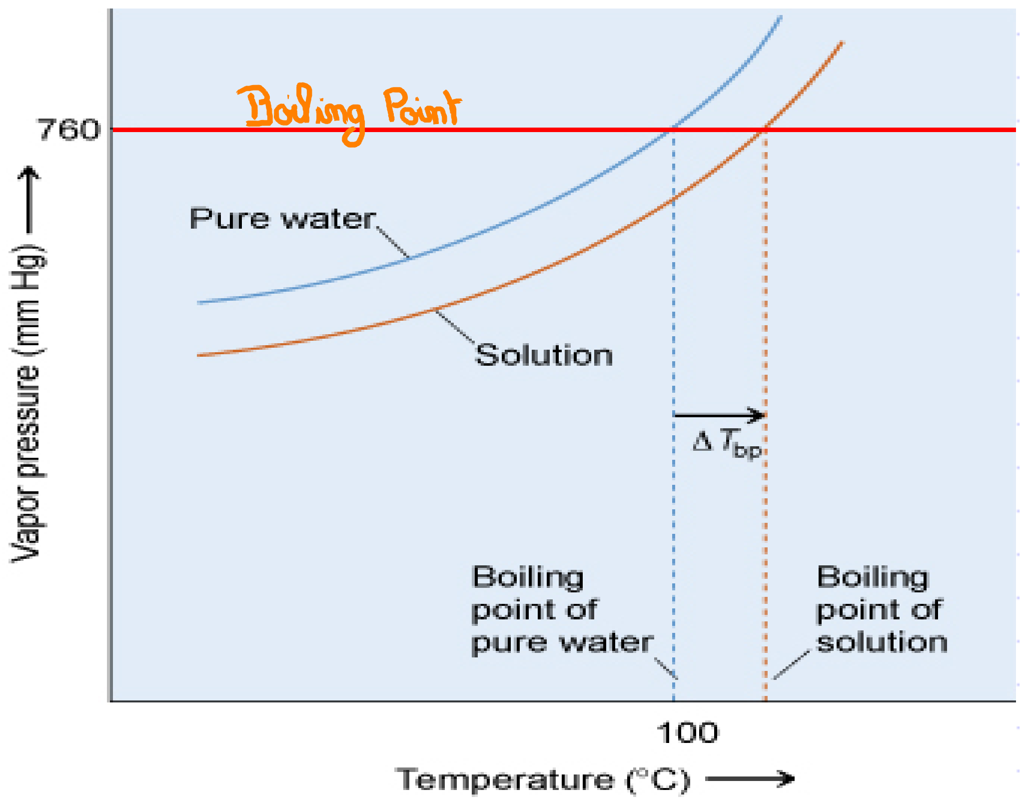
13.4 Colligative Properties

Vapor Pressure Lowering – Boiling Point Elevation



$\Delta T_{B.P.} = i \times K_{B.P.} \times m_{solute}$

$\Delta T_{B.P.}$: Change in Boiling Point.

K_{BP} : Boiling Point elevation constant for the solute.

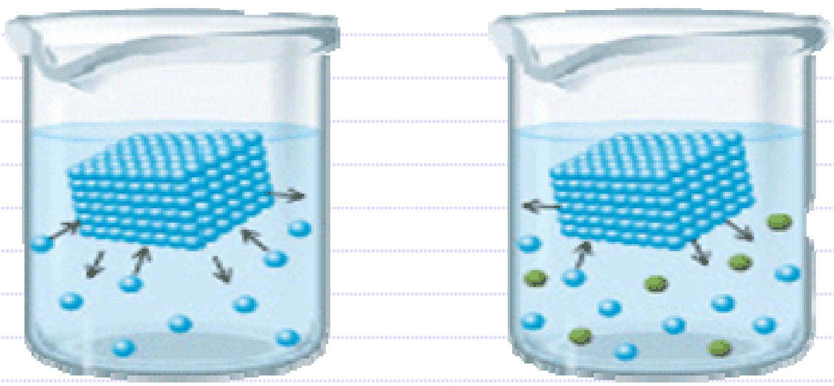
m_{solute} : Molality of the solute.

i : van't Hoff Factor.
For a nonelectrolyte, $i = 1$

13.4 Colligative Properties

Vapor Pressure Lowering – Freezing Point Depression

$$\Delta T_{fp} = i \times K_{fp} \times m_{solute}$$



(a) (b)

ΔT_{fp} : Change in freezing point.

K_{fp} : Freezing point depression constant for the solute.

m_{solute} : Molality of the solute.

i : van't Hoff factor. For a nonelectrolyte, $i = 1$.

13.4 Colligative Properties

Vapor Pressure Lowering – van't Hoff Factor?

In our disscussion of Raoult's Law we have stuck with non volatile liquids (nonelectrolytes) that dissolve in water.

What if we used soluble ionic compounds?

1M $NaCl_{(aq)}$ = 1M Na^+ + 1M Cl^- : $i = 2$

1M $CaCl_{2(aq)}$ = 1M Ca^{2+} + 2M Cl^- : $i = 3$

What about using a weak acid?

1M $HCN_{(aq)}$ $\rightleftharpoons$?M H^+ + ?M CN^- : $i > 0$ but < 2

13.4 Colligative Properties

Vapor Pressure Lowering – van't Hoff Factor?

Which of the following solutions would have the **highest boiling point**?

a)	0.19m NH_4NO_3	$NH_4^+ + NO_3^-$;	$i = 2$	$2 \times 0.19 = 0.38$
b)	0.18m KCH_3COO	$K^+ + CH_3COO^-$:	$i = 2$	$2 \times 0.18 = 0.36$
c)	0.21m NaCl	$Na^+ + Cl^-$:	$i = 2$	$2 \times 0.21 = 0.42$
d) ✓	0.44m Glucose (nonelectrolyte)	:	$i = 1$	$1 \times 0.44 = 0.44$ ✓

13.4 Colligative Properties

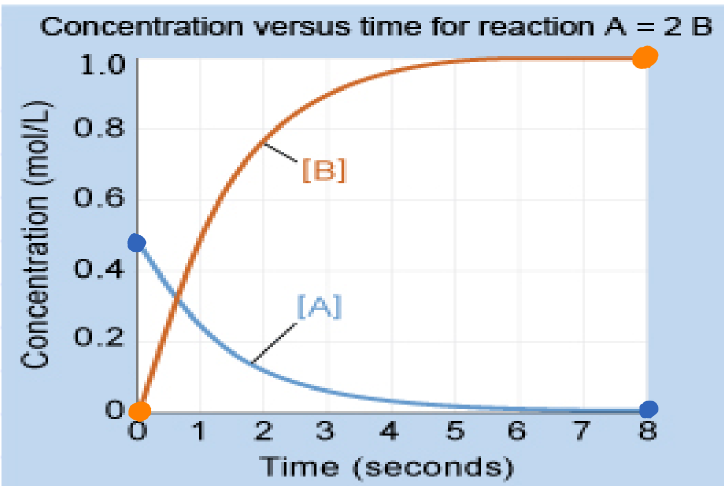
Vapor Pressure Lowering – van't Hoff Factor?

Which of the following solutions would have the **lowest freezing point**?

a)	0.15m CuI_2	$Cu^{2+} + 2I^-$	: $i = 3$	$3 \times 0.15 = 0.45$
b) ✓	0.17m $Zn(CH_3COO)_2$	$Zn^{2+} + 2\,CH_3COO^-$	: $i = 3$	$3 \times 0.17 = 0.51$ ✓
c)	0.14m CoI_2	$Co^{2+} + 2I^-$	: $i = 3$	$3 \times 0.14 = 0.42$
d)	0.47m Urea (nonelectrolyte)		: $i = 1$	$1 \times 0.47 = 0.47$

14.2 Expressing the Rate of a Reaction

Average Rate and Reaction Stoichiometry



A = 2B

Timed from 0 to 8 seconds

$$\text{Rate} = \frac{\Delta[B]}{\Delta t} = \frac{[B]_8 - [B]_0}{t_8 - t_0} = \text{Rate of Formation of B}$$

$$\text{Rate} = \frac{\Delta[A]}{\Delta t} = \frac{[A]_8 - [A_0]}{t_8 - t_0} = \text{Rate of Dissapearance of A}$$

For B:

$$\text{Rate} = \frac{1M - 0M}{8s - 0s} = 0.125\ M.s^{-1}$$

For A:

$$\text{Rate} = \frac{0M - 0.5M}{8s - 0s} = -0.0625\ M.s^{-1}$$

No surprise, A = 2B, that the average rate of formation of B is twice the average rate of Dissapearance of A.

14.2 Expressing the Rate of a Reaction

Average Rate and Reaction Stoichiometry

$$A = 2B$$

$$\text{Average Rate of Reaction} = \frac{1}{2}\frac{\Delta[B]}{\Delta t} = -\frac{1}{1}\frac{\Delta[A]}{\Delta t}$$

$$= \tfrac{1}{2}(0.125\ M.s^{-1})^{*} = -(-0.0625\ M.s^{-1})^{*}$$

$$= 0.0625\ M.s^{-1} = 0.0625\ M.s^{-1}$$

* See previous slide to see where these numbers come from.

Generalization: $aA + bB = cC + dD$

$$\text{Average Rate of Reaction} = -\frac{1}{a}\frac{\Delta[A]}{\Delta t} = -\frac{1}{b}\frac{\Delta[B]}{\Delta t} = \frac{1}{c}\frac{\Delta[C]}{\Delta t} = \frac{1}{d}\frac{\Delta[D]}{\Delta t}$$