Theoretical Physics, Statistical Physics and Nonlinear Dynamics, Prof. Dr. Michael Bestehorn

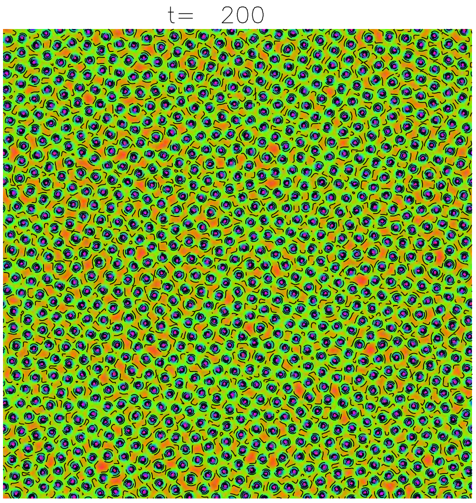
Thermodynamics, Heat and Mass Transfer

2+2 SWS, 6 CP (winter term)

In equilibrium thermodynamics, systems are described by a few state variables that are homogeneous in space and constant in time. 'Processes' are considered to be reversible and quasi-static, i.e. they are performed infinitely slowly. Then the systems can be considered being in thermodynamic equilibrium for all the time. But in general, quantities like temperature, pressure, density etc. do depend on space and time, and quite often in a very involved and irregular way (example: fluid dynamics of the atmosphere or the oceans). Moreover, real-life processes are not reversible and far from thermal equilibrium.

Fluxes like heat and mass flows have a finite size and, according to Onsager, are driven through generalized thermodynamic forces. As a consequence one has to extend equilibrium thermodynamics, leading to the discipline called *Irreversible Thermodynamics*.

The lecture gives an overview on the concepts and methods of *Irreversible Thermodynamics*. It is concerned with diffusion and transport processes in single an in multi-component systems, in fluid dynamics and in chemical nonequilibrium reactions. In the second part, the phenomenologically derived relations of part I are based on statistical grounds using the methods developed in *Kinetic Gas Theory*.



Spatial patterns may occur from a nonequilibrium chemical reaction.

Contents of lecture:

I Phenomenological thermodynamics

- **Equilibrium thermodynamics.** State equations, entropy, first and second law, Carnot process, multi-component systems
- **Out of equilibrium.** Local equilibrium, balance equations, entropy production, Onsager relations
- **Diffusion, transport and chemical reactions.** Heat equation, reaction diffusion equations, Brusselator, convection

II Statistical foundation

- **Kinetic theory of gases.** Many particles, entropy, diffusion, thermal conduction
- **Boltzmann equation.** Collisions, H-Theorem, Maxwell-Boltzmann distribution
- **Conservation and transport equations.** Statistical foundation of hydrodynamics, Chapman-Enskog expansion

Literature:

M. Bestehorn, lecture notes (moodle)
H.B. Callen, *Thermodynamics and an Introduction to Thermostatistics*, Wiley (1985)
S.R. de Groot, P.Mazur, *Non-Equilibrium Thermodynamics*, Dover (1984)
T.I. Gombosi, *Gaskinetic Theory*, Cambridge Univ. Press (1994)