AutoChem

It's about time

Reflux Efficiency

MiniBlockXT

SUMMARY

The reflux efficiency (solvent retention) of the MiniBlock XT (solution phase parallel synthesis) system was studied. Solvent loss was minimal, ranging from 0.1% to 1.0% per hour depending upon solvent and operating conditions.

Introduction

Reflux is often used in organic synthesis as a volatile component recovery technique or for maintenance of constant reaction temperature. Reflux, or solvent recovery efficiency, was evaluated for the MiniBlock XT product under a variety of experimental conditions including high, medium and low boiling solvents under both static and high gas flow conditions.

Experimental

The reflux efficiency of the MiniBlock XT was tested under ambient environment conditions in all three formats, including the 6, 12 and 24 position inserts. In each format a full complement of vessels was placed in the block insert and the appropriate size cross style stir bar was included in every vessel. The volume of solvent placed in each vessel was 40ml, 20ml and 7ml for the 6 position, 12 position and 24 position formats, respectively.

In the first set of experiments, the 6 position format was evaluated under ambient atmospheric conditions using the top plate and a pre-scored septum. Under these environmentally static conditions, reflux efficiency was evaluated using dichloromethane (DCM), tetrahydrofuran (THF) and dimethylformamide (DMF). During the entire course of the experiments, the reflux layer for the DCM, THF and DMF was set at 0°C, 10°C and 20°C, respectively, while the IKA heater / stirrer was set at 46°C, 75°C and 170°C, respectively. The stir bar speed for all three experiments was 250rpm.

In addition, each insert format was tested using both DCM and xylene in a set of experiments run with the inert gas manifold in place. The gas flow across the manifold was maintained at an elevated level of 3-5ml per minute during the entire experiment to mimic a worst-case scenario. Similar to the previous experiment, the DCM was evaluated with the reflux layer maintained at 0°C and the heater / stirrer set at 46°C. Xylene was tested with the reflux layer set at 20°C and the heater / stirrer at 150°C.

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All experiments were run for 20 hours under continuous reflux conditions. Reflux efficiency was determined gravimetrically by weighing vessels at room temperature before and after treatment.

Results

The MiniBlock XT was originally designed to be used at ambient pressure, but can be used in two different ambient pressure formats. One format includes covering the reaction vessels with the MiniBlock Top Plate and a septum that is pre-scored above each vessel. The set up would be used for ambient pressure reactions that do not require maintenance of an inert environment. The second format uses a septum piercing layer and an inert environment manifold to perform reactions at ambient pressure under inert environmental conditions. This inert gas manifold is a continuously purging manifold that supplies and removes inert gas to and from each vessel through a series of channels.

The first series of experiments performed to determine reflux efficiency used the top plate and pre-scored septum layer on the 6 position format. Table 1 shows the results of these three experiments.

Table 1. Reflux Efficiency Study Results

MiniBlock Format	IKA Set Point (C)	Solvent	Reflux Temp (C)	Total Loss (%)	Loss Rate (% / Hour)
6 Position	46	DCM	0	5.7	0.3
6 Position	75	THF	10	4.3	0.2
6 Position	170	DMF	20	2.1	0.1

As seen in Table 1, the highest total percentage loss of solvent during the 20 hour reflux period was 5.7% for DCM. The least amount of solvent loss seen during the study was for the highest boiling solvent (DMF) at 2.1% loss. In terms of loss per unit time, the range for all three solvents was from 0.1-0.3% loss per hour.

Utilizing the inert gas manifold, a second set of experiments was performed across all three formats. During these experiments, the gas flow across the manifold was maintained at an elevated level of approximately 3-5ml / minute and the stir bar speed was set at a very high mixing rate. These conditions were used to evaluate the reflux efficiency of the MiniBlock under worst-case scenarios. Table 2 shows the results of these 6 experiments.

Table 2. Reflux Efficiency Study Results

MiniBlock Format	IKA Set Point (C)	Solvent	Reflux Temp (C)	Total Loss (%)	Loss Rate (% / Hour)
6 Position	46	DCM	0	17.7	0.9
6 Position	150	Xylene	20	4.0	0.2
12 Position	46	DCM	0	15.9	0.8
12 Position	150	Xylene	20	2.1	0.1
24 Position	46	DCM	0	19.9	1.0
24 Position	150	Xylene	20	1.7	0.1

The data in Table 2 shows a similar reflux efficiency pattern as the data in Table 1. The low boiling solvent (DCM) shows a total percentage loss between 15.9% and 19.9% over the 20 hour test period. The high boiling solvent, xylene, shows a substantially lower solvent loss with a range from 1.7% to 4.0% over the same time period. These numbers calculate to a solvent loss rate of approximately 0.1% / hour for the xylene and 1.0 % / hour for the DCM.

Conclusions

Reflux, or solvent recovery, efficiency in the numerous formats of the MiniBlock XT product is affected by a number of factors including reaction vessel height, vessel diameter, reflux layer height, solvent volume, solvent type and mixing behavior. And, despite the multitude of factors affecting this behavior, reflux efficiency is generally quite good under all conditions tested.

Utilizing the MiniBlock XT with the top plate and pre-scored septum, the reflux efficiency, as tested in the 6 position format, was excellent across all solvents evaluated with a loss rate of approximately 0.2% / hour. This shows that in a static air environment the reflux efficiency of this type of device is excellent. The data from these three experiments also demonstrates that as the temperature difference between the solvent boiling point and the reflux layer temperature goes from a difference of 130°C to 60°C to 40°C the reflux efficiency continues to drop. Therefore, increasing the temperature difference will increase reflux efficiency, however, utilizing tap water as the recirculating fluid (i.e., 20°C) will work for most of the higher boiling solvents.

Using the continuous purging function of the inert gas manifold does have a substantial effect on the reflux efficiency of the block. Under worst-case conditions, reflux efficiency drops approximately tenfold to a loss rate 1% / hour, but is still quite acceptable for many reaction scenarios. And, this reflux efficiency can be improved simply by reducing the inert gas flow rate to a less stringent rate such as 0.5-1ml/minute. However, the gas flow rate cannot be reduced too much, or the effectiveness of the flow pattern in the channels will be reduced and the possibility for cross contamination between reaction vessels will increase. Another factor in these experiments that was maximized to effect worst-case conditions was the mixing rate. So, reflux efficiency can be improved here simply by reducing the mixing intensity to a less vigorous rate. The ability to make these changes, of course, will depend on the nature of the chemistry being performed.