

Exercise 4: Colligative properties

1. **Osmotic pressure:** We can model the nutrient transport system of a plant as a column of water which is in equilibrium with atmospheric pressure.

a. What is the minimum molarity of a sugar solution needed to maintain equilibrium at 20°C?

b. at 0°C?

c. What does this have to do with the fact that though species of maple trees grow all over the world, the best maple syrup comes from mid-continental, high-latitude areas like Vermont or Ontario?

2. **Freezing point depression:** Vapona is the ingredient found in flea collars and pesticide strips. A sample of 0.347 g of vapona was melted together with 35.0 g of camphor, and this mixture was cooled to give a solid. The solid was pulverized and its melting point was found to be 35.99°C. Using the identical thermometer, pure camphor was found to melt at 37.68°C. For camphor, $K_f = 37.7^\circ\text{C}/\underline{\text{m}}$. What is the **molar mass** of vapona?

3. **Boiling point elevation:** A solution of 8.32 g of PABA (para-aminobenzoic acid), a common sunscreen agent, in 150. g of chloroform boiled at 62.62°C. At the same pressure and with the same thermometer, pure chloroform boiled at 61.15°C. What is the **formula weight** of PABA? For chloroform, $K_b = 3.63 \text{ }^\circ\text{C}/\underline{\text{m}}$.

4. **Fractional crystallization:** The solubility of two salts are given in the table below:

	Solubility in water (g solute/100 ml water)		Solubility in ethanol (g solute/100 ml ethanol)
	0°C	100°C	25°C
RbCl	77	138.9	0.08
NaI	150	302	42.57

Suppose you are given a 50/50 (weight/weight) mixture of RbCl/NaI.

a. Will fractional crystallization in water be effective? Why or why not?

b. The table above suggests another way to separate the salts. What is it? Is it more effective than the method in (a)?

5. **Clausius–Clayperon Equation:** From the following data for liquid nitric acid, determine its heat of vaporization and its normal boiling point.

Temperature (°C)	Vapor pressure (mm Hg)
0.	14.4
10.	26.6
20.	47.9
30.	81.3
40.	133
50.	208
80.	670.

Expand the table by adding a “T (K)”, “1/T (K⁻¹)” and “ln P” columns, either on another sheet of paper or on an Excel worksheet. Then plot 1/T (x-axis) versus ln P (y-axis). **Make sure the y-axis of the graph extends to the equivalent of 1 atmosphere of pressure on that axis.** Eyeball and draw a best-fit line to the graphed points, or use a calculator’s linear regression function to determine the equation of the best-fit line, or use the “Add Trendline” function on Excel to draw the best-fit line and display the equation and correlation coefficient of the graphed points. Determine the following (don’t forget units):

a. Nitric acid heat of vaporization = _____

b. Nitric acid normal boiling point = _____

Attach the **worksheet** and **graph** to this handout.

c. Explain why the bold-faced instruction in the paragraph above (a) was necessary.