# Increasing Student Retention with Interactive Self-Study Modules

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Over 90 self-study modules for chemical engineering courses are available at https://LearnChemE.com/. They incorporate approaches that have been shown to increase learning: self-testing, interactivity, short screencasts with inserted questions, conceptual questions, simulations that ask students to predict behavior, example problems, and feedback. Most modules contain the following.

### Interactive Self-Study Module: Raoult's Law and Vapor-Liquid Equilibrium

**Overview:**

This module uses screencasts and interactive simulations to explain the vapor-liquid phase equilibrium of two liquids that form an ideal solution. Both pressure-composition and temperature-composition diagrams are explained. It then provides step-by-step quiz simulations and example problems to allow the user to test themselves. Your retention of material in this module will increase if you write down reasons for your answers to ConcepTests, questions in screencasts, and questions to answer before using interactive simulations, and you try to solve the example problems before watching the screencast solutions. We suggest using the learning resources in the following order:

1. Attempt to answer the multiple choice ConcepTest and solve the example problem before watching the screencasts or working with the simulations.
2. Watch the screencast that describes the phase diagrams and answer the questions within the screencast.
3. Use the interactive simulations to further understand the behavior of the phase diagrams.
4. Use the quiz interactive simulation(s) to test your understanding by carrying out step-by-step preparation of phase diagrams.
5. Try to solve the example problems before watching the solutions in the screencasts.
6. Answer the ConcepTests.
7. Look at the list of key points, but only after you try to list the key points yourself.

**Motivation:**

- The differences in compositions of liquid and vapor mixtures in equilibrium is the basis for the separation of mixtures by distillation.
- This module is intended for material and energy balances, thermodynamics, and separations courses.

**Before studying this module, you should be able to:**

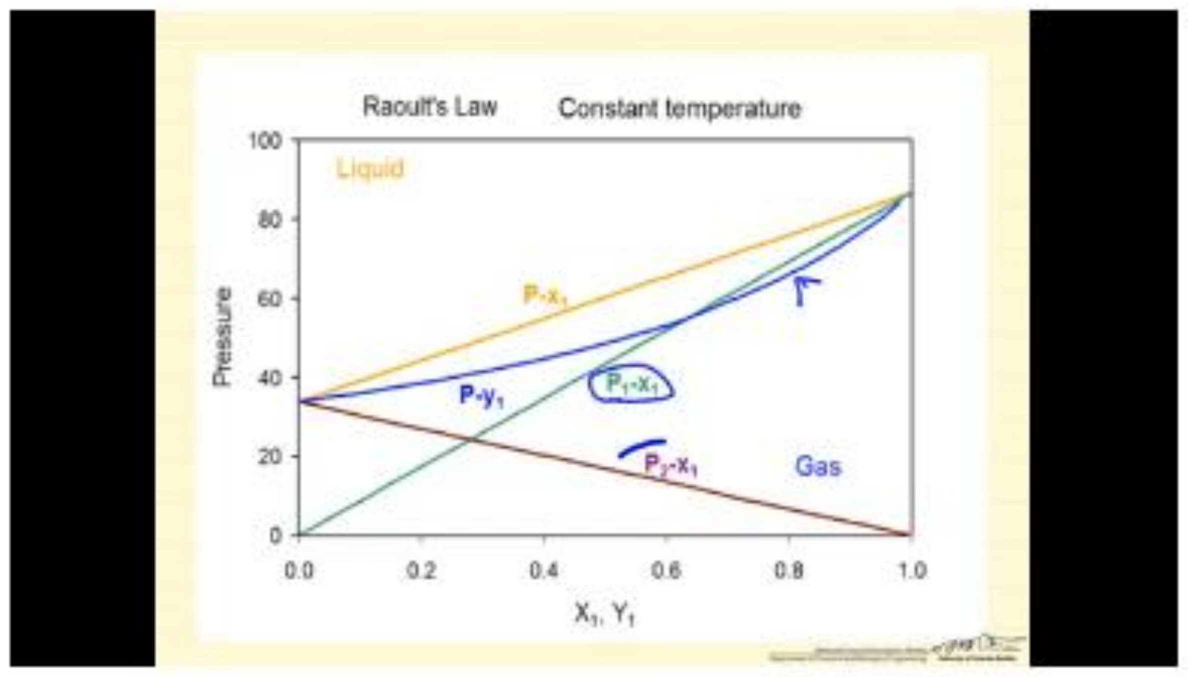
- Explain single-component vapor-liquid equilibrium.
- Apply the Antoine equation to determine saturation pressure of a single component at a given temperature.
- Calculate partial pressures for a mixture of ideal gases.

← **Overview:** goals, pre-requisites, links to other pages

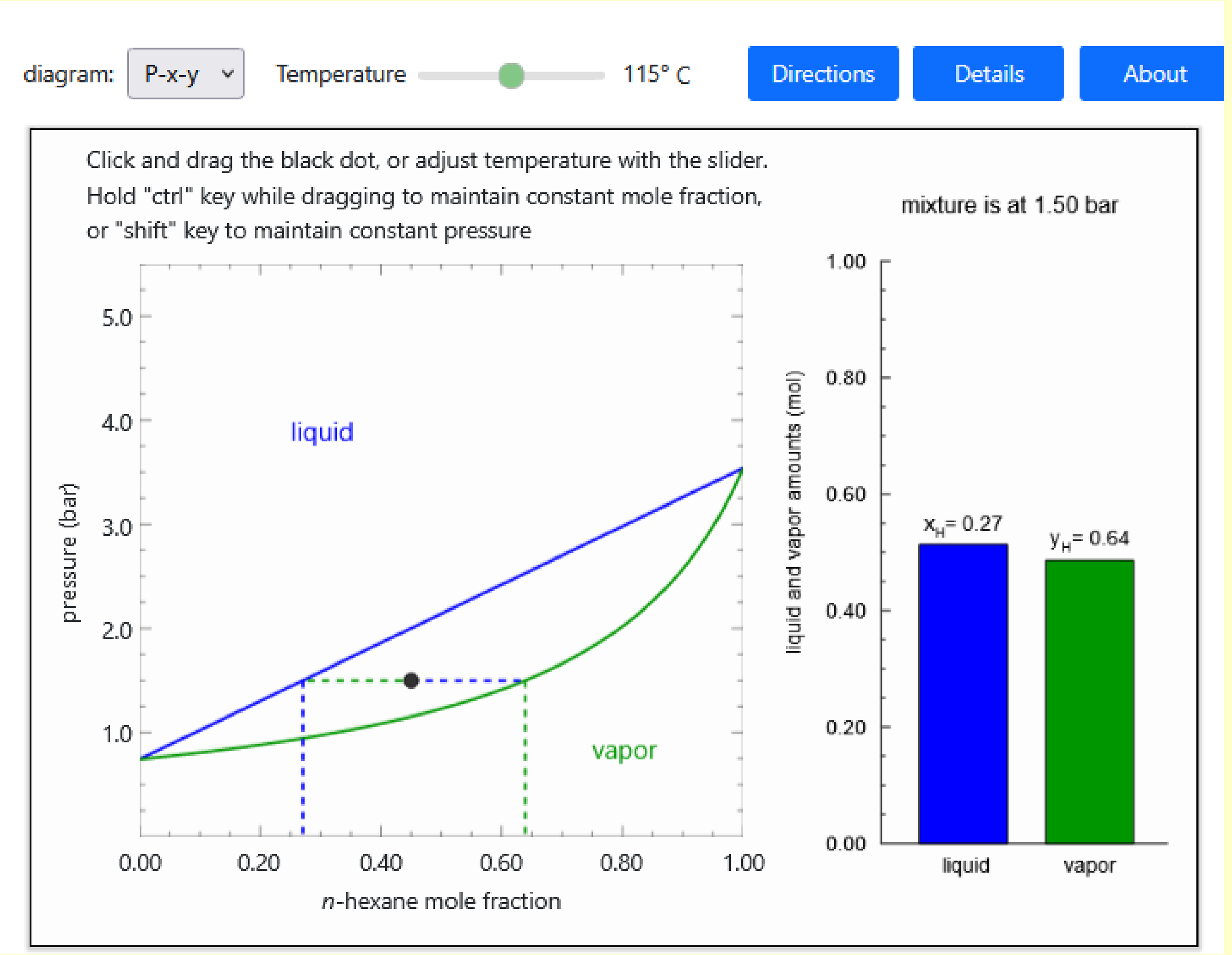
**ConcepTest and example problem** (not shown): attempting to answer questions before using module improves retention.

**Screencasts and Important Equations:** → introductory screencasts with inserted questions; equations and explanation of symbols

Explains the shapes of the P-x-y and the T-x-y diagrams using Raoult's Law.




We suggest you list the important points in this screencast as a way to increase retention.




← **Simulations:** asks students to predict behavior before using the simulations; screencasts describe simulation use

**Quiz-yourself simulations** (not shown): leads students through step-by-step tutorial with feedback.

### Example Problem 1

Calculate the bubble temperature at 85 kPa for a binary liquid with $x_1 = 0.40$. The liquid solution is ideal. The saturation pressures are ($T$ in °C):

$$P_1^{sat} = exp(14.3 - \frac{2945}{T + 224}) \qquad P_2^{sat} = exp(14.2 -$$

Bubble temperature calculation

Calculate the bubble temperature at 85-kPa pressure for a binary liquid with $x_1 = 0.40$. The liquid solution is ideal. The saturation pressures are:

$P_1^{sat} = exp[14.3-2945/(T + 224)]$   T in °C
$P_2^{sat} = exp[14.2-2943/(T + 209)]$

$y_1 = \frac{x_1 P_1^{sat}}{P}$   $y_2 = \frac{x_2 P_2^{sat}}{P}$

$y_1 + y_2 = 1$   T in solver

**Example Problems:** asks user to solve → problems before watching screencast solutions

A liquid mixture containing species A and B is boiled by increasing the temperature at constant pressure. The saturation pressure is greater for A than for B.
What happens?

A. $x_A$ increases and $y_A$ increases
B. $x_A$ increases and $y_A$ decreases
C. $x_A$ decreases and $y_A$ decreases
D. $x_A$ decreases and $y_A$ increases

← **ConcepTests:** 2 questions that user should now know how to answer

### Raoult's Law and Vapor-Liquid Equilibrium: Summary

The answers to the ConcepTests are given below and will open in a separate window.
ConcepTest 1 Answer
ConcepTest 2 Answer

**Key points from this module:**

- Raoult's law assumes ideal gases and ideal liquid solution. For similar molecules (e.g., n-hexane and n-octane), Raoult's law may be a good approximation.
- When a vapor mixture is cooled or its pressure is increased, both components condense.
- Bubble pressure is the pressure where the first bubble of vapor forms as the pressure above a liquid decreases at constant temperature.
- Bubble temperature is the temperature where the first bubble of vapor forms as the temperature of a liquid increases at constant pressure.
- Dew pressure is the pressure where the first drop of liquid forms as the pressure of a vapor increases at constant temperature.
- Dew temperature is the temperature where the first drop of liquid forms as the temperature of a vapor decreases at constant pressure.
- Unlike a pure component, at constant pressure a mixture does not evaporate at constant temperature.

**From studying this module, you should now be able to:**

- Given a vapor composition and saturation pressure versus temperature data, determine the dew temperature (at constant pressure) or the dew pressure (at constant temperature).
- Given a liquid composition and saturation pressure versus temperature data, determine the bubble temperature (at constant pressure) or the bubble pressure (at constant temperature).
- Use Raoult's law to calculate equilibrium compositions and/or equilibrium pressures for ideal solutions and ideal gases.

**Summary:** ConcepTest answers and → explanations; key points from module

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