

## On physical chemistry : education, research and government funding

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Inauguration  
prof.dr.ir. Remco Tuinier  
3 June 2016

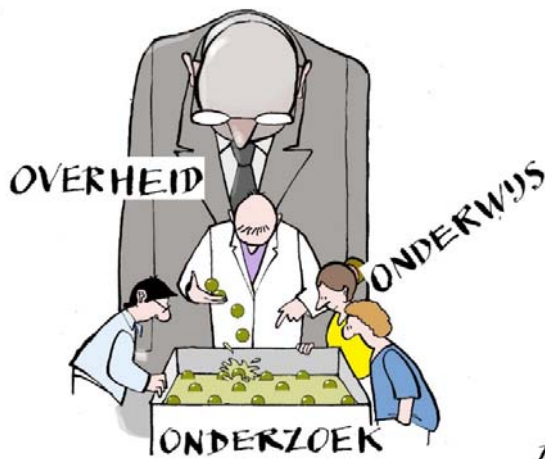
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# On Physical Chemistry: Education, Research and Government Funding

Where innovation starts



ZANDSTRA



# On Physical Chemistry: Education, Research and Government Funding

Inaugural lecture of Professor Remco Tuinier

Presented on June 3, 2016

at Eindhoven University of Technology

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## 1. Introduction

“Slowly the earth is dying.” With this sentence Queen Beatrix of the Netherlands started her Christmas message in the late 1980s. It was the time when I started my university studies in Wageningen. Suddenly, I entered a community where people spoke with a loud voice on environmental issues. In Wageningen I began to realise that fossil fuels, evolved over millions of years, are consumed rapidly by us. And that as a result we provide future generations with an energy problem. The Queen’s statement on the dying earth was, certainly in the 80s, risky; prophets of doom were not popular at that time. Is the statement that the earth is dying correct? The earth’s health can be connected to the concentration of CO<sub>2</sub> in air, which is increasing. The concentration of CO<sub>2</sub> in the earth’s air was around 0.3(wt)% for thousands of years. Following the industrial revolution the CO<sub>2</sub> concentration started to increase slowly<sup>1</sup>, increasing rapidly over the last few decades towards 0.4(wt)%. This is definitely worrying. The most significant issue is that this leads to global warming.

From the 1990s the molecule CO<sub>2</sub> has increasingly received negative publicity. For example, on the 8 o’clock news journalists spoke of “the poisonous CO<sub>2</sub>”. This terminology is misleading; the oxygen molecules that we all breathe are being converted into CO<sub>2</sub> and other compounds. Hence our bodies are full of CO<sub>2</sub>. On the issue of poisonous CO<sub>2</sub> Mr. Kees van Kooten and Mr. Wim de Bie comforted us through their satirical television program “Keek op de Week”: the CO<sub>2</sub> could easily escape through the hole in the ozone layer, therefore there is no problem.

What is actually the cause of the higher CO<sub>2</sub> concentration? The First Law of Thermodynamics says that energy is conserved. However, every time energy is transformed to another form there is less energy available to perform work. During energy conversions involving the use of fossil fuels, CO<sub>2</sub> is produced and potential chemical energy is transformed into heat and kinetic energy. In summary: the CO<sub>2</sub> concentration is actually an energy degradation meter. And to answer the question I raised earlier on: Yes, the earth is dying because the energy degradation meter is increasing.

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<sup>1</sup> D. Lüthi, M. Le Floch, B. Bereiter, T. Blunier, J.-M. Barnola, U. Siegenthaler, D. Raynaud, J. Jouzel, H. Fischer, K. Kawamura, T. F. Stocker, High-resolution carbon dioxide concentration record 650,000–800,000 years before present, *Nature* **453** (2008) 379-382.

In relation to environmental issues Chemistry had a bad name for a long time. With respect to the increase in CO<sub>2</sub> resulting from burning fossil fuels, the responsibilities of the large chemical companies receives quite some attention. I do think however, together with many of my colleagues, that chemistry as a discipline can provide many more sustainable solutions for the way we deal with energy and the use of materials. When humanity decides to radically change the way certain compounds are being used, nature demonstrates its buffering capacity. For example, the hole in the ozone layer is recovering because CFCs<sup>2</sup>, which were widely used as refrigerants, propellants (in aerosol applications), and solvents, have been replaced by more environmentally friendly compounds. It seems equilibria can be shifted. Later in this lecture I will show you some examples of our research that aim at contributing to a more sustainable world.

In this inaugural lecture I am going to explain to you what the discipline physical chemistry is, the plans I have with respect to education and research, what my view is on the role of the government in the Dutch research and educational landscape. But before we jump into physical chemistry I would like to share some thoughts on science, and in particular, beta sciences.

## 2. Science

From when human beings first walked on the earth the primary concern has always been survival. Progress in survival techniques such as the innovations in agriculture, allowed for more time for reflection and thinking. Initially, all that people did not understand, which was a lot, was considered as magic or supernatural. By magic I refer to something that is not understood. This led to people asking questions like: who takes care of the weather? Is the earth flat? Why is the sky blue? What causes lightning? Humans gradually discovered that there was a logical explanation for many phenomena. People started to propose laws that described and / or quantified nature. It appeared that the blue sky is not a miracle but the result of molecules in air that scatter light. Physics taught us blue light waves have a higher scattered intensity than, for instance, red and green light and that is why blue light dominates the colour of the sky. Unless there are clouds. And who controls the weather? That remains the mystery of weather stations.

It is hard to define what research is. For me it is an attempt to improve our understanding. In order to clarify some misconceptions in society it is useful to indicate what kind of activities cannot be qualified as research. The iPad generation thinks that internet “knows everything”, suggesting performing research is the same as “looking up”. Another mismatch with societal perceptions is that a researcher is curious. This often is not the case. A researcher is often very

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<sup>2</sup> CFCs = chlorofluorocarbons

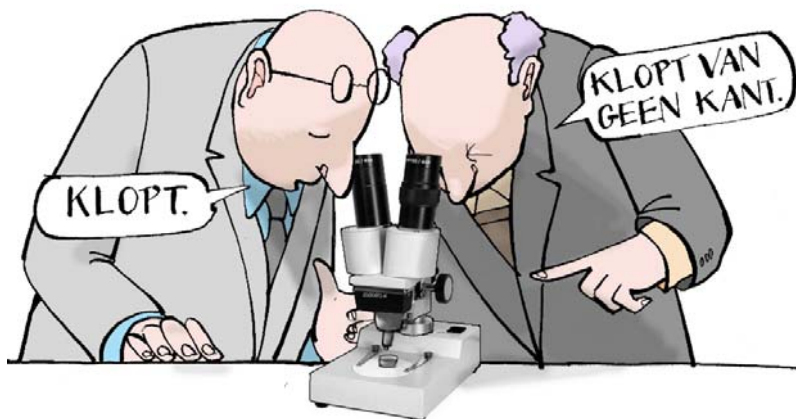
interested especially in his or her own field of specialisation. The result of an investigation is not an opinion. Somebody may have the opinion that energy arises spontaneously out of nothing. My friendly response would be: it sounds nice but it is incorrect. It conflicts with the First law of thermodynamics, which is solid as a rock.

Why do researchers investigate a particular topic? A researcher is usually driven by a certain problem that needs to be solved. Every solid investigation starts with a question. Often the question in the end turns out to be the wrong question. What drives research? Typically, a researcher makes an observation and says: why does it work like that? Why is the sky black at night? Why is a solution turbid? What makes a dispersion of gold particles red? Subsequently, a first hypothesis is developed based on logical argumentation to explain the observed phenomenon.

Good research yields an insight that teaches us something new. This sounds straightforward and appealing, but is complicated in practice. How does one usually attempt to solve a problem? A first trial often fails, see Fig. 1. Then one improves the method to find a solution until a solid method has been developed. Usually the path towards a breakthrough is not simple and most attempts to achieve progress actually fail.



**Figure 1.** Analogy of a typical research approach to get a car out of the water: (a) there is a problem one wishes to resolve; (b) one makes an attempt to solve the problem with a first approach; (c) and (d) such a first trial often fails; (e) subsequently one tries to learn and improves the approach until it works.



**Figure 2.** Failing and disagreeing is normal in science. Left scientist: "Correct". Right scientist: "Entirely incorrect."

Therefore I view a university as a learning organisation because at a university we continuously make mistakes, from which we have to learn to do better. For undergraduate students it can sometimes be a surprise that performing research is associated with many failures. They are trained not to make mistakes during exams of the courses they follow and in their graduation projects they suddenly end up in a situation where there are no guarantees for success, where failing is normal and contributes to knowledge (see Fig. 2).

When a study yields (apparently) useful results, subsequent criticism is essential. Scientists have the tendency to apply this critical approach in a broad sense. Scientists like to debate. In the end, the observation is always leading. Does the hypothesis contrast with the observation? Are the arguments based on proper statistics? If not, then the theory is not correct. If yes, the theory survives.

### 3. Physical Chemistry

What kind of discipline is physical chemistry? Within physical chemistry, concepts of physical laws and concepts of physics are used to study dynamic and equilibrium properties of materials on a molecular or mesoscopic level. It is a discipline at the interface between chemistry and physics. Within physical chemistry, theory, used to predict the physical properties of materials, and experiment are typically combined. A physical chemist must be capable of predicting simple properties of molecules or molecular systems. Quantification is key.

Last year, the department of Chemical Engineering and Chemistry at TU/e founded the Laboratory of Physical Chemistry. I am happy to share the scientific lead of this laboratory together with Catarina Esteves and Ilja Voets. In our group we focus both on molecular and especially on the mesoscopic properties of liquids and interfaces. The structures that interest us have length scales of, say, 1  $\mu\text{m}$  to 1 nm, reflecting colloidal particles, polymers and surfactants in solution and at interfaces.

A colloidal suspension<sup>3</sup> is a dispersion of particles in a continuous phase. Examples of colloidal systems are milk, paint, and whipped cream. A polymer in solution can be imagined as a necklace of connected molecules. Surfactants are molecules that consist of (at least) two different types of molecules sequestered in blocks. Some molecules like, while others dislike, the solvent. As a result, these molecules organise such that (self-)associated structures form, called micelles, vesicles or bilayers. Desired structures can be produced by selecting specific polymeric compositions. In water one can, for instance, encapsulate certain compounds in such structures that are otherwise insoluble. Food products, inks or paints are often suspensions consisting of colloidal particles, polymers and/or surfactants. The challenge is to relate the final functionality of such dispersions, including structure and stability, to the chemical compositions of polymers, surfactants and colloidal particles.

Such physical-chemical approaches have a long history. At the end of the 19<sup>th</sup> century, physical chemistry developed rapidly as a discipline thanks to various famous scientists. These include the Baltic-German Wo. Ostwald, the Swedish S. Arrhenius and J.H. van 't Hoff from Rotterdam, the Netherlands. Following Van 't Hoff, various Dutch scientists made seminal contributions to the field of physical chemistry. At Philips research here in Eindhoven, Verwey and Overbeek worked on theory to quantify the colloidal stability of charged colloidal particles in aqueous salt solutions<sup>4</sup>. They showed there is attraction between the particles, but also demonstrated that aggregation can be prevented by double layer repulsion. The range of the repulsion was shown to decrease upon increasing the salt concentration. Hence the theory predicted that dispersions of charged colloids start to aggregate above a certain salt concentration. Indeed, this corresponds to the practical situation. For various applications, this phenomenon is of significant importance. Let me give an example I expect will be appreciated by at least those coming from Holland as well as the Mechanical Engineers present here.

In the 19<sup>th</sup> century, an increasing number of problems evolved with respect to the accessibility of the growing harbour of Rotterdam. Improvement of the connection to the North Sea was badly needed because of progressive silting of existing routes. About 160 years

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<sup>3</sup> the term colloid originates from the old Greek word κόλλα (kolla) which means glue.

<sup>4</sup> E.J.W. Verwey, J. Th. Overbeek, *Theory of the stability of lyophobic colloids*, Elsevier, Amsterdam, 1948.



ago, engineer Pieter Caland designed a plan for the “Nieuwe Waterweg” (new waterway)<sup>5</sup>. During the execution of this visionary project major problems evolved. Via the Nieuwe Waterweg, river water (low salt) with dispersed charged colloidal clay particles was connected to sea water, containing a very high salt concentration. The clay particles directly started to aggregate, followed by sedimentation of aggregated flocs of particles. As a result, silt deposition in the shipping lane became a continuous problem. Hence, much more dredging was needed than expected. As for many infrastructural projects, the time as well as the budget allotted to the project were exceeded excessively and there was a lot of criticism, see Fig. 3. In the end, the costs were a worthwhile investment as the port of Rotterdam significantly grew in size<sup>6</sup>. However, if the physical chemistry of colloidal suspensions and the insights of Verwey and Overbeek had been developed earlier, Caland could have foreseen the problems and could have taken measures to prevent the obstacles. Aggregation is related to stability and phase behaviour, which fascinates me. I will return to that topic and will share my plans with our group on this matter. At a university high quality research and education are closely connected and therefore I first would like to share some thoughts on teaching.



**Figure 3.** Caland seems to fail. “Bagger” in Dutch means both “bad” and “dredging”.

<sup>5</sup> the “Nieuwe Waterweg” has been constructed between 1866 and 1872.

<sup>6</sup> And still is the largest harbour in Europe.

#### 4. Education

What is the role of physical chemistry in the education of chemical engineers and chemists? Physical chemistry is a basic discipline essential for any chemist or chemical engineer. A chemist that would, for instance, like to synthesise a certain compound must have knowledge of the phase diagram of the reaction mixture. How does mixing of the reactants affect stability? Is a certain reaction a chemist imagines really possible (thermodynamically)? Such questions can be answered provided there is a solid physical-chemical basis. A chemical engineer would like to execute a process such as a chemical reaction in a liquid or mixing of various compounds in a solid state in an efficient manner and tries to optimise various parameters like pressure, temperature and composition. The choices for the values of these parameters, however, affect physical properties of a liquid or solid such as the viscosity, the diffusion coefficients, the phase stability or adhesion to a wall. A physical-chemical basis helps to get insights into the relation between these properties and the parameters.

Teaching, educating people, is fascinating. Besides, when teaching one also learns a lot and it can provide ideas for research. A small fraction of the students that follow physical chemistry courses finally will undertake a MSc graduation project in our Physical Chemistry group, which contributes to our research efforts.

I have worries on the current view of the role of the university in modern society. It seems more and more people view the university as a production unit and that science should mainly yield measurable results, for instance in the numbers of citations, impact factors, and number of students that get their MSc degree. This follows societal developments in Europe; everything is expressed in money, number and weights. I believe, however, that value lies in much more than numbers only. This efficiency-only tendency is also reflected in the attitude of some students. In the final phase of my first lecture series here at TU/e one of the students asked me: "Which problems are you going to address at the exam?" It took a bit of time before I fully understood the question. Fortunately, there was another student who put the question in perspective when he subsequently asked: "and can you also provide the answers?" I asked the first student later on for the motivation of the question. The student said: "I want to pass the exam". This may sound nice, but this answer is not a good one. Why is the answer not a good one for me?



**Figure 4.** Dutch Teletext page announcing proposal by the government on university tuition fees per course.

The university is not a supermarket where only customer satisfaction is the leading priority and one can choose nice products for today's menu. Scientific staff members at a university are not re-stockers of shelves whose main goal is to make the customer happy. At a university the client is not always right. For that reason I oppose the proposal of the introduction of a tuition fee per course, see Fig. 4. These kinds of proposals mark the increased view of universities as a market. Would you like to save coupon stamps? Shall we offer a discount on the next course? Not happy, money back guarantee?

The government is stimulating this attitude because universities receive funding per student that finalizes their study. It would be much better to fund per student that is studying. In that way a high(er) level can be maintained. Currently, the government punishes Dutch universities when the level is too high for the students. This induces a continuous decrease of the level of academic education at Dutch universities<sup>7</sup>.

<sup>7</sup> G.J. Fleer "Ketens en Grenzen" (Chains and Borders), Farewell lecture, Wageningen University (2007).

Resulting from the attitude of some students regarding themselves as clients, the question arises whether there are too many students at Dutch universities. It seems there is a group of students that wish to receive some knowledge only to get their degrees. Therefore I am in favour of selecting students before they start. Is it dramatic that there will be a bit fewer academics? No, because what would you prefer: a world with many academics of mediocre quality or fewer very good academics?

How do I look at the role of the university? A university should be viewed as similar to a gym or an athletic club where people attempt to increase their strength, flexibility, and fitness as well as to develop/enhance their skills. Like coaches and trainers, university faculties have invested years of their lives in the acquisition of knowledge, attempting to apply it, and learning how to teach this knowledge to others. For me, students are athletes that are in development. I encourage the athletes to train a lot and not to avoid exercises, in order to increase endurance. As a trainer I like to stimulate people to become stronger, to stretch the mental muscles and reach beyond what they have achieved in the past. Students should be willing to sacrifice in order to reach their next degree. I recognize that long term quality of life often requires effort, pain, struggle, and sacrifice in the short run. Later on the compensation will come. Some people of my generation told me about the pain they experienced of not having studied higher education. This pain may last long(er).

The supermarket vision that is popular in society is also related to the perceived position of the teacher by Dutch society in general. The teacher receives little respect nowadays and, in spite of the efforts of some media, a scientist is seen as a peculiar person, perceived to be overly intellectual, unfashionable, and socially awkward. In my opinion teachers should not focus on marketing issues but on spreading knowledge and I call upon the scientific staff at universities to focus on expressing the independence of the university in Dutch society.

I have made a few critical remarks on the attitude of some students. Fortunately, there are also many students who are highly motivated, eager to learn and who are happy when you pay attention to them. For this category of students especially we should keep the level of education high and motivate them. In the end educating good students is an investment for society and of course also yields good PhD students and staff for our faculty and research group, which naturally brings me to my next topic: research.

## 5. Research

Preceding this inaugural lecture, there was a symposium on the current status and future of the research parts of Physical Chemistry that fascinate me. I would like to thank the speakers for their contributions to this wonderful day.

What are the main research themes within the new Laboratory of Physical Chemistry? Within our group the focus is on the physical properties of colloidal particles and polymers dispersed in solutions and the functionalisation of surfaces.

Phase behaviour of complex mixtures remains one of my relevant interests. During my PhD study<sup>8</sup>, and especially from 1999 onwards, I have specialized in the depletion interaction and resulting phase behaviour in mixtures of different colloids and/or polymers or surfactants<sup>9,10</sup>. This is relevant for instance in paint or the interior of a living cell or in food dispersions such as yoghurt or salad dressing. The phase stability of these mixtures containing colloidal particles and polymers interest me. The stability is determined by the concentration and effective interactions between the colloidal particles.

In complex mixtures excluded volume interactions or entropic forces play an important role. In mixtures of different particles excluded volume interactions can induce an attraction between the particles. This attraction is also denoted as depletion interaction<sup>11</sup>. In the 1950s the Japanese scientists Asakura and Oosawa were the first to develop a theory<sup>12</sup> for this attraction. The depletion effect in a colloid-polymer mixture is illustrated in Fig. 5.

The depletion effect in a colloid-polymer mixture is illustrated in an animation<sup>13</sup>. The depletion zones are the regions where the centre of a polymer coil cannot enter. When the depletion zones overlap, the polymer chains can no longer enter the region between the spheres due to the number of possible configurations of the polymers that is severely reduced inside the depletion zones. The polymers can, however, increase their total number of conformations by pushing the colloidal spheres closer together.

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<sup>8</sup> R. Tuinier, 'An exocellular polysaccharide and its interactions with proteins', PhD thesis Wageningen University, 1999.

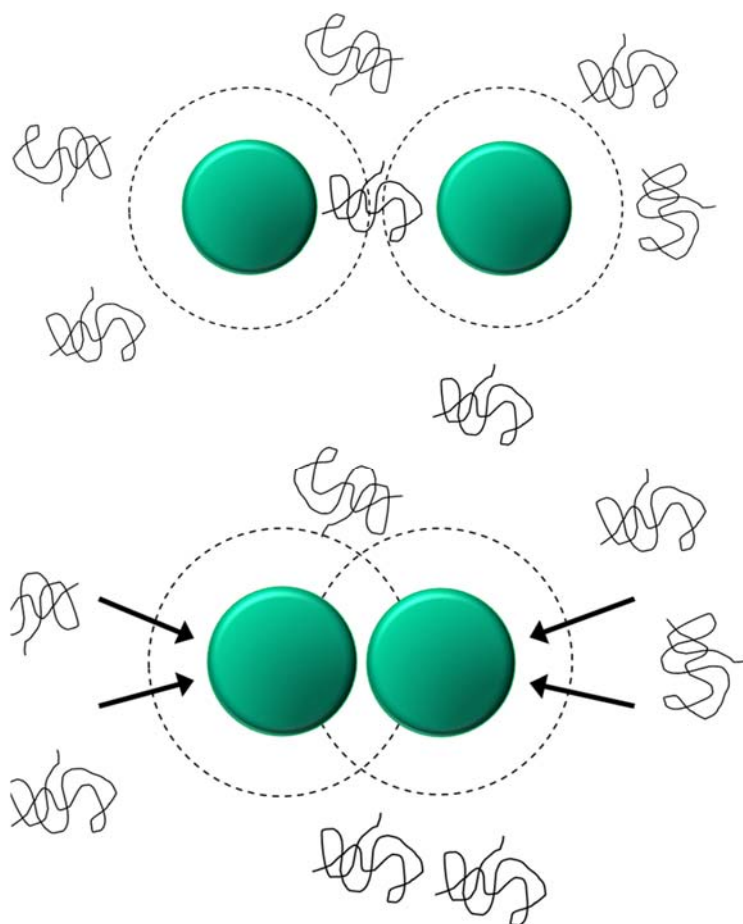
<sup>9</sup> C.G. de Kruif, R. Tuinier, *Food Hydrocolloids* **15** (2001) 555-563.

<sup>10</sup> R. Tuinier, J. Rieger, C.G. de Kruif, *Adv. Colloid Interface Sci.* **103** (2003) 1-31.

<sup>11</sup> The term depletion comes from "plere" (Latin for filling). Depletion hence is "defilled" = emptied out. The word "depletion" was probably introduced by the colloid scientist D.H. Napper.

<sup>12</sup> S. Asakura, F. Oosawa, *J. Chem. Phys.* **22** (1954) 1255.

<sup>13</sup> made by the ICMS animation studio.



**Figure 5.** Upper panel: two colloidal spheres with depletion zones (dashes) in a polymer solution. The chains mimic polymers. The centre of a polymer chain cannot come close to the sphere surfaces. Lower panel: upon overlap of depletion zones the polymers push the spheres together. In this situation a polymer chain cannot penetrate the area between the spheres. The direction of the forces on the spheres is indicated by the arrows.

Hence the polymers induce an indirect, effective attraction between the spheres, driven by attraction through repulsion<sup>14</sup>. The strength of this attractive interaction increases with increasing polymer concentration. This concept also holds when replacing the depletant from polymers to soap micelles, colloidal rods, plates or small spheres. When the depletion attraction is sufficiently strong a system containing many colloidal particles and polymers phase separates, typically into colloid-rich and polymer-rich phases. On this topic, colloids and the depletion interaction, Henk Lekkerkerker and I wrote a book that published in 2011. Within the market-thinking focus of modern universities I should point out to you the competitive price of this nice book<sup>15</sup>.

Colloid-polymer mixtures exhibit very interesting ways of demixing. Sometimes a mixture forms a gel, in other systems liquid-liquid demixing occurs and there are conditions where colloidal crystalline phases appear because of depletion effects. In some cases a three-phase system evolves, separated by sharp interfaces. In model studies where this phase behaviour

<sup>14</sup> This expression originates from prof. dr. A. Vrij, emeritus professor (Utrecht University).

<sup>15</sup> H.N.W. Lekkerkerker and R. Tuinier, *Colloids and the Depletion Interaction*, Springer, Dordrecht, 2011. <http://www.springer.com/materials/book/978-94-007-1222-5>

has been studied, rather idealised systems in organic solvents were used. The polymer chains are typically uncharged and relatively monodisperse in molar mass, while the colloidal particles behave hard sphere-like. In practice, the systems of interest are less ideal. The first complexity is that the polymers and particles are often charged. Furthermore, industrial systems are disperse in size and molar mass, and often they consist of multiple components.

Step by step, I plan to extend current existing theory towards more complex mixtures where charges and interactions occur beyond the hard-core model, and are more relevant for applications. Further I would like to use phase separation induced by depletion for more sustainable separation of compounds. By mixing liquids with components that induce demixing it is possible to concentrate particles differing in size and/or shape. Colloidal particles can thus be concentrated using depletion forces. This in fact is entropic separation technology.

Within the theme colloids and/or polymers at interfaces, led by Catarina Esteves, methods through which surfaces can be modified in order to give them a specific function are being investigated. In the Laboratory of Physical Chemistry such methods are being developed to make surfaces hydrophobic or hydrophilic, or make surfaces to which bacteria and proteins do not adsorb<sup>16</sup>. Dr. Esteves and her colleagues developed a coating in recent years that self-replenishes after it has been damaged. This is possible by using polymer chemistry to incorporate additional semi-mobile chains<sup>17</sup>, opening up many possibilities for a number of applications. It may be that cars have to be washed much less frequently in the future, the life time of contact lenses may be extended or fatty fingerprints on mobile phones could be history. Catarina Esteves is also developing materials that can absorb water or release water given an external stimulus; this could be helpful in areas in the world which are very dry.

Another theme of our group is self-organisation of colloids and polymers in solvents. Ilya Voets is leading a strong line of research in this field and she works for instance on supramolecular colloids<sup>18</sup>. Besides she also works on anti-freeze polymers. These are polymers that suppress the growth of ice crystals. The insights of dr. Voets and her team may lead to a future where we do not anymore need to scrape the windows of our cars when they are covered with ice.

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<sup>16</sup> C.M.C. Carcouët, A.C.C. Esteves, M.R.M.M. Hendrix, R.A.T.M. van Benthem, G. de With, *Adv. Funct. Mater.* (2014).

<sup>17</sup> A.C.C. Esteves, Y. Luo, M.W.P. van de Put, C.M.C. Carcouët, G. de With, *Adv. Funct. Mater.* **24** (2014) 986-992.

<sup>18</sup> M.A.J. Gillissen, T. Terashima, E.W. Meijer, A.R.A. Palmans, I.K. Voets, *Macromolecules* **46** (2013) 4120-4125; P. J. M. Stals, M. A. J. Gillissen, T. F. E. Paffen, T.A. de Greef, E.W. Meijer, A.R.A. Palmans, I.K. Voets, *Macromolecules* **47** (2014), 2947-2954.

When I worked at DSM I was first confronted with the theme self-organisation and its relevance for DSM in many applications. I became for instance aware of the relevance of the formation of colloidal particles via self-assembly of polymers<sup>19</sup> for the encapsulation of ingredients such as medicines or vitamins. I learned at DSM that the binder particles in paint usually consist of self-assembled polymers<sup>20</sup>. At DSM Coating Resins there is a lot of expertise on the specific types of polymers and the synthesis of these. Using physical-chemical expertise we can contribute to the link between chemistry and physical properties of the binder particles in paint.

Besides the scientific interest, the desire of DSM to make paint more “green” inspired me. Currently, about half of the paint produced is water-borne. What is being put on the walls inside houses is usually water-borne paint. Solvent-based paints with solvents such as acetone and ethyl acetate are often used outside.

The solvent-based paints induce environmental issues and are unhealthy for painters. Organic solvents contain volatile organic compounds: hydrocarbons that easily evaporate. The organic solvents contribute to smog formation and climate change. In Europe the number of acceptable volatile organic substances that are allowed in paints is being reduced more and more. For environmental reasons, and because of increasingly strict rules, paint producers are progressively stimulated to use water-borne paints.

Paint is composed of a complex set of components. Waterborne paint mainly consists of water, inorganic pigments, co-solvent, surfactants and polymers, the building blocks for the binder particles. The polymers that are used in paint typically self-assemble to spherical particles of 10-100 nm in size. These binder particles enable the smearing of paint and help to establish a well-covered coating after water evaporation.

Unfortunately, waterborne paint is in general of lower quality than classical solvent-based paint. In our group we would like to contribute to develop insights that enable the realisation of high quality, waterborne paint. Paint is considered high quality when it keeps its functionality, such as protection, colour and gloss, for a long time, as does classic paint based on organic solvents. The binder type is an essential parameter with respect to paint quality.

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<sup>19</sup> Patents: WO 2013171196 A1, Antifungal compositions, J.G.J.L. Lebouille, G.M.H. Meesters, P. van Hee, R. Tuinier; US 2011/0223206A1, Micelle composition and process for the preparation thereof, J.G.J.L. Lebouille, T. Kockelkoren, L.F.W. Vleugels, R. Tuinier; EU WO2013179206 A1, Iron coacervate for beverages, F. Li, L. Bremer, R. Tuinier.

<sup>20</sup> J.G.J.L. Lebouille, L.F.W. Vleugels, A. Dias, F.A.M. Leermakers, M.A. Cohen Stuart, R. Tuinier, *Eur. Phys. J. E* **36** (2013) 107; C. Gonzato, M. Semsarilar, E. R. Jones, F. Li, G.J.P. Krooshof, P. Wyman, O.O. Mykhaylyk, R. Tuinier, S. P. Armes, *J. Am. Chem. Soc.* **136** (2014) 11100–11106; F. Li, J. de Bont, M. Schellekens, R. Peters, A. Overbeek, F.A.M. Leermakers, R. Tuinier, *Macromolecules* **48** (2015) 1194-1203; F. Li, R. Tuinier, I. van Casteren, R. Tennebroek, A. Overbeek, F.A.M. Leermakers, *Macromol. Theory Sim.* **25** (2016) 16-27.

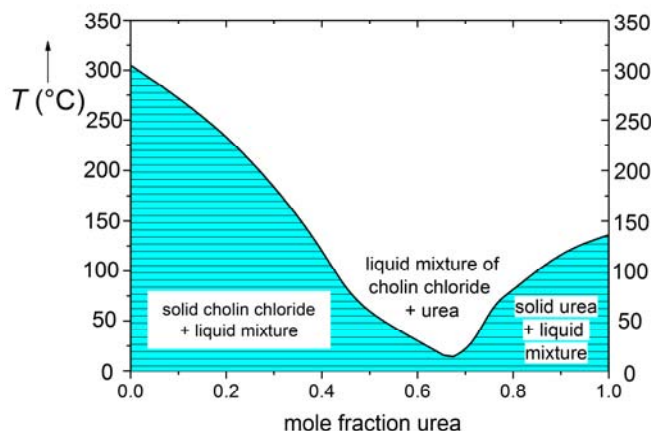


We are going to investigate how the properties of binder particles are related to the chemical composition of the polymers used and how the stability of mixtures of paints, binder particles and other components is influenced. This yields insights into how to tune the quality of the final coating. The final goal of these investigations is to reduce the use of volatile organic solvents, which contribute to global warming and to reduce health risks for painters.

We aim to tune the chemical composition of the polymers used and will verify whether a relationship can be found between the structure of the binder particles and the paint properties. Using numerical computations we can predict the relation between a change in chemical composition of the polymers and the internal structure and size of the binder particles. This works much faster than synthesising all kinds of possible polymers and testing them experimentally in the lab, see Fig. 6. Such an approach relates to one of my fundamental interests; finding answers to the question: “how does the chemical composition of complex polymers relate to the structures they form in solution and how can this be tuned?” To answer such a question the combined approach of experimental work, synthesis, and characterization as well as theoretical knowledge and capability is essential. This is all available in our group.



**Figure 6.** Combination of theory and experiment is efficient. (“Hebbes!” = Got it!)



**Figure 7.** Phase diagram of a mixture of choline chloride and urea<sup>35</sup>.

In order to reduce the use of volatile organic solvents there is an ongoing search for more sustainable solvents. Just over 10 years ago Abbott *et al.*<sup>21</sup> discovered a new group of solvents that have promising physical properties and can be regarded as being “green”. These materials are so-called eutectic liquids consisting of two components which both are solid at room temperature but form a liquid when mixed. An example of a phase diagram of a binary mixture from which a eutectic liquid at room temperature can be made is drawn in Fig. 7 for mixtures of choline chloride and urea. These components can be considered as being bio-based; choline chloride is an essential feed component for many animals and urea is used, for instance, as fertilizer. The pure substances are solids at room temperature; choline chloride melts at 302°C and urea at 134°C. When mixed a liquid is formed at room temperature. My former colleague Maaïke Kroon pointed out this work to me. With her group she investigated screening and various properties of these mixtures<sup>22</sup> at TU/e, and we started to collaborate on the behaviour of colloids and polymers in these eutectic solvents.

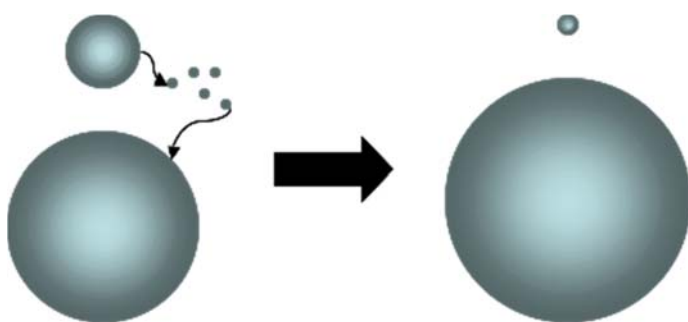
I would like to use this knowledge to dissolve compounds that cannot be dissolved in water. Subsequently, I would like to use expertise on phase behaviour to concentrate polymers and colloidal particles via phase separations. By using entropically driven phase transitions a spontaneous extraction takes place. This may enable the dissolution and separation of several kinds of biomass that cannot be separated easily using water. Within an EU project, co-funded by the European paper industry, we are investigating the possibilities of using these deep eutectic solvents in order to make paper production more sustainable. Further I would like to explore whether these eutectic solvents offer new possibilities to synthesize colloidal particles and polymers in a greener fashion.

<sup>21</sup> A.P. Abbott, G. Capper, D.L. Davies, R.K. Rasheed and V. Tambyrajah, *Chem. Commun.* (2003) 70–71.

<sup>22</sup> F. M. Casal, A. van den Bruinhorst, M.C. Kroon. *Angew. Chemie* **52** (2013) 3074-3085.

## 6. Government and university

Effectively thirteen years after having left Dutch academia, it is directly clear to me that the Dutch research landscape has changed radically. Soon I will be involved in it to such a degree that it is useful to share some of my observations with you at this moment. Firstly, a process is occurring that sociologists denote as the “Matthew effect”. I will illustrate this effect via a well-known physical-chemical process: the Ostwald ripening<sup>23</sup>, named after Wilhelm Ostwald. We consider an oil-in-water emulsion with a small and large oil droplet, see Fig. 8. The oil is slightly soluble in the aqueous phase. Because of the stronger curvature the Laplace pressure is bigger in the smaller droplet. Hence, oil is transported via the continuous aqueous phase to the bigger droplet (lower pressure). As a result, the bigger droplets grow at the expense of the smaller ones. Finally, the small ones disappear and only the large droplets survive.



**Figure 8.** Sketch of the Ostwald ripening process.

There is an analogy between this process and several phenomena in modern society, also in the academic community. When considering the way of distributing grants of NWO<sup>24</sup>, the number of PhD positions granted in the open competition has been reduced over the last 20 years, sacrificed for new grants such as BIG, Spinoza, “zwaartekracht” and “NWO groot”, with large budgets of many millions, sometimes tens of millions EUROS. One of the main disadvantages is that these programs are granted to a small group, see Fig. 9.

This leads to the formation of forced coalitions instead of spontaneous collaboration based on real common interest. For the so-called “zwaartekracht” grants it seems that an increasing number of ERC and Spinoza winners merge in coalitions only to increase the chance for success. “That is how the game is being played” is the response when a critical question is asked. Currently, the euros per project available through grants seems only to increase. It reminds me of the national lotteries with increasingly bizarre prizes for the winners of tens of

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<sup>23</sup> W. Ostwald, *Zeitschrift für Physikalische Chemie* **22** (1897) 289-330.

<sup>24</sup> NWO is the National Science Foundation of the Netherlands

millions of EUROS while many people would be very happy with, for instance, 50 kEURO. In my time at DSM I sometimes said: if I have to choose I prefer to talk with someone who has a dream and vision than to someone with funding only. I prefer small but thoughtful, increasing and improving the small good idea and letting that grow to something new. This is how the scientific giants like Newton, Huygens and Feynman worked.

A few more facts on NWO grants. There is heavy competition for grants and the chance of success is small: for most NWO grants the success rate is 10% or smaller. The current State Secretary for (or against; that is unclear) Culture and Education Sander Dekker states: "it's only about the top, it begins with writing more and more proposals for grants"<sup>25</sup>. The small success rate has the dramatic implication that many scientific staff members at Dutch universities spend an enormous amount of time to writing proposals that are not granted. Time needed to write these proposals would be much better spent to research, education and interacting with society, including collaborating with companies. It is however essential for most university research groups to try to get as many grants as possible. Hence the staff members are increasingly forced to do this (commonly) useless work.



**Figure 9.** Current way of distributing money by NWO.

<sup>25</sup> Interview in the Dutch newspaper de Volkskrant on 12 November 2013.

Another disadvantage of the current system is that renewal of research themes will be suppressed by this system. An application is only successful when it is based upon earlier successes. Therefore the content of the proposal cannot be entirely new anymore. Is it nice for the successful? No, because for the few successful, the pressure to keep on being successful is continuously increasing. And one has to promise a lot to be successful and in this way more and more castles in the sky are being built. And “castles built in the sky require heavy burdens”<sup>26</sup>.

The forced collaboration between those whose proposals are successful in getting grants leads to cartel formation: that is what is being rewarded. In turn this leads to an increasingly narrow view on the important scientific disciplines. Because only the already successful remain successful. In order to illustrate this I can use a soccer analogy: the Dutch national competition would, as a result of the Matthew effect, only consist of Ajax, Feyenoord and PSV. The other teams would go broke and all other leagues would be sacrificed because we only want the top performing teams.

The overvaluation of receiving grants is exemplified when there is a special announcement at a university nowadays. A special announcement at a university naturally makes me think of a great scientific breakthrough, but usually it concerns news on a new big grant. It seems as if a big grant is the new Holy Grail: grants seem more important than science or scientific results, which are also increasingly considered as merchandise. The more, the better and higher impact factors seems to be what pleases university boards. It should be noted however that the genuine novel findings often end up in normal scientific journals and it can take some time before cited.

I quote from my previous inaugural lecture<sup>27</sup>: “Science is an organised search for new insights. The trajectory of doing scientific research is like a tortuous path through a mountainous knowledge landscape, close to high peaks and dangerous abysses.” This implies we cannot promise anything because performing research is unpredictable. If it would be predictable, it would be useless because the result would be known beforehand. Research proposals are often filled with promises but research is only predictable when it is not new. Every promise in fact is empty. In order to perform good research and high level teaching patience and time are key, which are under pressure. Therefore I think our national grants should be distributed in a different manner. I think most people would agree we cannot let

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<sup>26</sup> Proposition by P.J.J. Jansens, PhD thesis “Fractional suspension crystallization of organic compounds”, TU Delft, 1994.

<sup>27</sup> R. Tuinier, “*Kolloïden, Kennis, Kunde en Kassa*” (Colloids, Knowledge, Expertise and Cashdrawer), inaugural lecture Utrecht University, 18 February 2014.

our best scientific staff members spend most of their time writing research proposals that are, in the end, not granted.

In conclusion, I propose to change the current system of distributing our national grants, and I feel this is supported by many in silence. I think we should disestablish NWO. It seems they are reorganising. Let us do it properly. The budgets that will be available should be transferred directly to the universities. The government would then make a strong statement that the universities are in fact independent. I think the universities are very capable to steer the research focus. Some of you may be shocked. But it gives us a nice extra topic to discuss at the reception following this lecture. Maybe you will reply by stating competition is good. Acquiring EU grants is also very competitive and we will be more successful in receiving such grants because staff members at Dutch universities will have more time to write them.

What should be the research topics the universities should focus on? On 12 December 2015 in Paris nearly 200 countries agreed on concrete goals to limit global warming. The Dutch government is enthusiastic on this agreement, but with respect to using fossil fuels, the Netherlands is not making a show of virtue. The report written by Lord Stern<sup>28</sup> indicates that the costs of climate change will be around 20% of GDP for the G7 countries in the coming decades. Without action, the Earth will, on average, be 4 degrees warmer by the year 2100. The Veerman committee advised the Dutch government to invest 1 billion EURO annually into strengthening the dykes, starting in 2020. Due to the energy degradation process that is occurring, billions of EUROS will be spent dealing with the consequences. This is fighting symptoms. As beta scientists we are trying to deal with the cause and can provide solutions to prevent environmental issues and make the world more sustainable. Therefore, it is essential to put all possible efforts into research that leads to products and processes that are more sustainable, reduce CO<sub>2</sub> emissions and use fewer volatile organic solvents. I think these themes offer enough challenges for the future and clear topics for the very scientists at the universities in the case the politicians in The Hague follow my advice to give NWO budgets back to the university.

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<sup>28</sup> N. Stern (2006). "Stern Review on The Economics of Climate Change (pre-publication edition). Executive Summary", <http://www.webcitation.org/5nCeyEYJr>. HM Treasury, London. Archived from the original on 31 January 2010.

## 7. Final Remarks

I am happy that our new group can give new life to physical chemistry in the Netherlands that has a long standing tradition with names including Van 't Hoff, Bakhuis Roozenboom, Cohen, Kruyt, Overbeek, Lyklema, Stein, Vrij, Lekkerkerker, de Kruif, Fleer and Cohen Stuart. I had the honour to collaborate directly with the last five scientists on this list. Because of the trust of my teachers I am who I am, but also thanks to my family and friends.

Just as at my first inauguration in Utrecht, I still miss my father, but I am happy for what he gave me. Fortunately my mother is still with us. Because of the stimulating atmosphere created at home by my mother I discovered as teenager how much fun it is to do math, physics and chemistry exercises and I thank you for that.

Dear Luuk, Tim and Mieke. You were happy in Sittard but joined me in Eindhoven and I am grateful for this. Even more grateful I am for the daily cosiness, joy, reminders of reality and warmth, especially when I come home after a disappointing interim exam or a rejected manuscript.

I would like to thank The Executive Board of Eindhoven University of Technology, the Departmental Board of Chemical Engineering and Chemistry and my other colleagues for the chance offered to me at TU/e. It is a great pleasure to work at TU/e, in Chemistry and the stimulating ICMS and I feel welcome at this, for me, new university. I am also very thankful with the members of the Laboratory of Physical Chemistry and I feel fortunate I can form the core of this group together with Catarina Esteves, Ilja Voets, Marco Hendrix, Ton Staring and, last but not least, Pleunie Smits. If I only had known how pleasant it would be to work with you, I would have come earlier. I am very pleased with the talented postdocs and PhD students in our group. I believe in co-creation, which contrasts to the general focus on individualism in science. Great breakthroughs will be the result of spontaneous and also interdisciplinary collaborations.





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