

Assigned questions for Lecture 16 are listed below. The questions occur in the following editions of “Physical Chemistry” by P.W. Atkins:

10th edition	9th edition	8th edition
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Note: The letter “P” in front of a number indicates that the question is in the “Problem” category as opposed to the “Exercise” category in Atkins’ books. Updates are highlighted in yellow.

Question 16.01

5A.7	5.1	5.1
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Same in all editions

5A.7(a) The partial molar volumes of acetone (propanone) and chloroform (trichloromethane) in a mixture in which the mole fraction of CHCl_3 is 0.4693 are $74.166 \text{ cm}^3 \text{ mol}^{-1}$ and $80.235 \text{ cm}^3 \text{ mol}^{-1}$, respectively. What is the volume of a solution of mass 1.000 kg?

5A.7(b) The partial molar volumes of two liquids A and B in a mixture in which the mole fraction of A is 0.3713 are $188.2 \text{ cm}^3 \text{ mol}^{-1}$ and $176.14 \text{ cm}^3 \text{ mol}^{-1}$, respectively. The molar masses of the A and B are 241.1 g mol^{-1} and 198.2 g mol^{-1} . What is the volume of a solution of mass 1.000 kg?

Question 16.02

5A.8	5.2	5.2
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Same in all editions

5A.8(a) At 25°C , the density of a 50 per cent by mass ethanol–water solution is 0.914 g cm^{-3} . Given that the partial molar volume of water in the solution is $17.4 \text{ cm}^3 \text{ mol}^{-1}$, calculate the partial molar volume of the ethanol.

5A.8(b) At 20°C , the density of a 20 per cent by mass ethanol/water solution is 968.7 kg m^{-3} . Given that the partial molar volume of ethanol in the solution is $52.2 \text{ cm}^3 \text{ mol}^{-1}$, calculate the partial molar volume of the water.

Question 16.03

5A.9	5.3	5.3
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Same questions in all editions.

5A.9(a) At 300 K, the partial vapour pressure of HCl (that is, the partial pressure of the HCl vapour) in liquid GeCl_4 is as follows:

x_{HCl}	0.005	0.012	0.019
$p_{\text{HCl}}/\text{kPa}$	32.0	76.9	121.8

Show that the solution obeys Henry’s law in this range of mole fractions, and calculate Henry’s law constant at 300 K.

5A.9(b) At 310 K, the partial vapour pressure of a substance B dissolved in a liquid A is as follows

x_B	0.010	0.015	0.020
p_B/kPa	82.0	122.0	166.1

Show that the solution obeys Henry's law in this range of mole fractions, and calculate Henry's law constant at 310 K.

Question 16.04

ST5A.2/3	ST5.2	ST7.2
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Same questions in all editions.

Using the Gibbs-Duhem equation:

Check out the worked-through examples (also discussed in class) and try one of the following, depending on what edition you are using:

Self-Test 5.2 (p. 141, Atkins 8th)

Self-Test 5.2 (p. 161, Atkins 9th)

Self-Test 5A.2/3 (p. 184, Atkins 10th)

Question 16.05

5B.1	5.4	5.4
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Same questions, different references back to previous questions.

5B.1(a) Predict the partial vapour pressure of HCl above its solution in liquid germanium tetrachloride of molality 0.10 mol kg^{-1} . For data, see Exercise 5A.10(a).

5B.1(b) Predict the partial vapour pressure of the component B above its solution in A in Exercise 5A.10(b) when the molality of B is 0.25 mol kg^{-1} . The molar mass of A is 74.1 g mol^{-1} .

5.4(a) Predict the partial vapour pressure of HCl above its solution in liquid germanium tetrachloride of molality 0.10 mol kg^{-1} . For data, see Exercise 5.3a.

5.4(b) Predict the partial vapour pressure of the component B above its solution in A in Exercise 3(b) when the molality of B is 0.25 mol kg^{-1} . The molar mass of A is 74.1 g mol^{-1} .

Question 16.06*

n/a	n/a	n/a
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Missing from 8th Ed. onward.

(7.8a, 7th edition) Calculate the cryoscopic and ebullioscopic constants of tetrachloromethane (hint: look up the $\Delta_{\text{vap}}H$ and $\Delta_{\text{fus}}H$, and melting and boiling points, in the back of your book).

(7.8b, 7th edition) Calculate the cryoscopic and ebullioscopic constants of naphthalene.

Question 16.07

5B.2	5.5	5.5
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Same questions in all editions.

5B.2(a) The vapour pressure of benzene is 53.3 kPa at 60.6 °C, but it fell to 51.5 kPa when 19.0 g of a non-volatile organic compound was dissolved in 500 g of benzene. Calculate the molar mass of the compound.

5B.2(b) The vapour pressure of 2-propanol is 50.00 kPa at 338.8 K, but it fell to 49.62 kPa when 8.69 g of a non-volatile organic compound was dissolved in 250 g of 2-propanol. Calculate the molar mass of the compound.

Question 16.08

5B.3	5.6	5.6
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Same questions in all editions.

5B.3(a) The addition of 100 g of a compound to 750 g of CCl₄ lowered the freezing point of the solvent by 10.5 K. Calculate the molar mass of the compound.

5B.3(b) The addition of 5.00 g of a compound to 250 g of naphthalene lowered the freezing point of the solvent by 0.780 K. Calculate the molar mass of the compound.

Answers

(7.8a, 7th edition) 5.22 K/(mol kg⁻¹); 32 K/(mol kg⁻¹)

(7.8b, 7th edition) 7.1 K/(mol kg⁻¹); 5.0 K/(mol kg⁻¹)

A-list answers for the 9th edition:

5.1 886.8 cm³

5.2 56.3 cm³ mol⁻¹

5.3 $K_B \approx 6.4 \times 10^3$ kPa

5.4 1.3×10^2 kPa

5.5 $M_A = 82$ g mol⁻¹

5.6 381 g mol⁻¹

Answer 16.06*

n/a	n/a	n/a
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Missing from 8th Ed. onward.

E7.8(a) Because the mole fraction of B is small,

$$x_B = \frac{n_B}{n_A + n_B} \approx \frac{n_B}{n_A}$$

The amount of solvent molecules in 1 kg of solvent of molar mass M is

$$n_A = \frac{1 \text{ kg}}{M}$$

Therefore,

$$x_B = \frac{n_B}{n_A} = n_B \times \frac{M}{1 \text{ kg}} = b_B \times M$$

where b_B is the molality of B. Hence, from eqn 6.34,

$$\Delta T = \left(\frac{RT^*{}^2 M}{\Delta_{\text{vap}} H} \right) b_B$$

and we can identify the ebullioscopic constant as

$$\begin{aligned} K_b &= \frac{RT^*{}^2 M}{\Delta_{\text{vap}} H} \\ &= \frac{(8.314 \text{ J K}^{-1} \text{ mol}^{-1}) \times (349.9 \text{ K})^2 \times (153.81 \times 10^{-3} \text{ kg mol}^{-1})}{30.0 \times 10^3 \text{ J mol}^{-1}} \\ &= \boxed{5.22 \text{ K}/(\text{mol kg}^{-1})} \end{aligned}$$

$$\begin{aligned} K_f &= \frac{RT^*{}^2 M}{\Delta_{\text{fus}} H} \text{ [by analogy with the above]} \\ &= \frac{(8.314 \text{ J K}^{-1} \text{ mol}^{-1}) \times (250.3 \text{ K})^2 \times (153.81 \times 10^{-3} \text{ kg mol}^{-1})}{2.47 \times 10^3 \text{ J mol}^{-1}} \\ &= \boxed{32 \text{ K}/(\text{mol kg}^{-1})} \end{aligned}$$

$$\begin{aligned} \text{E7.8(b)} \quad K_f &= \frac{RT^*{}^2 M}{\Delta_{\text{fus}} H} = \frac{8.314 \text{ J K}^{-1} \text{ mol}^{-1} \times (354 \text{ K})^2 \times 0.12818 \text{ kg mol}^{-1}}{18.80 \times 10^3 \text{ J mol}^{-1}} \\ &= \boxed{7.1 \text{ K kg mol}^{-1}} \end{aligned}$$

$$\begin{aligned} K_b &= \frac{RT^*{}^2 M}{\Delta_{\text{vap}} H} = \frac{8.314 \text{ J K}^{-1} \text{ mol}^{-1} \times (490.9 \text{ K})^2 \times 0.12818 \text{ kg mol}^{-1}}{51.51 \times 10^3 \text{ J mol}^{-1}} \\ &= \boxed{4.99 \text{ K kg mol}^{-1}} \end{aligned}$$