Can you provide brief explanation of the terms, Number of Theoretical Plates (N), Height Equivalent to a Theoretical Plate (H), Utilization of Theoretical Efficiency (UTE%), Resolution (RS), Phase Ratio (β)?

Brief explanation of the terms,Number of Theoretical Plates (N), Height Equivalent to a Theoretical Plate (H), Utilization of Theoretical Efficiency (UTE%), Resolution (RS), Phase Ratio (β),

Number of Theoretical Plates (N)

Also known as column efficiency, the number of theoretical plates is a mathematical concept and can be calculated using Equation 4. A capillary column/any chromatography column does not contain anything resembling physical distillation plates or other similar features. Theoretical plate numbers are indirect measure of peak width for a peak at a specific retention time.

$$N = 5.545\left(\frac{t_R}{w_h}\right)^2$$

N = number of theoretical plates
t_R = retention time
w_h = peak width at half height (in units of time)

Equation 4

Columns with high plate numbers are considered to be more efficient, that is, have higher column efficiency, than columns with a lower plate count. A column with a high number of theoretical plates will have a narrower peak at a given retention time than a column with a lower N number.

High column efficiency is beneficial since less peak separation (meaning lower alpha, α) is required to completely resolve narrow peaks. On stationary phases where the alphas (α) are small, more efficient columns are needed. Column efficiency is a function of the column dimensions (diameter, length and film thickness), the type of carrier gas and its flow rate or average linear velocity, and the compound and its retention. For column comparison purposes, the number of theoretical plates per meter (N/m) is often used.

Theoretical plate numbers are only valid for a specific set of conditions. Specifically, isothermal temperature conditions are required because temperature programs result in highly inflated, inaccurate plate numbers. Also, the retention factor (k) of the test solute used to calculate plate numbers should be greater than 5. Less retained peaks result in inflated plate numbers. When comparing theoretical plate numbers between columns, the same temperature conditions and peak retention (k) are required for the comparison to be valid.

Height Equivalent to a Theoretical Plate (H)

Another measure of column efficiency is the height equivalent to a theoretical plate denoted as H. It is calculated using Equation 5 and usually reported in millimeters. The shorter each theoretical plate, the more plates are "contained" in any length of column. This, of course, translates to more plates per meter and higher column efficiency.

$$H = \frac{L}{N}$$

L = length of column (mm)
N = number of theoretical plates

Equation 5

Utilization of Theoretical Efficiency (UTE%)

Coating Efficiency (CE%) is a historical term that compares the measured column efficiency and its theoretical maximum efficiency. It is calculated using Equation 6.

$$\text{UTE\%} = \left(\frac{H_{\text{actual}}}{H_{\text{theoretical}}} \right) \text{x } 100$$

Equation 6

Historically, Htheoretical was usually so heavily impacted by heterogeneities in the stationary phase film that extra-column contributions to Hactual could be ignored (such as injection anomalies, insufficient or misdirected make up gas, mechanical and electronic lag times). Because of improvements to coating efficiency this is no longer the case and Hactual is usually more heavily impacted by extra-column contributions than the column itself. Column contributions to Hactual become more meaningful with increasing film thickness or polarity, both of which affect stationary phase diffusion. Many authorities prefer the term "utilization of theoretical efficiency," UTE, which take the above factors into account. Typically, UTEs are 85 to 100% for non-polar stationary phases and 60 to 80% for polar phases.

Resolution (RS)

It is not surprising that the higher the resolution, the less the overlap between two peaks. Separation is only the distance or time between two peak maxima (alpha, α). Resolution takes into consideration both alpha (α) and the width of the peaks. It is calculated using either form of Equation 7. Baseline resolution usually occurs at resolution number 1.50; however, there is no visible baseline between the two peaks. Numbers greater than 1.50 indicate there is baseline between the peaks and numbers less than 1.50 indicate there is some degree of co-elution.

$$R = 1.18 \left(\frac{t_{R2} - t_{R1}}{w_{h_1} + w_{h_2}} \right)$$

$$R = 2 \left(\frac{t_{R2} - t_{R1}}{w_{b_1} + w_{b_2}} \right)$$

t_{R1} = retention time of first peak
t_{R2} = retention time of second peak
w_{h1} = peak width at half height (in units of time) of the first peak
w_{h2} = peak width at half height (in units of time) of the second peak
w_{b1} = peak width at base (in units of time) of the first peak
w_{b2} = peak width at base (in units of time) of the second peak

Equation 7

Phase Ratio (β)

A column's Phase Ratio, β, is a dimensionless value calculated using Equation 8.
If the same stationary phase and column temperature (program or isothermal) are maintained, the change in the phase ratio can be used to calculate the change in a solute's retention. This relationship is expressed by Equation 9. The Distribution Constant (KC) is the ratio of the solute concentration in the stationary phase and mobile phases. The distribution constant is fixed for the same stationary phase, column temperature and solute.

$$\beta = \frac{r}{2d_f}$$

r = column radius (micrometers, μm)
d_f = film thickness (micrometers, μm)

Equation 8

Thus, for a stationary phase and column temperature, the amount and direction of any change in retention upon a change in column diameter or film thickness can be determined. Equation 9 shows that an increase in the phase ratio results in a corresponding decrease in retention (k) since KC is a constant. Conversely, a decrease in the phase ratio results in a corresponding increase in retention (k).

$$\frac{c_S}{c_M} = K_c$$

$$K_c = k\beta = k\left(\frac{r}{2d_f} \right)$$

c_S = solute concentration in the stationary phase
c_M = solute concentration in the mobile phase

Equation 9

Equation 8 shows that the phase ratio decreases with a decrease in diameter or an increase in film thickness. Either of these column changes results in an increase in solute retention. The phase ratio increases with an increase in diameter or a decrease in film thickness. Either of these column changes results in a decrease in solute retention. Sometimes it is desirable to change column diameter or film thickness to obtain a specific effect (increased efficiency), without changing retention. This can be accomplished by proportionate changes in both column diameter and film thickness.

www.chem.agilent.com

Printed in USA August 7, 2007

Agilent Technologies