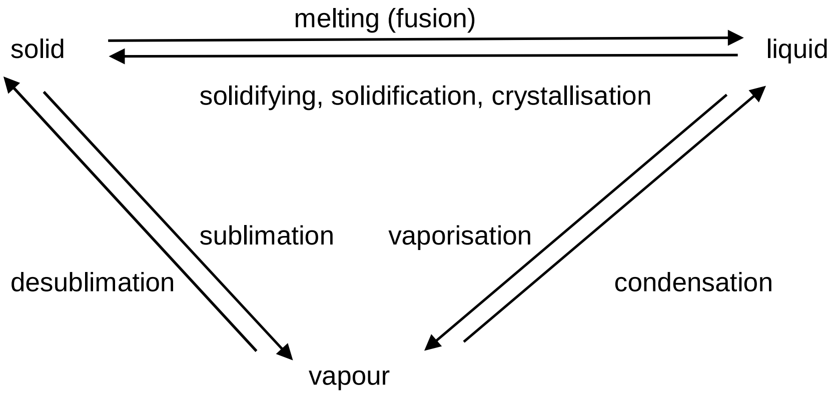
CHANGES IN STATES OF MATTER



1. Melting and solidifying (and fusion)

amorphous substances do not have a melting point – they melt gradually

X

crystalline substances melt at a certain *melting point* (t_m or t_t) = temperature which is typical for each substance and depends on the outer pressure (values in the book of data)

most substances have a bigger volume when liquid (particles further apart) and when we raise the outer pressure, melting point also ....

X

some substances (water, Bi, Ge, some alloys) have a bigger volume when solid and they have a lower melting point at higher pressure

http://www.youtube.com/watch?v=E1NsqSXhsM8

http://www.youtube.com/watch?v=bRKAECWdVhY

Q: Use the idea of distance between the particles and explain the previous statements.

substance	O_2	H_2O	Pb	Au	Cu
$\frac{t_m\,(at\ p_s)}{^\circ C}$	-219	0	327	1064	1083

note: alloys have a lower melting point than their components (explain why)

- *latent heat of fusion* = the amount of heat needed to apply to the object to change its state of matter without temperature change
  L_t
  $[L_t] = \text{J}$

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- *specific latent heat of fusion* = the amount of heat needed to apply to one kilogram of the substance to change its state of matter without temperature change

$$l_t = \frac{L_t}{m}$$

$$[l_t] = \mathrm{J \cdot kg^{-1}}$$

substance	W	Pb	Ag	Cu	Fe	ice	Al	NaCl
$\frac{l_t}{\mathrm{kJ \cdot kg^{-1}}}$	19	23	105	205	279	334	397	500

Questions:

1. How much heat should be applied to a copper object of mass 0.5 kg and temperature 20 °C to melt? Assume the specific heat capacity 383 J·kg·K^{-1}. Sketch Q-t graph!

Solidifying is the reverse process – heat is given out, but the values of the material constants are the same. For crystalline substances a word of *crystallisation* can be used

2. Sublimation and desublimation

some substances can become vapour directly from a solid state – iodine, CO_2, snow/ice, strongly smelling substances...

- *specific latent heat of sublimation/desublimation* = the amount of heat needed to supply to one kilogram of a substance at certain temperature to change its state of matter without temperature change

  depends on temperature – lower temperature – bigger values (explain)

  different values for different pressure, usually for the standard pressure p_s = 10^5 Pa

  ice at 0ºC : $l_s = 2.8\,\mathrm{MJ \cdot kg^{-1}}$

http://www.youtube.com/watch?v=J8mDGwf-5x0&feature=related

3. Vaporisation and condensation

- *vaporisation = evaporation + boiling*

Liquids can evaporate from the surface at any temperature. The effect is stronger at higher temperatures (closer to the *boiling point* (t_B or t_V), for bigger surface area, when mixing the liquid and blowing

gas - when $t \geq t_B$ X vapour – when $t \langle t_B$

boiling point represents the temperature at which the liquid vaporises in the whole volume and it depends on the outer pressure!!! Use the previous ideas (see “melting”) and state if it rises/decreases with the rising pressure or if we cannot state it without the specification of the substance.

- *latent heat of vaporisation* =
  the amount of heat needed to apply to an object at certain temperature to change its state of matter without temperature change

  L_V
  $[L_V] = \mathrm{J}$

- *specific latent heat of vaporisation*=
  the amount of heat needed to apply to one kilogram of a substance at a certain temperature to change its state of matter without temperature change

  depends on temperature – lower temperature – bigger values (explain)

  depends on the outer pressure – bigger pressure – bigger values (explain)

- *specific latent heat of boiling = the specific latent heat of vaporisation at the temperature of the boiling point – the „last“ value*

l_V

$[l_V] = \mathrm{J \cdot kg^{-1}}$

water at p_s: at 0 ºC: $l_V = 2.51\,\mathrm{MJ \cdot kg^{-1}}$

at 100 ºC: $l_V = 2.26\,\mathrm{MJ \cdot kg^{-1}} = l_B$

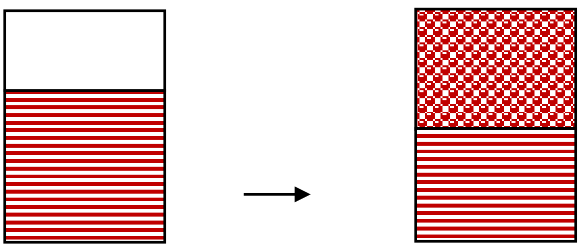
- *condensation = reverse process, the same amounts of heat at the same temperatures (and pressures) are given out*

http://www.youtube.com/watch?v=oSMiec0bECw&feature=related

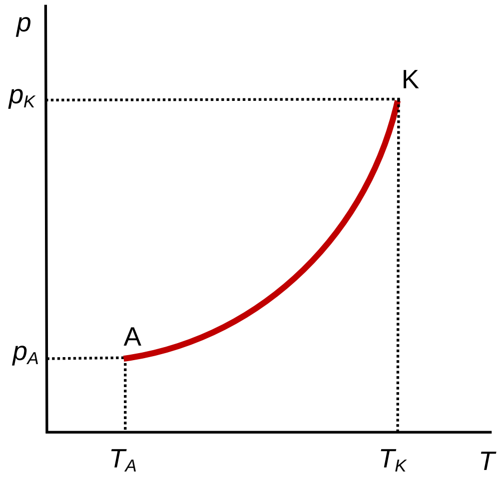
4. Saturated vapour

A liquid vaporises in a closed container (vacuum above – not air) – an amount of liquid decreases and vapour is created. After some time there is an equilibrium between the liquid and vapour (one molecule vaporises – one molecule condenses) and the saturated vapour is formed. Its pressure depends only on the type of substance and temperature; it does not depend on volume.

Is saturated vapour an ideal gas? Explain.



- *saturation vapour pressure (s.v.p.)* = pressure exerted by the vapour in equilibrium with the liquid
- *saturated vapour graph*



temperature rises – density of s.v. rises – density of liquid decreases – s.v.p. rises

each point of the curve represents one equilibrium state (liquid + saturated vapour)

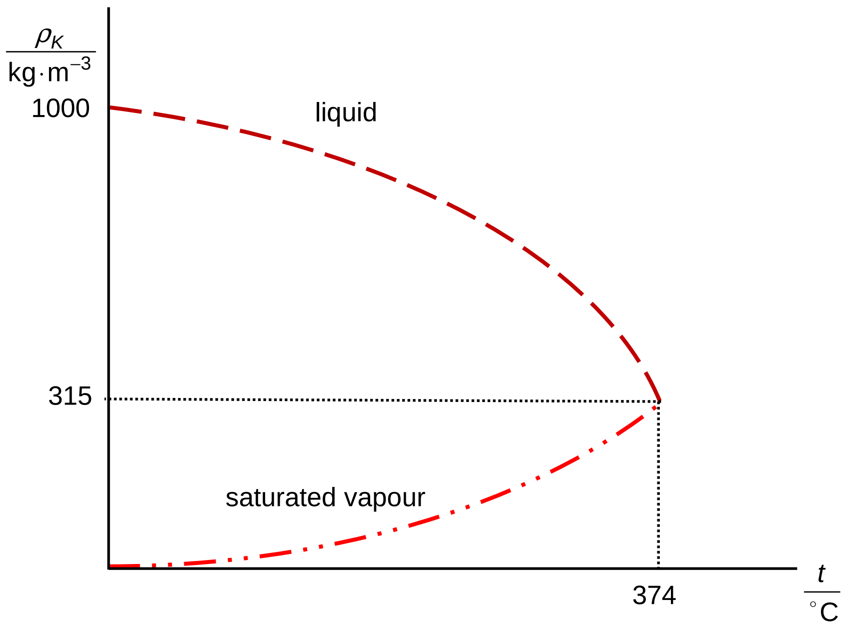
A ... the lowest temperature and pressure at which the equilibrium can be formed (melting point)

K ... critical point – no difference between the liquid and vapour – „uniform" substance

material constant – in the book of data

water: T_K = 647.3 K (374.115 ºC), p_K = 22.13 MPa, ρ_K = 315 kg·m^{-3}

water:

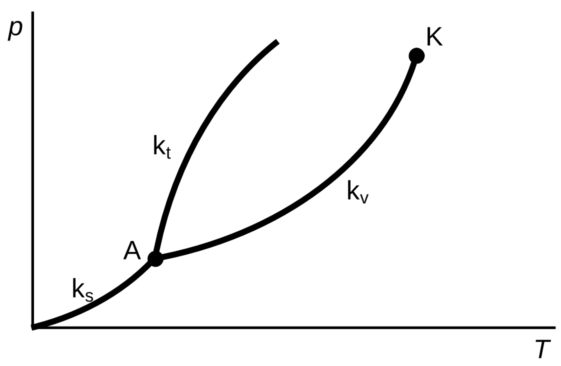


5. Phase diagram

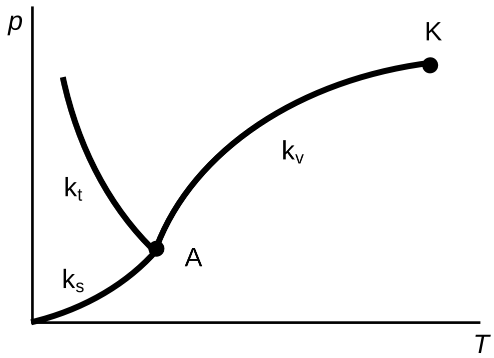
- each point on any curve in the graph below represents the equilibrium between 2(3) states of matter of the substance
- k_s ... sublimation curve (křivka sublimace)
- k_t ... fusion curve (křivka tání)
- k_v ... condensation curve (křivka vypařování)
- A ... triple point – the substance can be at any of the 3 states of matter

substance	$\frac{p_A}{\text{kPa}}$	$\frac{T_A}{\text{K}}$
water	0.61	273.16
oxygen	0.15	54.4

normal substances



water



Find which areas in the diagrams represent which state of matter.

Label the change from:

a) liquid to vapour raising the temperature only
b) solid to liquid decreasing (rising) the pressure only
c) solid to vapour raising the temperature only etc.

6. Calorimetric equation including changes in states of matter

heat taken in = heat given out the same principle as without the changes in states of matter

Questions:

2. A calorimeter of heat capacity 100 J·K^{-1} contains 1.5 kg of water at 25 ºC. When we put ice at -12 ºC, the balanced temperature is 10 ºC. How much ice was added? Use the book of data to find material constants.

3. An iron block of mass 40 kg and temperature 700 ºC is put into a container with 75 kg of water at 75 ºC. Ignore heat capacity of the container and calculate how much water becomes vapour. Use the book of data to find material constants, assume that vaporisation started at the boiling point.

4. 1 kg of ice at 0 °C is put into 1 kg of water at 50 °C poured in a calorimeter with a heat capacity of 0,1 $kJ \cdot K^{-1}$. Calculate the amount of ice that melts. (l_t = 334 $kJ.kg^{-1}$, c = 4 180 $J \cdot kg^{-1} \cdot .K^{-1}$)

5. 3 kg of ice at -10 °C (volume V_1) is changed at standard pressure into water of temperature 20 °C (volume V_2). Take specific heat capacity of ice 2,1 $kJ \cdot kg^{-1} \cdot K^{-1}$, specific heat capacity of water 4,18 $kJ \cdot kg^{-1} \cdot K^{-1}$, specific latent heat of ice 334 $kJ \cdot kg^{-1}$.

a) Use symbols <,>,= to compare volumes V_1 and V_2.
b) Will the mass of ice change during melting?
c) How much heat is absorbed by ice to heat from -10 °C to 0 °C?
d) How much heat is absorbed by ice to change to water at constant temperature 0 °C?
e) How much heat is absorbed by ice to change to water at 20 °C?

6. 60 litres of water at 15 °C is mixed with 80 litres of water at 80 °C. Final temperature is 50 °C. How much energy disappears into the surroundings?

7. How much heat is taken in by a steel object of mass 250 kg and melting point 1 350 °C, when it melts completely without a temperature change? Assume specific latent heat of fusion of steel 260 $kJ \cdot kg^{-1}$.

8. You want to cook pasta. You put 0.5 l of 18 °C water on cooker. Unfortunately you start to solve an interesting physics example and you forget about cooking the pasta. How much heat is needed to vaporize all the water? Neglect evaporation.

L3/154-173

7. Water vapour in atmosphere

- *absolute humidity* = the mass of water vapour present in unit volume of moist air (= “vapour concentration”)

$$\Phi = \frac{m}{V}$$

$$[\Phi] = kg \cdot m^{-3}$$

- *relative humidity*
  = ratio of the absolute humidity Φ over the maximum humidity Φ_m where the vapour in the atmosphere is saturated (at the same temperatures)
  = ratio of actual vapour pressure over the s.v.p. at the same temperature

$$\varphi = \frac{p}{p_s}$$

dry air has 0%, air with saturated vapour 100%, best for us 50-70%

$$[\varphi] = \%$$

- *hygrometers* – devices that measure the humidity, e.g. hair hygrometer
- *dew point (= temperature)* – when we IB cool the air with the given absolute humidity the water vapour becomes saturated at this temperature. When we cool the air more, water vapour starts to condensate or desublimate.

Answers:
1. 306 kJ
2. 0.24 kg
3. 1.3 kg
4. 0.64 kg
5. a) $V_1 > V_2$; b) no; c) 63 kJ; d) 1 002kJ; e) 1 316 kJ
6. 1.3 MJ
7. 65 MJ
8. 1.3 MJ