EngrD 2190 – Lecture 22

Concept: Process Analysis - Graphical Modeling

Context: Combined Mass & Energy Balances for Binary Mixtures:
Enthalpy-Composition (H-(x,y)) Maps

Defining Question: What are the differences between tie lines, mixing lines, and isotherms?

Read Chapter 4, pp. 267-272. Lecture 23 will follow the textbook.

Bring a Straightedge or Ruler to Lecture 23.

EngrD 2190 – Lecture 22

Homework 6 due today at noon.

Write team code and names of all *contributing* team members on all solutions. Indicate this week's Team Coordinator.

Submit *after* lecture or deliver to the EngrD 2190 mailbox in a cabinet in the hallway outside 116 Olin Hall (ChemE Business Office). **Not to my mailbox.**

Prelim 2

- Prelim 2: Thursday 10/30, 7:30-9:30 p.m., 245 and 128 Olin Hall

  Mathematical Modeling:

  energy balances and process economics

  mass balances on spreadsheets

  Graphical Modeling:

  graphical energy balances: energy lines.

  flash drums: T-(x,y) and P-(x,y) phase maps.

  Design using single-stage units (*L*-*V*, *L*-*L*, and *S*-*L* separators) with T-(x,y) and P-(x,y) phase maps.

  Open notes and open exercise solutions.

  Bring a calculator and a ruler. Graphing calculators are allowed.

- Practice exercises: 3.74, 3.76, and 3.79 – energy balances

  3.96, 3.97, and 3.99 – process economics

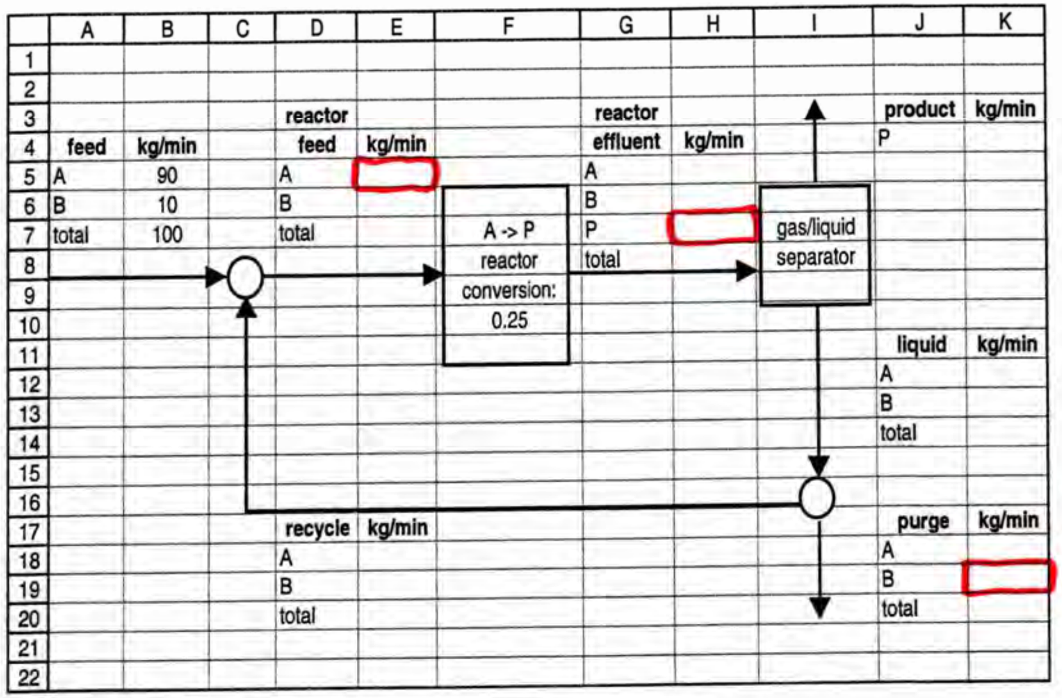
  4.3, 4.7, and 4.88 – graphical energy balances

  4.89 and 4.90 – design with flash drums

  Solutions are posted.

Example Spreadsheet Question for Prelim 2

2. (10 pts) We wish to use a spreadsheet to analyze a process that converts A to P. The reactant A is available as a mixture of 90 wt % A, 10 wt % B. Impurity B is inert in the reactor.



(A) Write the formula one would enter in cell E5, the flow rate of A in the reactor feed. If you use a language other than Excel, state the language.

(B) The reactor conversion is entered in cell F10. A conversion of 0.25 appears in cell F10, but we will want to change this in our simulations. Write the formula one would enter in cell H7, the flow rate of P in the reactor effluent.

(C) To remove B, 5% of the liquid from the gas/liquid separator will be purged. Write the formula one would enter in cell K19, the flow rate of B in the purge.

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Cornell NiCE Speaker Series

GRANT MILLS
US DEPARTMENT OF ENERGY

Grant Mills is a Technical Analyst in the U.S. Department of Energy's Grid Deployment Office, where his work helps keep nuclear power plants financially viable and provides guidance on how energy markets function. While studying at the UC Berkeley, he co-founded the first NICE club and conducted research on nuclear fuel recycling.

October 28 5-6 PM

Statler Hall, Room 445

PRINCIPAL INVESTIGATOR

2006 B.S. ChemE, Cornell

2007-2008 ExxonMobil Research & Engineering, Fairfax VA

2008-2012 PhD student in Nuclear Engineering, UC Berkeley

2012-2018 Assistant Professor, Engineering Physics, Wisconsin

2018-2023 Assistant Professor, Nuclear Engineering, UC Berkeley

2023- Associate Professor, Nuclear Engineering, UC Berkeley

Raluca O. Scarlat

scarlat@berkeley.edu

Professor Raluca O. Scarlat is an Associate Professor in the Nuclear Engineering Department at University of California Berkeley. Prof. Scarlat's research encompasses chemistry and materials for nuclear fusion and fission nuclear energy, as well as batteries, and critical minerals. Prof. Scarlat has expertise in electrochemistry and physical chemistry, corrosion, advanced nuclear reactors, reactor safety and thermal-hydraulics, and engineering ethics.


CINEMA
CINEMA
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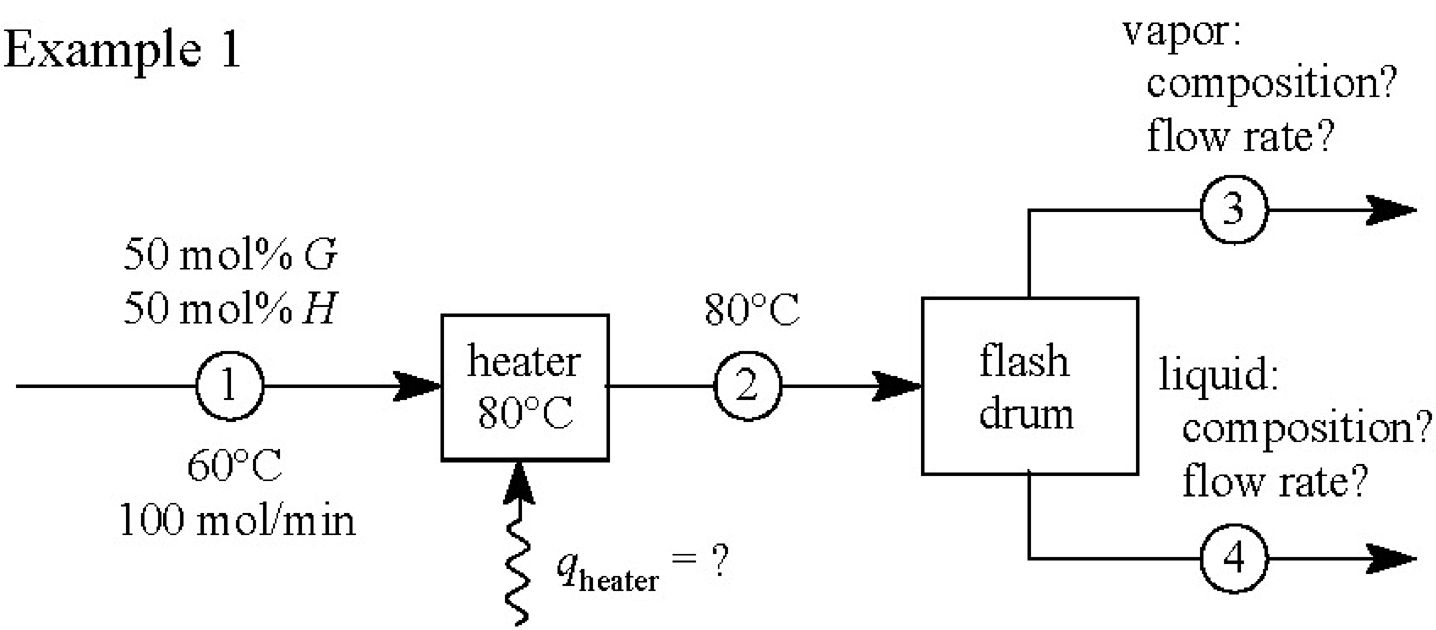
AIChE x ChemE Car Horror Movie Night
25 OCT
8 PM
FREE SNACKS AND DRINKS
145 Olin Hall
TAKE

Recap from Lecture 21

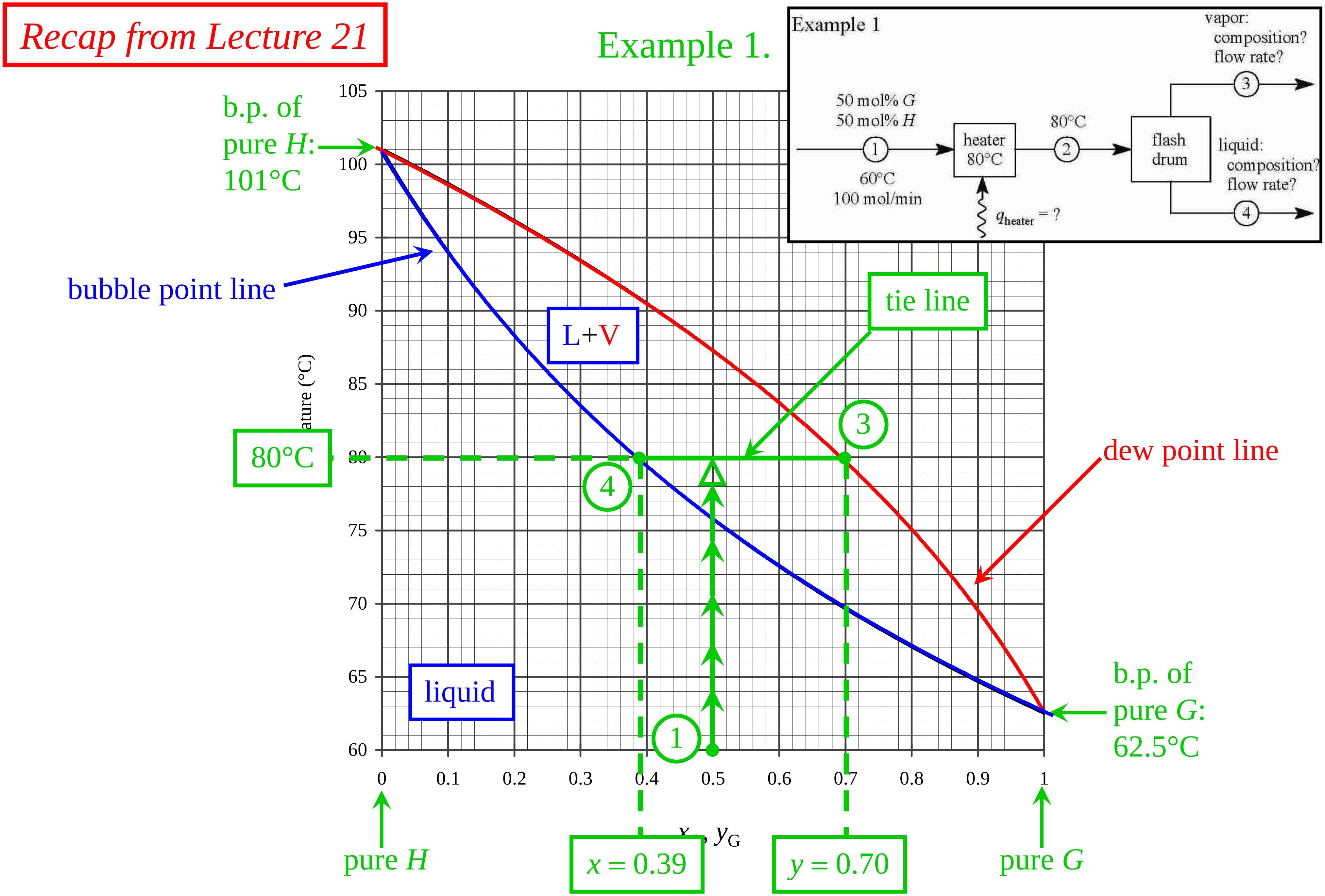
Combined Mass & Energy Balances on Binary Mixtures

Graphical Methods Examples

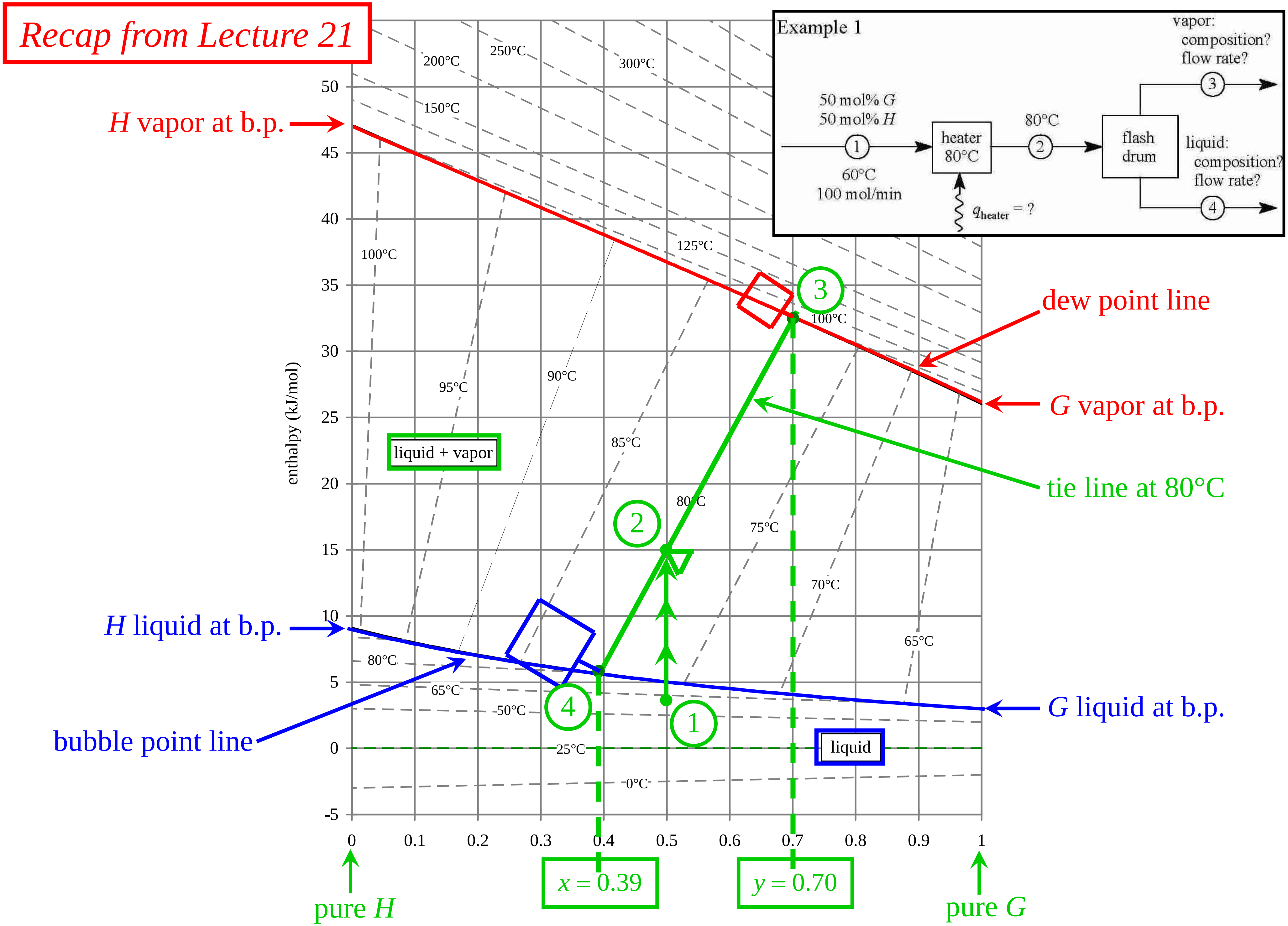
Example 1



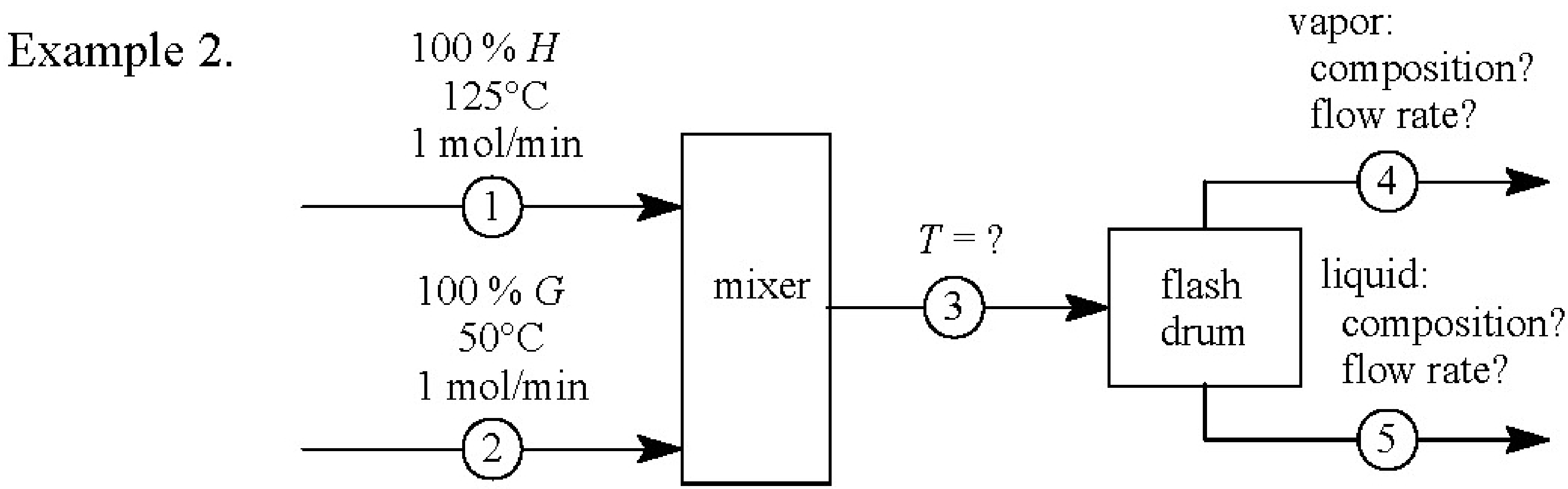
Temperature-Composition Phase Diagram for *G*+*H* Mixtures at 1 atm



Enthalpy-Composition Phase Diagram for G+H Mixtures at 1 atm



Graphical Energy Balance – Example 2



Enthalpy-Composition Phase Diagram for *G*+*H* Mixtures at 1 atm

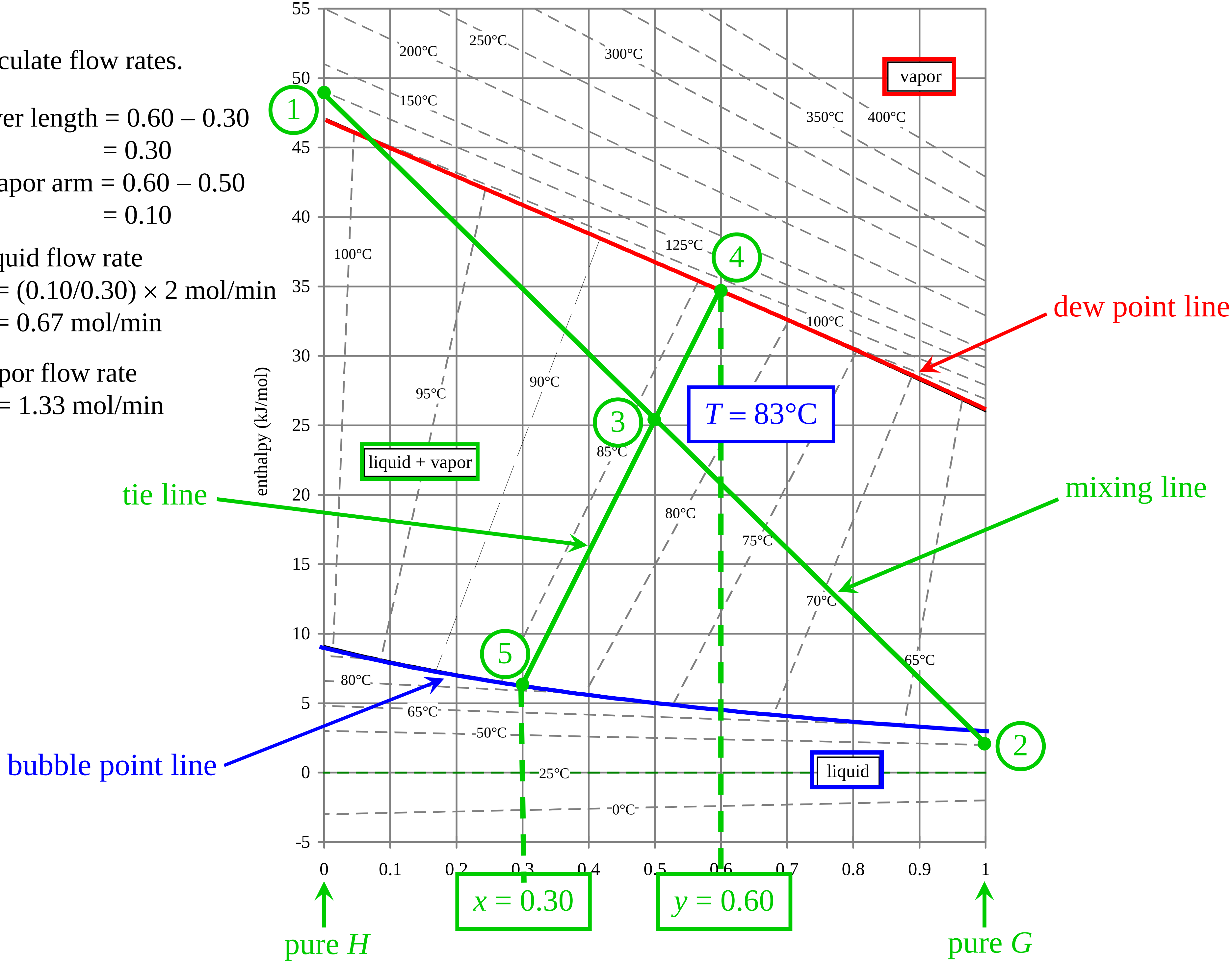
Calculate flow rates.

Lever length = 0.60 – 0.30
= 0.30

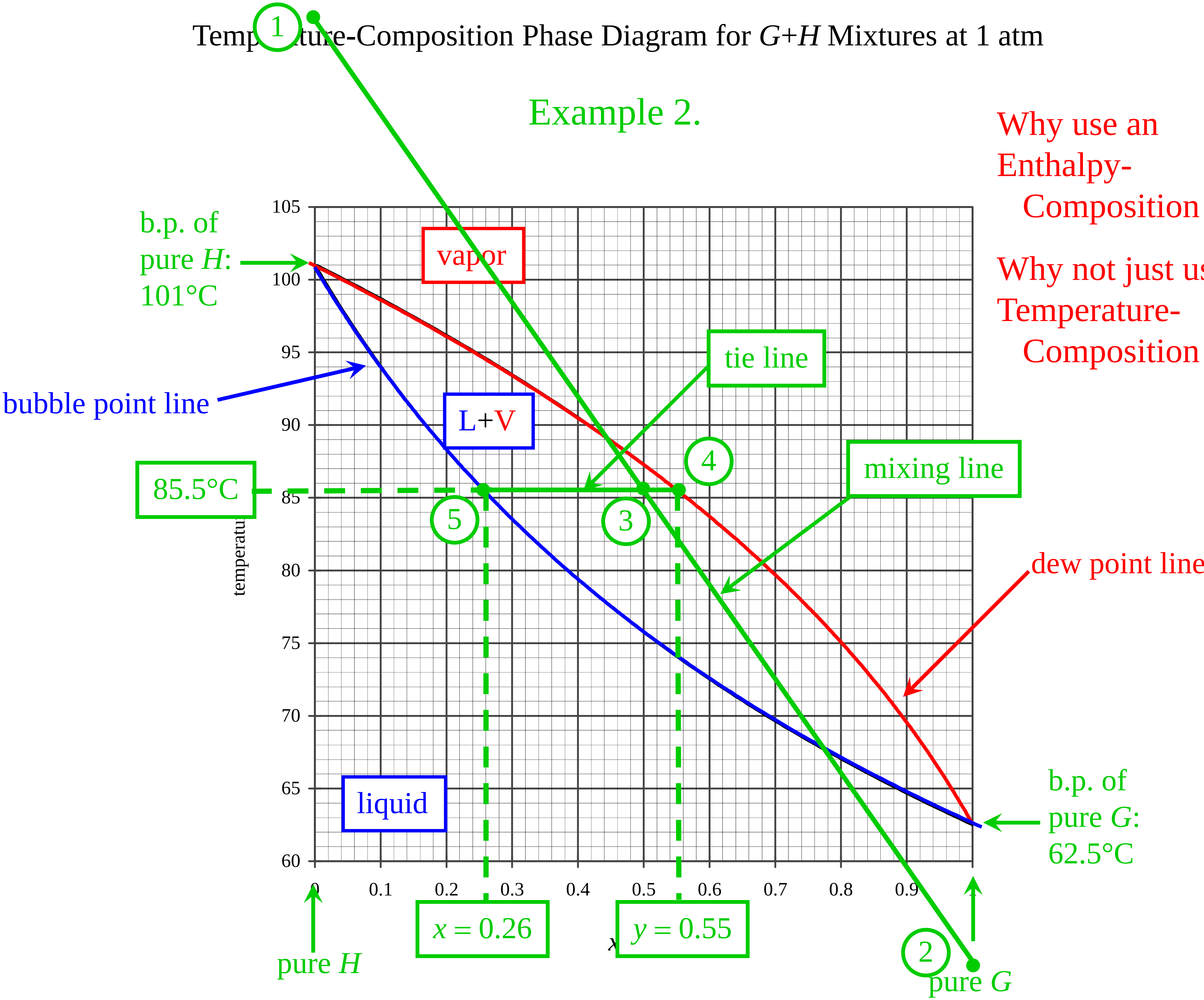
Vapor arm = 0.60 – 0.50
= 0.10

Liquid flow rate
= (0.10/0.30) × 2 mol/min
= 0.67 mol/min

Vapor flow rate
= 1.33 mol/min



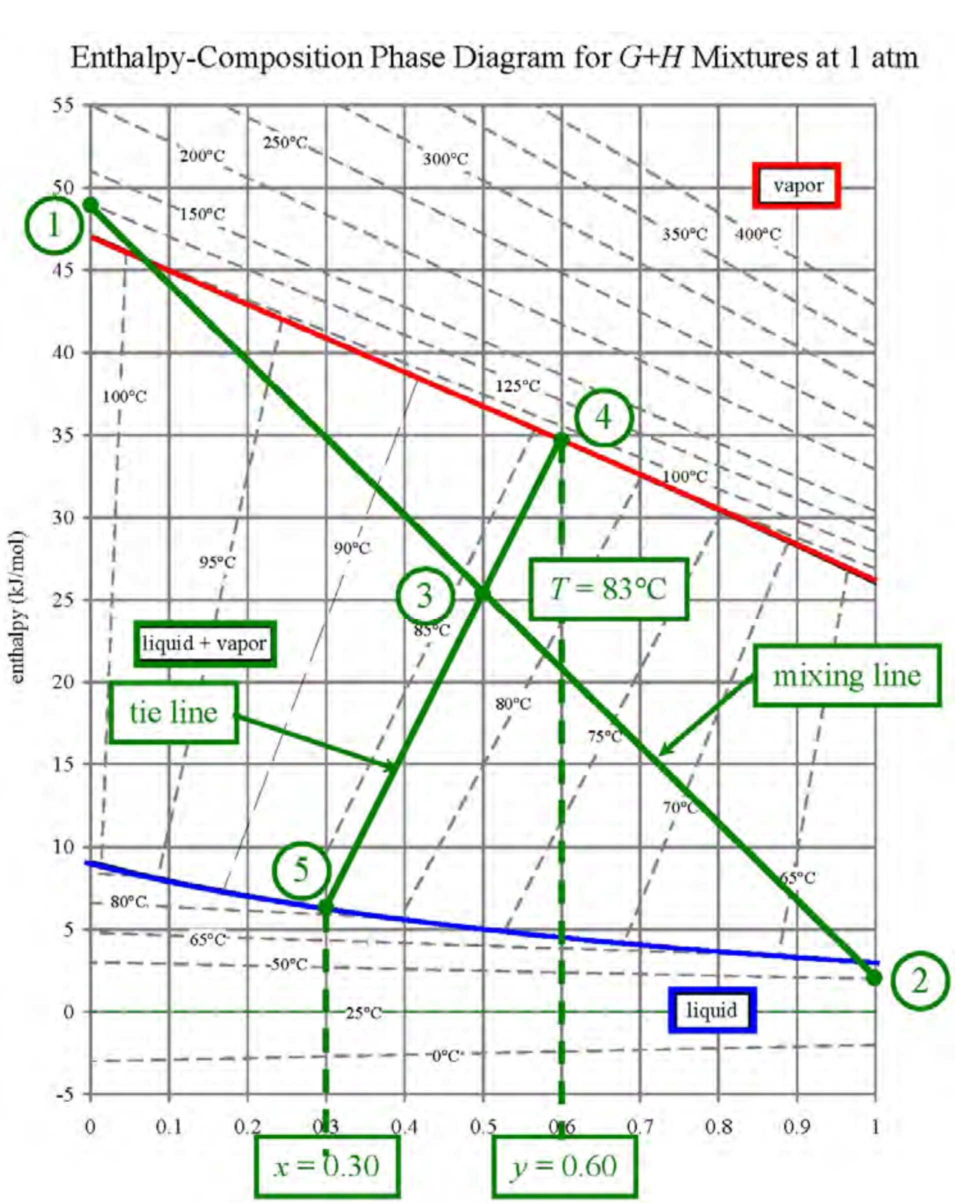
Example 2.



Why use an Enthalpy-Composition map?

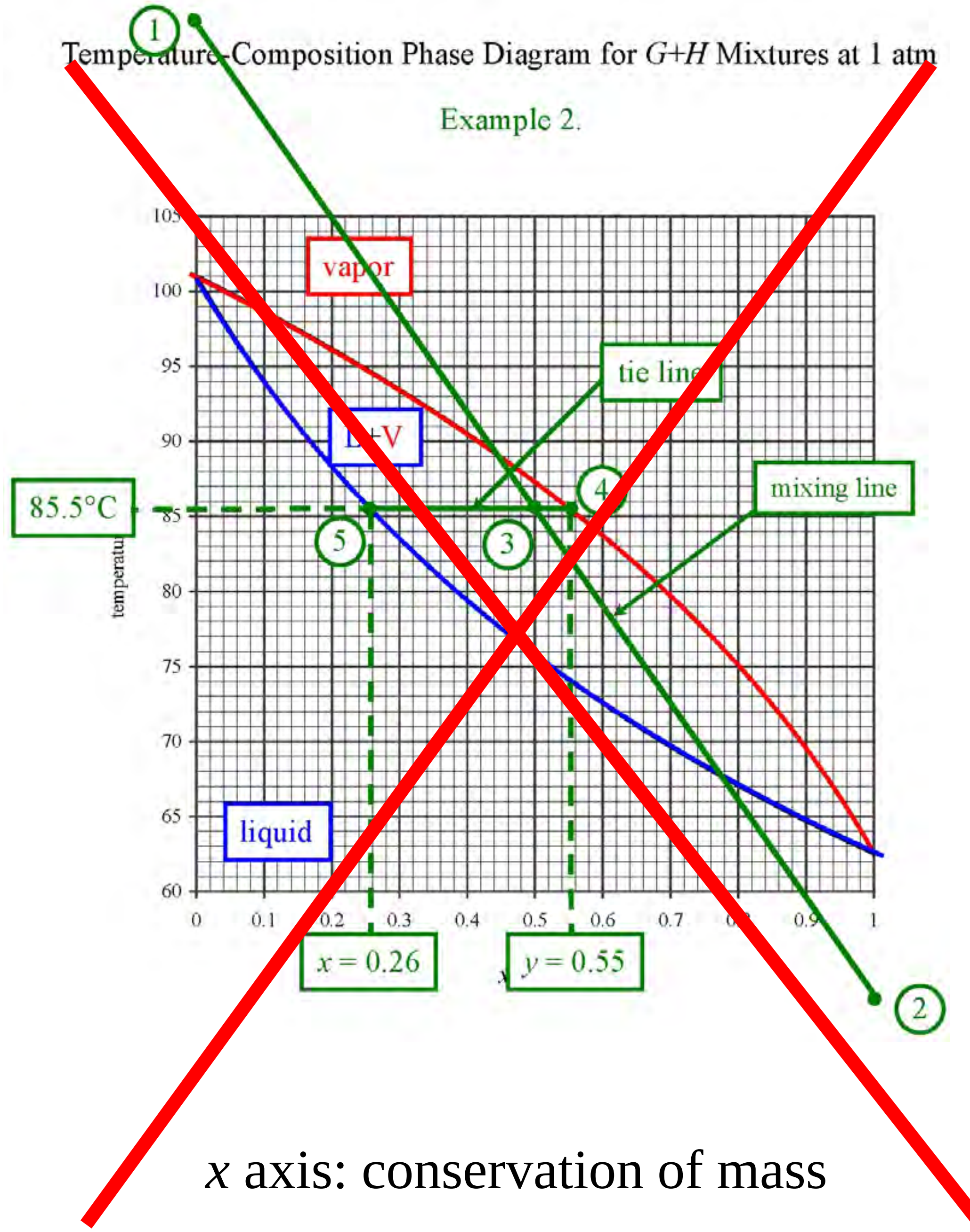
Why not just use a Temperature-Composition map?

Which is correct?



x axis: conservation of mass

y axis: conservation of energy

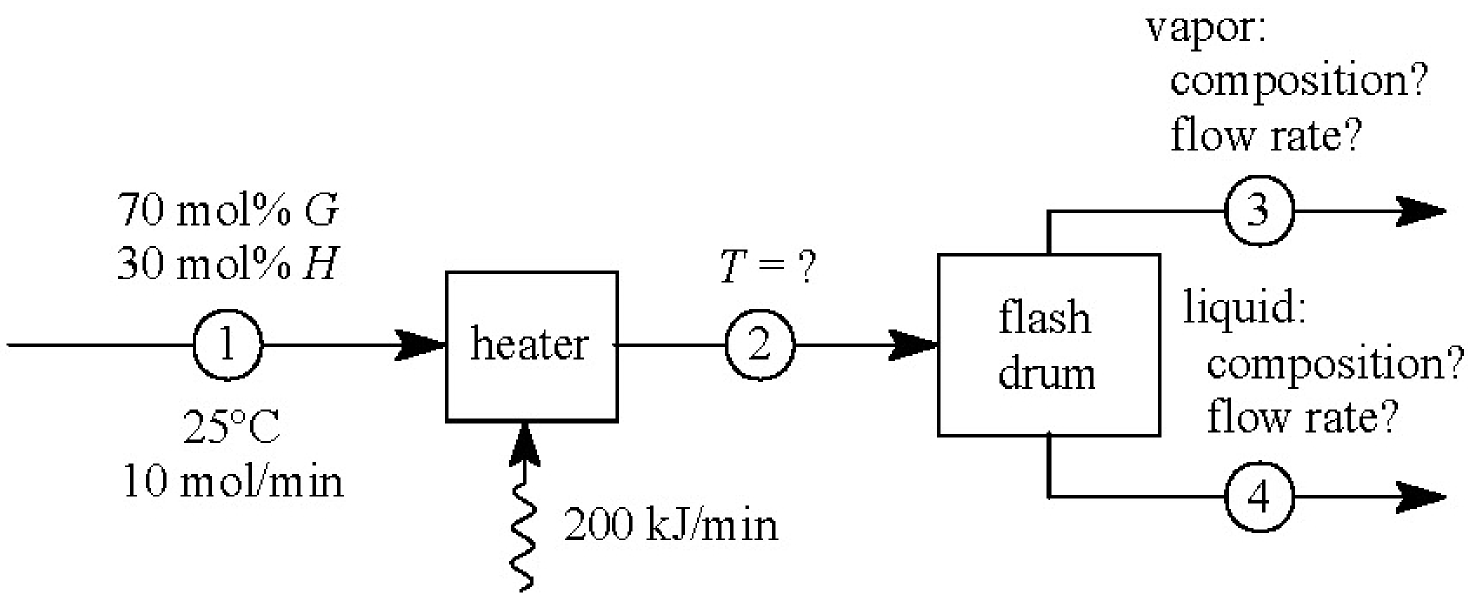


x axis: conservation of mass

~~y axis: conservation of temperature~~

Graphical Energy Balance – Example 3

Example 3.



Enthalpy-Composition Phase Diagram for $G+H$ Mixtures at 1 atm

Need *specific* energy

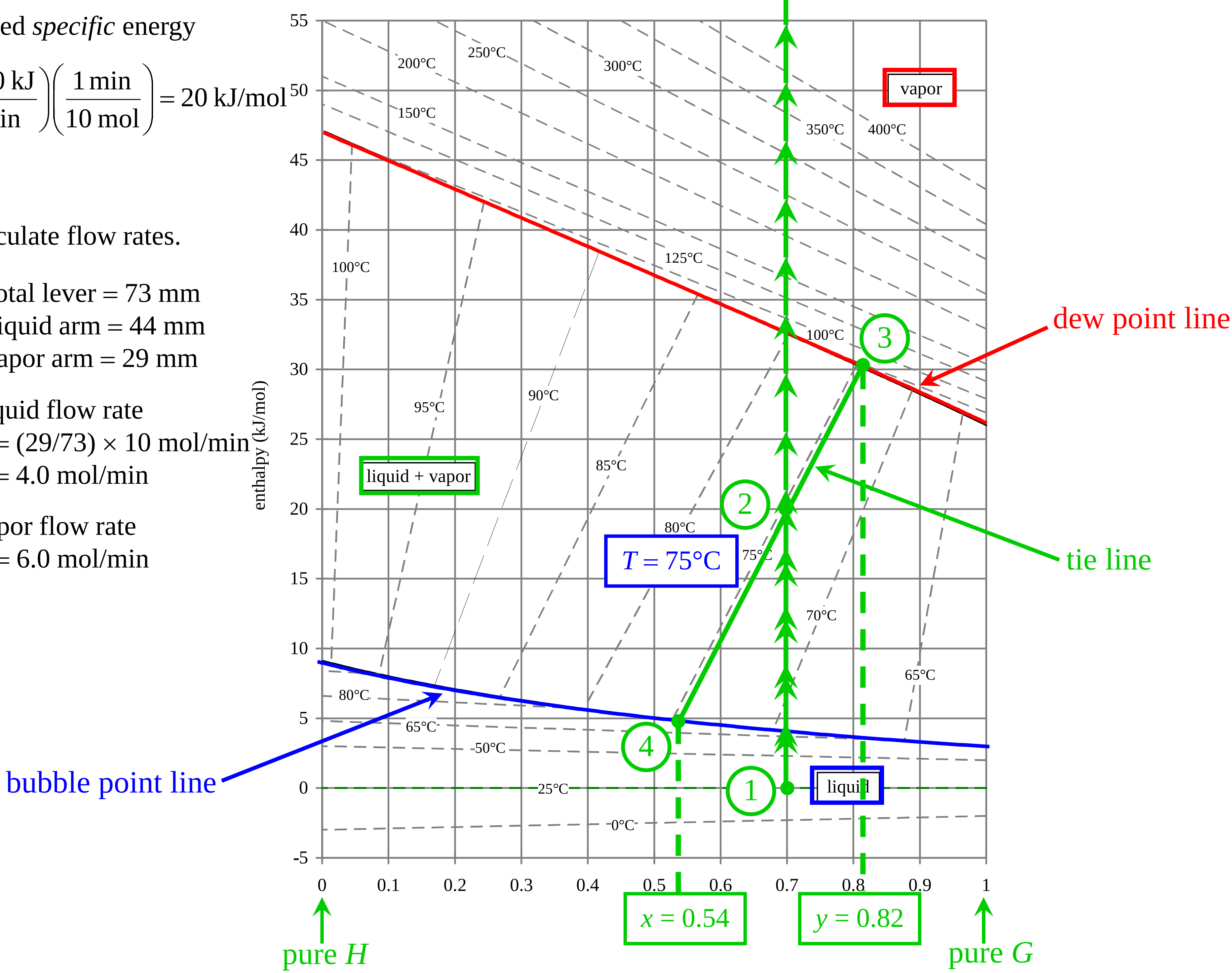
$$\left(\frac{200\ \text{kJ}}{\text{min}}\right)\left(\frac{1\ \text{min}}{10\ \text{mol}}\right) = 20\ \text{kJ/mol}$$

Calculate flow rates.

Total lever = 73 mm
Liquid arm = 44 mm
Vapor arm = 29 mm

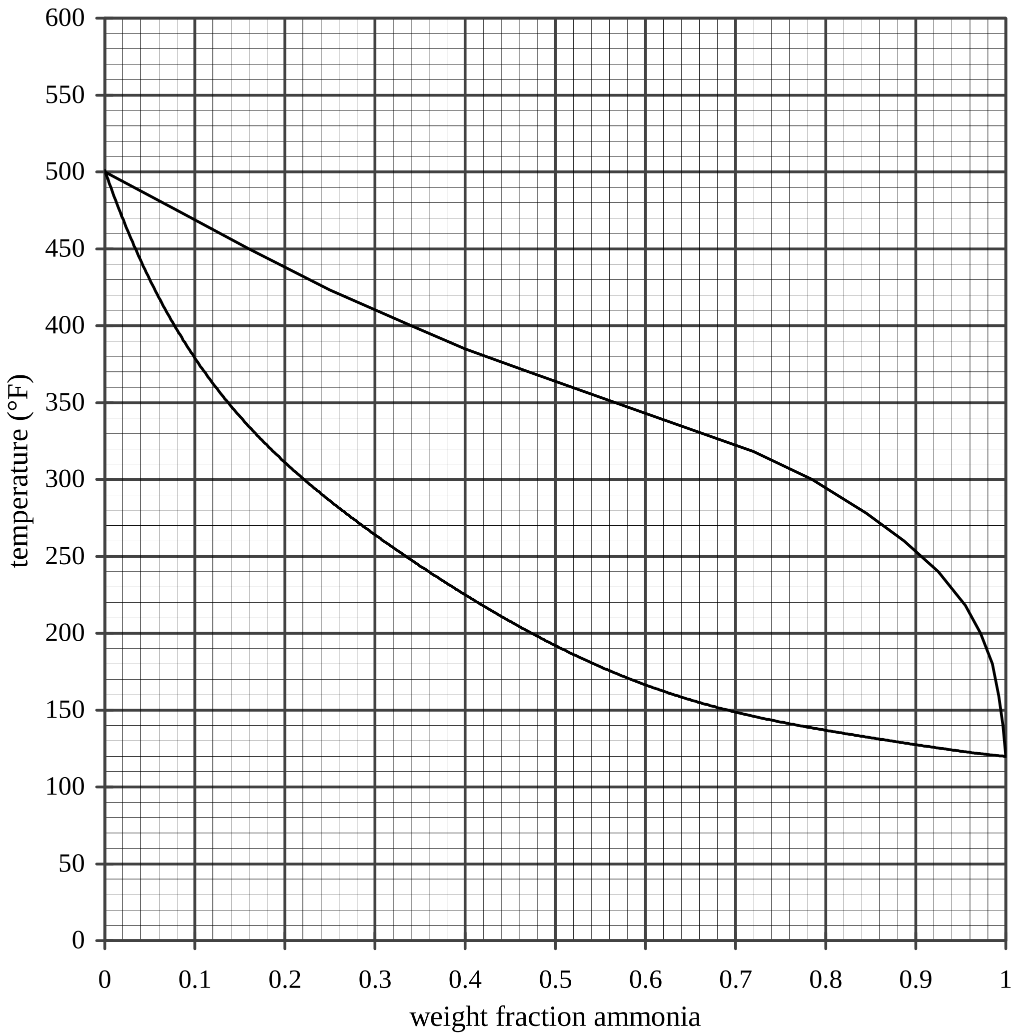
Liquid flow rate
= (29/73) × 10 mol/min
= 4.0 mol/min

Vapor flow rate
= 6.0 mol/min



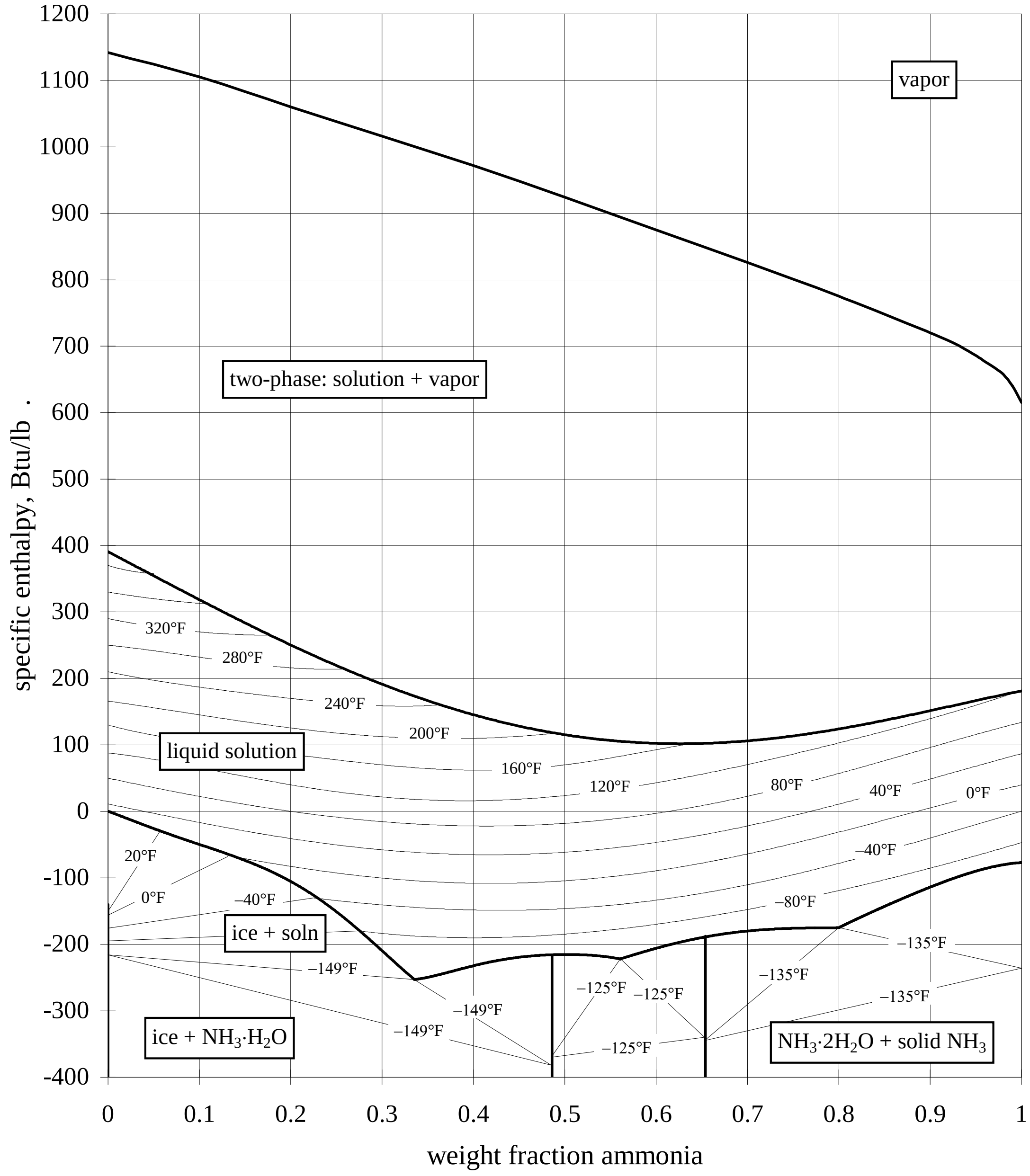
Non-ideal Mixtures

Temperature-Composition Phase Diagram for Ammonia+Water Mixtures at 300 psia (20.4 atm)



Non-ideal Mixtures

Enthalpy-Composition Phase Diagram for Ammonia+Water Mixtures at 300 psia (20.4 atm)

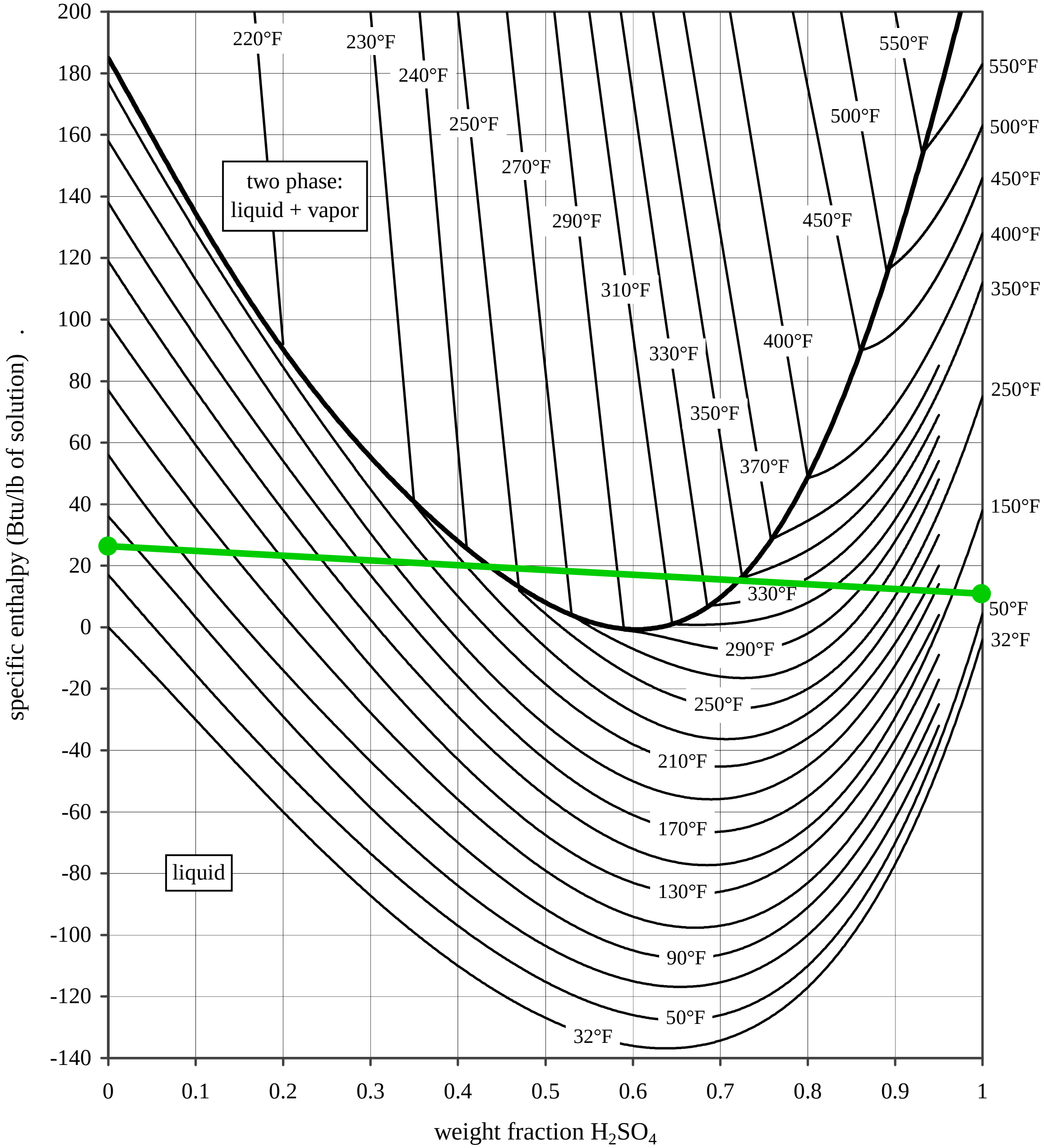


Non-ideal Mixtures

Enthalpy-Composition Phase Diagram for Water+Sulfuric Acid Mixtures at 1 atm.

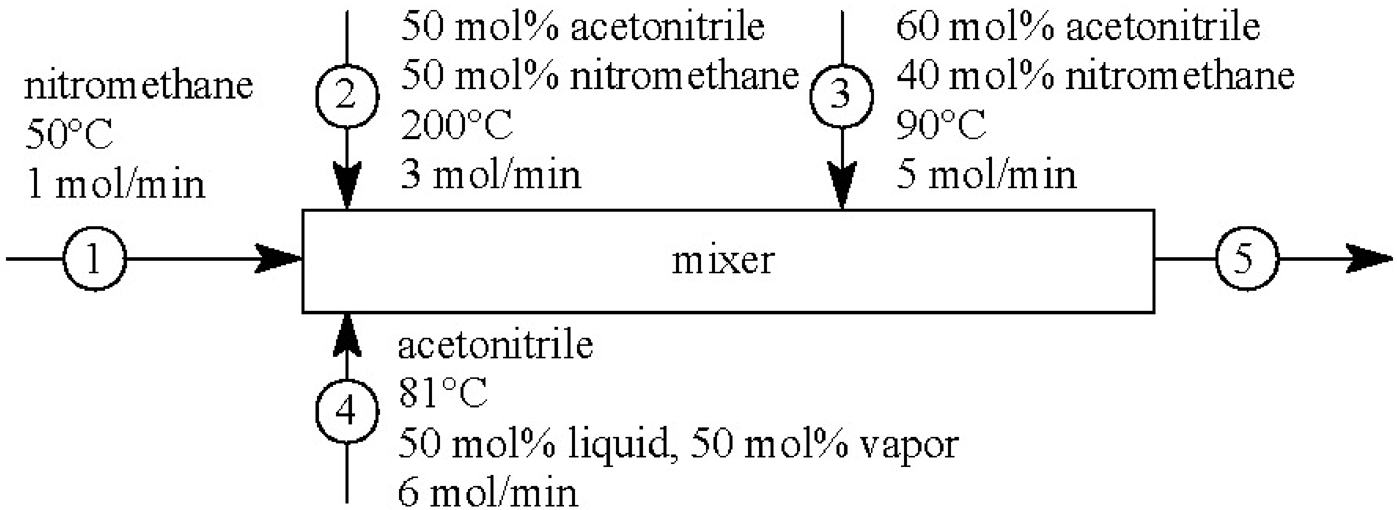
Mixing liquid sulfuric acid at 70°F with water at 70°F creates liquid+vapor: *a boiling mixture*.

“Do what you oughter, add acid to water.”



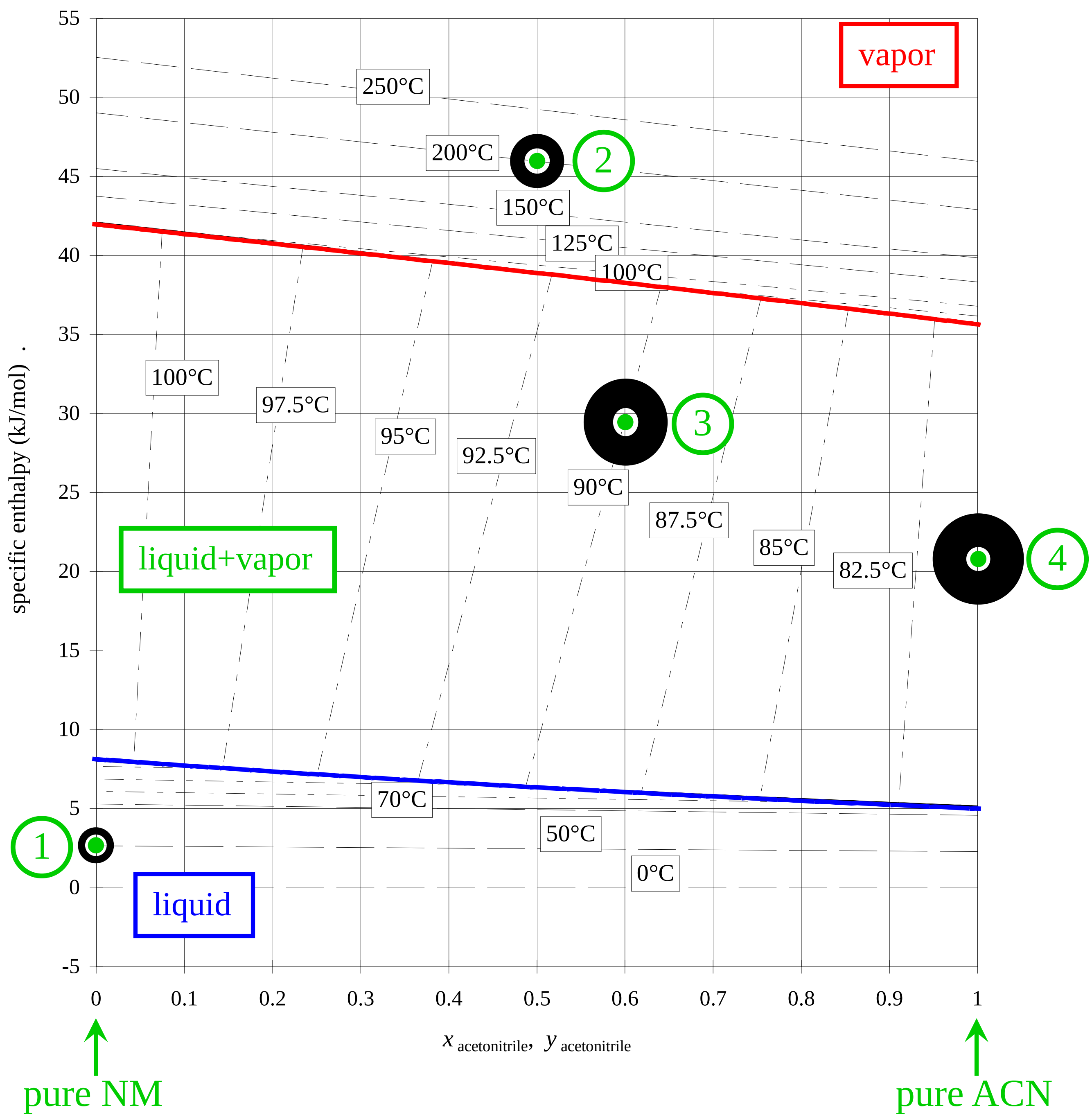
Graphical Energy Balance – Exercise 4.37

4.37 Consider the mixer below. What is the temperature of stream 5? What phase(s) is(are) present in stream 5?

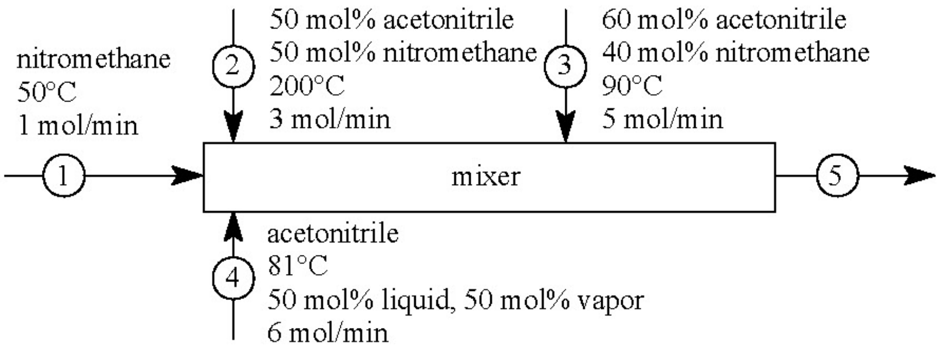


Enthalpy-Composition Phase Diagram for Acetonitrile+Nitromethane Mixtures at 1 atm

How to represent relative flow rates on a 2D map?



Exercise 4.37, cont'd. Solution is posted.



Tabulate the coordinates of streams 1, 2, 3, and 4.

stream	flow rate	mol fraction acetonitrile	specific enthapy
1	1 mol/min	0.0	2.5 kJ/mol
2	3	0.50	46
3	5	0.60	29.5
4	6	1.0	20.5

Use the center-of-mass formula to find the *x* axis first moment.

$$\text{center of mass} = \frac{(0.0)(1\text{ mol}) + (0.5)(3\text{ mol}) + (0.6)(5\text{ mol}) + (1.0)(6\text{ mol})}{1\text{ mol} + 3\text{ mol} + 5\text{ mol} + 6\text{ mol}}$$

$$= \frac{10.5\text{ mol}}{15\text{ mol}} = 0.7$$

Stream 5 is 70. mol% acetonitrile.

Use the center-of-mass formula to find the *y* axis first moment.

$$\text{center of mass} =$$

$$= \frac{(2.5\text{ kJ/mol})(1\text{ mol}) + (46\text{ kJ/mol})(3\text{ mol}) + (29.5\text{ kJ/mol})(5\text{ mol}) + (20.5\text{ kJ/mol})(6\text{ mol})}{1\text{ mol} + 3\text{ mol} + 5\text{ mol} + 6\text{ mol}}$$

$$= \frac{411\text{ kJ}}{15\text{ mol}} = 27.4\text{ kJ/mol}$$

Stream 5's specific energy is 27.4 kJ/mol.

Enthalpy-Composition Phase Diagram for Acetonitrile+Nitromethane Mixtures at 1 atm

From the tie line, stream 5 is 88°C. The liquid is 60. mol% ACN and the vapor is 74 mol% ACN

From the lever rule, stream 5 is 68 mol% vapor and 32 mol% liquid.