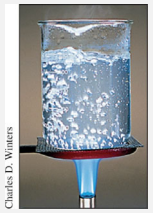
[TP] Bubbles in a pot of boiling water contain …

8% 1. Only $O_2(g)$ and $N_2(g)$
39% 2. Only $H_2O(g)$
4% 3. Only air
40% 4. $H_2O(g)$ and air
7% 5. All of the above equally
2% 6. None of the above



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Lecture 13 CH131 Fall 2020

Thursday, October 29, 2020

- Vapor pressure: Liquid-vapor equilibrium
- Vapor pressure and boiling point
- Phase diagrams

Next lecture: Complete phase diagrams; Ch11: Solutions: Vapor pressure lowering, $P_1 = x_1 P^\circ_1$; Boiling point elevation, $T_b - T^\circ_b = K_b m_c$; Freezing point depression, $T^\circ_f - T_f = K_f m_c$; Osmotic pressure, $\Pi = RTM_c$;

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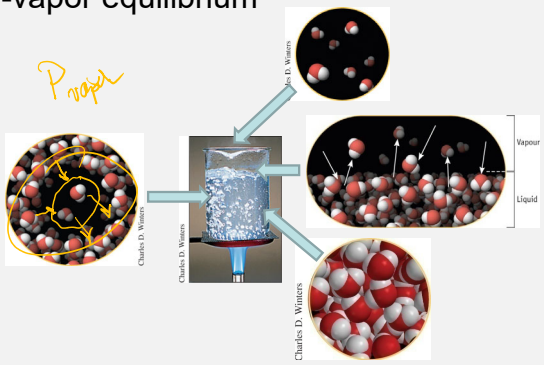
Liquid-vapor equilibrium



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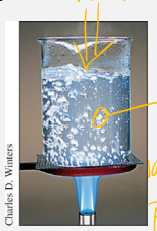
6

6

[TP] Bubbles in a pot of boiling water contain …

1% 1. Only $O_2(g)$ and $N_2(g)$
42% 2. Only $H_2O(g)$
1% 3. Only air
50% 4. $H_2O(g)$ and air
4% 5. All of the above equally
2% 6. None of the above



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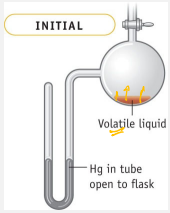
Equilibrium vapor pressure



Sketch what is going on at the surface at this point.

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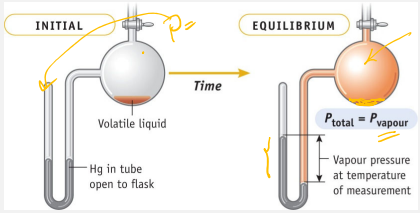
Equilibrium vapor pressure



Sketch what is going on at the surface now.

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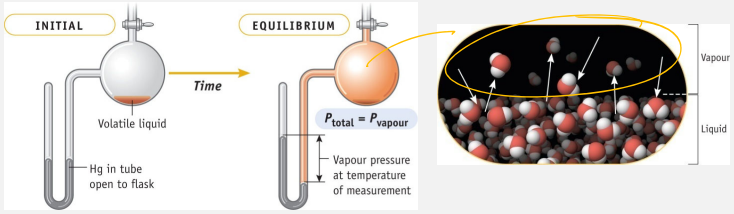
Equilibrium vapor pressure



Sketch how pressure must change with temperature.

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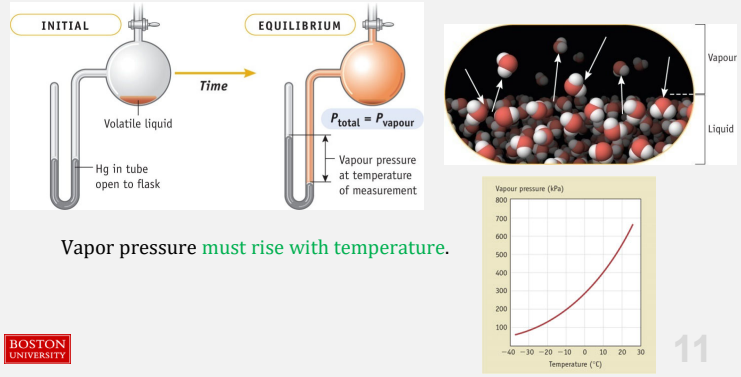
Equilibrium vapor pressure



Vapor pressure must rise with temperature.

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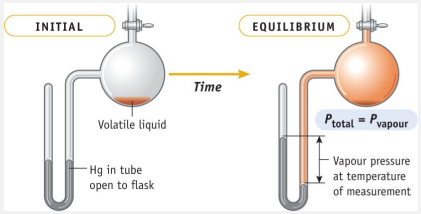
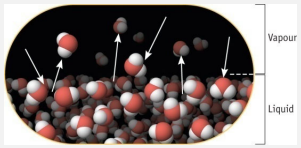
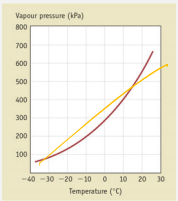
Equilibrium vapor pressure







Vapor pressure must rise with temperature.

Why is this so?

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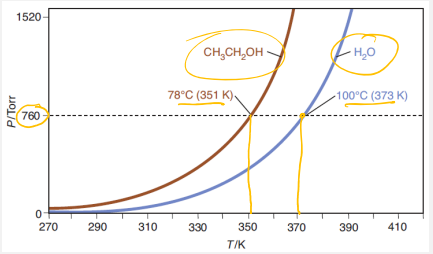
Evaporation

Vapor pressure rises with temperature.



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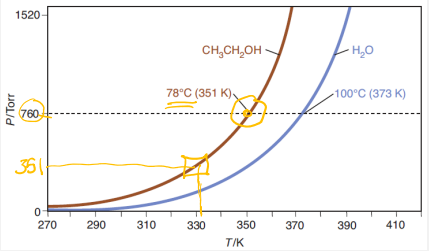
Evaporation

Vapor pressure rises with temperature.

- $T = 60.0°C, P_{vapor} = 351$ Torr
- $T_{bp} = 78.3°C, P_{vapor} = 760$ Torr



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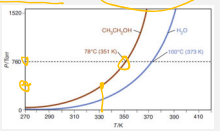
Evaporation

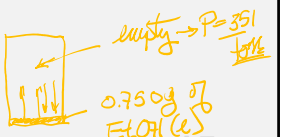
A 0.750-gram sample of ethanol (CH_3CH_2OH) is placed in a sealed 400-mL container. Is there any liquid present when the temperature is held at 60°C?

$T = 60.0°C, P_{vapor} = 351$ Torr, $R = 0.0820575 \frac{L\,atm}{K\,mol}$



$P = MRT$

351 Torr



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Evaporation

A 0.750-gram sample of ethanol (CH_3CH_2OH) is placed in a sealed 400-mL container. Is there any liquid present when the temperature is held at 60°C?

$T = 60.0°C, P_{vapor} = 351$ Torr, $R = 0.0820575 \frac{L\,atm}{K\,mol}$

$n = 0.0163$ mol, calculated from molar mass

17

Evaporation

A 0.750-gram sample of ethanol (CH_3CH_2OH) is placed in a sealed 400-mL container. Is there any liquid present when the temperature is held at 60°C?

$T = 60.0°C, P_{vapor} = 351$ Torr, $R = 0.0820575 \frac{L\,atm}{K\,mol}$

$n = 0.0163$ mol, calculated from molar mass

$P_{gas} = 846$ Torr, calculate from ideal gas law > $P_{vapor} = 351$ Torr

18

Evaporation

A 0.750-gram sample of ethanol (CH_3CH_2OH) is placed in a sealed 400-mL container. Is there any liquid present when the temperature is held at 60°C?

$T = 60.0°C, P_{vapor} = 351$ Torr, $R = 0.0820575 \frac{L\,atm}{K\,mol}$

$n = 0.0163$ mol, calculated from molar mass

$P_{gas} = 846$ Torr, calculated from ideal gas law > $P_{vapor} = 351$ Torr

$n_{vapor} = 0.00675$ mol, calculated from ideal gas law, using $P_{vapor} = 351$ Torr

19

Evaporation

A 0.750-gram sample of ethanol (CH_3CH_2OH) is placed in a sealed 400-mL container. Is there any liquid present when the temperature is held at 60°C?

$T = 60.0°C, P_{vapor} = 351$ Torr, $R = 0.0820575 \frac{L\,atm}{K\,mol}$

$n = 0.0163$ mol, calculated from molar mass

$P_{gas} = 846$ Torr, calculated from ideal gas law > $P_{vapor} = 351$ Torr

$n_{vapor} = 0.00675$ mol, calculated from ideal gas law, using $P_{vapor} = 351$ Torr

$n_{liquid} = n - n_{vapor} = 0.0163\text{ mol} - 0.00675\text{ mol} = 0.0096$ mol

20

Evaporation

A 0.750-gram sample of ethanol (CH_3CH_2OH) is placed in a sealed 400-mL container. Is there any liquid present when the temperature is held at 60°C?

$T = 60.0°C$, $P_{vapor} = 351$ Torr, $R = 0.0820575 \frac{L\,atm}{K\,mol}$

$n = 0.0163$ mol, calculated from molar mass

$P_{gas} = 846$ Torr, calculated from ideal gas law > $P_{vapor} = 351$ Torr

$n_{vapor} = 0.00675$ mol, calculated from ideal gas law, using $P_{vapor} = 351$ Torr

$n_{liquid} = n - n_{vapor} = 0.0163\text{ mol} - 0.00675\text{ mol} = 0.0096$ mol

Note, we have ignored the slight increase in vapor volume because of the decrease in liquid volume due to evaporation.

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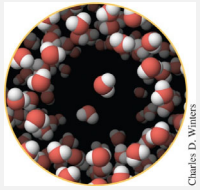
Vapor pressure and boiling point

Boiling means "bubbles".

Bubbles are pure vapor of the liquid.

Bubbles form only if they are able to hold back the liquid walls.

This means bubbles only exist if the vapor pressure is the same as the pressure acting on the liquid surface.



Charles D. Winters

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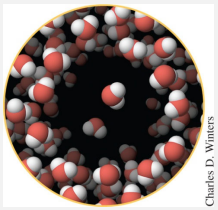
Vapor pressure and boiling point

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?



Charles D. Winters

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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[TP] The order of normal boiling points (lowest to highest) 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

63% 1. diethyl ether < acetone < ethanol

25% 2. ethanol < acetone < diethyl ether

9% 3. acetone < diethyl ether < ethanol

3% 4. ethanol < diethyl ether < acetone

0% 5. something else

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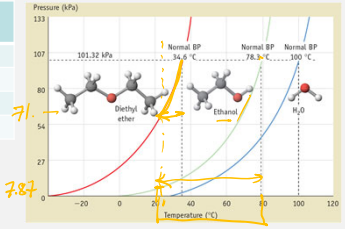
Vapor pressure and boiling point

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, $CH_3C(O)CH_3$	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



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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

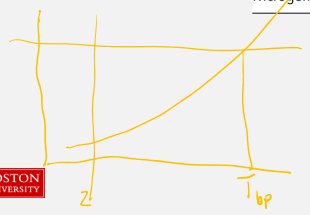
What do you predict for relative vapor pressures of these substances at −200°C?

26

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

3% 1. CH_4
64% 2. NH_3
3% 3. HCl
31% 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



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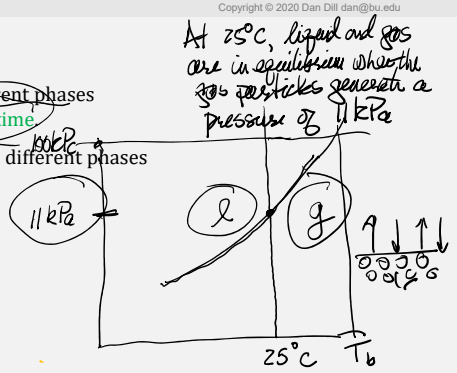
Phase diagrams

Lines of P versus T at which different phases are present at the same time.

That is, values of P and T at which different phases are in equilibrium.



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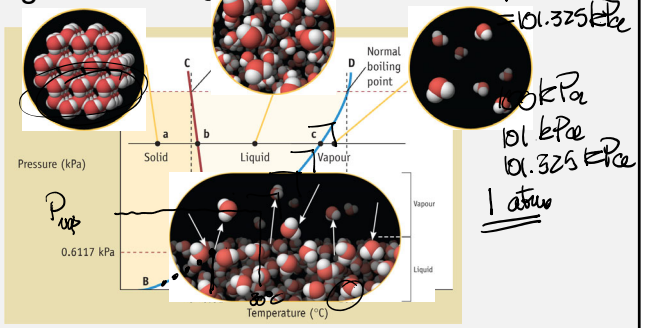
Phase diagrams



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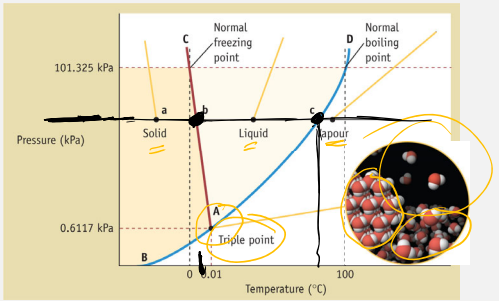
What about the intersection marked “A”



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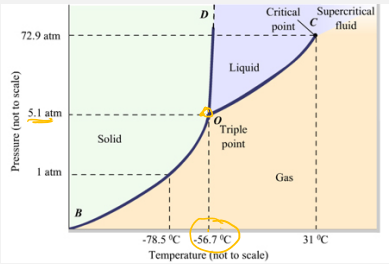
Triple point

Liquid tert-butyl alcohol, $C(CH_3)_3OH$, can boil and freeze at the same time...
http://goo.gl/4K1SR



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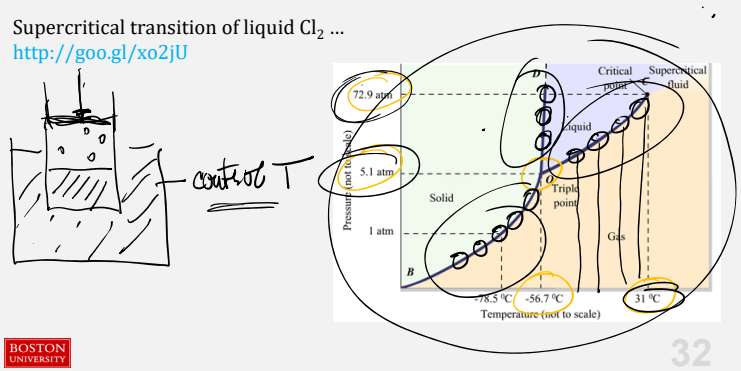
Supercritical fluid

Supercritical transition of liquid Cl_2 ...
http://goo.gl/xo2jU



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