Laboratory of
Computational
Systems
Biotechnology

EPFL

Introduction to Chemical Engineering

Teaching by:

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Office hours: Mondays 16h-19h (CH H4 625) or schedule by email

Fridays, 14h15 - 17h00
2024-2025

(Updated) Course Schedule

Date	Subject
13-Sep	**1. Fundamentals of Material Balances** 1.1. Process definition and classification 1.2. Material balance calculations
20-Sep	1.3. Balances on multiple-unit processes
27-Sep	**Review on Mass Balances (non-reactive)**
04-Oct	1.4. Chemical reaction stoichiometry **1.5.1 Balances on reactive processes (part 1)**
11-Oct	**1.5.2 Balances on reactive processes (part 2)** **1.6. Balances on multiple unit reactive processes** **Review on Mass Balances (non-reactive & reactive)**
18-Oct	**2. Fundamentals of Energy and Energy Balances** 2.1. Energy balances on closed systems 2.2. Open systems at steady state **3. Balances on Non-Reactive Processes** 3.1. Energy balance calculation 3.2. Changes in Pressure, Temperature, Phases
01-Nov	**4. Balances on Reactive Processes** 4.1. Introduction to the Enthalpy of Reaction 4.2. Heat of Reaction Method 4.3. Heat of Formation Method 4.4 General Procedure to solve energy balance in reactive systems
08-Nov	**Review on Balances on Non-Reactive Processes** Problems: Mass and Energy Balances on non-Reactive Systems
15-Nov	**Midterm Exam: Mass & Energy Balances non-Reactive Systems**
22-Nov	**Review Midterm**

Date	Subject
29-Nov	Review on Heat of Reaction vs Heat of Formation Methods 4.5 Hess's Law to compute the Heat of Reaction 4.6 Heat of Combustion
06-Dec	**5. Energy balances on mixing processes** **5.1 Distinction between ideal and real solutions** **5.2 Heat of Solution**
13-Dec	Review and Study Session • Summing up with Mass and Energy Balances on Reactive Systems with Recycle

Recommended textbook:
Elementary Principles of Chemical Processes, Richard M. Felder & Ronald W. Rousseau

Session VIII: Friday 06 December 2024

After studying this session, you will be able to:

Differentiate ideal and real solutions

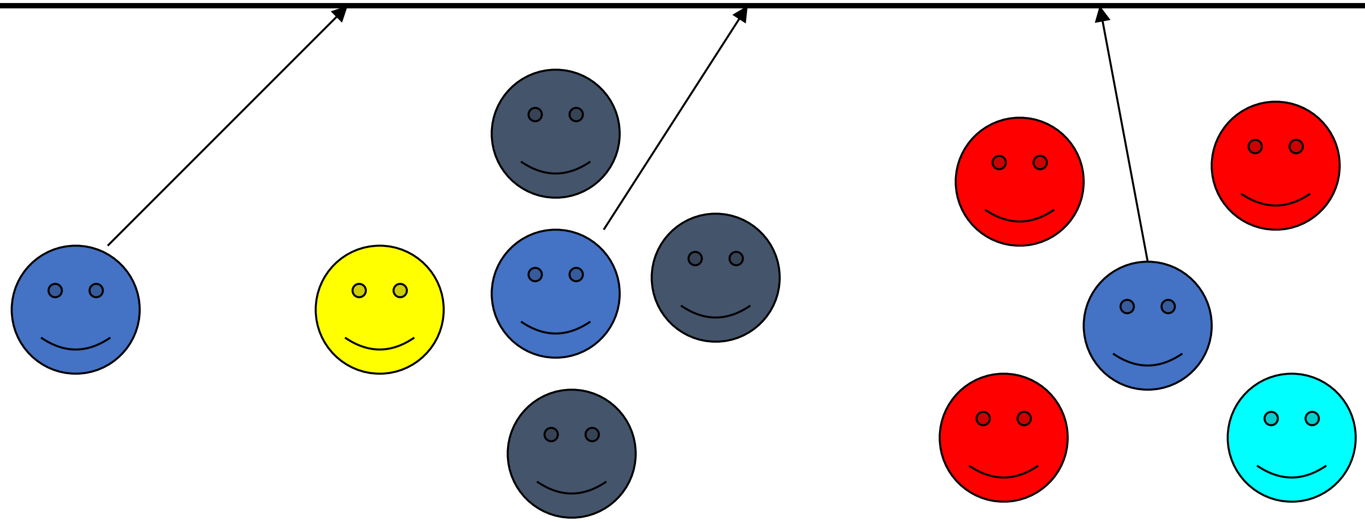
(Perform energy balances with considering heat of solution)

Ideal and Real Solutions

Are the properties of substances in a mixture the same as being single components?

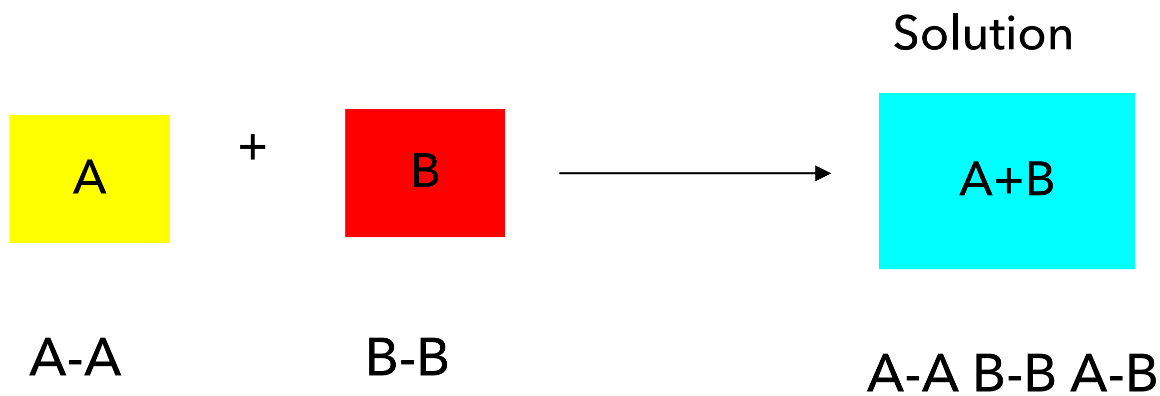
Why?

Would the same person have the same character in different groups?



Recall from
chemistry:
never add water to
sulfuric acid,
but slowly add the
acid to the water

The interaction between molecules



- A-A ≈ B-B A-B ≈ A-A≈B-B Ideal solution

- A-A < B-B
- A-A > B-B

A-B ≠A-A ≠ B-B Real solution

Types of mixtures:

- gas - gas
- gas - liquid
- gas – solid
- liquid– liquid
- liquid – solid
- solid - solid

Energy changes of mixing is negligible

Ideal solutions/mixtures

(1) $$\Delta_{mix} V = 0$$

(2) $$\Delta_{mix} H = 0$$

A stream consisting of several components:

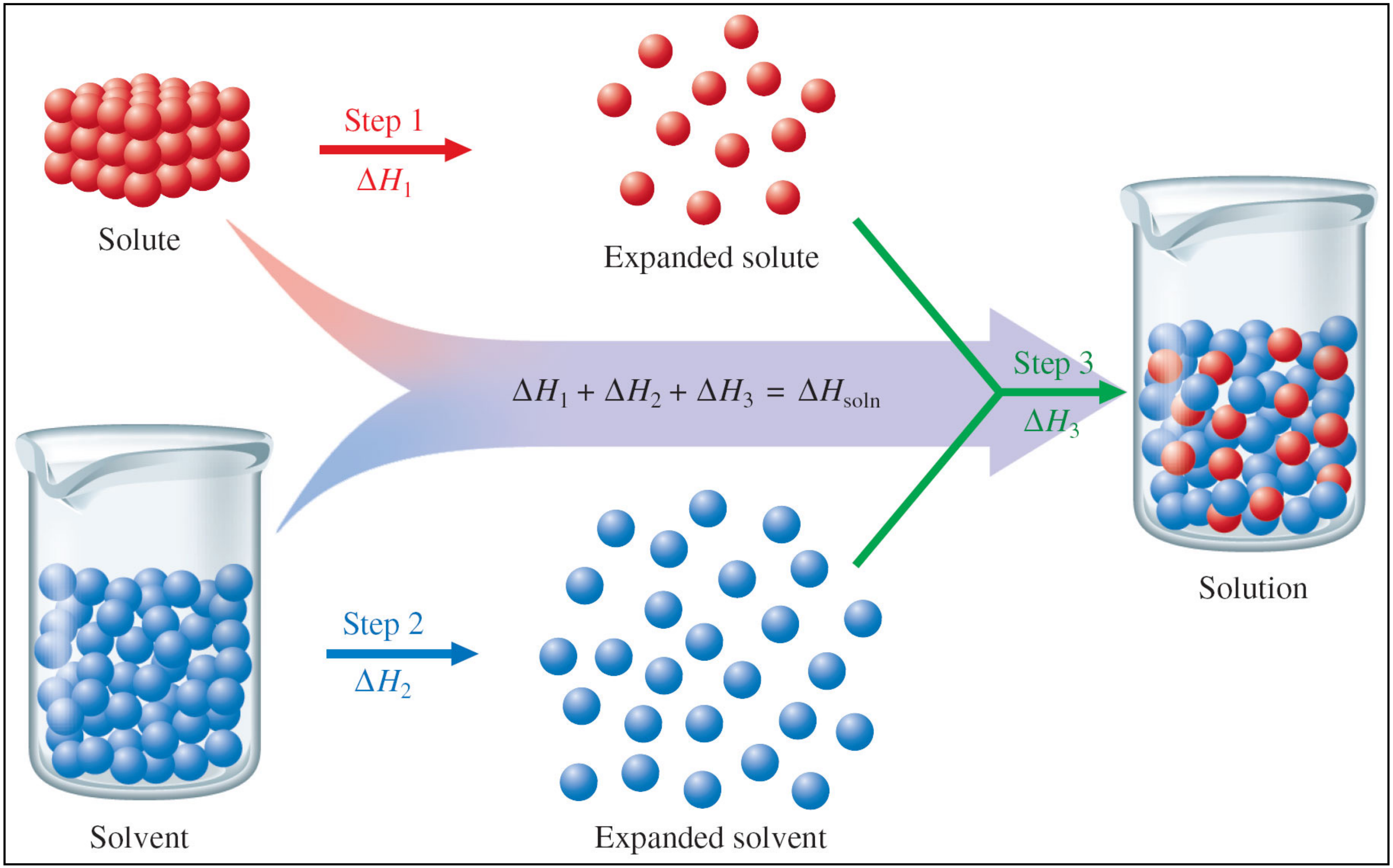
$$C_{P_{mixture}} = x_A \, C_{P_A} + x_B \, C_{P_B} + \cdots$$

$$\Delta\hat{H}_{mixture} = x_A \Delta\hat{H}_A + x_B \Delta\hat{H}_B + \cdots$$

Close look at real solutions

1. Separating the solute into its individual components (expanding the solute).
2. Overcoming intermolecular forces in the solvent to make room for the solute (expanding the solvent).
3. Allowing the solute and solvent to interact to form the solution.

Steps in the Dissolving Process



Steps in the Dissolving Process

- Steps 1 and 2 require energy, since forces must be overcome to expand the solute and solvent.
- Step 3 usually releases energy.

→ Steps 1 and 2 are endothermic, and step 3 is often exothermic.

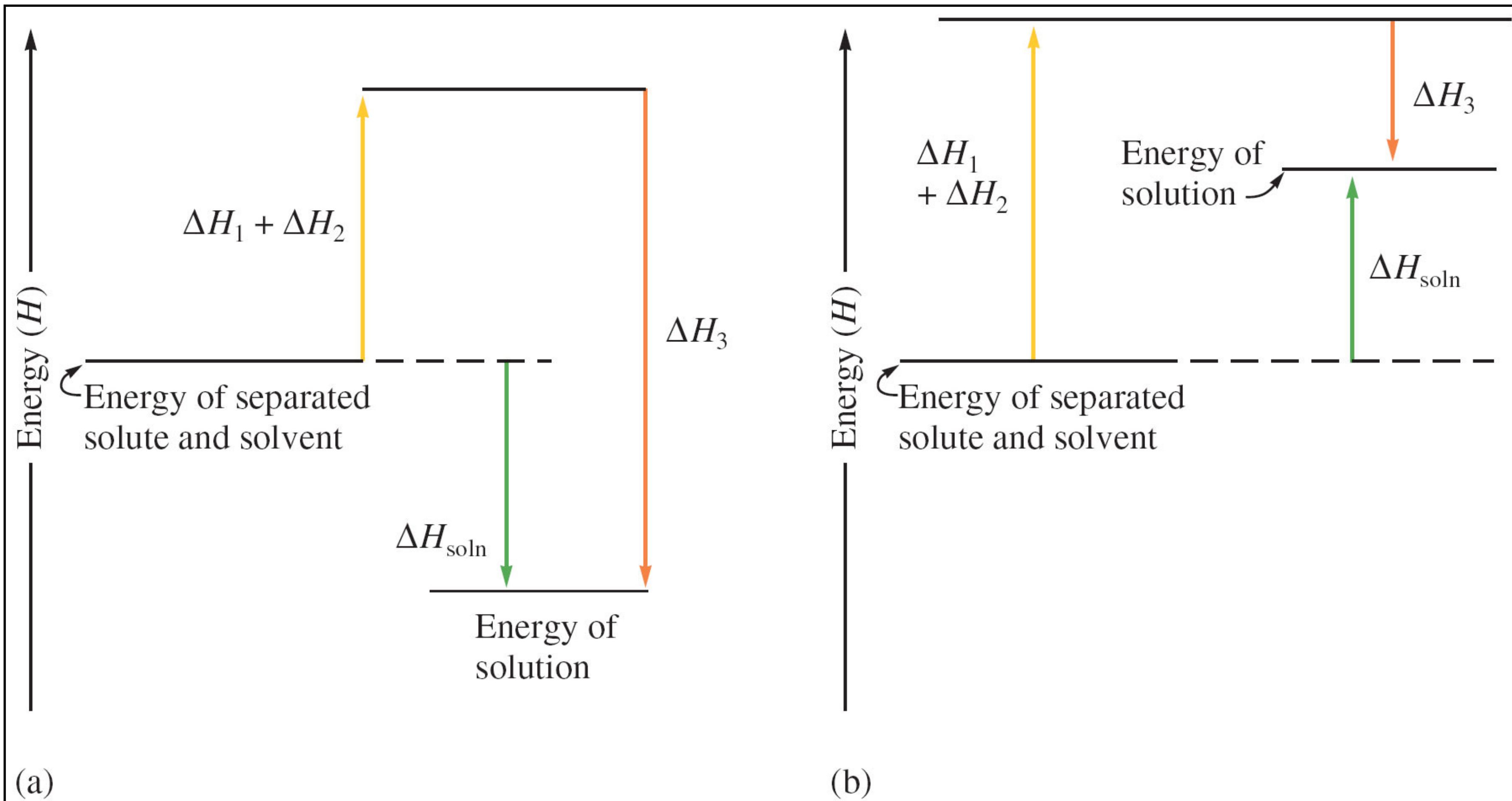
Enthalpy (Heat) of Solution

- Enthalpy change associated with the formation of the solution is the sum of the ΔH values for the steps:

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

- ΔH_{soln} may have a positive sign (energy absorbed) or a negative sign (energy released).

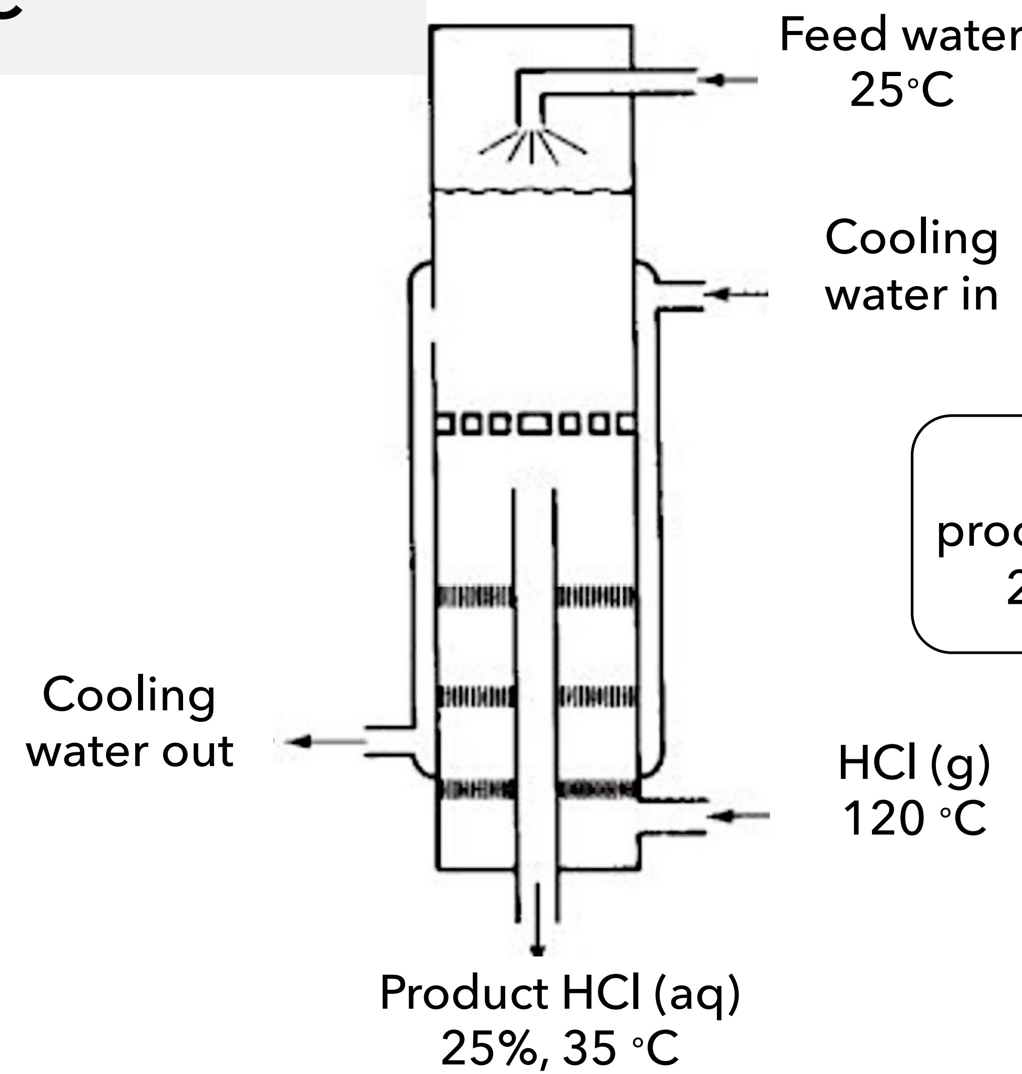
Enthalpy (Heat) of Solution



Concept Check!

Explain why water and oil (a long chain hydrocarbon) do not mix. In your explanation, be sure to address how ΔH plays a role.

Example



Non reactive process, steady state
2 components

Component	kg	Mol. wt.	kg mol	Mole Fraction
HCl	25	36.37	0.685	0.141
H_2O	75	18.02	4.163	0.859
Total	100		4.848	1.000

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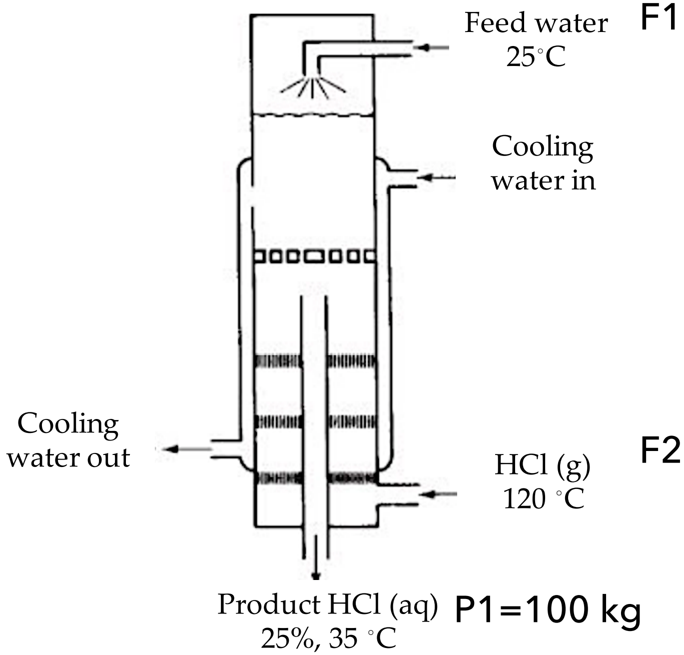

mass balances (mol balance)

H2O: F1 = 0.859 P1
HCL: F2 = 0.141 P1

Stream	g mol	T(°C)	$\Delta\hat{H}_f^o$(J/g mol HCl)	$\Delta\hat{H}_{sensible}$ (J/g mol)
OUT				
HCl (aq)				
IN				
$H_2O(\ell)$			—	
HCl(g)				

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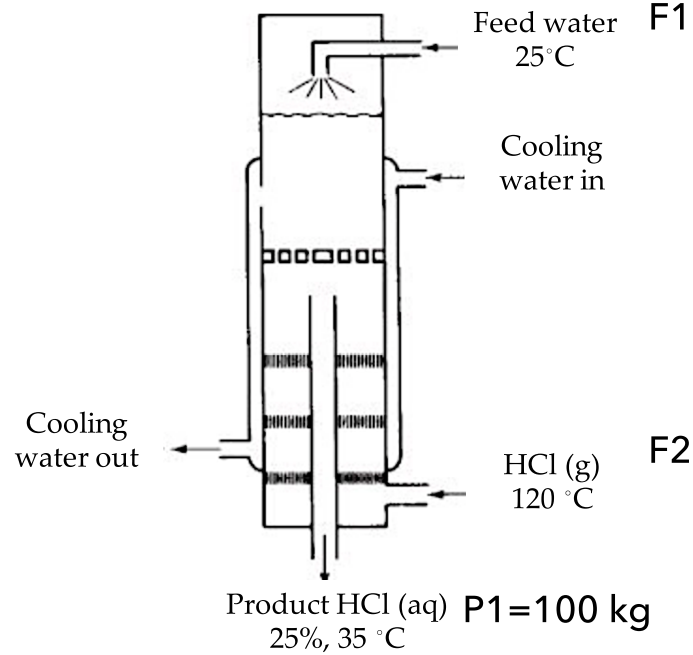

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Stream	g mol	T(°C)	$\Delta\hat{H}_f^o$(J/g mol HCl)	$\Delta\hat{H}_{sensible}$ (J/g mol)
OUT				
HCl (aq)	4.848			
IN				
$H_2O(\ell)$	4.163			
HCl(g)	0.685			

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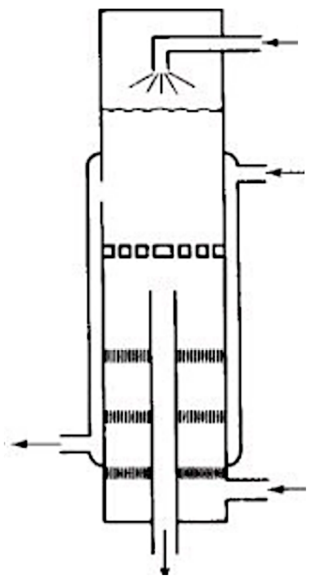

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OUT				
HCl (aq)	4.848	35		
IN				
$H_2O(\ell)$	4.163	25	—	
HCl(g)	0.685	120	−92,311	$\int_{25°C}^{120°C}(29.13-0.134\times10^{-2}\,T)\,dT$ $= 2758$

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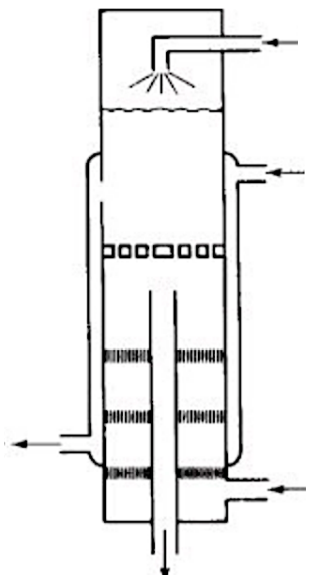

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OUT				
HCl (aq)	4.848	35	?	?
IN				
$H_2O(\ell)$	4.163	25	—	
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4.163 mol H2O / 0.685 mol HCl -->
6.077 mol H2O / mol HCl

Table 13.1. Heat of Solution Data at 25°C and 1 atm

Composition	Total Moles H_2O Added to 1 mole HCl	$\Delta\hat{H}^o$ for Each Incremental Step (J/g mol HCl)	Integral Heat of Solution (Cumulative $\Delta\hat{H}^o$) (J/g mol HCl)	Heat of Formation $\Delta\hat{H}_f^o$ (J/g mol HCl)
HCl(g)	0			−92,311
HCl[1H_2O(aq)]	1	−26,225	−26,225	−118,536
HCl[2H_2O(aq)]	2	−22,593	−48,818	−141,129
HCl[3H_2O(aq)]	3	−8033	−56,851	−149,161
HCl[4H_2O(aq)]	4	−4351	−61,202	−153,513
HCl[5H_2O(aq)]	5	−2845	−64,047	−156,358
HCl[8H_2O(aq)]	8	−4184	−68,231	−160,542
HCl[10H_2O(aq)]	10	−1255	−69,486	−161,797
HCl[15H_2O(aq)]	15	−1503	−70,989	−163,300
HCl[25H_2O(aq)]	25	−1276	−72,265	−164,576
HCl[50H_2O(aq)]	50	−1013	−73,278	−165,589
HCl[100H_2O(aq)]	100	−569	−73,847	−166,158
HCl[200H_2O(aq)]	200	−356	−74,203	−166,514
HCl[500H_2O(aq)]	500	−318	−74,521	−166,832
HCl[1000H_2O(aq)]	1000	−163	−74,684	−166,995
HCl[50,000H_2O(aq)]	50,000	−146	−75,077	−167,388
HCl[∞H_2O]		−67	−75,144	−167,455

SOURCE: National Bureau of Standards Circular 500, U.S. Government Printing Office, Washington, DC (1952).

$$\Delta\widehat{H}^{o}_{f\ solution} = \text{Cummulative } \Delta\widehat{H}^{o} + \Delta\widehat{H}^{o}_{f\ solute}$$

1 mol of solute is dissolved in n mol of solvent

Table 13.1. Heat of Solution Data at 25°C and 1 atm

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$$\Delta\widehat{H}^o_{f\ \text{solution}} = \text{Cummulative } \Delta\widehat{H}^o + \Delta\widehat{H}^o_{f\ \text{solute}}$$

-156,358 = -64,047 -92,311

1 mol of solute is dissolved in n mol of solvent

Table 13.1. Heat of Solution Data at 25°C and 1 atm

Composition	Total Moles H_2O Added to 1 mole HCl	$\Delta\hat{H}^o$ for Each Incremental Step (J/g mol HCl)	Integral Heat of Solution (Cumulative $\Delta\hat{H}^o$) (J/g mol HCl)	Heat of Formation $\Delta\hat{H}^o_f$ (J/g mol HCl)
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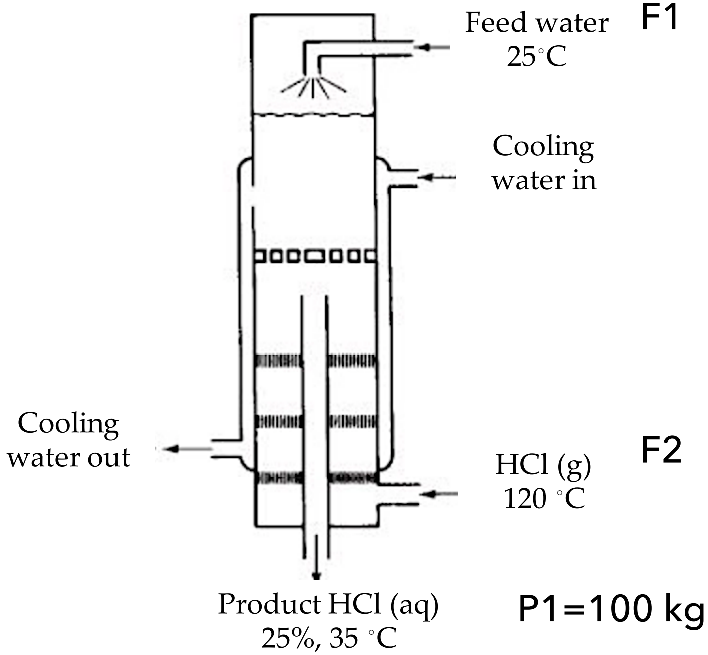

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OUT				
HCl (aq)	4.848*	35	−157,753	
IN				
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HCl(g)	0.685	120	−92,311	$\int_{25°C}^{120°C}(29.13-0.134\times10^{-2}\,T)\,dT = 2758$

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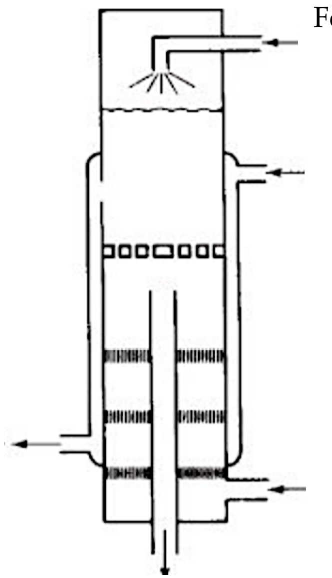

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The Cp of the product is approximately 2.7 J/(g)(°C)

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$$\begin{aligned} &\qquad\qquad\qquad\quad \textit{out} \qquad\qquad\qquad\qquad\qquad\qquad\qquad \textit{in} \\ &= [0.685(-157{,}753) + 4.848(27)] - [0 + 0.685(-92{,}311) + 0.685(2758)] \\ &= -46{,}586 \text{ J} \end{aligned}$$