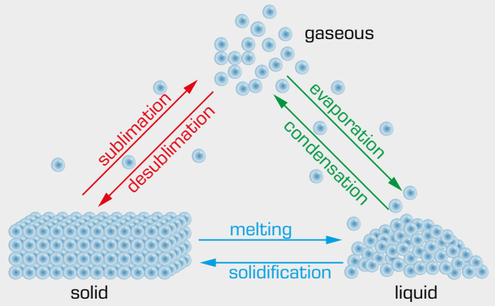
Basic knowledge

Phase transition

Phase transition

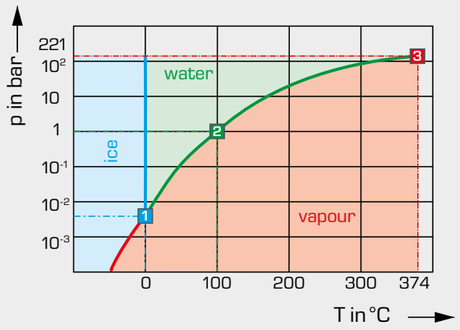
A gaseous, liquid or solid state in a homogeneous system of substances is called a phase. The phase depends on the thermodynamic state variables pressure **p** and temperature **T**.

The conversion from one phase to another is called a phase transition:



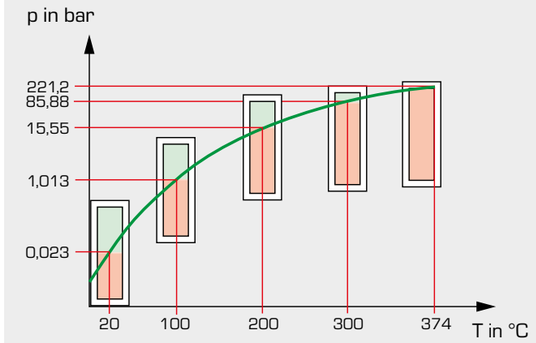
Above the critical point 3 the gaseous and liquid phases of some systems of substances, e. g. water, cannot be differentiated anymore. The physical properties of the fluid lie somewhere between the two phases: The density corresponds to the density of the liquid phase, the viscosity to that of the gaseous phase. This phase is known as the “supercritical” phase. In this phase, the fluid can neither evaporate nor condense.

Another particularity in some systems of substances, such as water, is known as the triple point 1. At this point the solid, liquid and gaseous phase are in equilibrium. All six phase changes occur simultaenously.



Temperature-pressure diagram of water

1 triple point, **2** boiling point, **3** critical point;
sublimation curve,
boiling point curve,
melting point curve



Closed system along the vapour pressure curve of water

vaporisation curve,
water,
vapour;
p pressure, **T** temperature

In a closed system filled with liquid, a thermodynamic equilibration sets in between the liquid and its vaporised phase. This state is called the saturation state. The prevailing pressure is referred to as vapour pressure, in case of water steam pressure or saturated steam pressure, and the temperature is known as saturation temperature. The vapour pressure curve can be derived from both. This curve is shown in the phase diagram of water.

Evaporation process

Steam is used for a variety of processes in engineering. The most common applications are heating processes as well as steam turbines in power plants.

Typical applications of steam in processes include:

- heating: e.g. shell-and-tube heat exchangers to heat up a product
- propulsion: e.g. steam turbines, steam engines
- propellant: e.g. steam ejectors to separate process gases
- atomization: steam for the mechanical separation of fluids, e.g. in gas flares, to reduce soot particles in the exhaust gas
- cleaning: steam cleaners to loosen dirt
- product moistening: paper production
- air humidification: steam humidifiers in air ducts

We distinguish between ideal gas, real gas and vapour. In an ideal gas, pressure and volume are exactly inversely proportional, in a real gas only by approximation. In vapours, the pressure changes only slightly with the volume, depending on the degree of saturation.

Steam occurs in various forms:

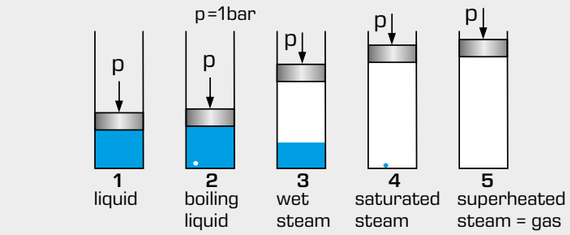
Wet steam: Liquid and gaseous state of the water molecules in a system, some water molecules have released their evaporation heat and condense into fine water droplets.

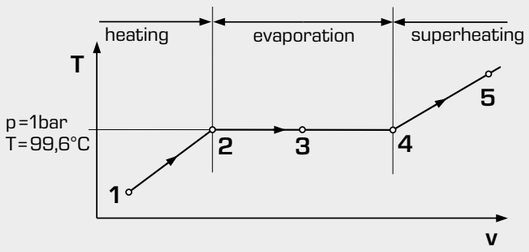
Saturated steam: Boundary area between wet steam and hot steam, state in which the last drop of water changes from liquid to gaseous. The addition of further heat beyond the boiling point produces hot steam or superheated steam.

Hot steam: A distinction is made between **superheated steam** and **supercritical steam.**

Superheated steam: Steam with a temperature above the boiling temperature, purely gaseous state of the water molecules. Real gas is present.

Supercritical steam: Phase at temperatures above the critical point





Evaporation of water: change of state when heating water under constant pressure **p** = 1 bar

T temperature,
v specific volume;
1 liquid,
2 boiling liquid,
3 unsaturated (wet) steam,
4 saturated steam,
5 superheated steam (gas)