

Lecture 14 CH101 A2 (MWF 11:15 am) Fall 2018 Copyright © 2018 Dan Dill dan@bu.edu

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

Substance	Vapor pressure at 25 °C, kPa	Normal (1 atm) boiling point °C
Acetone, $\text{CH}_3\text{C}(\text{O})\text{CH}_3$	30.8	
Diethyl ether, $(\text{CH}_3\text{CH}_2)_2\text{O}$	71.7	
Ethanol, $\text{CH}_3\text{CH}_2\text{OH}$	7.87	
Water, $\text{H}_2\text{O}$	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

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## Lecture 14 CH101 A2 (MWF 11:15 am) Friday, October 5, 2018

For today ...

- Vapor pressure and boiling

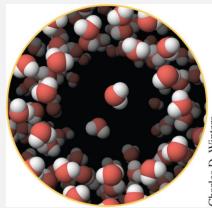
Next lecture: intermolecular forces; hydrogen bonding; polarity; dipole-dipole vs. temporary dipole (dispersion)

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### Boiling: Fig 6.7, p 164

Boiling means "bubbles"  
 Bubbles are pure vapor of the liquid



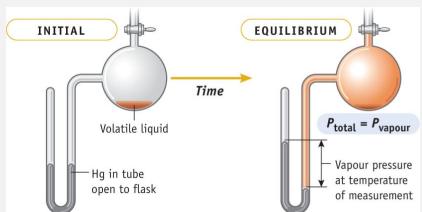
Charles D. Winters

Substance	Equilibrium Vapour Pressure (kPa)
Water, $\text{H}_2\text{O}(l)$	3.17
Ethanol, $\text{C}_2\text{H}_5\text{OH}(l)$	7.87
Hexane, $\text{C}_6\text{H}_{14}(l)$	20.2
Bromine, $\text{Br}_2(l)$	28.7
Acetone, $\text{CH}_3\text{COCH}_3(l)$	30.8
Carbon disulfide, $\text{CS}_2(l)$	48.2
Diethyl ether, $\text{C}_2\text{H}_5\text{OC}_2\text{H}_5(l)$	71.7

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### Equilibrium vapor pressure



**INITIAL** **EQUILIBRIUM** **Time**  **$P_{total} = P_{vapour}$**  **Vapour pressure at temperature of measurement**

1 Pa = force/area = 1 kg m/s<sup>2</sup> / m<sup>2</sup> = 1 kg m<sup>-1</sup> s<sup>-2</sup>  
 1 bar = 100 kPa (exactly)  
 1 atm = 101.325 kPa (exactly)

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### Equilibrium vapor pressure

**INITIAL** **EQUILIBRIUM**

Volatile liquid  
Hg in tube open to flask

$P_{\text{total}} = P_{\text{vapour}}$

Vapour pressure at temperature of measurement

Vapour  
Liquid

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5

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### Equilibrium vapor pressure

**INITIAL** **EQUILIBRIUM**

Volatile liquid  
Hg in tube open to flask

$P_{\text{total}} = P_{\text{vapour}}$

Vapour pressure at temperature of measurement

Vapour pressure (kPa)

Temperature (°C)

Low temperature  
→ Few particles in vapor  
→ Low equilibrium vapor pressure

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6

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### Equilibrium vapor pressure

**INITIAL** **EQUILIBRIUM**

Volatile liquid  
Hg in tube open to flask

$P_{\text{total}} = P_{\text{vapour}}$

Vapour pressure (kPa)

Temperature (°C)

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

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7

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### Equilibrium vapor pressure

**INITIAL** **EQUILIBRIUM**

Volatile liquid  
Hg in tube open to flask

$P_{\text{total}} = P_{\text{vapour}}$

Vapour pressure at temperature of measurement

Vapour pressure (kPa)

Temperature (°C)

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

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8

## 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?

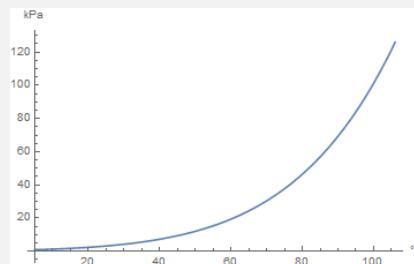
Let's see ...

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9

## Vapor pressure and boiling

Vapor pressure rises with temperature.

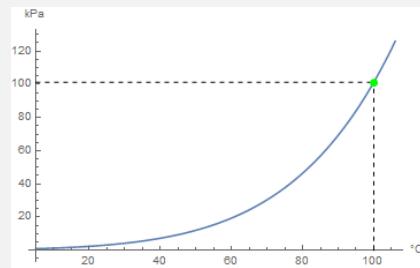


10

## 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**

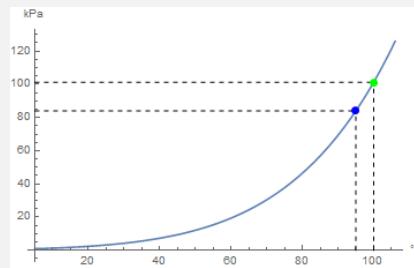


11

## Vapor pressure and boiling

Bubbles appear when vapor pressure = applied pressure

A **vacuum pump** allows boiling at **lower temperature**.



12

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## Vapor pressure and boiling

Bubbles appear when vapor pressure = applied pressure

A **pressure cooker** delays boiling to **higher temperature**.

The graph plots vapor pressure (kPa) on the y-axis (0 to 120) against temperature (°C) on the x-axis (0 to 100). A blue curve starts near (0,0) and rises sharply towards 100°C. A horizontal dashed line at 100 kPa intersects the curve at 100°C, marked with a green dot. A vertical dashed line from this intersection point meets the x-axis at 100°C, marked with a red dot.

**13**

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## 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, $\text{CH}_3\text{C}(\text{O})\text{CH}_3$	30.8	
Diethyl ether, $(\text{CH}_3\text{CH}_2)_2\text{O}$	71.7	
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Water, $\text{H}_2\text{O}$	3.17	100

**16**

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

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20% 5. something else

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## 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, $\text{CH}_3\text{C}(\text{O})\text{CH}_3$	3: 30.8	3: 56
Diethyl ether, $(\text{CH}_3\text{CH}_2)_2\text{O}$	4: 71.7	4: 35
Ethanol, $\text{CH}_3\text{CH}_2\text{OH}$	2: 7.87	2: 78
Water, $\text{H}_2\text{O}$	1: 3.17	1. 100

The graph shows vapor pressure (kPa) on the y-axis (0 to 133) versus temperature (°C) on the x-axis (-20 to 120). Four curves are plotted: Acetone (red), Diethyl ether (green), Ethanol (blue), and Water (black). The curves intersect the 1 atm (101.32 kPa) line at their respective normal boiling points: 56 °C (acetone), 35 °C (diethyl ether), 78.3 °C (ethanol), and 100 °C (water). Labels indicate these points on both the curves and the pressure axis.

**18**

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## 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?

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

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

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