a narrow, specialized glass column with one or more glass beads from a flask to receive the vapor. Unlike nitrogen blowdown and rotary evaporation, the sample is vigorously boiled. However, the glass balls sit on a glass lip that causes a liquid seal to form, and when the vapor is forced to pass through the liquid seal, entrained sample is removed and flows back down the apparatus. As the sample liquid returns, it washes splatter material from the sidewalls back into the base of the flask.

The advantage of Kuderna-Danish is that it can quickly evaporate larger samples with little capital investment. The glassware is available from many sources, as are water baths for heating the sample flasks. However, Organomation produces several models for multiple-sample Kuderna-Danish evaporation.

The Future

Two trends can be seen in benchtop evaporators. One is the move into new industries with 96-well nitrogen blowdown evaporators. The other is increased automation that may improve in future evaporators. Labconco's RapidVap evaporators feature the highest degree of automation and can stop evaporation when the sample has been reduced to a certain volume.

Although evaporators offer some automation and timers, using the proper evaporator for the job appears to be the most efficient means of saving time. Large samples can take a long time for some evaporators, while other evaporators cannot handle small samples. And while evaporators may serve a basic laboratory need, they still require thought. Applequist says, "I get people who call in to get an evaporation unit, and they don't understand; they have forgotten their basic physics and chemistry."

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