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DVS Application Note 29

# Moisture Desorption of Creams and Calculation of Diffusion Constants

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***In this application note, we describe the measurement of moisture (and organic vapour) loss in creams using DVS and apply it to the calculation of diffusion coefficients.***

## Introduction

Cream formulations are widely used in a variety of applications, from cosmetics such as hand cream and suntan cream to medical uses such as antiseptic cream. The moisture content of creams and the rate of moisture loss under different conditions are important for determining factors such as the texture, the feeling on the skin and the efficacy of the cream.

In this application note, we describe the measurement of moisture (and organic vapour) loss in creams using DVS and apply it to the calculation of diffusion coefficients.

## Method

The moisture (and organic vapour) loss of two different commercial creams, a hand cream and a baby moisturising lotion, was measured on a DVS-Advantage-1 system at 25˚C. A 100 µm thick film of cream was evenly deposited onto a microscope slide, which was horizontally placed into the DVS. The sample was then exposed to decreasing steps in humidity (ranging from 95% down to 0% RH). Each step was set to a fixed period of time of 24 hours.

## Results

***Moisture content at different humidities***

Figure 1 shows the kinetics of desorption for the two creams for steps from 95% RH to 60%, 40%, 20% and 0% RH. The red and green lines show the change in mass referenced to the dry mass (i.e. the mass at the end of the analysis) for the hand cream and baby moisturising lotion respectively, and the blue line corresponds to the humidity profile as a function of time.

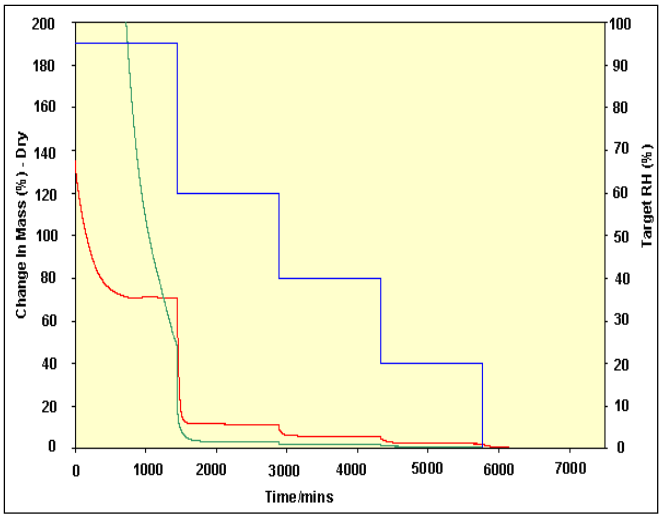


*Figure 1. Moisture desorption kinetics at 25 ℃ for two different creams (— hand cream and — baby moisturising lotion)*





Both samples have reached equilibrium at each humidity step, except for the first step at 95% RH for the baby moisturising lotion. The moisture contents at equilibrium (referenced to the dry mass) of the creams at different humidities are in Table 1 below:

*Table 1. Equilibrium moisture contents for hand cream and baby lotion.*

| Target RH (%) | Moisture Content (%) | |
|---|---|---|
| | **Hand Cream** | **Baby Lotion** |
| **Initially** | 134.9 | 839.0 |
| **95** | 70.8 | <50 |
| **60** | 11.2 | 3.2 |
| **40** | 5.5 | 1.8 |
| **20** | 2.4 | 0.9 |
| **0** | 0.00 | 0.00 |

The baby moisturising lotion initially contains a lot more moisture (and organic vapour) than the hand cream. However, whatever the humidity considered (for RH < 95%), the moisture content at equilibrium is higher for the hand cream than for the baby moisturising lotion which implies that the hand cream retains moisture more easily. These two creams show a completely different desorption isotherm.

### *Diffusion coefficients*

For a single step in humidity and a one sided thin film of thickness d, the initial kinetics of desorption may be described by the equation (1):

$$\frac{M_t}{M_\infty} = \frac{2}{d}\sqrt{\frac{Dt}{\pi}} \qquad (1)$$

where: $M_t$ is the mass of the sample at time t, $M_\infty$ the mass of the sample at thermodynamic equilibrium, and D is the diffusion constant. This equation is generally valid for values of $M_t/M_\infty < 0.4$, where a plot of $M_t/M_\infty$ against $t^{1/2}/d$ should be linear. For each discrete step in humidity, a linear least squares analysis is performed on the initial slope ($M_t/M_\infty < 0.4$). An example of a $M_t/M_\infty$ versus $t^{1/2}/d$ plot (red trace) along with the linear fit (blue trace) is shown in Figure 2.

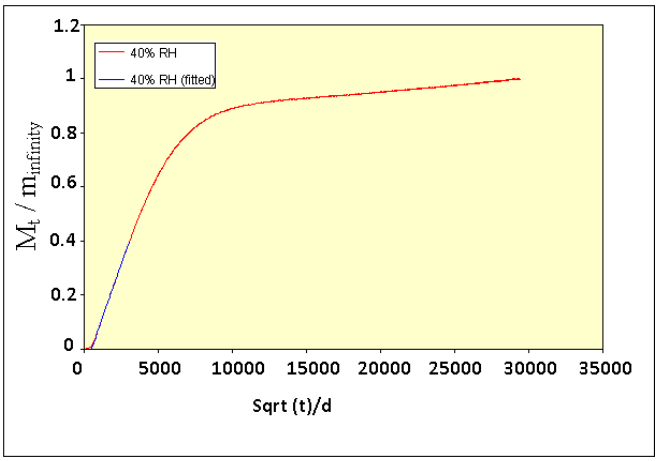


Figure 2. Diffusion plot for 60% RH to 40% RH step in humidity at 25°C on a 100 µm film of hand cream.

From this type of plot, values of the initial diffusion coefficients are calculated for both cream samples, and displayed in Table 2.

*Table 2. Initial diffusion coefficients for the hand cream and baby cream samples.*

| Previous RH (%) | Target RH (%) | Hand Cream | | Baby Lotion | |
|---|---|---|---|---|---|
| | | **Diff. Coeff. ($cm^2/s$)** | **R-sq. (%)** | **Diff. Coeff. ($cm^2/s$)** | **R-sq. (%)** |
| **95** | 60 | $2.87 * 10^{-8}$ | 99.53 | - | - |
| **60** | 40 | $1.87 * 10^{-8}$ | 99.95 | $4.87 * 10^{-8}$ | 99.76 |
| **40** | 20 | $7.93 * 10^{-9}$ | 99.76 | $2.73 * 10^{-8}$ | 100.00 |
| **20** | 0 | $3.45 * 10^{-9}$ | 99.85 | - | - |

For the same size of humidity steps, the values of the initial diffusion coefficients decrease with decreasing humidities. The values of the initial diffusion coefficient are higher for the baby moisturising cream than for the hand cream, at least for the two steps in humidity considered. Therefore the rate of loss of moisture for the baby moisturising cream is higher than for the hand cream.

## Conclusion

The above described DVS methodology may be used to rapidly assess the desorption isotherm and the kinetics of moisture loss of creams. The analysis of the experimental data may be performed using the Advanced Data Analysis add-in suite, facilitating rapid and reliable evaluation of experimental data.

The two creams analysed in this application note show big differences in their initial moisture content, their moisture content at equilibrium under different humidity conditions and in their diffusion coefficients. These differences illustrate the two creams' differences in texture and feeling on the skin, and explain their use for a different purpose.

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