The Scholars Programme

What Do Chemical Engineers Do?

Key Stage 4 Programme – Autumn 2016

Pupil Name _____

Researchers in Schools

Lampton School
a DfE Outstanding Academy & Teaching School

The Brilliant Club

The UCL Academy

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1 (Introductory Course)			
2			
3			
4			
5			
6			

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1		
Tutorial 2		
Tutorial 3		
Tutorial 4		
Tutorial 5		

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after 4.00pm	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

The Scholars Programme – Autumn 2016 – Pupil Feedback Report

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at first year undergraduate level
2:1	60-69	Performing to a good standard at first year undergraduate level
2:2	50-59	Performing to an excellent standard at A-Level
3rd	40-49	Performing to a good standard at A-Level
Workings towards a pass	0-39	Workings towards a pass
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Name of PhD Tutor			
Title of Assignment			
Name of Pupil			
Name of School			
ORIGINAL MARK / 100		**FINAL MARK / 100**	
DEDUCTED MARKS		**FINAL GRADE**	

If marks have been deducted (e.g. late submission, plagiarism) the PhD tutor should give an explanation in this section:

Learning Feedback Comment 1 - *Enter Key Learning Priority Here*	
What you did in relation to this Key Learning Priority *Enter feedback here*	**How you could improve in the future** *Enter feedback here*
Learning Feedback Comment 2 – *Enter Key Learning Priority Here*	
What you did in relation to this Key Learning Priority *Enter feedback here*	**How you could improve in the future** *Enter feedback here*
Learning Feedback Comment 3 – *Enter Key Learning Priority Here*	
What you did in relation to this Key Learning Priority *Enter feedback here*	**How you could improve in the future** *Enter feedback here*
Resilience Comment	
How you showed learning resilience during the course *Enter feedback here*	**How you could build learning resilience in the future** *Enter feedback here*

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Course Rationale

One of the key features of learning at UCL Academy is the idea of connected curriculum. This is based on the premise that students can learn best when they make meaning and sense from learning and are able to see the links among various subjects. This course is designed to further promote the idea behind UCL Academy's connected curriculum. One of the key aims of this course is to allow students to see the amazing links among the STEM subjects. We think that the best way to achieve this is to introduce the students to the discipline of chemical engineering. This is because chemical engineering applies the principles of physical and biological sciences (Physics, Chemistry, and Biology) and mathematics to transform and efficiently use material and energy. So, chemical engineering is essentially concerned with converting raw material and energy into useful products: food and beverages, pharmaceuticals, textiles, fuels and many more.

This course will introduce you to some exciting fundamental concepts in chemical engineering that will draw on your knowledge of maths, physics, chemistry and biology. We will begin by learning about the important roles that chemical engineers play in the modern society and how they use their knowledge and expertise to daily improve our lives. We will then examine how chemical engineers use their scientific and mathematical knowledge to solve process problems that may arise during manufacturing processes.

It is my hope that by the end of this course, students will be well exposed to the field of chemical engineering and will appreciate how maths, physics, chemistry, biology and real life situations are all connected.

Glossary of Keywords

ACCELERATION: The rate of change of velocity with time.

BIOMEDICINE: A branch of medical science that applies biology and other natural sciences to clinical practice.

BIOTECHNOLOGY: A technology that uses living systems to develop and make new products.

CONSERVATION: A principle by which we regard the total value of a quantity as unchanged irrespective of external influence.

CRYOGENIC: Processes occurring at very low temperatures.

DIMENSION: Measurement of a quantity.

ENGINEERING: Application of mathematics, science, economic and practical knowledge to build, design, improve and maintain structures, machines, materials, processes and organizations.

FEEDSTOCK: Raw material that is used to obtain a given product.

FLUID: A substance, usually liquid or gas, that deforms when acted on by a force.

HETEROGENEOUS: A system whose structure is not uniform throughout.

HOMOGENEOUS: A system having uniform structure throughout.

LINEAR: A mathematical equation that can be represented using a straight line.

NANOTECHNOLOGY: A branch of technology that deals with materials that are really very small in size, usually less than 100 nanometres.

NON-LINEAR: A mathematical equation that cannot be represented using a straight line.

PRESSURE: The force acting over a certain area.

STEADY: A system whose properties do not change in time.

SYNTHETIC: Substances made by chemical synthesis rather than those made by nature (naturally occurring)

TEMPERATURE: A measure of how hot or cold an object is relative to some standard value.

UNITS: Ways of expressing measurements.

UNSTEADY: A system whose properties change in time.

VELOCITY: The rate of change of displacement with time.

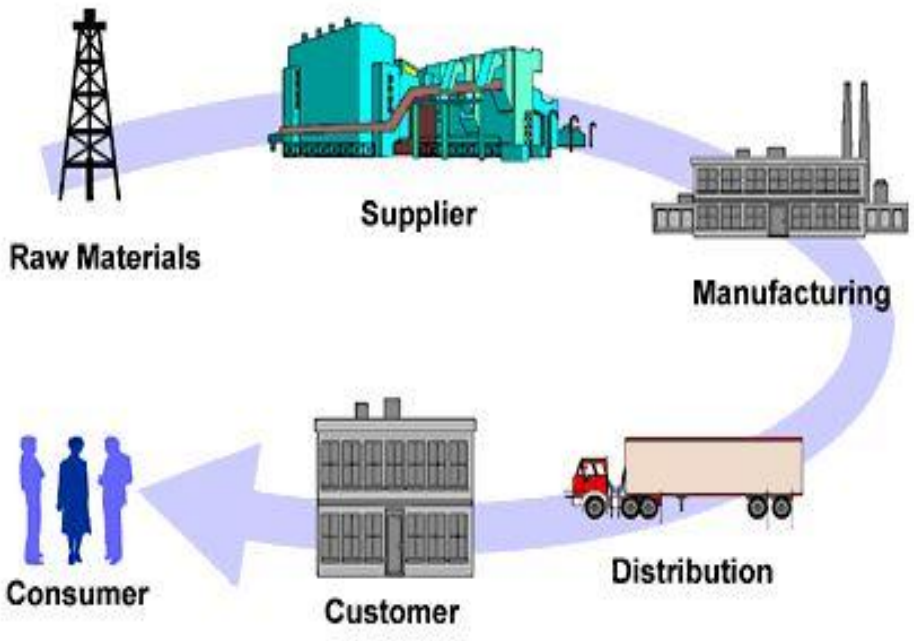
Tutorial 1 – Introduction to the course

The objectives of Tutorial 1 are:

- To know what Chemical Engineering is.
- To know what Chemical Engineers do.

1.1 What is Chemical Engineering?

- A branch of engineering that is concerned with the application of physical science (for example, Physics and Chemistry), life sciences (for example, Biology, Microbiology, Biochemistry), and **Mathematics** to the process of converting raw materials to useful products.



- Nowadays, Chemical Engineering is also concerned with developing new materials and techniques. This involves areas such as Nanotechnology, Biochemical Engineering and Biomedical Engineering.

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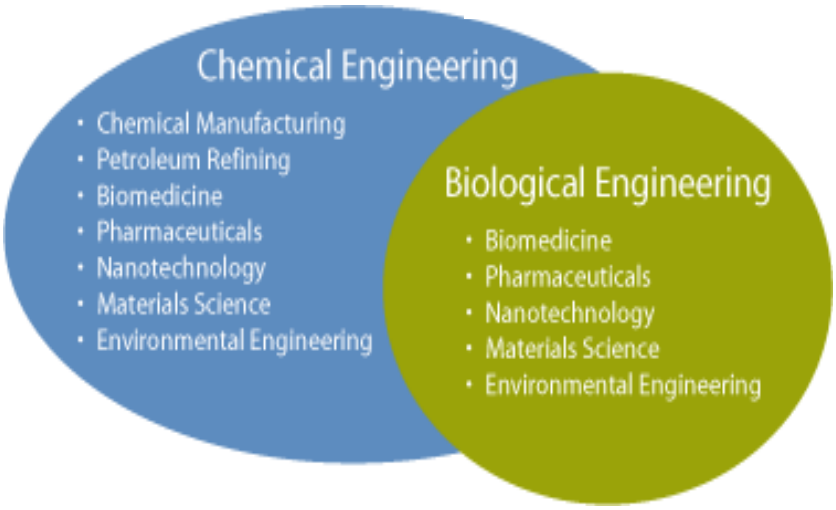
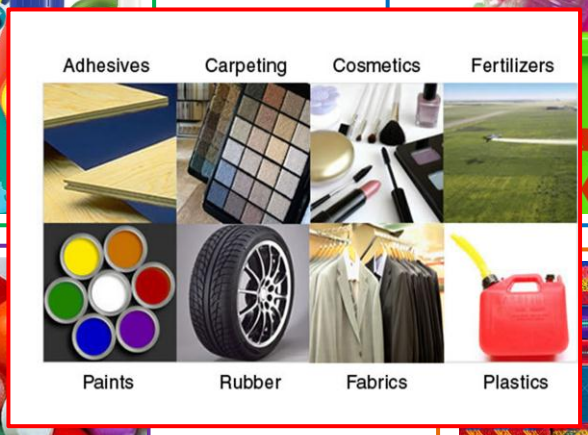


- Most times Chemical Engineering involves the design, improvement and maintenance of processes involved in chemical and biological transformation.

Activity 1.0: From the pictures on the next page, identify at least 10 products where chemical engineers are directly involved.

he
GAIN
all
mighty

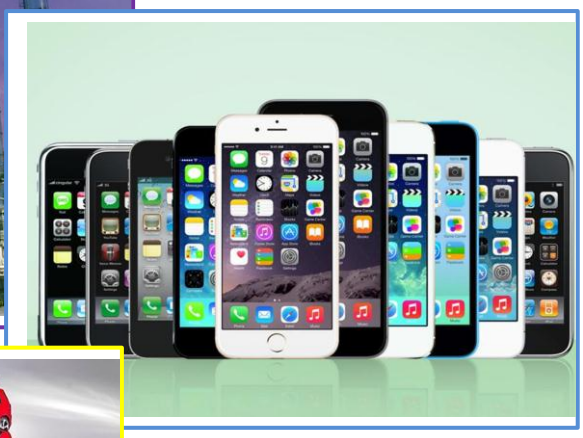
Plastic


Adhesives
Carpeting
Cosmetics
Fertilizers
Paints
Rubber
Fabrics
Plastics

CHOCAPIC
Cheeri
Digestive
nutella

STAR
FILLER

ASUS
ASPIRE



Activity 2.0: Please unscramble the words below

LEYVITCO

PRATEREEUTM

ENILAR

OOENMSUOHEG

TKDCOFSEE

NCORCGYIE

MEALNINO

SUTIN

GYHLNENOACNTOO

YSADUNTE

LNCEHGTOBYIOO

COAINAECTRLE

ONIBMIDICEE

Notes

1.2 Who is a Chemical Engineer?

- Like all engineers, Chemical Engineers use the knowledge of Maths, Physics, Economics and sometimes Computer Science to solve technical problems. In addition to these, Chemical Engineers often use the knowledge of Chemistry, making them different from other engineers. Chemical Engineers are sometimes called 'Universal Engineers' because of their vast scientific and technical knowledge.

- Chemical Engineers improve food processing techniques to increase the quantity and quality of food available.

- They also make the synthetic fibers that make our clothes more comfortable and water resistant; they invent methods to mass-produce drugs, making them more affordable; and they create safer, more efficient methods of refining petroleum products, making energy and chemical sources more productive and cost effective.

- Chemical engineers also find solutions to environmental problems, such as pollution control and remediation.

- Chemical Engineers work in a wide range of industries

Activity 2.0: From the Figure on the next page, identify the organizations/industries where chemical engineers can work.

Assignment 1.0

1. Conduct an in-depth review on the roles of Chemical Engineers in the society. Your review should include the revolutionary works of different Chemical Engineers who made historic and significant contributions to the world (Your review should be at least 500 words).

2. A chemical engineer measures the volumetric flow rate of a process fluid, V (cm /s), is measured five times, with the following results:

Measurement	1	2	3	4	5
$\dot{V}$(cm³/s)	232	248	227	241	239

a. Calculate the sample mean ($\bar{V}$), range, sample variance (S^2), and sample standard deviation (S).
b. There is a high probability (above 90%) that a measured value of will fall within two standard deviations of the mean. Report the value of in the form

$$\dot{V} = a \pm b$$

Choose the values of a and b to define this range.

Tutorial 2 – Chemical Engineering Calculations 1

https://www.pinterest.com/pin/427630927088662709/

What is the Purpose of Tutorial 2?

- To understand the meaning of dimension and dimensional consistency
- To convert a quantity expressed in one unit into a different equivalent unit
- To be able to use conversion tables
- To perform simple chemical engineering calculations using the methods of dimensional consistency and unit conversion

2.1 Units and Dimensions

- Dimensions are basic concepts of measurements such as mass, length, time, temperature and so on. Dimensions can also be referred to as properties that can be measured.

- Units are means of expressing dimensions such as centimetres for length, kilograms for mass, minutes or seconds for time and so on.

- Dimensions and their units can be classified as either *fundamental* or *derived*. Fundamental units/dimensions are those that can be measured independently and are sufficient to describe essential physical quantities, while Derived dimensions/units are those that can be obtained in terms of the fundamental dimensions/units.

Table 2.1: Some fundamental and derived quantities

Physical Quantity	Name of unit	Symbol	Definition of unit
Fundamental SI Unit			
Mass	kilogram	kg	
Length	meters	m	
Time	seconds	s	
Amount of substance	mole	mol	
temperature	kelvin	K	
Luminous intensity	candela	cd	
Derived SI Unit			
Energy	joule	J	$kg.m^2/s^2$
Force	newton	N	$kg.m/s^2$
Power	watt	W	$kg.m^2/s^3$
Density	Kilogram per cubic meter		Kg/m^3
Pressure	Newton per square meter (pascal)		N/m^2

- There are two commonly used systems of unit: SI, formally called Le Systeme Internationale d'Unites, and informally called SI. The other system is AE or American Engineering system of units. The Table below shows the comparison between the two units for fundamental units.

Table 2.2: SI and AE systems of units

Physical Quantity	SI unit	AE unit
Mass	Kilogram, kg	pound, lb
Length	Meters, m	Foot, ft
Time	seconds, s	Second, minutes, hours, day
Amount of substance	Mole, mol	Pound mole, lb mol
temperature	Kelvin, K	degree Rankine or degree Fahrenheit, ^oR or ^oF

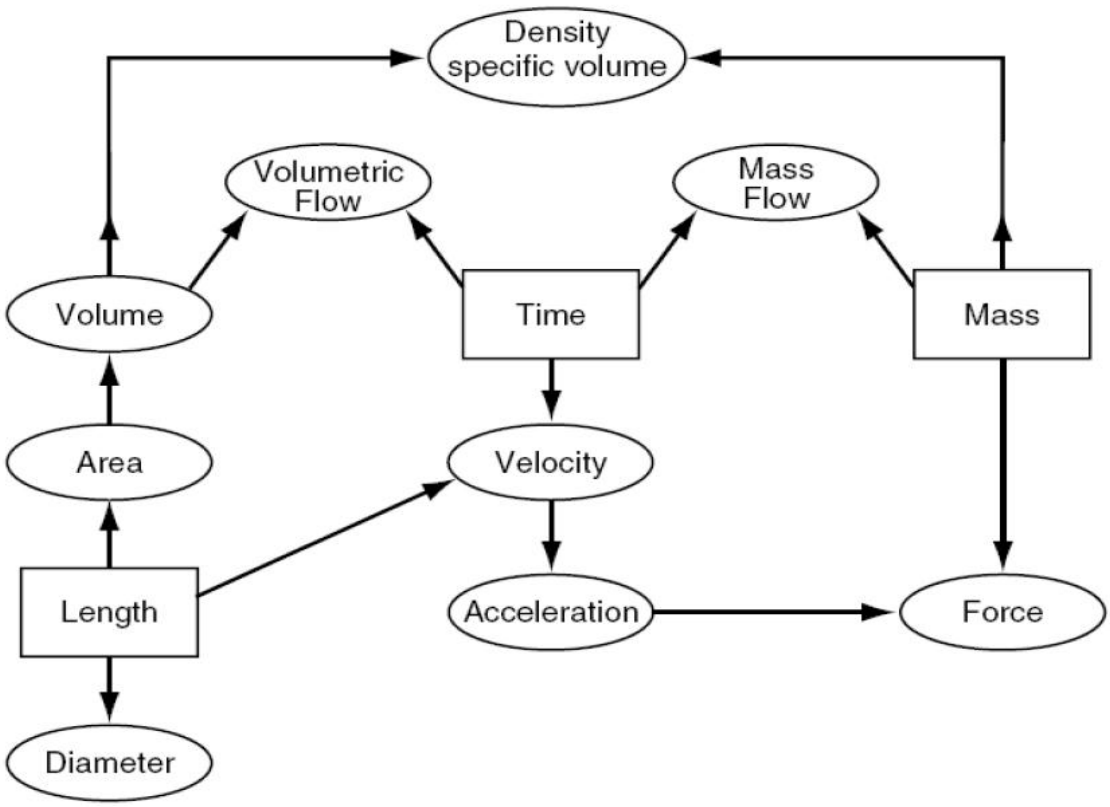


Figure 2.1: Relationship between basic and derived dimensions. Can you add to the above figure?

2.1.1 Operations with Units

The following rules are for handling units

- You can add, subtract or equate numerical quantities only if their dimensions are the same. Thus, you can perform the following operations because their dimensions are the same (length):

5 meters + 5 meters

600 centimetres + 5meters

However, you cannot perform the following operations because their dimensions are different:

5 meters + 7 kilograms

8 seconds + 10 meters

- You can multiply or divide quantities irrespective of their dimensions, thus:

$$5\ kg\ \times 3\ \frac{m}{s} = 15\ kg.m/s$$

In this case, you can treat the units like algebraic variables.

Exercise 2.1

1. $10kg + 5\ lb$
2. $40\ s + 1hr$
3. $30\ kg + 60m$
4. $15\ kg/m^3 \times 5m^3$
5. $0.05N/m^2 \div 0.5m^2$

2.1.2 Conversion of Units and Conversion Factors

Convert 2 km to mile

$$\frac{2\ \text{km}}{} \left| \frac{1\ \text{mile}}{1.61\ \text{km}} \right. = 1.24\ \text{mile}$$

Convert 400 $in.^3\ /\ day$ to $cm^3/\ min$

$$\frac{400\ \text{in.}^3}{\text{day}} \left| \left(\frac{2.54\ \text{cm}}{1\ \text{in.}} \right)^3 \right| \frac{1\ \text{day}}{24\ \text{hr}} \left| \frac{1\ \text{hr}}{60\ \text{min}} \right. = 4.55\ \frac{\text{cm}^3}{\text{min}}$$

Exercise 2.2

Convert the following:

1. 20 ft/s to miles/hr
2. 60 cm/s^2 to km/yr^2
3. 0.879 g/cm^3 to kg/m^3
4. 32 ft/s^2 to m/s^2
5. 1.0 $lb_m/(ft^3)(s)$ to $kg/(m^3)(s)$

2.1.3 Dimensional consistency

- Equations must be dimensionally consistent
- Consider the van der Waal's equation below. Analyse the equation for dimensional consistency

$$\left(\boldsymbol{p}+\frac{\boldsymbol{a}}{\boldsymbol{V}^2}\right)(\boldsymbol{V}-\boldsymbol{b})=\boldsymbol{RT}$$

If p is in atm, V is in cm^3, T is in K. What are the units of a, b and R.

- Consider the equation below:

$$\boldsymbol{d}=\mathbf{16.2}-\mathbf{16.2}\boldsymbol{e}^{-\mathbf{0.02}\boldsymbol{t}}$$

Where d is in μm, and t is in $seconds$. What are the units associated with the numbers 16.2 and 0.021. Convert the relation becomes expressed in $inches$ and t in $minutes$.

Problems 2.1

1. What are the applications of units and dimensions in everyday life:
   - Business
   - Home Economics
   - Monetary Systems
   - Engineering

2. Electronic communication via radio travels at approximately the speed of light (186000 miles/second). The edge of the solar system is roughly at Pluto, which is 3.6×10^9 miles from earth at its closest approach. How many hours does it take for a radio signal from Earth to reach Pluto?

3. The density of a certain liquid is given an equation of the following form:

$$\boldsymbol{\rho}=(\boldsymbol{A}+\boldsymbol{Bt})\boldsymbol{e}^{\boldsymbol{CP}}$$

   Where ρ is density in g/cm^3

   t is temperature in ^oC

   P is the pressure in *atm*

   a. The equation is dimensionally consistent. What are the units of A, B and C?

   b. In the units above ,

      A = 1.096 ; B = 0.00086; C = 0.000953. Find A, B and C if ρ is expressed as lb/ft^3, t in ^oR and P in $lb_f/in.^2$

4. A relation for a dimensionless variable called the compressibility is

$$\boldsymbol{z = 1 + \rho B + \rho^2 C + \rho^3 D}$$

Where ρ is the density in gmol/cm^3.

a. What are the units of B, C and D?

b. Convert the coefficients in the equation for z so that the density can be introduced into the equation in the units lb$_m$/ft^3 thus

$$\boldsymbol{z = 1 + \rho^* B^* + (\rho^*)^2 C^* + (\rho^*)^3 D^*}$$

Where ρ^* is in lb$_m$/ft^3

i. Give the units of B^*, C^* and D^*

ii. Give the equations that relate $B\ to\ B^*$, $C\ to\ C^*$ and $D\ to\ D^*$

5. The density of a fluid is given by the following equation

$$\boldsymbol{\rho = 70.5 e^{8.27\times10^{-7}P}}$$

Where ρ is the density in lb$_m$/ft^3 and P is the pressure in *lb$_f$/in.^{2}*

a. What are the units of 70.5 and 8.27×10^{-7}

b. Derive a formula for ρ in g/cm^3 and P in N/m^2

6. The volume of a microbial culture is observed to increase according to the formula

$$V(cm^3) = e^t$$

Where t is time in seconds

a. Calculate the expression for $V(in.^3)$ in terms of $t(hour)$

b. Both the exponential function and its argument must be dimensionless. The given equation seems to violate both of these rules, and yet the equation is valid. Explain this paradox. (Hint: observe the result of part(a)

Notes

Tutorial 3– Chemical Engineering Calculations 2

What is the Purpose of Tutorial 3?

- Explain the difference between absolute and relative temperature
- Convert a temperature in any of the common scale (^{o}C, K, ^{o}F, R)
- Understand how Chemical Engineers convert an expression involving units of temperature and temperature difference

3.1 Absolute and Relative Temperature Scales

- Absolute temperature scale has their zero point at the lowest temperature that we believe can exist. The absolute scales are Kelvin (**K**) and degree Rankine (**°R**).

- Relative temperature scale does not have zero at the lowest temperature. They are degree Celsius (**°C**) and degree Fahrenheit (**°F**).

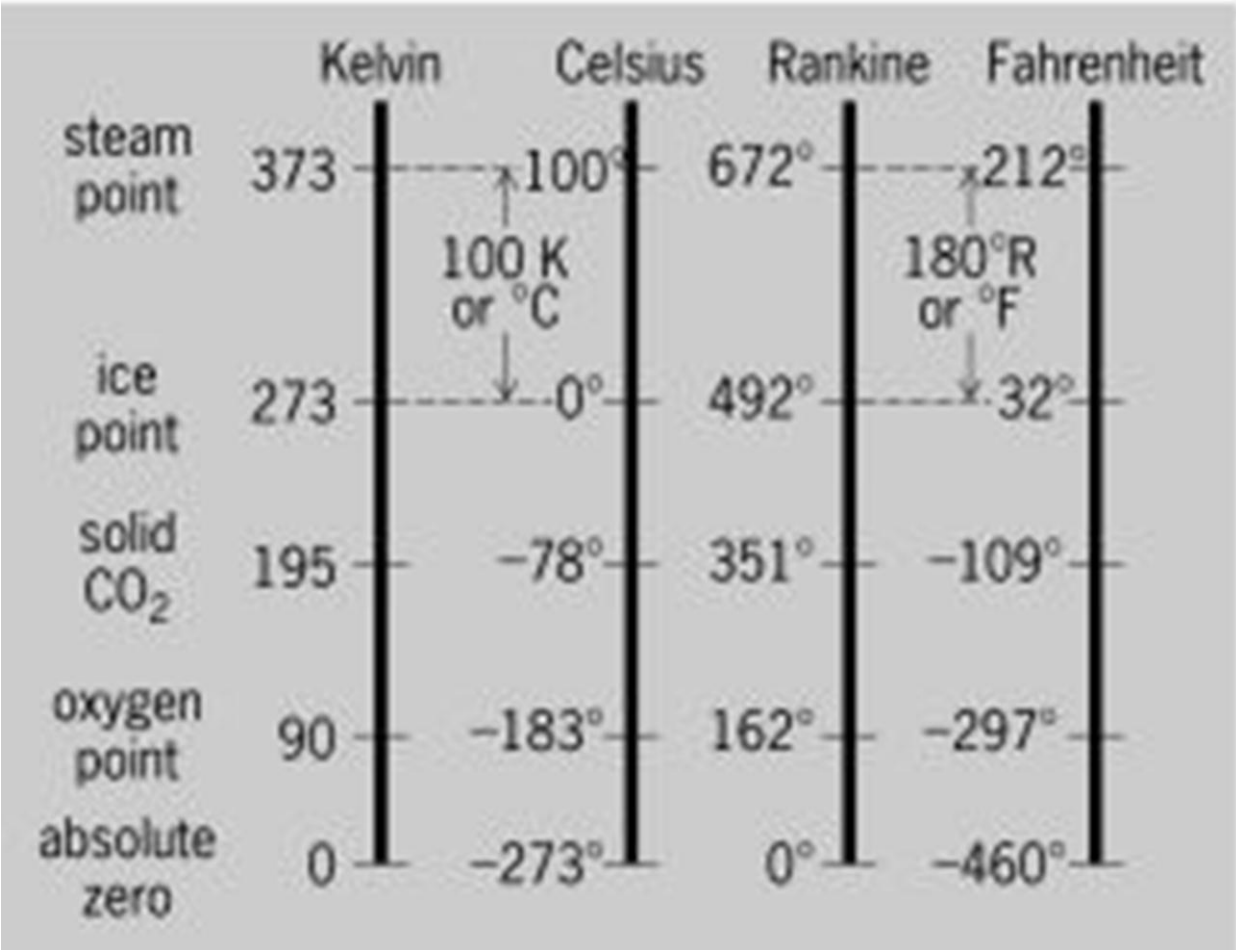


Figure 3.1: Temperature scales

3.2 Temperature conversion

To convert from one Temperature scale to another, we may use the following relationships

$$T(K) = T(^{o}C) + 273.15$$

$$T(^{o}R) = T(^{o}F) + 459.67$$

$$T(^{o}R) = 1.8T(K)$$

$$T(^{o}F) = 1.8T(^{o}C) + 32$$

Exercise 3.1:

1. Convert 75 ^{o}C to
   a. K
   b. ^{o}F
   c. ^{o}R

2. Derive an expression for converting $T(^{o}C)$ to $T(^{o}F)$

- A degree is both a temperature and a temperature interval. For instance an interval of 1 degree Celcius or Kelving contains 1.8 Farenheit or Rankine. This leads to other conversion factors:

$$\mathbf{1\Delta\,^{o}C = 1.8\Delta\,^{o}F}$$

$$\mathbf{1\Delta\,^{o}K = 1.8\Delta\,^{o}R}$$

- Notice that the conversions above refer to temperature intervals, not temperatures.

Example 3.2:

The heat capacity of sulphuric acid has the units J/(gmol)(^{o}C), and is given by the relation:

$$heat\ capacity = 139.1 + 1.56 \times 10^{-1}T$$

where T is expressed in ^{o}C. Modify the formular so that the resulting expression has the associated units of Btu/(lbmol) (^{o}R) and T is in ^{o}R.

Solution

$$heat\ capacity = \left\{139.1 + 1.56 \times 10^{-1}\left[(T_R - 460 - 32)\frac{1}{1.8}\right]\right\}\frac{1\,J}{(g\ mol)(°\mathrm{C})}\ \frac{1\,Btu}{1055\,J}\ \frac{454\,gmol}{1\,lb\,mol}\ \frac{1°\mathrm{C}}{1.8\,R}$$

$$heat\ capacity = 23.06 + 2.0710^{-3}T_R$$

Notes

Problem 3.1

1. Convert the following temperatures to the requested units:
   a. 10 ^{o}C to ^{o}F
   b. 20 ^{o}C to ^{o}R
   c. -25 ^{o}F to K
   d. 255K to ^{o}R

2. Heat capacities are usually given in terms of polynomial functions of temperature. The equation got carbon dioxide is

$$C_p = 8.4448 + 0.5757 \times 10^{-2}T - 0.2159 \times 10^{-5}T^2 + 0.3059 \times 10^{-9}T^3$$

   Where T is in ^{o}F and C_p is in Btu/(lb mol)(^{o}F). Convert the equation so that T can be in ^{o}C and C_p will be in J/(g mol)(K).

3. Calculate all the missing temperatures in the table below

	a	b	c	D	E	f	g	h
^{o}F					1000			
^{o}R			200			800		
K		1000					800	
^{o}C	140			- 40				800

4. The emissive power of a blackbody depends on the fourth power of the temperature and is given by:

$$W = AT^4$$

   Where W = the emission power, Btu/ (ft^2)(hr)

   A = Stefan-Boltzman constant, 0.171×10^{-8} Btu/ (ft^2)(hr)(^{o}R)^4

   T = temperature, ^{o}R

Notes

Tutorial 4 – Introduction to Material Balances

What is the Purpose of Tutorial 4?

- Understand the meaning of material balances
- Express material balances through mass conservation equation
- Solve simple industrial problems involving material balances

4.1 What are Material Balances?

- A material balance is the application of the law of conservation of matter.
- The law of conservation of matter states that matter is neither created nor destroyed.
- Material balances can be related to the flow of money in and out of an account:

Table 4.1: Customer Summary Information (Himmelblau & Riggs, 2004)

Dates	Notes	Deposit	Withdrawal	Balance
3/1	Beginning balance			1253.89
3/2	Deposit from ABC Co.	1500.00		2753.89
3/3	Cheque No. 2133		550.00	2203.89
3/3	ATM withdrawal 3/2		200.00	2003.89
3/5	Cheque No. 2134		401.67	1602.22
3/15	Cheque No. 2135		321.83	1280.39
3/18	ATM withdrawal		200.00	1080.39
3/20	Deposit at the bank	1250.00		2330.39
3/23	Cheque 2136		442.67	1887.72
3/31	Service charge		10.00	1877.72
3/31	Closing balance			1877.72

- Can you write an expression that expresses the closing balance in terms of the beginning balance, deposit and withdrawal?

Closing balance – Beginning balance = Sum of deposits – Sum of withdrawals

Or

Final condition – Initial condition = Sum of inputs – Sum of outputs

Or

Accumulation = Sum of inputs – Sum of outputs

- The concept of material balances is similar to the illustration above. In fact the concept of balancing money and material is the same; the only difference is that in material balances we are balancing material instead of money.

- Thus we can generalize the material balance equation for single component system as:

$$\begin{Bmatrix} \textbf{Accumulation of material} \\ \textbf{within the system} \end{Bmatrix} = \begin{Bmatrix} \textbf{Total flow into} \\ \textbf{the system} \end{Bmatrix} - \begin{Bmatrix} \textbf{Total flow out of} \\ \textbf{the system} \end{Bmatrix}$$

4.2 Definition of terms

- **System**: Any arbitrary portion of or a whole process that you want to consider for analysis. This may be a reactor, a section of a pipe or an entire distillation column.
- **Closed system**: A system where material neither enters nor leaves. This means no material crosses the system boundary.

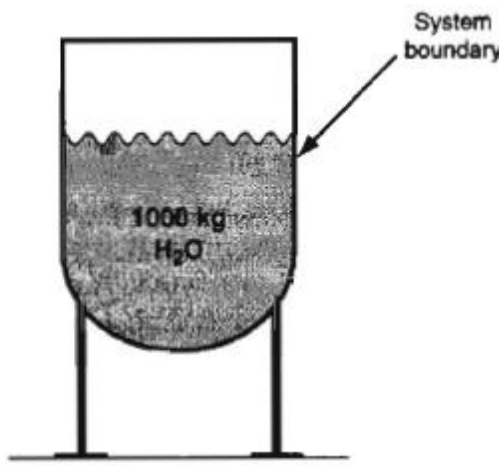


Figure 4.1: A closed system

- **Open or flow system**: A system or process where material crosses the system boundary.
- **Steady state process or system**: A system or process where all the conditions (for example, temperature, pressure, flow rate etc.) remain unchanged with time.

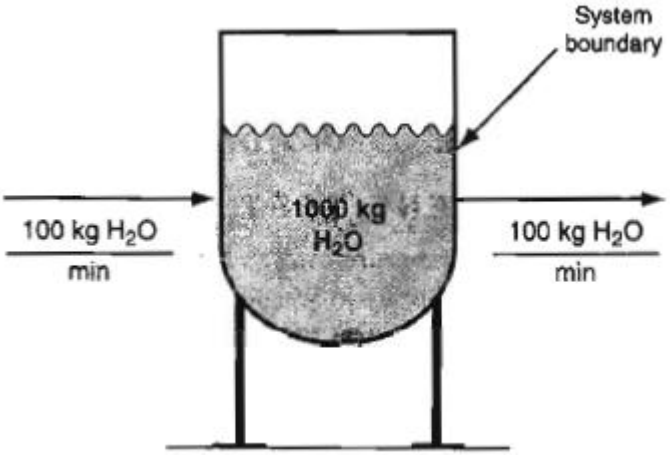


Figure 4.2: An open steady state system

- **Unsteady state or transient system**: A system or process where not all the conditions (for example, temperature, pressure, flow rate etc.) remain constant with time.

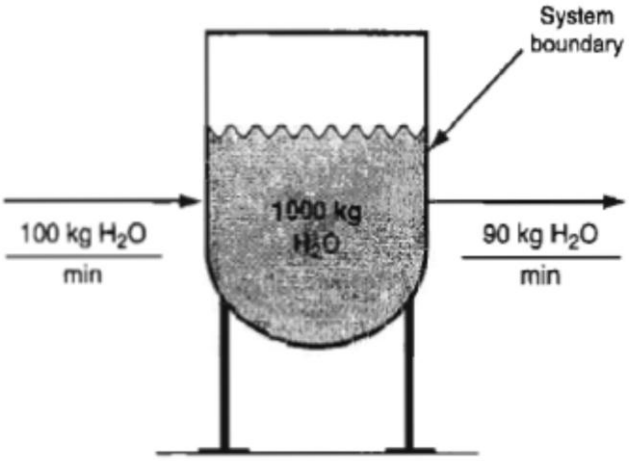


Figure 4.3: Initial condition for an open unsteady system with accumulation

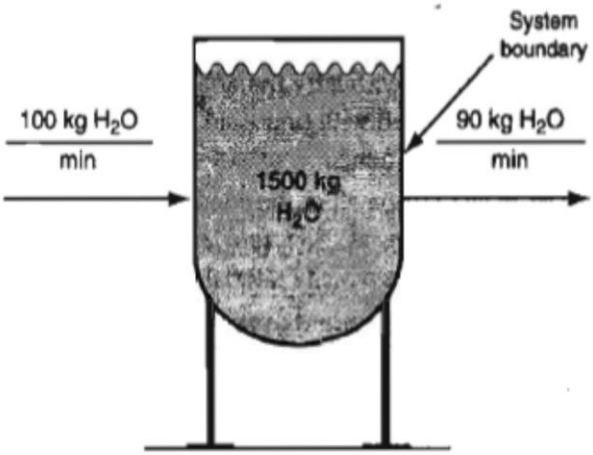


Figure 4.4: The condition for an open unsteady system with accumulation after 50 minutes

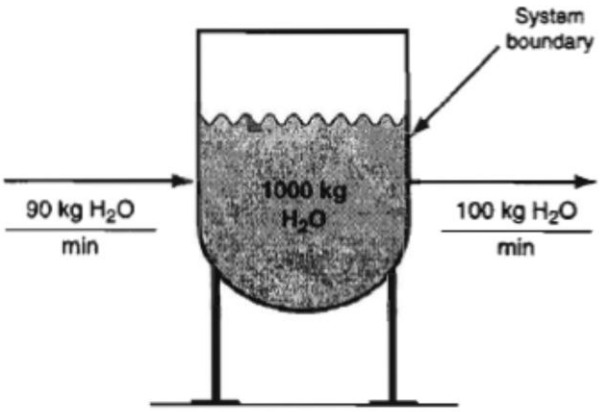


Figure 4.5: Initial condition for an open unsteady system with negative accumulation

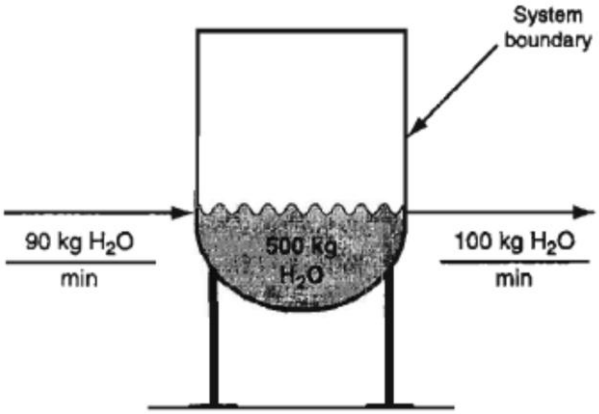
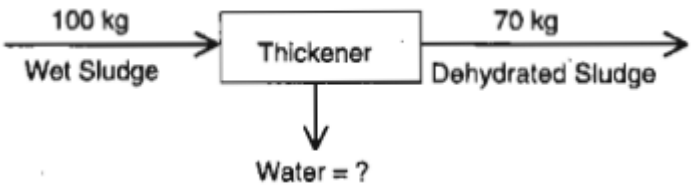


Figure 4.6: The condition for an open unsteady system with negative accumulation after 50 minutes

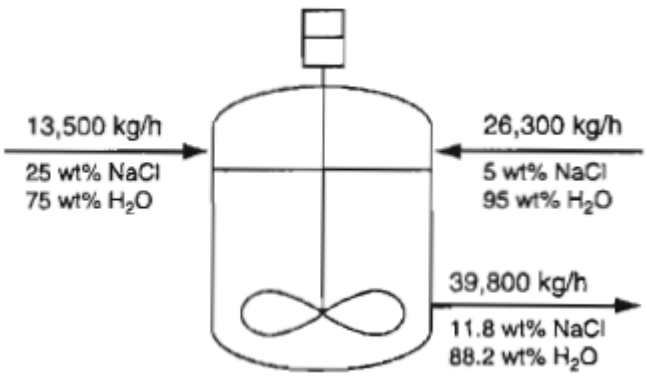
- **Batch process**: A process where no material leaves the system boundary between the time when the feed is charged and the time the product is removed.
- **Continuous process:** A system where there is input and output of material throughout the duration of the process.
- **Semi-batch process:** A process where material enters the system during the operation, but do not leave. So it is neither batch nor continuous.

Exercise 4.1

1. A thickener in a waste disposal unit of a plant removes water from wet sewage sludge as shown below. How many kilograms of water leave the thickener per 100 kg of wet sludge that enter the thickener? The process is in the steady state.



2. Mixers can be used to mix streams with different compositions to produce a product stream with an intermediate composition. The Figure below shows a diagram of such a mixing process. Evaluate the closure of the overall material balance and the component material balances for this process. Closure means how closely the inputs agree with the outputs for a steady state process.

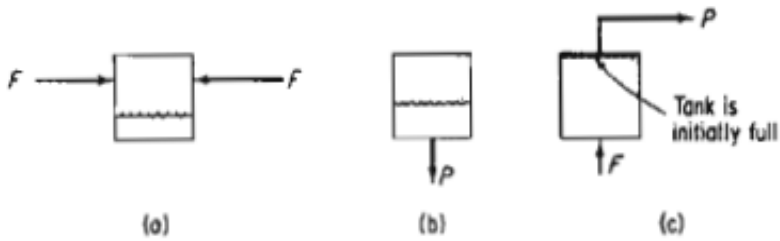


3. A continuous mixer mixes NaOH with H_2O to produce an aqueous solution of NaOH. Determine the composition and flow rate of the product if the flow rate of NaOH is 1000 kg/hr and the ratio of the flow rate of the H_2O to the product solution is 0.9.

4. 1000 kg/hr of a mixture of benzene (**B**) and toluene (**T**) containing 50% benzene by mass is separated by distillation into two fractions. The mass flow rate of benzene in the top stream is 450 kg **B**/hr and that of toluene in the bottom stream is 475 kg **T**/hr. The operation is at steady state. Write balances on benzene and toluene to calculate the unknown component flow in the output streams.

Problem 4.1

1. Consider the processes represented below. Each box represents a system.

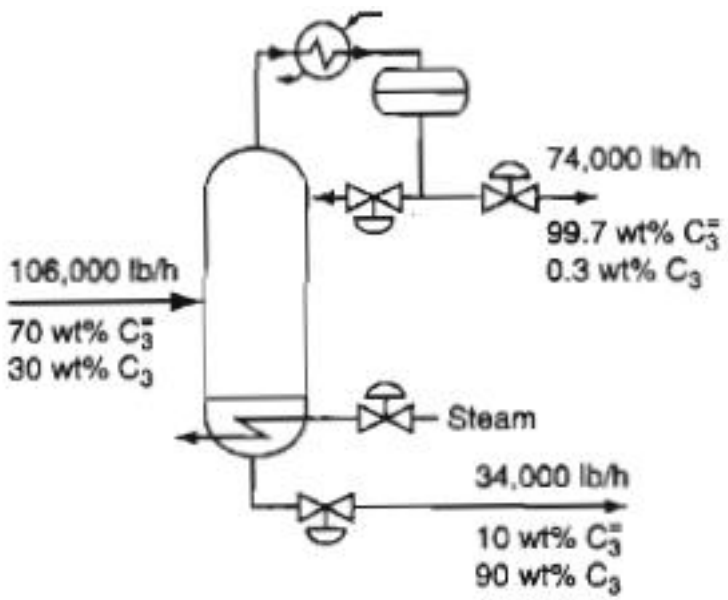


For each system, state whether

a. The process is in the
   i. Steady state
   ii. Unsteady state
   iii. Unknown condition

b. The system is
   i. Closed
   ii. Open
   iii. Neither, or
   iv. both

2. Distillations columns are used to separate light boiling components from heavier boiling components, and makeup 95% of the separation systems for the chemical process industries. A commonly used distillation column is a propylene-propane splitter. The overhead product from this column is used as a feedstock for the production of polypropylene, which is the largest quantity of plastic produced worldwide.
   a. Determine if the overall material balance is satisfied for this system.
   b. Evaluate the component material balances as well.
   c. What can you conclude?



3. A paint mixture containing 25 % of a pigment and the balance water sells for $ 18.00 /kg, and a mixture containing 12.0% pigment sells for $ 10.00 /kg. A paint retailer produces a blend containing 17.0% pigment.
   a. Draw a flow chart of the process
   b. Calculate how much ($ /kg) the retailer should sell the blend to yield a 10% profit

The content s of this chapter and the next are mostly from Himmelblau & Riggs, 2004.

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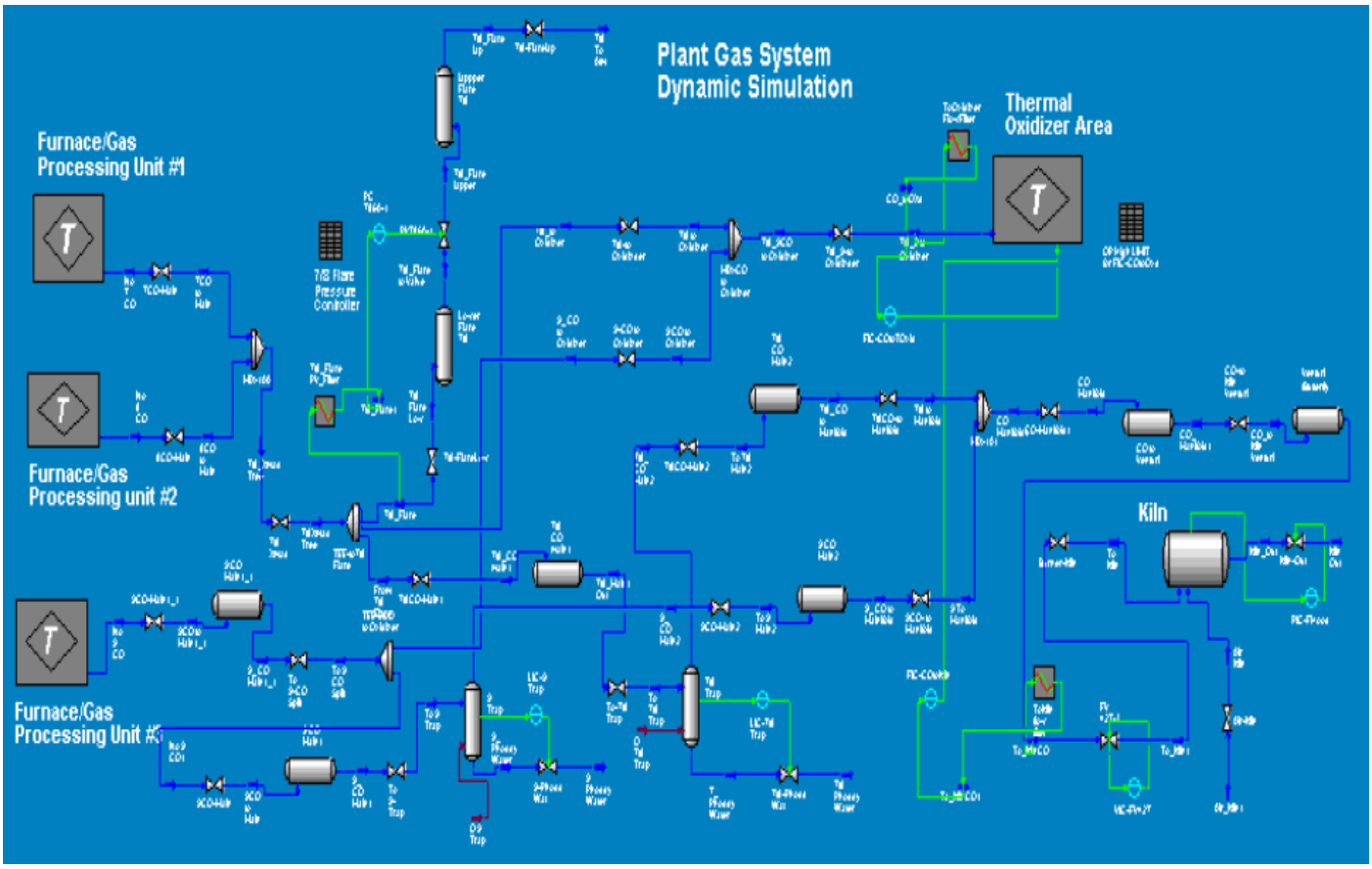
Tutorial 5 – Strategies for Solving Material Balance Problems



What is the Purpose of Tutorial 5?

- Comprehend the strategies of solving complex material balance problems in the industry
- Solve material balance problems involving multiple sub-systems
- Solve material balance problems of multicomponent systems

5.1 Strategies for Solving Problems

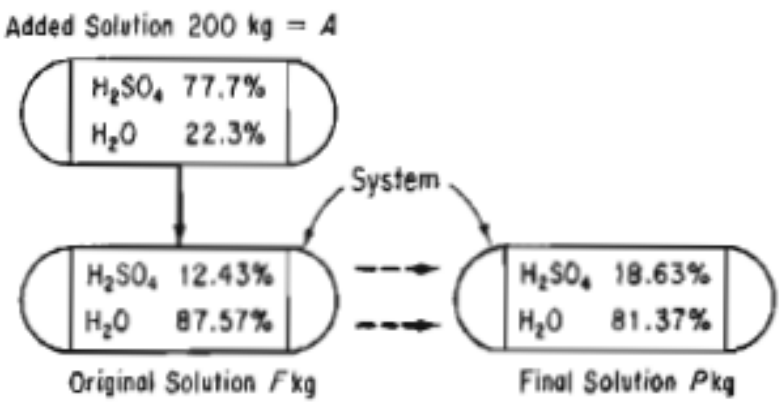
The following strategies will greatly help develop your skills in solving material balance problems

- Read and understand the problem statement
- Draw a sketch of the process and specify the system boundary
- Place labels on the diagram for all the known flows, materials and compositions
- Obtain any data that you need to solve the problem, but are missing
- Choose a basis
- Determine the numbers of variables whose values are unknown
- Choose a basis
- Write down the equations to be solved
- Solve the equations and calculate the quantities asked for

Example: Mixing of sulphuric acid

You are asked to prepare a batch of 18.63% battery as follows. A tank of old weak battery acid (H_2SO_4) solution contains 12.43 % H_2SO_4 (the remainder is pure water). If 200kg of 77.7% H_2SO_4 is added to the tank, and the final solution is to be 18.63% H_2SO_4, how many kilograms of battery acid have been made?

Solution:



Overall balance: $$200 + \boldsymbol{F} = \boldsymbol{P} \quad (1)$$

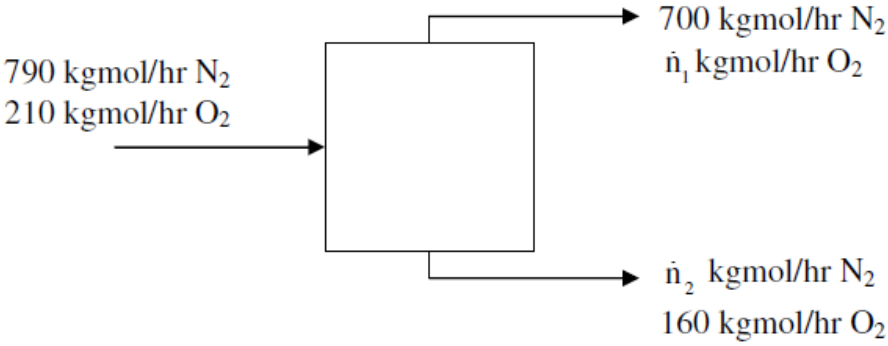
Component balance (H_2SO_4): $$0.777(200) + 0.1243\boldsymbol{F} = 0.1863\boldsymbol{P} \quad (2)$$

By solving Equations 1 and 2 we obtain the values of $\boldsymbol{F}$ and $\boldsymbol{P}$

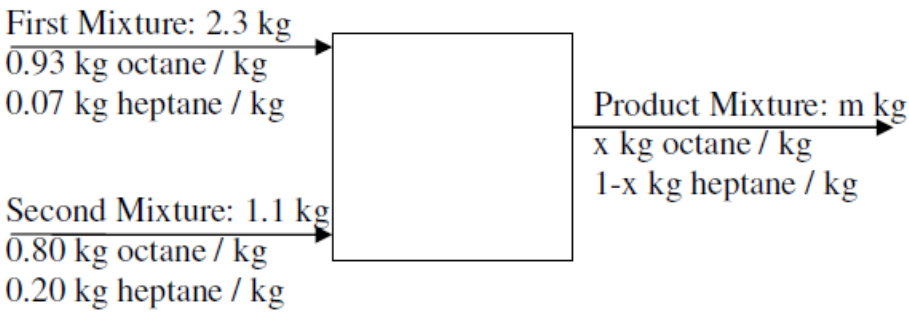
$$\boldsymbol{F} = 2110\ kg$$
$$\boldsymbol{P} = 1910\ kg$$

Practice Problems

1. A cryogenic distillation unit has a feed of 1000 kgmol/hr air. The top stream has 700 kgmol/hr nitrogen and the bottom stream has 160 kgmol/hr oxygen. The process is illustrated in the block diagram below. Write balances on the oxygen and nitrogen to determine the unknown component molar flow rates.



2. Two octane-heptane mixtures are contained in separate tanks. The first mixture contains 93 wt% octane and the second mixture contains 80 wt% octane. In order to have a fuel that can be used in a vehicle, 2.3 kg of the first mixture is mixed with 1.1 kg of the second mixture. What is the mass and composition of the product? A schematic of the process is shown below.



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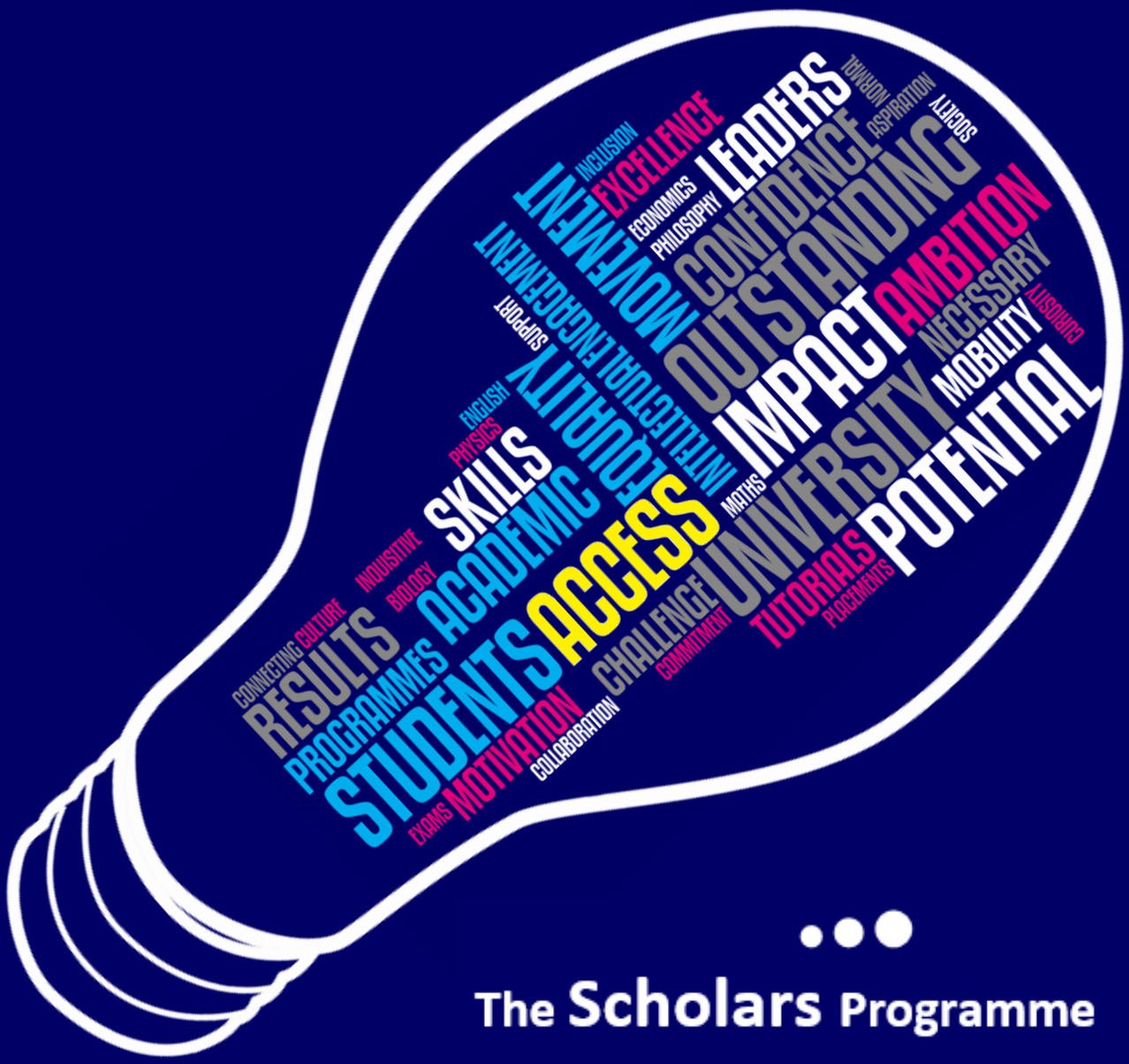
University Applications Guidance

For course choices and careers information:	www.brightknowledge.org.uk
For information and statistics on universities and course:	www.unistats.direct.gov.uk
For comprehensive information on universities, including rankings:	www.thecompleteuniversityguide.co.uk



The Scholars Programme