Introduction

In many scientific and engineering problems, we often deal with quantities like mass, volume, or the number of molecules/atoms of a substance. When solving such problems, it's essential to make calculations based on some reference or "basis." The choice of this basis can make the problem easier to solve and interpret.

A basis is essentially a starting point or a unit of reference that you use for your calculations. It's a specific quantity you choose to simplify your problem. By choosing an appropriate basis, you can make comparisons, perform calculations, and break down the problem into manageable steps.

The choice of basis is important because it determines how you express all other quantities in the problem. In other words, the whole problem is set up relative to the basis you choose. A good basis will make your math and reasoning easier, while a poor choice can complicate things unnecessarily.

Understand the Problem: What are you calculating, and what units are involved? If the problem is about mass conservation, a mass-based basis might be best. If the focus is on a chemical reaction, especially for gases, a mole-based basis may make more sense.

Example 2.14 Choosing a Basis

The dehydration of the lower-molecular-weight alkanes can be carried out using a ceric oxide (CeO) catalyst. What are the mass fraction and mole fraction of Ce and O in the catalyst?

Solution

Start the solution by selecting a basis. Because no specific amount of material is specified, the question "What do I have to start with?" does not help determine a basis. Neither does the question about the desired answer. Thus, selecting a convenient basis becomes the best choice. What do you know about CeO? You know from the formula that 1 mole of Ce is combined with 1 mole of O. Consequently, a basis of 1 kg mol (or 1 g mol, or 1 lb mol, etc.) would make sense. You can get the atomic weights for Ce and O from Appendix B, and then you are prepared to calculate the respective masses of Ce and O in CeO. The calculations for the mole and mass fractions for Ce and O in CeO are presented in the following table:

Basis: 1 kg mole of CeO

Component	kg mol	Mole Fraction	Mol. Wt.	kg	Mass Fraction
Ce	1	0.50	140.12	140.12	0.8975
O	1	0.50	16.0	16.0	0.1025
Total	2	1.00	156.12	156.12	1.0000

Example 2.15 Choosing a Basis

Most processes for producing high-energy-content gas or gasoline from coal include some type of gasification step to make hydrogen or synthesis gas. Pressure gasification is preferred because of its greater yield of methane and higher rate of gasification.

Given that a 50.0 kg test run of gas averages 10.0% H_2, 40.0% CH_4, 30.0% CO, and 20.0% CO_2, what is the average molecular weight of the gas?

Solution

Let's choose a basis. The answer to question 1 is to select a basis of 50.0 kg of gas ("What do I have to start with?"), but is this choice a good basis? A little reflection will show that such a basis is of no use. You cannot multiply the given *mole percent* of this gas (remember that the composition of gases is given in mole percent unless otherwise stated) times kilograms and expect the result to mean anything. Try it, being sure to include the respective units. Thus, the next step is to choose a "convenient basis," which is, say, 100 kg mol of gas, and proceed as follows:

(*Continues*)

Email (Zainab.Hassan.Ali@uomus.edu.iq)

Example 2.15 Choosing a Basis (*Continued*)

Basis: 100 kg mol or lb mol of gas

Set up a table such as the following to make a compact presentation of the calculations. You do not have to, but making individual computations for each component is inefficient and more prone to errors.

Component	Percent = kg mol or lb mol	Mol. Wt.	kg or lb
CO_2	20.0	44.0	880
CO	30.0	28.0	840
CH_4	40.0	16.04	642
H_2	10.0	2.02	20
Total	100.0		2382

$$\text{Average molecular weight} = \frac{2382 \text{ kg}}{100 \text{ kg mol}} = 23.8 \text{ kg/kg mol}$$

Check the solution by noting that an average molecular weight of 23.8 is reasonable because the molecular weights of the components range only from 2 to 44 and the answer is intermediate to these values.

Temperature

Temperature can be seen as a measure of the kinetic energy of molecules or as a way to describe a system's ability to transfer energy (as heat).

There are four main temperature scales:

Relative scales: Fahrenheit (°F) and Celsius (°C). These are based on a reference point - 0°C (or 32°F) is the freezing point of water (The Kelvin scale is based on Celsius but starts at absolute zero)

Absolute scales: Kelvin (K) and Rankine (°R). These scales start at absolute zero, the theoretical lowest temperature possible(The Rankine scale is based on Fahrenheit and starts at absolute zero)

Email (Zainab.Hassan.Ali@uomus.edu.iq)

The following relationships can be used to convert from °F to °R, from °C to K, from °C to °F, and from °F to °C, respectively:

$$T_{°R} = T_{°F}\left(\frac{1\ \Delta°R}{1\ \Delta°F}\right) + 460 \tag{2.6}$$

$$T_{K} = T_{°C}\left(\frac{1\ \Delta K}{1\ \Delta°C}\right) + 273 \tag{2.7}$$

$$T_{°F} - 32 = T_{°C}\left(\frac{1.8\ \Delta°F}{1\ \Delta°C}\right) \tag{2.8}$$

$$T_{°C} = (T_{°F} - 32)\left(\frac{1\Delta°C}{1.8\Delta°F}\right) \tag{2.9}$$

Example 2.21 Temperature Conversion

Convert 100°C to (a) K, (b) °F, and (c) °R.

Solution

a. $(100 + 273)°C\frac{1\ \Delta K}{1\ \Delta°C} = 373\ K$

or, with suppression of the Δ symbol,

$$(100 + 273)°C\frac{1\ K}{1°C} = 373\ K$$

b. $(100°C)\frac{1.8\ \Delta°F}{1\ \Delta°C} + 32°F = 212°F$

c. $(212 + 460)°F\frac{1\ \Delta°R}{1\ \Delta°F} = 672°R$

or $(373\ K)\frac{1.8\ \Delta°R}{1\ \Delta K} = 672°R$

Email (Zainab.Hassan.Ali@uomus.edu.iq)

Example 2.22 Temperature Conversion

The heat capacity of sulfuric acid in a handbook has the units J/[(g mol) (°C)] and is given by the relation

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

where T is expressed in degrees Celsius. Modify the formula so that the resulting expression yields the heat capacity with the associated units of Btu/[(lb mol) (°R)] with T in degrees Rankine.

Solution

The symbol °C in the denominator of the heat capacity stands for the unit temperature difference, Δ°C, not the temperature, whereas the units of T in the equation are in °C. First you have to substitute the proper equation in the formula to convert T in °C to T in °R, and then multiply by conversion factors to convert the units in the right-hand side of the equation to Btu/(lb mol) (°R) as requested.

(Continues)

Example 2.22 Temperature Conversion (*Continued*)

$$\text{heat capacity} =$$

$$\left\{139.1 + 1.56 \times 10^{-1}\left[\overbrace{(T_{°R} - 460 - 32)\frac{1}{1.8}}^{T_{°C}}\right]\right\}$$

$$\times \frac{1}{(\text{g mol})(°\text{C})}\underbrace{\left|\frac{1\ \text{Btu}}{1055\ \text{J}}\right|\frac{454\ \text{g mol}}{1\ \text{lb mol}}\left|\frac{1°\text{C}}{1.8°\text{R}}\right.}_{\text{conversion factors}} = 23.06 + 2.07 \times 10^{-2}T_{°R}$$

Note the suppression of the Δ symbol in the original units of the heat capacity and in the conversion between Δ°C and Δ°R.

Home work

1. Complete the following table with the proper equivalent temperatures:

°C	°F	K	°R
−40.0	____	____	____
____	77.0	____	____
____	____	698	____
____	____	____	69.8

Email (Zainab.Hassan.Ali@uomus.edu.iq)

Pressure

Pressure is defined as the force applied per unit area, specifically the perpendicular (normal) force per unit area.

In the SI system, pressure is measured in pascals (Pa), where 1 pascal = 1 newton per square meter (N/m^2). However, since pascals are a small unit, kilopascals (kPa) are often used instead.

In the AE system, pressure is measured in pounds force per square inch (psi).

Other units for pressure are listed in Table 2.6, which includes various ways to express pressure, all equivalent to 1 standard atmosphere (atm). Standard atmosphere is a unit of pressure commonly used in weather reports and other scientific contexts.

Some of these common pressure units are:

Atmosphere (atm): The standard atmospheric pressure at sea level.

Millimeters of mercury (mmHg): A unit that measures pressure based on the height of a mercury column.

Torr: Essentially equivalent to mmHg.

Bar: Often used in meteorology and other sciences, with 1 bar = 100 kPa.

Email (Zainab.Hassan.Ali@uomus.edu.iq)

Table 2.6 Convenient Conversion Factors for Pressure

Pressure Units	Conversion Factor
bar	1.013 bar = 1 atm
kPa	101.3 kPa = 1 atm
Torr	760 Torr = 1 atm
mm Hg	760 mm Hg = 1 atm
in. Hg	29.92 in. Hg = 1 atm
ft H_2O	33.94 ft H_2O = 1 atm
in. H_2O	407 in. H_2O = 1 atm
psi	14.69 psi = 1 atm

Examine Figure 2.3. Pressure is exerted on the top of the mercury in the cylinder by the atmosphere. The pressure at the bottom of the column of mercury is equal to the pressure exerted by the mercury plus that of the atmosphere on the mercury. The pressure at the bottom of the static (nonmoving) column of mercury (also known as the hydrostatic pressure) exerted on the sealing plate is :

$$p = \frac{F}{A} = \frac{mg}{A} + p_0 = \frac{mgh}{Ah} + p_0 = \frac{mgh}{V} + p_0 = \rho gh + p_0 \qquad (2.10)$$

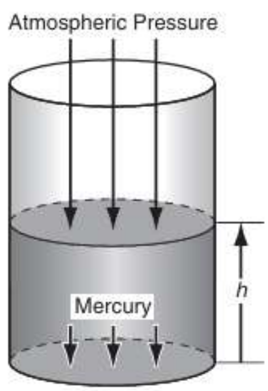

Figure 2.3 Pressure is the normal force per unit area. Arrows show the force exerted on the respective areas.

Email (Zainab.Hassan.Ali@uomus.edu.iq)

where the first term after the pressure p is the definition of pressure, the second term is the combination of atmospheric pressure and the pressure change due to the column of liquid, the third shows how h can be added to the numerator and denominator to get the volume in the denominator, in the fourth term volume is substituted for area times height, and in the fifth term the density is substituted for mass divided by volume. The notation used is as follows:

p = pressure at the bottom of the column of fluid
F = force
A = area
ρ = density of fluid
g = acceleration of gravity
h = height of the fluid column
p_0 = pressure at the top of the column of fluid

Pressure, like temperature, can be expressed in either absolute (**psia**) or relative scales. Rather than using the word *relative*, the relative pressure is usually called **gauge pressure** (**psig**). The atmospheric pressure is nothing more than the barometric pressure. The relationship between gauge and absolute pressure is given by the following expression:

$$p_{\text{absolute}} = p_{\text{gauge}} + p_{\text{atmospheric}}$$

Another term with which you should become familiar is **vacuum**. When you measure the pressure in "inches of mercury vacuum," you are reversing the direction of measurement from the reference pressure, the atmospheric pressure, and toward zero absolute pressure, that is,

$$p_{\text{vacuum}} = p_{\text{atmospheric}} - p_{\text{absolute}}$$

As the vacuum value increases, the value of the absolute pressure being measured decreases. What is the maximum value of a vacuum measurement? A pressure that is only slightly below atmospheric pressure may sometimes be expressed as a "draft" in inches of water, as, for example, in the air supply to a furnace or a water cooling tower.

Example 2.23 Pressure Conversion

The pressure gauge on a tank of CO_2 used to fill soda-water bottles reads 51.0 psi. At the same time the barometer reads 28.0 in. Hg. What is the absolute pressure in the tank in psia? See Figure E2.23.

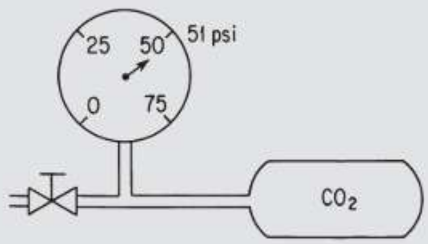

Figure E2.23

Solution

The first thing to do is to read the problem. You want to calculate a pressure using convenient conversion factors. Examine Figure E2.23. The system is the tank plus the line to the gauge. All of the necessary data are known except whether the pressure gauge reads absolute or gauge pressure. What do you think? Is it more probable that the pressure gauge is reading psig, not psia? Yes. Let's at least assume so for this problem. Because the absolute pressure is the sum of the gauge pressure and the atmospheric (barometric) pressure expressed in the same units, you have to make the units the same in each term before adding or subtracting. Let's use psia. Start the calculations by changing the atmospheric pressure to psia:

$$\frac{28.0 \text{ in. Hg}}{} \left| \frac{14.7 \text{ psia}}{29.92 \text{ in. Hg}} \right. = 13.76 \text{ psia}$$

The absolute pressure in the tank is 51.0 + 13.76 = 64.8 psia.

Email (Zainab.Hassan.Ali@uomus.edu.iq)

Example 2.24 Vacuum Pressure Reading

Small animals such as mice can live at reduced air pressures down to 20 kPa absolute (although not comfortably). In a test, a mercury manometer attached to a tank as shown in Figure E2.24 reads 64.5 cm Hg and the barometer reads 100 kPa. Will the mice survive?

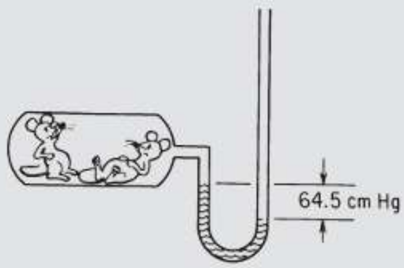

Figure E2.24

Solution

First read the problem. You are expected to realize from the figure that the tank is below atmospheric pressure. How? Because the left leg of the manometer is higher than the right leg, which is open to the atmosphere. Consequently, to get the absolute pressure you subtract the 64.5 cm Hg from the barometer reading.

We ignore any temperature corrections to the mercury density for temperature and also ignore the gas density above the manometer fluid because it is so much less than the density of mercury. Then, because the vacuum reading on the tank is 64.5 cm Hg below atmospheric, the absolute pressure in the tank is

$$p_{\text{absolute}} = p_{\text{atmospheric}} - p_{\text{vacuum}} = 100 \text{ kPa} - \frac{64.5 \text{ cm Hg}}{} \left| \frac{101.3 \text{ kPa}}{76.0 \text{ cm Hg}} \right.$$

$$= 100 - 86 = 14 \text{ kPa absolute}$$

Email (Zainab.Hassan.Ali@uomus.edu.iq)