

Achieve higher distillation efficiency when using a rotary evaporator – Impact of immersion angle

Summary

The evaporation rate of a rotary evaporator depends to a large extent on the immersion angle of the evaporating flask. The flatter the immersion angle, the higher the evaporation rate. This is, among other reasons, due to the fact that a flat immersion angle increases turbulence inside the evaporating flask, hence accelerating the evaporation. However, with a flatter immersion angle the evaporating flask cannot be as deeply immersed in the heating bath medium compared with a steep immersion angle. This can be an issue especially working with smaller evaporating flasks. Generally speaking, a 40 degrees immersion angle leads to a maximum efficiency rate without restriction in handling or risking losing parts of the sample due to over spilling and bumping into the receiving flask.

Introduction

Only a matter of decades ago, the rotary evaporators' immersion angles were rather flat. Furthermore, only a few sizes of evaporating flasks were available, features were limited and the heating bath a separate unit, hence manually movable. Nowadays the rotary evaporator and heating bath are most often a single unit. They are designed to operate with a wide range of evaporating flask sizes and several different glass assemblies are available so that the rotary evaporators are adjustable for various applications.



Figure 1: First generation of rotary evaporators with rather flat immersion angles (BUCHI Rotavapor, 1957).

With modern rotary evaporators, the immersion angle is adaptable to different circumstances. The main impacts of different immersion angle are:

- If the axis is vertical, there is almost no mixture inside the evaporating flask and heat transmission is limited to the immersion area of the flask. Moreover, there is only little turbulence in the heating bath. As a consequence, only limited heat transfer occurs within the heating bath.
- Flattening the immersion angle, leads to better mixing of the content. A larger percentage of the rotating evaporating flask is wetted by the heating bath medium. This generates a more effective heat transfer for faster evaporation and prevents local overheating.
- In the case of a very flat immersion angle, an even larger percentage of the flask is covered by the

heating bath medium. Through the rotation, a thin film of the water/oil of the heating bath is distributed almost over the whole surface of the rotating evaporating flask. Moreover, the heating medium is more agitated, which leads to more even heat distribution, resulting to more efficient heat transfer. However, a flatter angle creates a risk of the solvent that is being held in the flask, of pouring over into the receiving flask.

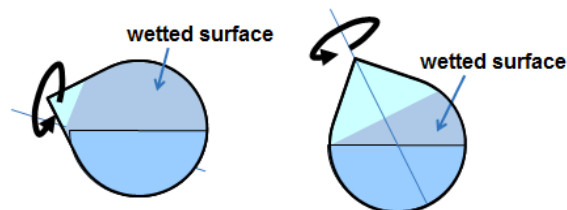


Figure 2: Representation of the wetted surface of an evaporating flask. A flatter immersion angle results in a larger wetted surface area inside the flask (left); a steeper immersion angle results in a smaller wetted surface area inside the flask (right).

A disadvantage of a flatter immersion angle is that the evaporating flask cannot be inserted as deeply in the heating bath. This is especially an issue with smaller flasks. Moreover, the sample solution is, due to less volume of the flask, more likely to bump and foam over.

Experiment

The factor of different angles is, in comparison with other variables of the evaporation process, relatively significant. For that reason is it worthwhile to find out the evaporation's effectiveness by applying different immersion angles.

The aim of the following experiment was to analyze the influence of different angles on the evaporation rate of a solvent single-stage distillation. The experiment was executed with a BUCHI Rotavapor®.

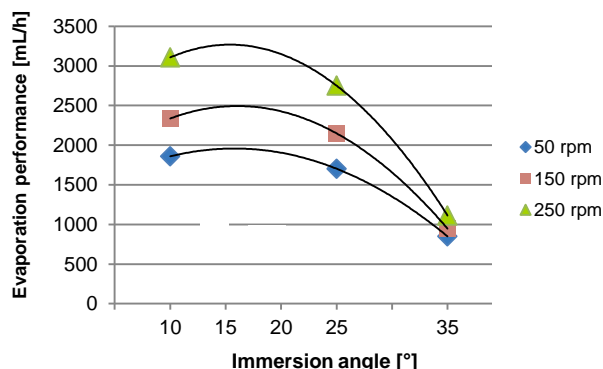
For the experiment the evaporation output of acetone was measured using immersion angles of 10, 25 and 35 degrees, each at a rotation speed of 50, 150 and 250 rpm.

Parameter

Solvent	acetone
Heating bath temperature	60 °C
Cooling temperature	10 °C
Pressure	556 mbar
Flask size	1 L
Content	500 mL
Immersion depth	fill level

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Result



Graphic 1: Illustration of the influence of the immersion angle on the evaporation output.

As shown in the graphic above, an immersion angle of 10 degrees, compared to an immersion angle of 35 degrees, led to a significant higher output of the evaporation rate, from 119 % (at 50 rpm) up to 180 % (at 250 rpm). An immersion angle of 10 degrees, compared to an immersion angle of 25 degrees, led to a 13 % higher evaporation output (at 250 rpm). The main increase in performance led the modification of an immersion angle from 35 to 25 degrees. In all three position, the disparity was always more significant at higher rotation speeds.

Interpretation

The experiment shows that the tests with a 10 and 25 degrees immersion angles (flat and standard position) obtained significantly more evaporation output compared to the tests with a 35 degrees immersion angle (steep position). This is for the simple reason that due to a flatter immersion angle, the active surface area inside the evaporating flask is enlarged, thus, accelerating the evaporation rate significantly. Though, the impact between the settings of 10 and 25 degrees was less noteworthy.

Recommendation

The immersion angle selected should be as flat as possible to produce maximum turbulence inside the evaporating flask. Moreover, in order to perform best, the flask's immersion depth should be set at least as deep that the level of the solvent is equal to the level of the heating bath medium.

The BUCHI Rotavapor® R-300 is manually adjustable to seven different immersion angles within 40 degrees and the lift movable 220 mm in the vertical axis. [1] Furthermore, the Heating Bath B-305 is movable horizontally to enable 50 mL up to 5 L evaporating flasks to be completely inserted into the heating bath and, thus, to be adjusted to each individual distillation situation.



Figure 3: Rotavapor® R-300 pictured in 3 different immersion angle positions.

The take home message is using an immersion angle at 25 degrees guarantees most efficient evaporation rate without jeopardize losing parts of the sample.

References

- [1] Technical Datasheet, Rotavapor® R-300