CHALMERS

Determination of diffusion and partition coefficients for release of encapsulated substances in aqueous suspension

Bachelor of Science Thesis

Course: KBTX11 (15 hp)

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Abstract

To protect a painted house from mold and algae, anti-fouling agents is usually mixed in color. Heavy metals that were used in the past as application of protection for different color systems are now banned due to the negative impact on the environment. In the current situation, less harmful metal-free biocides re used instead, which is mixed directly into the painting. However, today's color system loses its ability to protect against growth way before its intended lifespan due to leakage of the biocide from the color matrix. This because of the high diffusivity of biocide, i.e. of the molecular movement in the paint film causes leakage of the biocide which will disappear from the surface of the water or rainfall with time. One way to prevent fast loss of biocide is by encapsulation of biocides and by reducing the rate of diffusion to the surface. In this project, the biocide OIT is encapsulated in homogeneous polymeric microspheres, by using the method of *internal phase separation by solvent evaporation*. Since biocide release from the microsphere is controlled, makes this type of system more possible to extend the surface protection. Experimental release data could be put into perspective by using size distribution of microsphere and adaptation of previously developed model release. Mathematical model fitting resulted in calculated diffusion- and partition coefficients.

Sammanfattning

För att skydda ett målad hus från mögel och alger, är anti-påväxtmedel vanligtvis blandad i färgen. Tungmetaller som förr användes som tillämpning av skydd för olika färgsystem är idag förbjudet på grund av den negativa påverkan på miljön. I dagsläget används istället mindre skadliga metallfria biocider, som blandas direkt i målningen. Dock förlorar dagens färgsystem sin förmåga att skydda mot tillväxt långt före sin avsedda livslängd på grund av läckage av biociden ur färgmatrisen. Detta beror på biocidens höga diffusivitet, d.v.s. molekylära rörelse, i målarfilmen som orsakar läckaget av biociden vilken därefter försvinner från ytan av vatten eller regnfall. Ett sätt att förhindra snabb förlust av biocid ärgenom inkapsling av biocider och genom det minska diffusionshastigheten ut till ytan. I detta projekt har biociden OIT inkapslats i homogena polymetriska mikrosfärer genom att använda metoden *internalphase separation by solvent evaporation.* Eftersom biocidens frisättning från mikrosfären är kontrollerad, gör den här typen av system det mer möjligt att förlänga ytskyddet.Experimentella frisättningsdata kunde sättas i perspektiv genom användning avmikrosfärernas storleksfördelning samt anpassning av tidigare utvecklad frisättningsmodell. Matematisk anpassning resulterade i beräknade diffusion- och partitionsskoefficienter.

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1. Introduction

1.1 Background

Paint has for a long time been useful to protect underlying surfaces to minimize the growth of mold and algae. The way to maintain this has come to change over time, most because of the environmental effects that has been caused before. Toxic metal substances containing tin and lead has been used earlier but are nowadays forbidden for treatment. Instead, metal-free and less hazardous biocides are utilized as a protection against growth and most microorganisms. However, the maximal amount of biocide that is acceptable to use in paint has decreased successively in time because of the environmental impact. Biocides are generally small hydrophobic molecules that are built to destroy or repulse organism from mold and algae by biological or chemical reaction. Biocides are usually added directly into the paint during the formulation in industrial production [1].

The biocides protect by destroying growth at the surface area of the paint coating by being able to move easily inside the polymeric paint matrix in order to migrate to the outermost surface. One problem is specific target selectivity of the biocide requires a mixture of different kinds of biocide to give the best protection as possible. Another major disadvantage is that inside the paint matrix, the diffusivity is high and conduces to fast leakage of biocide. This means that majority of biocide will be rinsed away after typically a few years, which leads to premature loss of surface protection, and do not give the desirable and prolonged protection as the previously used metal-based preservatives [2].

The reason why the biocides protect the paint matrix for only a few years is because the release rate of biocide depends on the concentration of biocide. This also gives an unnecessary high release of biocide in the beginning of the lifespan of paint since the concentration of biocide is high, and only after few years will the level of release decrease as low as it can count as a complete loss [2].

A way to prevent the loss of biocide and to extend the surface protection against micro-organic growth is to encapsulate the biocide in microcapsules, which was made in this project. The solid microcapsules which exist in a range of micrometer (1-1000 micrometer) size in diameter can either be of core-shell structure or homogenous polymer matrices. The size of the microcapsules makes them too big to diffuse inside the paint matrix, but they are at the same time well homogenously mixed in the paint and enclosed in the dry coating. This will facilitate the control effect of the release of biocide into the paint matrix and increase the lifespan of paint matrix, since the biocide first has to diffuse inside the microcapsule then by that release from it and diffusing inside the paint matrix. Thereafter it will migrate to the outermost surface. In addition, this will require less amount distribution of biocide in the environment since repainting is not needed as much anymore, as well as the production of the biocide [1].

1.2 Purpose and objectives

The main purpose of this work was to gain better understanding on the mechanisms that affects the release from microcapsules. By understanding these different parameters, a controlled and prolonged surface protection of paint and other similar layers can be accomplished. The objective of this work was to quantify the release of the biocide OIT (2-n-octyl-4-isothiazolin-3-one) from monolithic microcapsules based on PMMA (poly-methylmethacrylate) in a range of different release media in order to obtain the effective diffusion coefficient of OIT within the microcapsules.

2. Theory

2.1 Surface- and interfacial tension

Surface tension depends on a lack of balance in attractive interactions at the interface fluid-air, while for interfacial tension depends instead at the interface fluid-fluid. This tension is described as the free energy per area of a boundary layer. That is, the tension is the energy that is needed to expand the boundary layer between two immiscible phases. This kind of tension occurs when molecules near the interface do not get affected by the same attractive interactions in all directions.

One way to decrease the interfacial tension between two immiscible systems and therefore make the system disperse is by utilize surface-active substances, principally surfactants or surface-active polymers, which are therefore often used as emulsifiers and stabilizers. It is required that a surface-active substance decrease the interfacial tension between the hydrophilic and hydrophobic phases to form an emulsion, and by that make it possible for dispersing. What happens is that the emulsifier search for the interface between the two immiscible systems and prevent these two from coalescences. This way of preventing coalescence is utilized when stabilizing emulsions and suspensions. This will unfortunately only occur temporarily because it will never get completely thermodynamically stable. That is, the two phases will separate with time [3].

2.2 Dispersion

Dispersion is a collective name for unstable thermodynamic systems where two immiscible phases temporarily create a mixture. The two immiscible phases consist of one continuous- and one dispersed phase, where the continuous phase encompasses the dispersed one. A dispersion is always thermodynamically instable. The more the dispersion is instable, the faster it will be exposed for destabilizing mechanisms that generate a phase separation with time [1]. The two kinds of dispersions of interest in this work are denoted emulsion and suspension.

2.2.1 Emulsion

Emulsion is a dispersion where both the continuous- and dispersed phase are liquids [1], but of different kind. One liquid phase most often exists as water while the other one is an organic substance, frequently named as oil. To create and stabilize an emulsion of oil and water, addition of surface-active substances, called surfactants emulsifiers and stabilizers respectively, is required to support the decrease of the interfacial tension between the phases and rapidly diffuse to and stabilize the recently created interface. This will facilitate the mechanical creation of small drops, either of oil in water or the opposite [3]. One reason why surfactants are used in this case is because of their amphiphilic existence, which means that they consist of at least two parts where the hydrophilic part is soluble in water, while the hydrophobic part in non-polar environment [1].

2.2.2 Suspension

Suspension is another kind of dispersion that has many similarities to the emulsion, but in this case is the dispersed phase solid that exists in the continuous liquid phase. In general, the stability decreases with larger particles, in particular for suspensions where the density difference between dispersed and continuous phase often is larger than that of emulsions. In some cases, products consist of both emulsion and suspension, e.g. hybrid paint.At the

emulsified binding agent with a lower density than water will float up to the surface, while the denser pigment will drop down to the bottom [3].

2.2 Biocides

As mentioned before, biocide is a name for certain chemicals substances and has been used as protection in coatings and materials against growth and algae since the early 1950's [1]. Biocides have been utilized in most industries where fouling has been a major problem. The main problems that could occur from fouling are the corrosions of paint matrix [4]. The field of application for biocide is wide and different kinds of biocides have various and specific action modes against different microorganisms. Hence, many products consist of a mixture of biocides to resist the existence of multiple microorganisms. As mentioned above, large amount of biocides are not only toxic against microorganisms, but can also affect against non-targeted living organisms. Therefore follows regulations what biocides and what amount are allowed to utilize [4], [5].

One group of well-known biocides is the isothiazolinones, which consist of heterocyclic aromatic structures. In this project OIT (2-n-octyl-4-isothiazolin-3-one) has been in focus, a semi-hydrophobic biocide that is used commercially in paint industry, in leather- and cardboard products, as well in polymeric materials like PVC [1].

There is a major problem with the isothiazolinones though especially it involves OIT in paint. The biocide could act as softener or plasticizer that can change the thermo-mechanical properties of the paint [1].

3. Method and materials

3.1 Microencapsulation

Microencapsulation is a formulated method where small (1-1000 µm) active solid particles, liquid droplets, or gas bubbles are covered with a thin layer of shell or coating for purpose to protect the active ingredient from reacting with surrounded mechanisms in the environment. The active ingredient is present in the core material, as the surrounding material forms the shell. The reason why encapsulation is used depends on the aim of application but in many cases it is for protect and/or control the release of an active substance. Microencapsulation is industrially employed in a diverse range of fields around the world, where microcapsules are very common for example in the chemical- and pharmaceuticals industry as transportation reservoirs for drugs as well as cosmetics and printing. Microencapsulation is also used in industrial sectors as agriculture, textiles, even in the coating industry and food [6].

There exist many different formulation routes produce microcapsules where one is based on internal droplet phase separation, so called coacervation. There are several variations of this method that are used if long-term controlled release is regarded, and in this project *Internal Phase Separation by Solvent Evaporation* has been utilized [7].

3.1.1 Internal Phase Separation by Solvent Evaporation

The internal phase separation by solvent evaporation is a physical- and straightforward useful method. The reason why this method is useful in many areas is because it almost brings a full encapsulation yield of the active substance, in this case OIT, by using an emulsifier in the water phase, in this case PVA. The method begins with the configuration of an oil/water emulsion where the continuous phase consists of water, and a water-soluble and surface-active polymer. The dispersed phase in the emulsion consists of a volatile solvent (dichloromethane), the polymer (PMMA) and OIT [1].

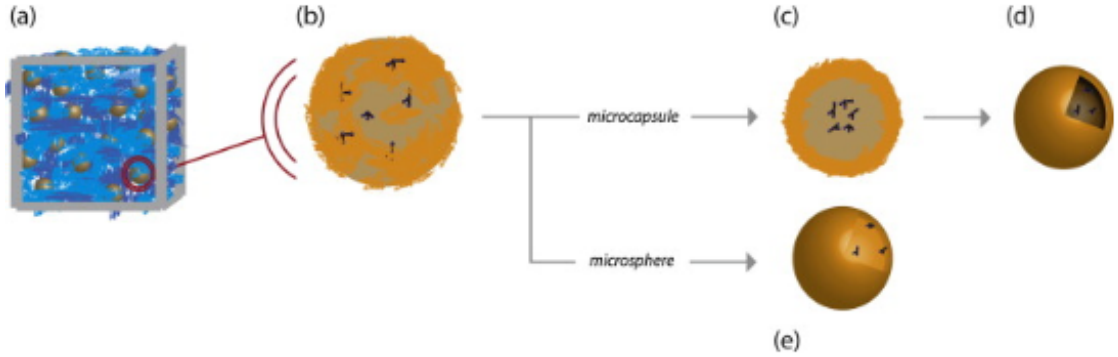

Figure 1: *A schematic image of the method internal phase separation by solvent evaporation for creation of microcapsules, described by Loxley and Vincent 1998* [7].

As shown in Figure 1(a), the oil phase is carried by a volatile solvent that has a low miscibility in water. The volatile solvent has to be a good solvent for the shell-forming polymer and the active substance. (b) After this emulsion step, the volatile solvent is let to evaporates, and a phase separation of the polymer within the droplets will occur. (c) Thereafter, the polymer-rich phase will migrate to the interface. (d) The microcapsules will get its final form of core-shell structure when all of the volatile solvent has evaporated. (e) The setup is almost identical when forming monolithic microcapsules, except no core-material is used and will instead get a structure as a homogenous polymer matrix [1], [6], [8].

3.2 Performance

3.2.1 The formulation

The standard recipe in this work gives PMMA-based microcapsules with 10wt% OIT [1], [8]. First of all, the water phase, consisting of 1 wt% PVA (95 % hydrolyzed) was prepared in Milli-Q water. The oil phase consisted of dichloromethane (DCM), PMMA (350 000 Mw) and OIT, which is obtained in Figure 2. The oil phase was prepared by weighing 4.95 g PMMA, which was dissolved in 50 ml DCM during stirring. In a separate vial 0.55 g of OIT was dissolved in 3 ml DCM upon added to the PMMA-mixture. Thereafter 80 ml water consisting of 1wt% PVA was prepared in a three-headed round bottle placed in a room temperature water-bath. A homogenizer (*SilentCrusherM tool 22F*) was installed in the water solution. The oil phase was then slowly pour in the three-headed water bowl during a time of 120 seconds under homogenization. Thereafter emulsification was carried out during 1 hour at 10 000 rpm. The reason why this step must be done is because the DCM particles have to be crushed into smaller ones. An opaque oil in water emulsion was produced after the hour had passed [1].

The emulsion was poured into 120 ml of water, consisting of 1 wt% PVA, and gently stirred in open beaker standing in a fume hood overnight. In that way DCM could evaporate under magnetic stirring at 200 rpm. The final suspension of microcapsules was then diluted up to 200 ml by using Milli-Q the next day [8]. This can be seen in Figure 4.

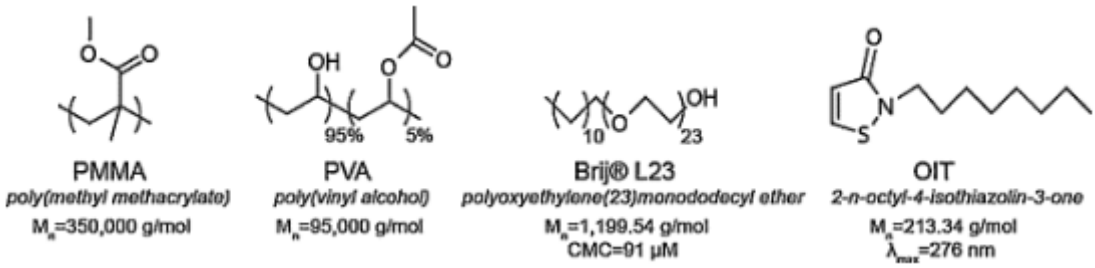

Figure 2: *Molecular structure and contractions of the chemicals used for the encapsulation and controlled release of OIT, as well as the chemical name, molecular weight (M_n), critical micelle concentration (CMC) and UV adsorption maximum were the most relevant included ones* [8].

As can be obtained in Figure 6, one drop of suspension diluted 1:4 with water, was put on a glass microscope slide and covered with a cover glass in order to examine the microcapsules with optical microscope, equipped with camera for image analysis [8].

3.2.2 Release methodology

The laboratory equipment and materials required to accomplish the release studies of an active from microcapsules to a release medium are crucial in the release setup. The analysis step compasses the procedure of data sampling and a proper analytical technique to quantify the concentration of active at a given time. The evaluation step brings up the results into places and perspective by the use and application of the studied release model [8].

There are two important parameters that have to be regarded when designing the release setup. The first thing is knowledge of saturation concentration of the biocide in the release medium. The second is that an estimate of the equilibrium distribution of the biocide between the microcapsule and the release medium has to be known [2], [8].

As shown in Figure 3 b), it should be noted that semi-permeable dialysis tube is one common setup to utilize for release studies and measurements from capsules to an aqueous solution, where the size its pore of the dialysis membrane is significantly smaller than the microcapsules. The tube will then be filled with the suspension and by evolving time samples are taken from the surrounding, aqueous solution, whereafter the concentration of the release active outside the membrane is analyzed. One problem with this setup is that the microcapsules agglomerate over time because of the lack of proper mixing, which changes and affects the behavior of the release. Another problem is that equilibrium cannot be reached outside the membrane between two data samples [2].

This setup in this project relied on other experimental designed setup, which included the release of encapsulated active substance from microcapsules in an aqueous microcapsule suspension without any semi-permeable membrane, which is obtained in Figure 3 a). The active substance OIT and the release medium was an aqueous solution of Brij®L23. Three separate investigations were examined where different concentration of Brij®L23 was used: 3, 6, and 10wt% Brij®L23 respectively.Brij®L23 is a non-ionic surfactant which increases the aqueous solubility of OIT dramatically without affecting the microcapsules. Various concentrations of Brij®L23 were used to accomplish various values of equilibrium distribution of the biocide between the microcapsule and the release medium. In addition, the experiments were conducted with three replicas of each Brij®L23 concentration.

Prior to the start of the OIT release, 246.25 ml of eachBrij®L23-solution was poured in each beaker of the release baths. These beakers were then put under magnetic stirring with a moderate rate. Before doing all that, a strict planning was done for how many measurements and how long time between the each measurement were needed to get as reasonable values as possible; and how many syringes and filters were required to prepare before starting therelease study.

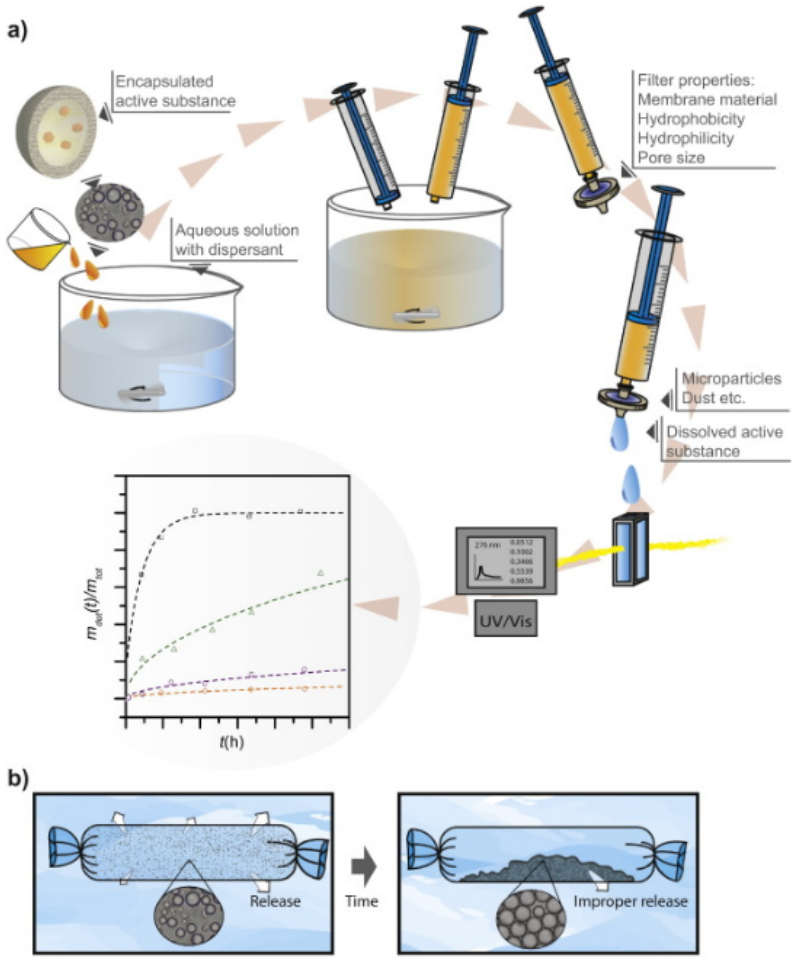

Figure 3: **a)** *Experimental methodology for the analysis of the release of encapsulated active substance from microcapsule in an aqueous-microcapsule suspension.* ***b)*** *Semi-permeable dialysis tube* [2].

The time of release was started after 3.75 ml of the microcapsule suspension was poured in the Brij®L23 release medium. By time intervals, logarithmically increased, approximate 5 ml of the release suspension was pipette by syringe and then pressed through a filter, called Fluorodyne membrane with the pore size of 0.20 um, by first pressing all the air and a little of the eluate before pressing all the rest in a8 ml vial [2]. This procedure removed all the microcapsules, dust and so on, giving an aqueous solution with only dissolved active substance. All vials were kept in dark storage until analysis. Samples were taken less than each minute in the beginning but the time-interval increased over time. 15-20 measurements were taken for each release system providing a complete study time for more a week. A diffusion model was then fitted to the result comprising released OIT fraction versus time [8], see Figure 7.

3.2.3 Instrumentation

UV/Vis spectrophotometry is a well-established analytical tool for determining the quantity and quality of samples. This tool is useable for direct determination of concentration since the Beer Lambert law point out that the absorbance is directly proportional to the concentration, especially in a assured absorbance magnitude range with lower border (limit) given by instrumental noise and upper border affected by deviation from Beer Lambert law linearity, in

this case an absorbance between 0.1-1 is reliable, and that is why the standard curve was ranging from 0-1 before the curve bended above that absorbance range [1]. It is important to construct a standard curve to facilitate and establish the determination of absolute relationship between absorbance and concentration of specific active, which is obtained in Figure 5.

The maximum release of OIT in the system gave an absorption value 1.2, which was still within linear Beer Lambert relationship, obtained in Eq. (1). The absorbance of the collected samples, containing OIT, were analyzed at a wavelength 276 nm, and each one of the samples were measured three times for being sure of that the result of each one did not differ from the other one. The mean value for the absorbance then provided the concentration value using the standard curve [1], see table 1, 2 and 3.

$$A = \log\left(\frac{I_o}{I}\right) = \varepsilon c l \qquad (1)$$

where A corresponds to the absorbance, I_o and I corresponds to the intensities of the monochromatic light before and after passing through the sample, ε the extinction coefficient, c the concentration of the (active) substance and l the length path (in cm).

SilentCrusherM tool 22F is a homogenizer which is used for create emulsions. It is made of rotating metal blades, small knives, to mix different substances together. The operative rotation speed for the homogenizer exists in a range of 5000-20000 rpm and the noise level is at 35 dB [9].

Axio Imager M2 – LightMicroscopy is utilized to investigate and taking picture of emulsions and suspensions, and is manufactured by Zeiss. The light microscopy can polarize light in many ways, and can at the same time uses a range of different techniques to discern the images, as well as Brightfield (BF), Differential interference contrast (DIC) and Darkfield (DF). The magnification of the microscopy can change in several steps between 100x and 1000x [10].

ImageJ is an image structural program which is utilized to perform size measurements of the microcapsules that have been made. This is done by inserting an image in the program and clarify contrasts. The size measurements can either be achieved manually by doing measurements on each of the chosen part or automatically by letting the program recognizing the color differences in the image. Thereby, a size distribution of selected lengths of the image can be developed. The size distribution is a necessary parameter when describing the release. In Figure 6 it can be seen, by using ImageJ, histograms of the size distribution for different suspensions can be calculated by measuring several hundreds of capsules [1].

4. Results

This part will include all data from the release studies.

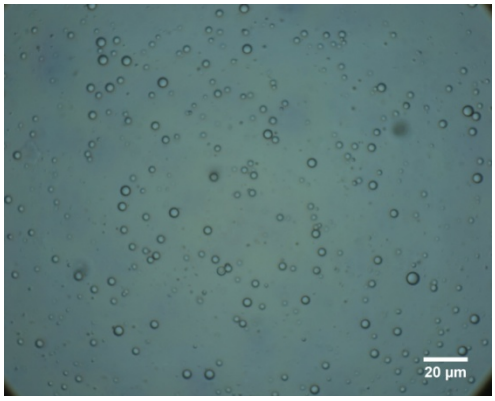

Figure 4: *A picture of the microcapsules from the pure suspension, picture taken from the Light Microphotometry , with a dilution ratio at 4:1. That is, 0.5 ml suspension was diluted with 2.0 ml Milli-Q (Milli-Q:Suspension). In this case was 1 wt% PVA (95% hydrolyzed) as an emulsifier.*

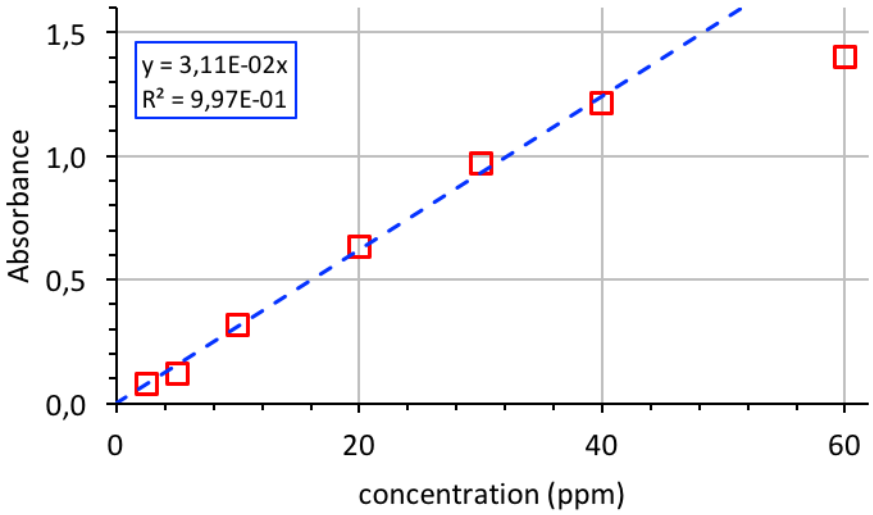

Figure 5: *UV/Vis standard curve of OIT.*

The standard curve of OIT gives the slope k=0.031. By knowing the slope k and the absorbance of each sample of released OIT, the concentration of each sample could be calculated, using the values from table 1, 2 and 3.

In Figure 6, the size distribution of microcapsules was provided elsewhere [8].

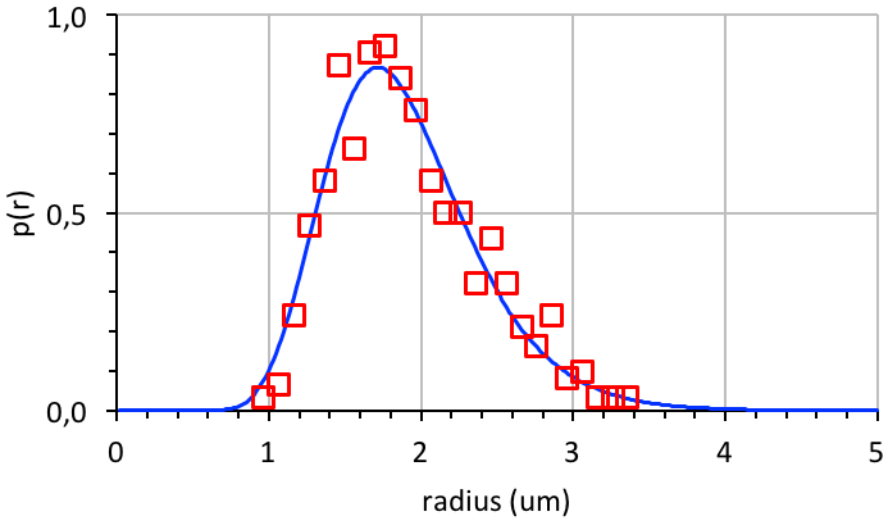

Figure 6: *Size distribution of microcapsules fitted with a log normal distribution function.*

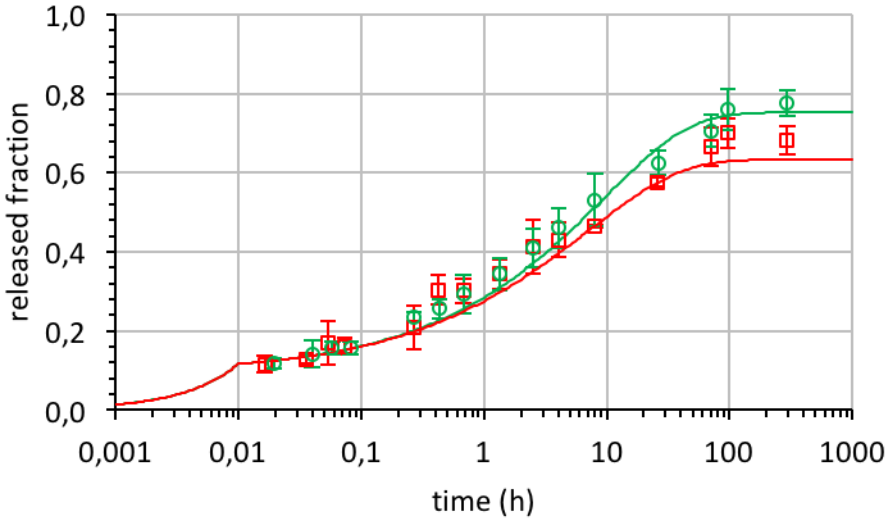

Figure 7: *The release of OIT from microcapsules. The figure shows the entire release over time (h) on a logarithmic scale. The red data from 3wt% Brij®L23-aqueoussolution, while the green line the 6 wt% Brij@L23-aqueoussolution. Lines are fitted diffusion models.*

<u>The results:</u>
Effective diffusion coefficient:

D = 4.2 +/- 0.3 (10^{-18} m^2/s)

Partition coefficient between microcapsule and release medium:

K = 1968 +/- 140 (för 3 % Brij®L23)
K = 1085 +/- 128 (för 6 % Brij®L23)

<u>Previous results</u> [8]:

D = 4.2 +/- 0.4 (10^{-18} m^2/s)
K = 982 +/- 24 (för 6 % Brij®L23)

Table 1: *The data that were given from the release study of OIT, using 3wt% Brij®L23-aquoeoussolution.*

	3 wt%Brij®L23-solution					
	Time 1 (h)	Sample 1 (ppm)	Time 2 (h)	Sample 2 (ppm)	Time 3 (h)	Sample 3 (ppm)
A	0.02	6.34	0.01	5.57	0.01	7.92
B	0.04	7.27	0.03	7.99	0.03	6.70
C	0.06	13.31	0.05	7.64	0.05	7.95
D	0.08	10.51	0.07	8.28	0.07	8.81
E	0.30	9.25	0.25	15.37	0.25	10.96
F	0.42	16.66	0.43	15.50	0.43	19.68
G	0.68	15.84	0.67	16.50	0.67	19.16
H	1.34	17.48	1.38	21.75	1.32	19.47
I	2.52	28.02	2.52	21.06	2.50	21.39
J	4.05	27.23	4.01	23.76	4.02	22.47
K	8.00	26.37	8.00	26.28	8.05	26.57
L	25.57	33.21	25.58	33.06	25.63	31.99
M	71.00	35.15	71.00	40.60	71.00	38.04
N	96.60	37.59	96.48	41.90	96.47	40.13
O	294.00	36.91	294.00	41.049	294.00	38.48

Table 2: *The data that were given from the release study of OIT, using 6wt% Brij®L23-aquoeoussolution after the third time performing the same release study.*

	6 wt%Brij®L23-solution					
	Time 4 (h)	Sample 4 (ppm)	Time 5 (h)	Sample 5 (ppm)	Time 6 (h)	Sample 6 (ppm)
A	0.02	5.96	0.02	6.74	0.02	7.54
B	0.04	6.27	0.04	7.95	0.03	10.02
C	0.06	7.94	0.06	9.59	0.06	9.17
D	0.08	7.92	0.09	9.61	0.08	9.38
E	0.29	12.61	0.26	13.90	0.26	13.79
F	0.46	12.98	0.43	15.84	0.41	14.86
G	0.68	13.47	0.67	18.07	0.68	18.37
H	1.36	17.00	1.35	21.42	1.33	20.35
I	2.50	20.16	2.51	24.41	2.50	25.49
J	4.04	22.83	4.02	28.00	4.02	27.72
K	7.98	25.99	8.00	33.33	7.98	31.39
L	26.15	33.50	26.05	42.39	26.07	40.33
M	71.00	37.74	71.00	36.66	71.00	36.61
N	96.00	40.40	96.00	43.02	96.00	46.31
O	294.00	43.05	294.00	43.99	294.00	46.23

Table 3: *The data that were given from the release study of OIT, using 10wt% Brij®L23-aquoeoussolution.*

	10 wt%Brij®L23-solution					
	Time 7 (h)	Sample 7 (ppm)	Time 8 (h)	Sample 8 (ppm)	Time 9 (h)	Sample 9 (ppm)
A	0.02	9.81	0.01	10.06	0.018	9.01
B	0.04	11.71	0.04	8.24	0.038	7.64
C	0.06	10.88	0.06	8.59	0.058	8.41
D	0.11	13.57	0.11	12.03	0.09	9.51
E	0.27	11.99	0.28	12.20	0.26	10.69
F	0.42	14.34	0.45	16.47	0.43	14.72
G	0.72	23.47	0.67	15.41	0.68	13.78
H	1.34	18.55	1.39	18.61	1.31	20.24
I	2.56	25.18	2.55	27.60	2.57	19.24
J	4.07	25.69	4.00	23.55	3.91	21.37
K	8.23	33.36	7.71	29.17	7.70	29.98
L	24.67	37.32	24.03	33.22	24.02	34.58
M	222.00	43.16	222.00	40.89	222	40.49

5. Discussion

The first time the release study was performed (6 wt% Brij®L23 solution), the mistake that was done was that each release bath was filled with the suspension the night before it had to be done. Samples were not taken until the day after, which should bring a high value of absorbance for each sample taken when analyzing them by UV/Vis spectrophotometry. However, there were only absorbance values below noise threshold that were received, which considered unexpected because that means that none absorbance was received. It had to be investigated where the problem occurred, and was done by check the absorbance in pure, non-filtered and filtered, suspension, diluted with the equivalent volume of MeOH. It turned out that the absorbance values were consistent with expected content of OIT. I could not find where the problem occurred.

The entire 6wt%-release study was made all over again. This time exactly as the prescribed method, but this time high values of absorbance, about0.7, were detected already in the beginning of release and kept constant till one day passed. Not until after one day higher values of absorbance were received, up to 1.0. Plenty of filter and syringes were used when performing all this, which resulted that more of these materials had to be ordered. It is necessary to use certain type of filter to accomplish complete flow-through of OIT. Unfortunately, the materials ran out earlier than expected for the release study when using 10wt% Brij®L23-solution as release medium, which one measurement could only be received compared to the other two release studies. This was not enough to obtain a value of its partitions coefficient due of its uncertainty.

A previously prepared microcapsule suspension was therefore used in the project. This time reasonable values of absorbance were received for the all three release studies, the higher content of Brij®L23 in the solutions the higher fraction of OIT was released as expected due to lower partition coefficient between microcapsule and release medium.

6. Conclusion

As one can see from the Figure 7, the results of the release studiesare well reproducing earlier published results [8]. The hypothesis to vary the content of Brij®L23-solutions was a successful approach to acquire high-quality data of the diffusivity in the microcapsules as was the aim of this work. Since only one measurement was received after one day for the 10 wt%-release study, while three measurements were made for the other two release studies after one day, the 10 wt%-release study could not be evaluated as more measurements are needed at the release plateau for appropriate fitting conditions. The reason why this happened was because the filters ran out and new material did not arrive in time.

7. References

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