Chemical Engineering: General Revision

1. Units and Unit Conversions

Chemical Engineers need to be proficient in using and converting between different engineering units. This is because Chemical Engineering projects are often international, with engineers from across the globe. There can be major issues with a design if mistakes are made in unit conversions!

Systems of Units

Typically we will use SI Units ("Systeme Internationale d'Unites), which is a system of units used internationally. Sometimes we will use the AE (American Engineering) System, or the CGS (centimeter-gram-second) System.

Can you identify or guess, for the table below:

a) to which system the following units belong?
b) What base dimension they apply to, for example, length?

meter, m	kelvin, K	foot, ft
gram, g	pounds per square inch, psi	Celcius, ^{o}C
hour, h	pound, lb	second, s
Fahrenheit, ^{o}F	second, s	centimeter, cm
pascal, Pa	kilogram, kg	atmospheres, atm

Pressure units

Often when we refer to pressure, we will give units with a suffix of "a" or "g", indicating "absolute" or "gauge". Absolute pressure uses absolute zero as its zero point, while gauge pressure uses atmospheric pressure as its zero point. So atmospheric pressure can be written as 1.01325 bara, or as 0 barg.

It's important to realise that because atmospheric pressure can vary, gauge pressure measurements are not always precise, while absolute pressure readings are definite.

Some exercises –

- Convert 50 psia to kPa
- Convert 250 kPa to atm
- Convert 3 bara to barg
- Convert 150 Pa to barg

Data: atmospheric pressure is defined as 1 atm, 101 325 Pa, 1.01325 bara, or 14.696 psia.

Case studies

Following the above, there have been several incidents due to errors in unit conversions. Two cases are presented on the next page for you to read about – if you are interested to read more, have a go at researching each topic. This will also be good practice for research elements of your course.

Case 1: NASA

On 23rd September 1999, NASA lost the Mars Climate Orbiter spacecraft, which cost $125 million and which had travelled 286 days to get to Mars. Calculations needed to be done to make sure thrusters were fired in the right direction, to ensure the craft stayed on course. This data was then relayed to the NASA navigation team who performed the necessary course corrections. Unfortunately, the company performing the calculations was sending thruster data in pounds (English units), while the NASA navigation team was expecting metric units (Newtons). This difference slowly sent the craft off course by 60 miles in total, meaning it missed its intercept with Mars!

Problem: We wish to order a rocket booster which should produce a total of 10 million pounds of thrust. If this number is mistaken as 10 million Newtons of thrust, by how much, in pounds, will the thrust be in error?

Data: 1 pound = 4.5 Newtons

Case 2: Disneyland Space Mountain

On 5th December 2003, an axle broke on the roller coaster "Space Mountain" at Tokyo Disneyland, causing the train to derail mid-ride – luckily there were no injuries. After investigation, it was determined that the cause of this failure was that a part was the wrong size – all because a conversion was done incorrectly. The axles had been ordered using a specifications given in inches, instead of the current specification in centimetres.

Problem: A bolt is ordered with a thread diameter of 1.25 inches. What is the diameter in millimetres? If the bolt were mistakenly ordered as 1.25 centimetres, by how many millimetres would the bolt be in error?

Data: 1 inch = 2.54 cm

2. Background knowledge

Ideal gases

Watch this video: https://youtu.be/BxUS1K7xu30

- What is Boyle's Law and how does it relate to ideal gases?
- Who was actually responsible for developing Boyle's Law?
- When can you use the ideal gas law?

Partial pressure and vapour pressure

Watch this video: https://youtu.be/JbqtqCunYzA

- What is Dalton's Law of Partial Pressures?
- How would you determine a mol fraction? What is a mol fraction?
- How does Dalton's Law link to vapour pressure?

3. Fluor Pilot Plant

The Fluor Pilot Plant is a £1.7m facility which includes a fully operational pilot plant. You will get to experience this plant in action in your third year, when you will operate and take charge of production for a week as part of the Process Operations and Management module. This is great experience in the operations aspect of chemical engineering and helps give an appreciation for the real-life aspects! You can even have a look around a digital version of the pilot plant by following this link.

Introduction

Watch this video in which two of our students, Ishanki and Zarif, give a tour of the University of Surrey's Fluor Pilot Plant: https://youtu.be/NKZA8qdT8QM

While watching the video, see if you can identify what the Pilot Plant does.

- What is the main product?
- What are the feeds to the process?
- Can you name two pieces of equipment present in the process?

Chemistry

The reactions that are happening inside the reactor are:

$$2\ NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2\ (g)$$

$$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3\ (s) + 2\ \mathbf{NaCl}$$

The video linked below gives a visual example of the chemistry inside the reactor. If you have calcium chloride salt and baking powder, you could have a go at home!

https://surrey.cloud.panopto.eu/Panopto/Pages/Viewer.aspx?id=0782a41a-86bc-44d5-936a-acda00fb3225

Once you've watched the video, answer these questions:

- The reaction was quite slow. What could we do to encourage a reaction?
- What do you think is causing the small bubbles that were formed?

The next video, linked below, continues this example with an attempt to speed up the reaction.

https://surrey.cloud.panopto.eu/Panopto/Pages/Viewer.aspx?id=c641df35-1b56-4362-892b-acda00fcc1af

After watching this video, answer the following questions:

- Was the attempt to speed up the reaction effective?
- Why does the final powder present in the vessel look different to the salt powder added at the start?
- What is left undissolved in the final mixture?
- How could this substance be separated from the rest of the mixture?
- Are there any other waste products produced?