

[TP] The order of normal boiling points is ...

Substance	Vapor pressure at 25 °C, kPa	Normal (1 atm) boiling point °C
Acetone, $CH_3C(O)CH_3$	30.8	
Diethyl ether, $(CH_3CH_2)_2O$	71.7	
Ethanol, CH_3CH_2OH	7.87	
Water, H_2O	3.17	100

20% 1. diethyl ether < acetone < ethanol
20% 2. ethanol < acetone < diethyl ether
20% 3. acetone < diethyl ether < ethanol
20% 4. ethanol < diethyl ether < acetone
20% 5. something else

Response Counter 10

Lecture 13 CH101 A1 (MWF 9:05 am)

Friday, October 6, 2017

For today ...

- Vapor pressure and boiling

Next lecture: Intermolecular forces; hydrogen bonding; dipole-dipole interaction (polarity); temporary dipole attraction (dispersion); relative boiling points

[TP] From e6.4 (p 163): A bubble in a pot of boiling water contains...

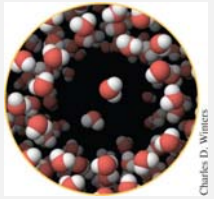
17% 1. Only $O_2(g)$ and $N_2(g)$
17% 2. Only $H_2O(g)$
17% 3. Only air
17% 4. $H_2O(g)$ and air
17% 5. All of the above equally
17% 6. None of the above

Liquid-vapor equilibrium

Boiling: Fig 6.7, p 164

Boiling means "bubbles"

Bubbles are pure vapor of the liquid



Substance	Equilibrium Vapour Pressure (kPa)
Water, $H_2O(\ell)$	3.17
Ethanol, $C_2H_5OH(\ell)$	7.87
Hexane, $C_6H_{14}(\ell)$	20.2
Bromine, $Br_2(\ell)$	28.7
Acetone, $CH_3COCH_3(\ell)$	30.8
Carbon disulfide, $CS_2(\ell)$	48.2
Diethyl ether, $C_2H_5OC_2H_5(\ell)$	71.7

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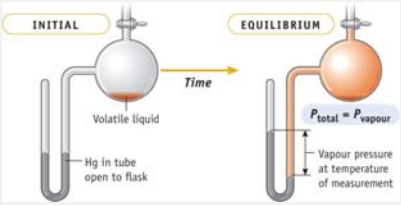
Equilibrium vapor pressure



1 Pa = force/area = 1 kg m/s² / m² = 1 kg m^{-1} s^{-2}

1 bar = 100 kPa (exactly)

1 atm = 101.325 kPa (exactly)

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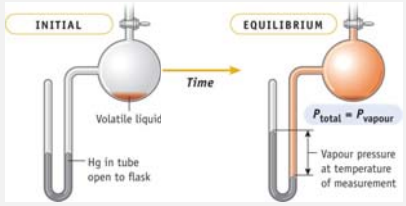
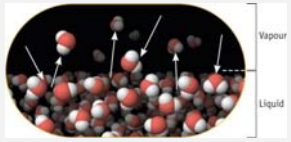
Equilibrium vapor pressure





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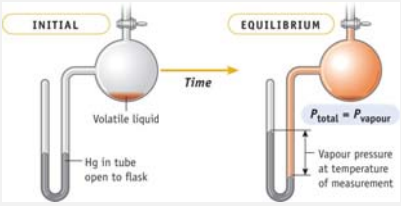
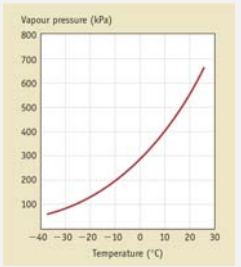
Equilibrium vapor pressure





Low temperature

→ Few particles in vapor

→ Low equilibrium vapor pressure

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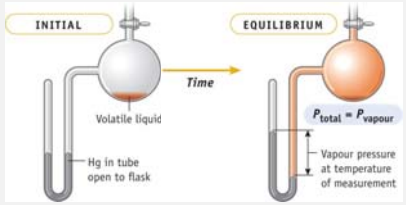
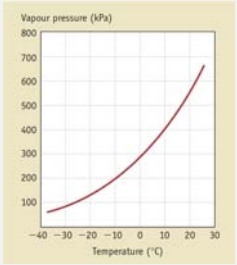
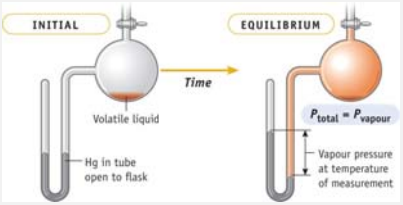
Equilibrium vapor pressure

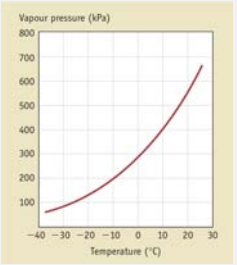




Higher temperature
→ More particles in vapor
→ Higher equilibrium vapor pressure

Equilibrium vapor pressure





Normal boiling temperature
→ Maximum particles in vapor
→ 1 atm equilibrium vapor pressure

Vapor pressure and boiling point

The normal boiling point is the temperature at which bubbles form at 1 atm.

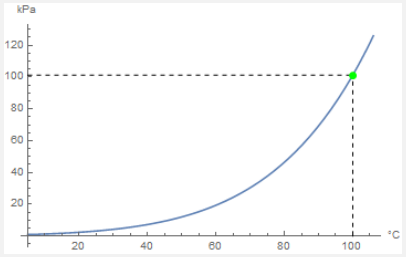
Can we make bubbles (and so "boil") at a lower temperature?

Let's see …

Vapor pressure and boiling

Bubbles appear when vapor pressure = applied pressure

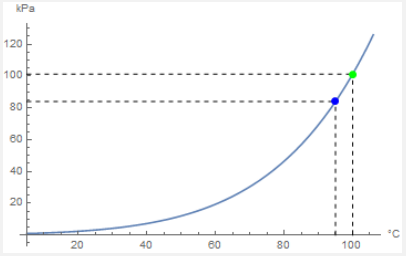
"Normal" boiling point is when vapor pressure is exactly 1 atm = 101.325 kPa



Vapor pressure and boiling

Bubbles appear when vapor pressure = applied pressure

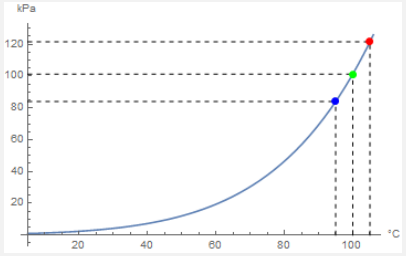
A vacuum pump allows boiling at lower temperature.



Vapor pressure and boiling

Bubbles appear when vapor pressure = applied pressure

A pressure cooker delays boiling to higher temperature.



Vapor pressure and boiling point

The normal boiling point is the temperature at which bubbles form at 1 atm.

What do you predict for relative boiling points of these substances?

Substance	Vapor pressure at 25 °C, kPa	Normal (1 atm) boiling point °C
Acetone, $CH_3C(O)CH_3$	30.8	
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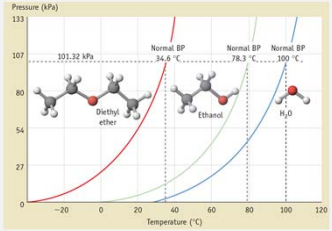
Response Counter 10

Vapor pressure and boiling point

The normal boiling point is the temperature at which bubbles form at 1 atm.

What do you predict for relative boiling points of these substances?

Substance	Vapor pressure at 25 °C, kPa	Normal (1 atm) boiling point °C
Acetone, $CH_3C(O)CH_3$	3: 30.8	3: 56
Diethyl ether, $(CH_3CH_2)_2O$	4: 71.7	4: 35
Ethanol, CH_3CH_2OH	2: 7.87	2: 78
Water, H_2O	1: 3.17	1. 100



Relative normal boiling point, T_b

The normal boiling point is the temperature at which bubbles form at 1 atm.

Substance	T_b
Water (H_2O)	100 °C
Ammonia (NH_3)	−33.3 °C
Hydrogen chloride (HCl)	−84.8 °C
Methane (CH_4)	−161.5 °C
Nitrogen (N_2)	−195.8 °C

What do you predict for relative vapor pressures of these substances at −200 °C?

[Quiz] The substance with the lowest vapor pressure substances at −200 °C is ...

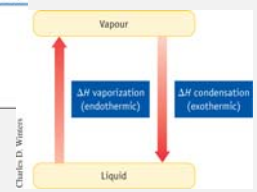
25% 1. CH_4
25% 2. NH_3
25% 3. HCl
25% 4. N_2

Substance	T_b
Water (H_2O)	100 °C
Ammonia (NH_3)	−33.3 °C
Hydrogen chloride (HCl)	−84.8 °C
Methane (CH_4)	−161.5 °C
Nitrogen (N_2)	−195.8 °C

Response Counter 10

Enthalpy change of vaporization, $\Delta_{vap}H$

Substance	$\Delta_{vap}H$ (kJ mol^{-1})
Water (H_2O)	40.7
Ammonia (NH_3)	23.3
Hydrogen chloride (HCl)	16.2
Methane (CH_4)	8.2
Nitrogen (N_2)	5.6



$H_2O(l) \rightleftharpoons H_2O(g)$, $\Delta_{vap}H = 40.7$ kJ/mol at 100 °C
$NH_3(l) \rightleftharpoons NH_3(g)$, $\Delta_{vap}H = 23.3$ kJ/mol at −78 °C
$N_2(l) \rightleftharpoons N_2(g)$, $\Delta_{vap}H = 5.6$ kJ/mol at −196 °C
etc.