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Chapter 12
Physical Properities of solutions

→ **A solution:** / Homogenous mixture of 2 or more substances.

→ **The solute:** / is the substance present in the smaller amount. "المادة المذابة"

→ **The solvent:** / is the substance present in the larger amount. "المُذيب"

* أمثلة عن الحالات الفيزيائية لمكونات المحلول :

→ Gas + Gas ⟹ Gas
→ Gas + Liquid ⟹ Liquid
→ Gas + Solid ⟹ Solid
→ Solid + Liquid ⟹ Liquid

* Types of solutions *

- Saturated Solution
- Unsaturated solution
- supersaturated Solution

"محلول مشبع"

a. **Saturated solution:** / Contains the maximum amount of a solute. يحتوي على الكمية القصوى من المذاب التي يمكنها الذوبان في كمية معينة من المذيب.

"محلول غير مشبع"

b. **Unsaturated solution:** / Contains less solute than the solvent. يحتوي على كمية من المذاب أقل من الكمية التي باستطاعة المذيب الوجود واذابتها ⟵ "في مجال إذ ضافة المزيد من المذاب"

"محلول فوق مشبع"

c. Supersaturated solution: / Contains more solute than is present in a saturated solution.

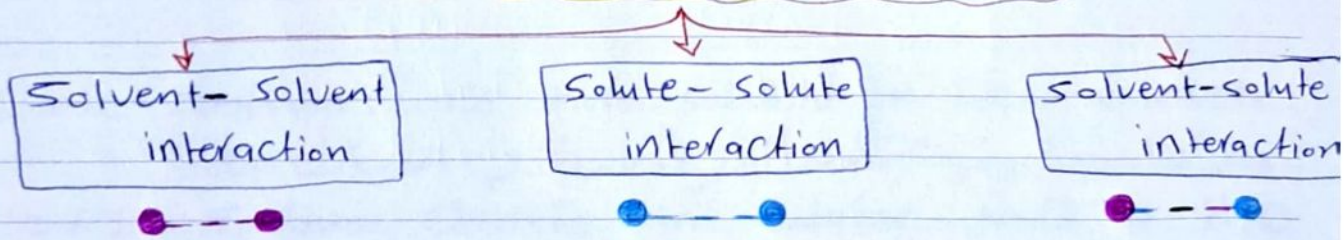
يحتوي على كمية من المذاب أكثر من المحلول المشبع
لم يتم إذابة هذه الكمية الزائدة عن طريق استخدام طرق كيميائية مختلفة مثل "التسخين"

عند إضافة كمية صغيرة جداً من المذاب على محلول فوق مشبع يتشكل Crystals مباشرة.

supersaturated solution is unstable.

"أقسام التفاعلات داخل المحلول".

Interactions in the solution



* if the solute - solvent attraction (●---●) is bigger than (solute-solute ●---● and solvent solvent ●---●) attraction
↳ The solution process is favorable.

يعني إذا كانت قوى التجاذب بين جزيئات المذيب والمذاب أكبر من قوى تجاذب كل من - جزيئات المذيب مع بعضها - وجزيئات المذاب مع بعضها ، في هذه الحالة يكون عملية تكوين المحلول مفضلة.

* Formation of solutions *

ΔH_1 : Break up of solvent. تكسير الروابط بين جزيئات المذيب
ΔH_2 : Break up of solute. تكسير الروابط بين جزيئات المذاب
ΔH_3 : Mixing them. دمج جزيئات المذيب و المذاب.

$$\Delta H_{solution} = \Delta H_1 + \Delta H_2 + \Delta H_3$$

Like dissolves Like

* المواد التي تمتلك نفس قوى التجاذب بين جزيئاتها تكون أكثر احتمالية للذوبان مع بعضها البعض.

→ Non-Polar molecules are soluble in non-Polar solvents.
← الجزيئات غير القطبية تذوب في المذيبات غير القطبية.

ex: Carbon tetrachloride in benzene
CCl_4 in C_6H_6

→ Polar molecules are soluble in Polar solvents.
← الجزيئات القطبية تذوب في المذيبات القطبية.

ex: ethanol in water.
C_2H_5OH in H_2O

→ Ionic compounds are more soluble in Polar solvents.
← المركبات الأيونية تكون أكثر ذوبانية في المذيبات القطبية

ex: - Sodium Chloride in Water $NaCl$ in H_2O
- sodium Chloride in liquid ammonia ⇒ $NH_3(\ell)$

Concentration Units

* وحدات القياس للتركيز

• **Concentration:** The amount of solute present in a given quantity of solvent or solution.

① Percent by mass.

$$\% \text{ by mass} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$$

* Mass of solution = mass of solvent + mass of solute

Question: A sample of 0.892g of Potassium chloride (KCl) is dissolved in 54.6g of water. What is the Percent by mass of KCl in the solution ?

$$\% KCl = \frac{\text{mass of KCl}}{\text{mass of KCl + mass of water}} * 100\%$$

$$= \frac{0.892}{0.892 + 54.6} * \%100 = \boxed{1.6\ \%}$$

$$\% H_2O = 100\% - 1.6\% = \boxed{98.4\ \%}$$

Question: A sample of mineral Contains barium Carbonate $BaCO_3$, if 1.68g sample of this mineral were to react with 24.6ml of 0.2558M HCl. what would be the percent of barium Carbonate in the mineral?

$$* BaCO_3 + 2HCl \longrightarrow BaCl_2 + CO_2 + H_2O$$

HCl $\Longrightarrow$ molarity = 0.2558 M

↳ Volume = $24.6 * 10^{-3}$ litre

moles of HCl = Volume * molarity

$$= (24.6 * 10^{-3}) * (0.2558) = \{6.29 * 10^{-3}\ mol$$

$$\begin{bmatrix} 2\ mol\ HCl = 1\ mol\ BaCO_3 \\ 6.29 * 10^{-3}\ mol\ HCl = ? \end{bmatrix}$$

$$\text{n mol of } BaCO_3 = \frac{6.29 * 10^{-3}}{2} = \underline{3.145 * 10^{-3}\ mol}$$

$$n = \frac{\text{mass}}{\text{molecular weight}} \Rightarrow \text{mass} = \underline{n \text{ of } BaCO_3} * (m.w)$$

$$= (3.145 * 10^{-3}) * (197) = \boxed{0.62g}$$

$$\% BaCO_3 = \frac{0.62}{1.68} * 100\% = \boxed{36.9\%}$$

#

// اليــ لا وحدة قيا ســ // "الأكثر الحوليــ"

[2] Mole Fraction

← الطريقة الثانية لحساب التراكيز

* يمثل عدد مولات المادة بالنسبة للمحلول ككل.

$$x_A = \frac{\text{moles of A}}{\text{sum of moles of all components}}.$$

Question: An aqueous solution of sodium carbonate was prepared containing 14.0% Na_2CO_3 by weight. What is the mole fraction of Na_2CO_3 in this solution?

← لنفرض وجود كمية 1 لتر من المحلول.

every 1g → 1ml, so 1 litre = 1000 g

$\% Na_2CO_3 = 14\%$

$$\text{mass of } Na_2CO_3 = \frac{14 * 1000}{100} = 140\,g$$

$$n \text{ of } Na_2CO_3 = \frac{140}{((23*2)+12+(3*16))} = 1.32\,mol$$

$$\text{mass of } H_2O = 1000 - 140 = 860\,g$$

$$n \text{ of } H_2O = \frac{860}{18} = 47.78\,mol$$

$$x_{Na_2CO_3} = \frac{1.32}{1.32+47.78} = 0.027$$ #

[3] Molarity

$$M = \frac{\text{moles of solute}}{\text{Volume of solution}}$$

→ In litre.

[4] Molality

$$m = \frac{\text{moles of solute}}{\text{mass of solvent}}$$

→ In Kilogram

Question 1 Calculate the molality of a sulfuric acid solution containing 24.4g of sulfuric acid in 198g of water. The molar mass of sulfuric acid is 98.09.

* Sulfuric acid " H_2SO_4"

→ n of $H_2SO_4 = \frac{m}{m.w} = \frac{24.4}{98.09} = \boxed{0.249\ mol}$

→ mass of solvent (Kg) = $198 * 10^{-3} = \boxed{0.198\ Kg}$

$$molality = \frac{n\ of\ solute}{mass\ of\ solvent\ (Kg)} = \frac{0.249}{0.198} = \boxed{1.256\ m}\ \#$$

Question 2 The density of a 2.45M aqueous solution of methanol (CH_3OH) is 0.976 g/mℓ. What is the molality of the solution? The molar mass of methanol is 32.04 g.

• بما أنو مش معطيني حجم في السؤال ← بفرض الحجم 1 لتر •

⇒ suppose we have 1 litre of solution.

$$Density = \frac{mass}{Volume} \rightarrow mass = Density * Volume$$

$$mass\ of\ solution = 0.976\ \frac{g}{m\ell} * 1000\ m\ell$$

↳ ∴ mass of solution = $\boxed{976\ g}$

$$Molarity = \frac{n\ of\ ethanol}{volume\ (Litre)} \Rightarrow n = 2.45 * 1 = \boxed{2.45\ mo}$$

mass of methand (CH_3OH) = $2.45 * (12+4+16) = \boxed{78.5g}$

mass of solvent (H_2O) = 976 − 78.5 = 897.5g

↳ mass of H_2O = 0.8975 Kg

$$molality = \frac{n\ of\ solute}{m\ of\ solvent} = \frac{2.45}{0.8975} = \boxed{2.73m}\ \#$$

Question: What is the molality of a 5.86 M ethanol (C_2H_5OH) solution whose density is 0.927 g/ml

← نفس فكرة السؤال السابق، نفرض الحجم = 1 لتر

→ suppose the Volume = 1 litre

* $\text{Density} = \frac{\text{mass}}{\text{Volume}}$ ⟹ mass = Density * Volume

mass of solution = $0.927 \frac{g}{ml} * 1000\ ml = \boxed{927\ g}$

* $\text{Molarity} = \frac{\text{n of solute}}{\text{Volume}}$ ⟹ n of $(C_2H_5OH) = 5.86 * 1 = \boxed{5.86\ mol}$

* moles of solute

* mass of C_2H_5OH = n * molar mass

$= 5.86 * [(12*2) + (1*6) + (16*1)]$

∴ mass of ethanol = 269.56 g.

* mass of solvent (H_2O) = mass of solution − mass of ethanol

$= 927 - 269.56 = 657.44\ g$

mass of solvent $= 657.44 * 10^{-3} = 0.65744\ Kg.$

* $\text{molality} = \frac{\text{moles of solute}}{\text{mass of solvent (Kg)}} = \frac{5.86}{0.65744} = \boxed{8.913\ m}$ #

Question: Calculate the molality of a 35.4 % (by mass) aqueous solution of Phosphoric acid (H_3PO_4). The molar mass of Phosphoric acid is 97.99 g.

→ suppose the Volume = 1 litre.

→ In 100 gram of solution.

Percent by mass $= \frac{\text{mass of } H_3PO_4}{\text{mass of solution}} \times 100\ \% = 35.4\ \%$

$100 * \frac{\text{mass of } (H_3PO_4)}{100} = 35.4 \Rightarrow ms\ (H_3PO_4) = \boxed{35.4\ g}$

mass of solvent = $100 - 35.4 = 64.6 * 10^{-3} = \boxed{0.0646\ Kg}$

$\text{molality} = \frac{\text{n of } (H_3PO_4)}{\text{mass of solvent}} = \frac{\left(\frac{35.4}{97.99}\right)\frac{m}{m.w}}{0.0646} = \boxed{5.59\ m}$

Question: By dissolving 0.2 mol of FeI_3 in water and diluting to 725ml, the respective concentrations (M) of Fe^{3+} and I^- will be:?

* General equation: #

$$FeI_3 \longrightarrow Fe^{3+} + 3\,I^-$$

n of solute (FeI_3) = 0.2 mol

Volume of solution = $725 * 10^{-3}$ litre

→ From the equation: \

1 mol of FeI_3 ⟹ 1 mol of Fe^{3+}

∴ n of Fe^{3+} = n of FeI_3 = 0.2 mol

Molarity of Fe^{3+} = $\frac{0.2}{725 * 10^{-3}}$ = 0.276 M #

→ From the equation: \

1mol of FeI_3 ⟹ 3 mol of I^-

∴ n of I^- = 3n of FeI_3 = $3 * 0.2$ = 0.6 mol

Molarity of I^- = $\frac{0.6}{725 * 10^{-3}}$ = 0.828 M #

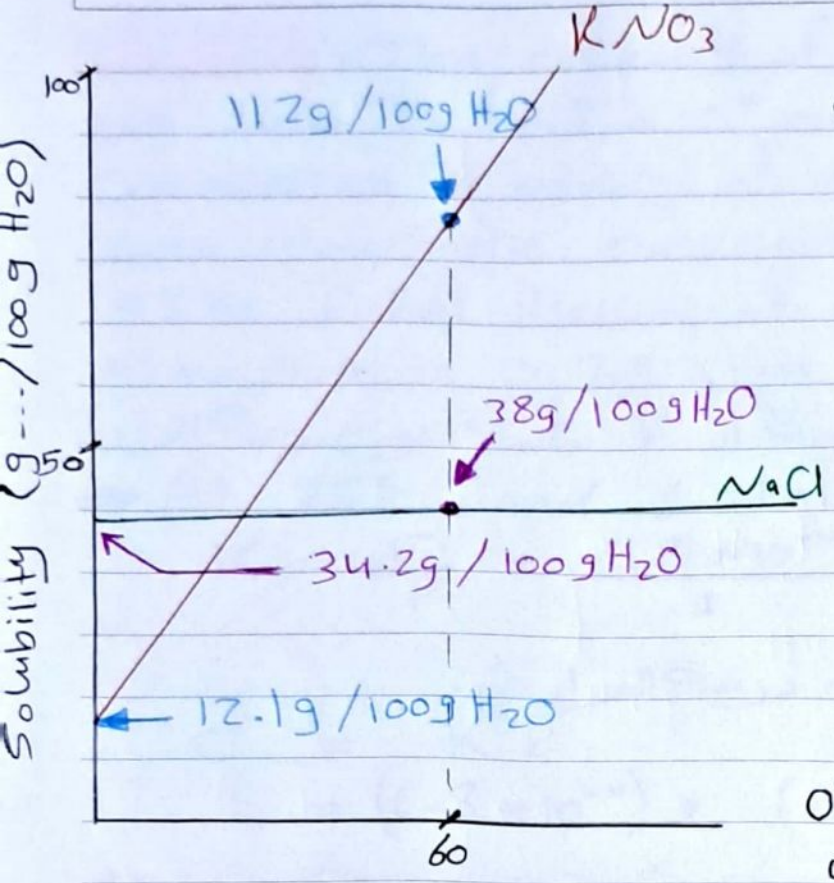
The effect of temperature on solubility

Solubility of a solid increases with temperature.

↳ Exceptions: ⟹ Na_2SO_4 , $Ce_2(SO_4)_3$

* Fractional crystallization: \ is the separating of a mixture of substances into pure components on the basis of their differing solubilities.

* يعني في عملية فصل الخليط الكوني عدة مواد إلى مكوناته النقية "Pure Components" بناءً على الفرق بين درجة الذوبانية لكل مادة .



* على فرض إنو عنّا كمية
90 g of KNO_3 and
10 g of NaCl

← بدي أعملهم فصل باستخدام
Fraction crystallization

1 بذوب العينة في 100ml
من الماء في درجة حرارة 60°C
2 تبريد المحلول ⇐ 0°C

* ذوبانية NaCl عند درجة حرارة 0°C
بتساوي 34.2g/100g ⇐ بالتالي
هيكون كل 10g من NaCl ذائبة

* ذوبانية KNO_3 عند درجة حرارة 0°C بتساوي 12.1g/100g
بالتالي هيذوب فقط 12.1g من KNO_3 وهترسب الكمية المتبقية
$90 - 12 = 78$ g Precipitate of KNO_3

Solubility of gazes ⇒ Decreases with temerature.
ذوابية الغازات تقل مع زيادة الحرارة.

The effect of Pressure on the solubility of gazes

* Henry's Law ∥ The solubility of a gas in a liquid is Proportional to the Pressure of the gas over the Solution.

* يعني الذوابية للغازات في السائل تتناسب طردياً مع الضغط الواقع على سطح المحلول

$$C = KP$$

C: Concentration تركيز الغاز المذاب
K: Constant for each gas
P: Pressure

Question: The solubility of nitrogen gas at 25°C and 1 atm is $6.8 * 10^{-4}$ mol/ℓ. What is the concentration (in molarity) of nitrogen dissolved in water under atmospheric conditions ?

"The Patial Pressure of nitrogen gas in the atmosphere is 0.78 atm.

* فكرة السؤال تعتمد على إنو قيمة الـ K ثابتة بثبوت درجة الحرارة .

→ At 25°C and 1 atm

$$K = \frac{C}{P} = \frac{6.8 * 10^{-4}}{1} = 6.8 * 10^{-4} \ \frac{mol}{L * atm}$$

∴ قيمة K ثابتة بثبوت درجة الحرارة .

$$C = KP$$

$$= (6.8 * 10^{-4}) * (0.78) = 5.3 * 10^{-4} \ M \ \#$$

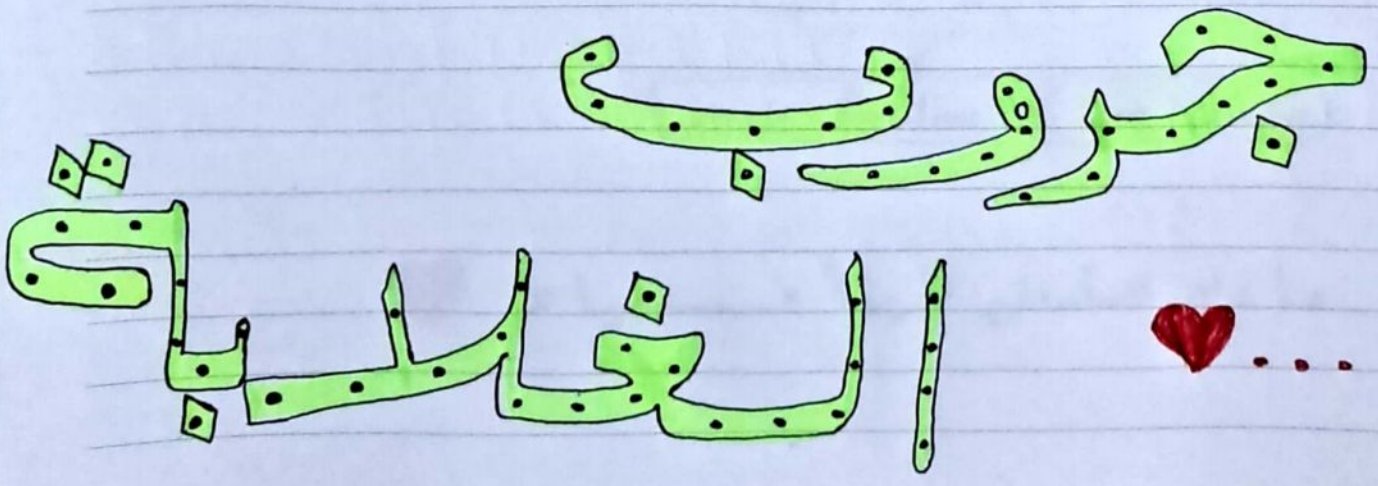
Question: Calculate the concentration of Co_2 in a soft drink after the bottle is opened and equilibrates at 25°C under a Co_2 Patial Pressure of $3 * 10^{-4}$ atm. The Henry's law Constant for Co_2 in water at this temperature is $3.1 * 10^{-2}$ mol/ℓ.atm.

→ $P = 3 * 10^{-4}$ atm , $K = 3.1 * 10^{-2}$ mol/ℓ.atm

$$C = KP = (3.1 * 10^{-2}) * (3 * 10^{-4})$$

$$C = 9.3 * 10^{-6} \ M \ \#$$

* سؤال طويل عريض وحل طريف .....



Colligative Properties of Nonelectrolyte

Colligative Properties: / Properties that depend only on the number of solute particles in solution.

← هي الخواص التي تعتمد فقط على عدد جزيئات المذاب
لا ليس لها علاقة / لا تعتمد على طبيعة المذاب.

Types of solutes

متطاير

Volatile solute

* Does have a measurable Vapor Pressure.
* يتحول بسرعة من الحالة السائلة إلى الحالة الغازية.

Nonvolatile solute

Doesn't have a measurable Vapor Pressure.

Vapor-Pressure lowering: (الضغط قبل إضافة المذاب)

* Raoult's law

$P_1 = \chi_1 P_1^\circ$

- P_1: for the solution
- P_1°: Vapor Pressure of Pure solvent
- χ_1: mole fraction of the solvent

→ If the solution Contains only one solute:

$\Delta P = P_1^\circ - P_1$

$\Delta P = \chi_2 P_1^\circ$

- P_1°: Vapor Pressure of Pure solvent
- χ_2: mole fraction of the solute

ما دام الأمل طريقاً فسنحياه

Question: Calculate the vapor pressure of a solution made by dissolving 218g of glucose (molar mass = 180.2 g/mol) in 460 mL of water at 30°C. H_2O desity = $1 \frac{g}{mL}$
Vapor pressure of H_2O at 30°C is 31.82 mmHg.

n of H_2O → mass of H_2O = Density * Volume
= 1 * 460 = 460 mL

$$n \text{ of } H_2O = \frac{\text{mass}}{\text{molar mass}} = \frac{460}{18} = 25.5 \text{ mol}$$

$$n \text{ of glucose} = \frac{\text{mass}}{\text{molar mass}} = \frac{218}{180.2} = 1.21 \text{ mol}$$

$$\text{mole fraction of the solvent} = x_1 = \frac{25.5}{25.5 + 12.1} = 0.678$$

$$P_1 = x_1 * P_1^\circ$$
$$= 0.678 * 31.82 = 21.58 \text{ mmHg}$$

 # Ideal solution: Any solution that obeys Raoult's law.
* أي محلول ينطبق عليه القانون.
→ ΔH of solution = 0
* التغير في المحتوى الحراري "الإنثالبي" يساوي صفر يعني أثناء عملية تكوين المحلول لا يتم إطلاق أو امتصاص حرارة.

Note → The vapor pressure of solution is Less than a pure solvent because pure solvent has greater order.
يعني بكون الضغط البخاري للمحلول أقل من الضغط البخاري للمذيب بشكل منفرد، لأن المذيب النقي يمتلك ترتيباً أكبر.

 # If the components of solution are Volatile:

$$P_T = x_A P_A^\circ + x_B P_B^\circ$$ → Total Pressure الضغط الكلي

P_A° → P_{1A} , P_B° → P_{1B}

If the Components (A,B) of solution are volatile:

يعني قوى الترابط

$A-B < A-A$ $A-B < B-B$	$A-B > A-A$ $A-B > B-B$
Vapor pressure is grater than predicted by Raoult's Law	Vapor pressure is less than predicted by Raoult's Law
"endothermic"	"exothermic"

Fractional distillation: A Procedure for separating Liquid Components of a solution based on their different boiling points.

* هي عملية فصل مكونات المحلول بناءً على اختلاف درجات الغليان لهم

Boiling - Point elevation

الفرق في درجة الغليان

$\Delta T_b = T_b - T_b^\circ$

T_b: Boiling Point of the solution

T_b°: Boiling Point of the Pure solvent

$\Delta T_b = K_b\, m$

m: molality

K_b: The molal boiling-Point elevation Constant

$T_b > T_b^\circ$

$\Delta T_b > 0$

درجة غليان المحلول أكبر من درجة غليان الـ Pure solvent

Freezing-Point Depression

$\Delta T_f = T_f^\circ - T_f$ ⟹ Freezing-Point of the solution

T_f° ⇓ Freezing Point of Pure solvent

* Another Law ⇒ $\Delta T_f = K_f \, m$ ⟹ molality

K_f ⇓ molal freezing-point depression constant ($^\circ C/m$)

$T_f^\circ > T_f$ $\qquad$ $\Delta T_f = 0$

When Calculating ΔT_b, ΔT_f, we can't use Molarity because it changes with temperature.

Question: Ethylene glycol, CH_2OHCH_2OH, is a common automobile antifreezing. It is water soluble and fairly nonVolatile (b.p = 197 °C). Calculate the freezing point of a solution containing 651 g of this substance in 2505 g of water. molar mas of ethylene glycol = 62.01 g.

* Ethylene glycol = (EG)

⇒ n of EG = $\frac{\text{mass}}{\text{molar mass}} = \frac{651}{62.01} =$ **10.5 mol**

molality = $\frac{\text{n of EG}}{\text{m of } H_2O \text{ (Kg)}} = \frac{10.5}{2505 * 10^{-3}} =$ **4.19 m**

$\Delta T_f = K_f * m = 1.86 * 4.19 = 7.79\,^\circ C$ ← الفرق في درجة التجمد

$\Delta T_f = T_f^\circ - T_f$

T_f of the solution = **−7.79 °C**

#

Questions: What is the freezing-point of a solution containing 478g of ethylene glycol in 3202g of water? The molar mass of ethylene glycol is 62.01g/mol. K_f water = 1.86°C/m

* n of ethylene glycol = $\frac{478}{62.01}$ = **7.7 mol**

molality = $\frac{\text{n of solute}}{\text{m of solvent (Kg)}}$ = $\frac{7.7}{3202 * 10^{-3}}$ = **2.41 m**

$\Delta T_f = K_f m = 1.86 * 2.41 =$ **4.48°C**

$\Delta T_f = T_f^\circ - T_f$

$4.48 = 0^\circ C - T_f \rightarrow$ **∴ $T_f = -4.48^\circ C$** #

Osmotic Pressure (π)

 # Osmosis: is the selective passage of solvent molecules through a porous membrane from a dilute solution to a more concentrated one.

هي عملية مرور جزيئات المذيب خلال جدار نافذ من محلول مخفف إلى محلول أكثر تركيزاً. "عشان يعمل توازن في التركيز"

 # Osmotic Pressure: is the pressure required to stop osmosis.

يعني الضغط اللازم لوقف عملية انتقال المذيب بين المحاليل

$\pi = MRT$ → The temperature (Kelvin)

M → Molarity, R → Gas Constant

* Isotonic * لو كانو المحلولين الهم نفس التركيز بنسميهم

* لو كانوا ملهمش نفس التركيز:

* Hypertonic solution ← الأعلى تركيزاً بنسميه

* Hypotonic solution ← الأقل تركيزاً بنسميه

* Question: A 7.85 g sample of a compound with the empirical formula C_5H_4 is dissolved in 301 g of benzene. The freezing point of the solution is 1.05°C below that of pure benzene. What are the molar mass and molecular formula of this compound?

* $K_f = 5.12\ °C/m$ *

→ mass of solute = 7.85 g

→ mass of solvent = 301 g

بحكيلي درجة تجمد المحلول أقل من تجمد المذيب بـ 1.05 ∴ $\Delta T_f = 1.05°C$

$$\Delta T_f = K_f\, m \Rightarrow m = \frac{\Delta T_f}{K_f} = \frac{1.05}{5.12} = \boxed{0.21\ m}$$

$$\text{molality} = \frac{\text{n of solute}}{\text{m of solvent (Kg)}} \Rightarrow \text{n of solute} = 0.21 * (301 * 10^{-3})$$

∴ n of solute = $\boxed{0.062\ mol}$

$$n = \frac{\text{mass}}{\text{molar mass}} \Rightarrow \text{molar mass} = \frac{7.85}{0.062} = \boxed{127.2\ g/mol}\ \#$$

* Question: The osmotic pressure of blood is 7.65 atm at 37°C. How much of glucose ($C_6H_{12}O_6$) should be added to make an aqueous solution of 1.0 ℓ that has the same osmotic pressure as blood? ($R = 0.082$)

→ $\pi = 7.65$ atm

$$\pi = MRT \Rightarrow M = \frac{\pi}{RT} = \frac{7.65}{0.082 * (37 + 273)}$$

∴ $M = 0.3$ mol/litre

$$M = \frac{n}{\text{Volume}(\ell)} \Rightarrow n = M * V(\ell)$$

$$= 0.3 * 1 = \boxed{0.3\ mol}$$

$$n \text{ of glucose} = \frac{\text{mass of glucose}}{\text{molar mass}}$$

$$\therefore \text{mass} = n * \text{molar mass}$$

$$= 0.3 * 180 = \boxed{54\ g}\ \#$$

Colligative Properties of Electrolyte Solutions

* 0.1m NaCl solution ⟹ 0.1m Na^+ & 0.1m Cl^-
* 0.1m NaCl solution ⟹ 0.2m ions

Van't Hoff factor = $\frac{\text{Actual number of Particles in soln after dissociation}}{\text{number of formula units initially dissolved in solution}}$

ex:\ ① $CaCl_2$ ⟹ ① Ca^{2+} + ② Cl^-

$$\text{Van't Hoff factor} = \frac{1 + 2}{1} = \boxed{3}^{(i)}$$

Question:\ The osmotic pressure of 0.01 M Potassium iodide (KI) solution at 25°C is 0.465 atm. Calculate the Van't Hoff factor (i) for KI at this concentration.

نضيف على القانون (i) لأن KI مركب أيوني و يتجزأ أيونات في المحلول.

$$\pi = iMRT$$

$$i = \frac{\pi}{MRT} = \frac{0.465}{0.01 * 0.082 * (25 + 273)}$$

$$\boxed{i = 1.9}$$

Thanks ♡

عروب الغلاييني