Chemistry 5, General Chemistry

Self Test

Are you prepared for Chem 5? Probably. You don’t need to have had a super chemistry course before taking Chem 5; in fact, you don’t need to have taken any chemistry beforehand! If you have, that will certainly make the introductory material at the start of Chem 5 much more understandable, but if you haven’t, don’t worry. You’ll catch on as long as you pay attention in class, work hard outside class, and ask questions when you’re stuck.

There are several basic tools of any quantitative science course, such as Chem 5, that you should have at your fingertips, however. The web page titled “What you need to know” found at http://www.dartmouth.edu/~genchem/know.html describes many of them, and this document provides you with a short self test on them. In addition, the page on dimensional analysis and units at http://www.dartmouth.edu/~genchem/units.html reviews the basic language and ideas behind the important topic of physical quantity units. You may want to review that page as well.

Work through these questions on your own, without looking up anything, but take notes on those parts that you do not know. This will give you two important bits of information: a sense of your preparation and a list of tools, techniques, definitions, or ideas that you should review and master. Once you have finished these questions, but not before, you should download and look at the companion solutions handout for this self test. Use it to guide your review.

If you take this self test and find yourself overwhelmed with uncertainty about what to do, what the questions are asking, or what the questions have to do with chemistry, then maybe you should consider talking to a chemistry faculty member about your concerns and options. We’re here to help!

So let’s get started. Remember: these questions are designed to direct you toward basic skill areas that you might need to review. They are not designed to teach you any Chem 5 topic! That will happen as you take the course.

Unit conversions

1. Vitamin D deficiency is a serious condition. Reactions in the liver convert vitamin D₃ into a compound known as calcidiol. This compound can be observed in blood serum, and its concentration can be easily measured. Normal concentrations fall in the range of about 30–75 ng/mL; values below 30 ng/mL are causes for concern and therapy. If a patient has a total blood volume of 5.6 L, a typical average value, how many grams of calcidiol would this patient’s blood contain at the threshold 30 ng/mL concentration?

2. Problem 1 introduced the compound calcidiol and mentioned that a common unit for calcidiol blood concentration is ng/mL. These units are used in the US, but other countries use nM ("nanomolar") or nmol/L units. The molar mass of calcidiol is
400.64 g/mol. By what factor should you multiply a concentration in ng/mL to convert it to nmol/L units?

3. Electrical energy is typically measured and sold in kW h (“kilowatt hour”) units. How many joules of energy are represented by 1.0 kW h of energy? (Hint: one watt is a power, or rate of energy transfer, equal to one joule per second.)

4. You have two solutions of sugar in water in two separate containers. In one, you dissolved 60 g of sugar in 1.5 L of water. In the other, you dissolved 20 g of sugar in 800 mL of water. If you mix 20 mL of the first solution with 30 mL of the second in a fresh beaker, what will be the sugar concentration (in g/L units) of the new solution?

Algebraic manipulations

5. Certain chemical reactions can start with an initial concentration of a reactant, which we will symbolize as \( C_0 \), and after initiating the reaction and waiting a time \( t \), one finds that the concentration of that reactant has fallen to a value \( C < C_0 \). These quantities are related in this type of reaction by the expression

\[
\frac{1}{C} = \frac{1}{C_0} + kt
\]

where \( k \) is a constant. In one such reaction, it is found that after a time of 140.0 s, the concentration of a particular reactant has fallen to \( 4.25 \times 10^{-2} \, \text{mol L}^{-1} \). What was the initial concentration of that reactant if \( k = 0.049 \, \text{L mol}^{-1} \, \text{s}^{-1} \)?

6. In Chem 5, we will spend a significant amount of time looking into the ways temperature changes various measurable quantities. Suppose theory says that one such quantity, which we’ll symbolize \( A \) here, varies with absolute temperature \( T \) according to the expression

\[
A = e^{-B/T}
\]

where \( B \) is a constant. Given a list of measured values of \( A \) and their corresponding temperatures, how would you construct a graph of those data to yield a straight line? How would you use that graph to find the value for the constant \( B \)?

7. Here’s a problem that has nothing to do with the science discussed in Chem 5, but nevertheless is useful because it lets you practice a skill—dimensional analysis—that is invaluable to master in any science course. The random motion of a large molecule diffusing through a liquid of smaller molecules is described by a quantity know as the diffusion constant, symbolized \( D \), and expressed in units of area per unit time, such as \( \text{m}^2 \, \text{s}^{-1} \). For large molecules that can be approximated as spherical in shape, \( D \) can be calculated from the radius \( r \) of the molecule, the absolute temperature \( T \) of the solution, the viscosity \( \eta \) of the solvent (which is expressed in units of pressure times time, such as \( \text{Pa s} \)), and two common universal constants: \( N_A \), the Avogadro constant, \( 6.02 \times 10^{23} \, \text{mol}^{-1} \) and \( R \), the universal gas
constant, 8.31 J mol$^{-1}$ K$^{-1}$. These quantities are connected through an equation known as the Einstein-Stokes equation. This equation is one of the following four, (a) – (d):

$$D = \frac{RT\eta}{6\pi r N_A} \quad \text{(a)}$$

$$D = \frac{r\eta N_A}{6\pi RT} \quad \text{(b)}$$

$$D = \frac{R T}{6\pi r \eta N_A} \quad \text{(c)}$$

$$D = \frac{N_A T}{6\pi r \eta R} \quad \text{(d)}$$

Use careful dimensional analysis to figure out which of these four choices is the actual Einstein-Stokes equation.

**Basic chemical ideas**

8. There are many common chemical compounds that enter everyday life, through news stories or otherwise. Many of these are known by their chemical name and formula, such as water, H$_2$O, carbon dioxide, CO$_2$, and atmospheric oxygen, O$_2$. See how many of the following you can either name given the formula or write the formula given the name.

- NaCl ____________ carbon monoxide ____________
- N$_2$ ______________ ozone ____________
- SO$_2$ _____________ hydrochloric acid ____________

9. It is often very helpful to visualize a physical situation, either in your mind or by a written sketch. Here are verbal descriptions of some situations we will encounter in Chem 5. See if you can draw a simple sketch of them, labeling the various phases that are present (i.e., solids, liquids, solutions and their solvents and solutes, and/or gases).

(a) The solid compound silver chloride, AgCl, is not very soluble in water. What little of it that does dissolve does so by falling apart (dissociating) in the water into silver ions, Ag$^+$, and chloride ions, Cl$^-$, as shown in the net reaction below.

$$\text{AgCl}(s) \rightleftharpoons \text{Ag}^+(aq) + \text{Cl}^-(aq)$$

Sketch a beaker with water that is saturated with AgCl$(s)$. (Do you understand what the “$(s)$” and “$(aq)$” notation means?)

(b) The liquid called hexane, C$_6$H$_{14}$, is fairly volatile at room temperature. It evaporates into gaseous hexane molecules. Imagine a container that has previously been evacuated. Some liquid hexane is introduced into this container, but not enough to completely fill the container with the liquid. There are two possible physical pictures that can result from this procedure. What are they? Draw sketches of each that distinguish them from each other.
The compound *silicon nitride*, Si$_3$N$_4$, is a solid compound at ordinary temperatures containing silicon, Si, and nitrogen, N. It has useful ceramic properties, and it can be made by a reaction between gaseous *silicon tetrachloride*, SiCl$_4$, and gaseous *ammonia*, NH$_3$, which react directly to form Si$_3$N$_4$ and *hydrogen chloride*, HCl, which is formed as a gas. Write a balanced net chemical reaction expressing this transformation which in words is simply

silicon tetrachloride + ammonia $\rightarrow$ silicon nitride + hydrogen chloride