Chapter 5. Cracolice, 2/e. Chemistry X11.

Schedule note. We skip Ch 4 for now; we will pick it up later, along with Ch 13.

Web info: (This information is usually at the end of each chapter handout.)

- The “**Download**” and “**Chemistry practice problems**” pages, available from the main page or the X11 page, contain some items of interest. Among them, for now:
  - My **periodic table** handout. (PDF file)
  - My self-help worksheets on **dimensional analysis** and **density** (both mentioned for Ch 3). Other such worksheets are available here, too.
  - **ChemFormula**, a macro for Microsoft Word, to assist with writing chemical formulas.
- The “**Internet resources**” page for Introductory Chemistry contains several links relevant to current material:
  - pictures of atoms, by atomic force microscopy
  - nuclei, isotopes, atomic weights; nucleosynthesis, astrochemistry
  - information about names of newer elements (101-111).
  - information about the search for heavier elements. Includes some information about the elements from 112-118, and some introduction to the ideas of how and why scientists try to make these new elements. (An initial report of discovering one of these was retracted.) There is also information about the new claim (April 2008) of discovering element #122 in nature; this claim is controversial, and should be taken only as tentative for now.
  - periodic table -- various ways to show it (including tables in over 100 languages), and some humor. Includes information about Mendeleev’s original PT. Includes link to Tom Lehrer singing his song “The Elements”.
  - a chemistry clock -- on a web page that has lots of chem fun.
- There is a “**practice quiz**” for Ch 5.

Chapter 5

This is the first of two chapters on atomic structure. You will learn about atoms, nuclei, protons and electrons, ions, chemical symbols, atomic number, etc. You need to be able to use these terms as basic vocabulary, even while developing a conceptual understanding of them; that development will continue as we go on. Atomic structure (particulate view) is key background for understanding chemical properties (macroscopic view).

Sect 5.1. Dalton’s atomic theory is conceptually important. With our modern understanding of matter, we can criticize details of Dalton’s theory (and that is useful to do). Nevertheless, logically it is substantially correct, and it provides a very helpful perspective on the nature of chemical compounds and reactions.

Sect 5.2 & 3. Core material. Most of Table 5.1 is important (mass in grams is not). Questions such as Example 5.1 and #11 (which also depend in part on Sect 5.4) should become routine.

Sect 5.6 provides a formal introduction to the periodic table (PT). The key idea of the PT is that it organizes much of our knowledge about the elements. As you proceed through your study of chemistry, you learn how to “read” more and more information from the PT. (I prefer the “Current American usage” for group numbers. But be careful: you will find other systems in common use.) Note the elements with unusual symbols (eight of them on p 128).

Some of the groups have "common names"; these are shown in Fig 10.13 (p 282).

A "nuisance topic" in Ch 5 is neutrons and isotopes. If neutrons were massless (or had as little mass as the electrons), we would probably ignore them in beginning chemistry.

Neutrons do not (ordinarily) affect chemical behavior. A nucleus with 19 protons is a K (potassium) nucleus; if it is surrounded by 19 electrons, we have a neutral K atom; if there are only 18 electrons, we have a K^+ ion. These are important statements about the chemical nature of K; they involve the protons and the electrons, but not the neutrons. K atoms and K^+ ions are very different chemicals.

Unfortunately, neutrons do have mass. As a result, you need to know about neutrons and isotopes to understand the atomic masses on the periodic table, including why they are "odd" numbers. However, questions such as Example 5.2 or #14-18 are not important in this course.

⇒ Be sure to distinguish mass number (of a specific isotope) and atomic mass (of an element, average).

> [There are special applications of isotopes. For example, some isotopes are used as "labels": the isotope ^{14}C (C-14) is radioactive, and can be used to label many biochemicals. In fact, C-14 occurs naturally, and the amount of C-14 remaining in old materials of biological origin can be used to date them. See Ch 21, which is beyond our course, for an introduction to radioactivity.
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> We commonly say that isotopes have the same chemical properties. That is substantially -- but not precisely -- true. Many processes, both biological and geological, do distinguish isotopes -- very slightly. The differences in isotope composition measured are typically reported in parts per thousand (‰). See the Further Reading section, below, for interesting applications of isotope analysis.]

For class discussion: #25 (and your questions).

The second chapter on atomic structure is Ch 10.

Further reading (See Old Articles page at web site for more. Also see Ch 10 handout; the material for these chapters overlaps.)

P de Marcillac et al, Experimental detection of α-particles from the radioactive decay of natural bismuth. Nature 422:876, 4/24/03. A bit of elemental exotica. It is commonly said that the heaviest stable (non-radioactive) nucleus is that of bismuth-209. Here they show that that nucleus does decay -- with a half life of about 2×10^{19} years.

M W Cronyn, The proper place for hydrogen in the periodic table. J Chem Educ 80:947, 8/03. Cracolice shows H in two places on the PT. Why? Because H has some properties typical of each group. Here Cronyn discusses the properties of H; he actually prefers yet a third possible position for H. I emphasize that discussion of the properties is more important than trying to determine one "correct" place for H. (Plus an accompanying article, p 952, on the proper place for zinc. This is a more complex issue, well beyond our course for the most part.) Also see Scerri (2008).

C Holden, Forensic geochemistry: Isotopic data pinpoint iceman's origins. Science 302:759, 10/31/03. This is a news story about a man we call Ötzi, who lived in the Alps 5000 years ago, and whose frozen body was recovered a few years ago. Isotope analysis of teeth and bones was compared to samples from a range of nearby areas. Teeth retain their composition from the time of formation, but bones are continually remodeled. Thus the analysis of various structures gave clues both about where he spent his childhood and where he lived as an adult.

P D Nellist et al, Direct sub-angstrom imaging of a crystal lattice. Science 305:1741, 9/17/04. They report a technological development with electron microscopy that allows atom-level resolution.

D Hinde & M Dasgupta, Neutron halo slips. Nature 431:748, 10/14/04. News. Atomic exotica. Some isotopes of light atoms, such as He-6 and He-8, have more neutrons than will fit in the nucleus. The extra neutrons are loosely bound in a "halo" around the ordinary nucleus. The particular story here deals with nuclear reactions involving those halo neutrons.

R Zingales, From masurium to trinacrium: The troubled story of element 43. J Chem Educ 82:221, 2/05. Technetium is the lightest element that has no stable isotopes; it was first officially recognized in material produced at the Berkeley cyclotron, and processed in Italy by Emlio Segre in 1937. This article tells the story of many false discoveries of element #43. For an important follow-up to this article, see an exchange of letters, 83:213, 2/06.

C Dissanayake, Global voices of science: Of stones and health: Medical geology in Sri Lanka. Science 309:883, 8/5/05. Essay. Examples of the issues he discusses are the effects of local geology on water quality, and of local radiation on health. A specific example is the effect of F content of local minerals.

J J Cowan & C Sneden, Heavy element synthesis in the oldest stars and the early Universe. Nature 440:1151, 4/27/06. Review (part of a set on the "Early Universe"). Discussion of the elemental composition of stars -- especially the very earliest ones formed in the universe, which had low abundance of heavy elements.

S Levy, Conservation at a distance: Atomic detectives. Nature 442:504, 8/3/06. News. Measurement of the isotopes found in birds provides information about their migration routes. It reflects the food they ate, and the isotopic composition of the food has known geographical variation.

M A Stoyer, Nuclear physics: Island ahoy! Nature 442:876, 8/24/06. News. People try to make new elements partly out of simple curiosity. Beyond that, the stability of new elements is a test of theoretical models of the details of nuclear structure. The models generally predict an "island of stability" -- some more stable elements, for heavy isotopes of elements somewhere around #114 or slightly higher. Models differ in their precise predictions, making the work to find new elements of particular interest. Here, Stoyer discusses the background and some new developments. Caution: The details are rather advanced physics. However, the basic story is fun. Worth a browse. Also see Janssens (2009).

M Balter, Geochemistry: Radiocarbon dating's final frontier. Science 313:1560, 9/15/06. News Focus. The principle behind radiocarbon dating is simple enough, but in practice there are complications. A major concern is calibrating the results, to take into account variations in the CO_2 isotopic composition of the atmosphere. Over time, this is worked out, and more sensitive detection methods now allow use of C-14 dating back to about 50,000 years -- though not without controversy.

C H Atwood, Radon in homes: recent developments. J Chem Educ 83:1436, 10/06. Radon exposure is now considered the second leading cause of lung cancer in the US (behind smoking).

J G Bell et al, Discrimination of wild and cultured European sea bass (Dicentrarchus labrax) using chemical and isotopic analyses. J Agric Food Chem 55:5934-5941, 7/25/07. Can you -- or at least, a well-equipped lab -- tell whether that fish is "wild" or from a farm? Yes, they say here, by analyzing the fat. They analyze both the chemical composition of the fat and -- more relevant here -- its isotopic composition. The differences reflect the food.

A Brandon, Planetary science: A younger Moon. Nature 450:1169, 12/20/07. News. "The most recent study of lunar rocks indicates that the Moon formed later than previously thought -- a conclusion that requires our view of the early history of the inner Solar System to be revised." And why is this paper listed here? Because the work is based on analysis of isotopes in lunar rocks. Isotope analyses are not always straightforward, because multiple processes may be occurring. Much of the concern here is validating the methodology, and resolving inconsistencies in previous data.

E R Scerri, The past and future of the periodic table. American Scientist 96:52, 1/08. Eric Scerri is a chemist at UCLA -- with a special interest in the philosophy of science. Here he brings his novel perspective to the story of the periodic table, and discusses what the "right" way to show it is. A very readable and thought-provoking article. Also see Cronyn (2003).

W B Jensen, Why tungsten instead of wolfram? J Chem Educ 85:488, 4/08. A short discussion of why element 74 has two names in use, plus some broader discussion of the history of element names and symbols. A "fun" item from a regular J Chem Educ column that is full of nice tidbits, Ask the Historian.

L Khriachtchev et al, A small neutral molecule with two noble-gas atoms: HXeOXeH. J Am Chem Soc 130:6114-8, 5/14/08. The first compound of a noble gas was made in the early 1960s. Articles reporting the first compounds of Ar and of Kr are on the Old Articles page at web site. Here they report a small molecule with two noble gas atoms. A fun field!

J C Meyer et al, Imaging and dynamics of light atoms and molecules on graphene. Nature 454:319, 7/17/08. (+ News, p 283.) Direct electron microscopic observation of individual atoms of carbon and hydrogen. The trick was using graphene as the support material. Graphene is a sheet of graphite one atom thick -- a strong but almost transparent support material. From Alex Zettl's lab at UC Berkeley. Links to a news story at Science News and to the paper itself, posted at Zettl's web site, are on the page of Intro Chem Internet resources. The paper is quite readable -- with nice pictures.

D Grimm, Physics: The mushroom cloud's silver lining. Science 321:1434, 9/12/08. News. Testing of nuclear weapons above ground, in the 1950s and 60s, led to a burst of C-14 in the atmosphere. Thus, biological materials from that time contain a high level of C-14. This has allowed some interesting tests to be done. For example, recent human remains can be dated to within a year or so, based on the C-14 content. Further, study of the C-14 content in specific tissues is yielding information on the slow regeneration of fat and brain cells. Note that this method is distinct from the usual C-14 dating, as it is based on an unusual pulse of C-14 created by human activity. In contrast, ordinary C-14 dating is based on the radioactive decay of C-14, which works on a much longer time scale.

N C Thomas, Connecting element names with the names of U.S. towns. J Chem Educ 86:181, 2/09. Maybe you have heard of Leadville, Colorado, or Copperopolis in the Sierra Nevada foothills of California. How about Tungsten, Nevada, or Arsenic Tubs, Arizona? In this delightful article, Thomas lists numerous U.S. places that bear chemistry-related names, and tells a bit of their stories. Did you know there is a real historical story why a leading brand of borax is "20-Mule Team"? See his item for Boron, California. Electron, Washington? Who knows.

T Elliott, Earth science: Restoration of the noble gases. Nature 459:520, 5/28/09. News. Geologists study the distribution of the noble gases, and specific isotopes, in the earth to help understand the earth's internal motions. For helium, for example, the isotope He-3 is primordial, whereas He-4 is continually produced by radioactive decay of heavy elements. Unfortunately, there are many uncertainties in studying these seemingly simple elements. This new story discusses some recent work, and a new model, on helium.

R V F Janssens, Nuclear physics: Unexpected doubly magic nucleus. Nature 459:1069, 6/25/09. News. We often note that the search for new heavy elements is done in part to help understand nuclear structure. However, even for lighter atoms, our understanding is incomplete. We really do not know the maximum possible number of neutrons (N) for most elements. Here they discuss the isotope O-24, which -- surprisingly -- turns out to be "doubly magic" (both numbers of P and N). Also see Stoyer (2006).

G Bollen, Nuclear physics: Weighing up the superheavies. Nature 463:740, 2/11/10. News. Discusses work that measured the mass of nobelium atoms to unprecedented precision. Why do we care? As noted above (Stoyer, 2006), understanding heavy nuclei focuses on understanding their stability: their energy. But the mass is our window to their energy, because of the Einstein relation, $E = mc^2$.

1) Yu. Ts. Oganessian et al, Synthesis of a new element with atomic number Z = 117. Physical Review Letters 104:e142502, 4/9/10.
2) S Hofmann, Exploring the island of superheavy elements. Physics 3:31, 4/9/10.
These two articles are about the discovery of element #117, reported in April 2010. The first is the actual report; the second is an accompanying news story. Both are freely available on the web; see my page of Internet Resources for intro Chem, for Element #117.

A Millevolte, Nuclear stability and nucleon-nucleon interactions in introductory and general chemistry textbooks. J Chem Educ 87:392, 4/10. An introduction to the nucleus, intended as an example of how it might be presented in a basic chem course. The article introduces the strong nuclear force, an attractive force between all nucleons (N & P). In so doing, it introduces the quarks, and their interactions. This short article can be a good place to start for those who wonder how a bunch of positively charged protons can stay together.