

## Chapter 3 (and course introduction). Ouellette, 2/e. Chemistry X402.

Ch 3. Alkanes and cycloalkanes.

See the “Chapter handouts” and “Homework” sections of the General Information handout (syllabus).

**Written assignment**, due week 3.

Ch 3: 2, 4b, 6a, 12d, 20, 24c (show them), 32b, 38a, 42, 48, 50. “Advanced”: 8a, 10, 14, 18a.

This brief assignment will let me spot check how you are doing; it is a subset of the “Suggested” problems, below. It is not intended to be sufficient for you to learn the material. By turning this in at class 3, you will get it back in class 4, so you will have a little time to look at the feedback before the test. (I assigned even-numbered problems here; you should first work on the accompanying odd-numbered ones, to try to make sure you have the idea.)

⇒ A practice quiz for Alkanes and cycloalkanes is at the web site.

### **Also read: Background chapters**

We formally start with Ch 3, but Ch 1-2 provide important background material. I encourage you to look at my web page on “Background information” for more information about these first two chapters.

⇒ Along with Ch 3, you are responsible for Ch 1 Sect 1-4, 7, 10, 11 and Ch 2 Sect 1. Some of these are referred to specifically below.

### **General plan**

In classes 1-3, we will cover Ch 3-4, on most of the major types of hydrocarbons. Test 1 is in class 4, and will probably cover these two chapters.

Ch 3-4 not only introduce simple classes of organic chemicals, but they lay the groundwork for most of what follows.

### **Week 1**

Introduction. We will talk about the scope of organic chemistry and biochemistry, and about some of the background chemistry that you should be familiar with. Most of this is in Ouellette Ch 1-2, but you may prefer to use a familiar book. It is “normal” for X402 students to review their general chemistry, whether from Ouellette or other sources, throughout the course.

**Ch 3**

We may start Ch 3 in class 1, but will discuss most of it in class 2. Read Ch 3 for class 2, if you haven't already. Start doing the problems, at least those within the chapter. [If you are reading from another book, read the sections that provide a general introduction to organic chemistry, alkanes, organic nomenclature.]

**What are you responsible for?** (General; specifics for this Ch)

In general, you are responsible for the assigned parts of a chapter, regardless of coverage in class. You are not responsible for the "Essay" sections, unless they are explicitly assigned (see below). Within a chapter, certain topics will be marked "skip" or "advanced". These designations are described below, and will help you to set priorities. The book, modified by notes in these Ch handouts, defines the course, not coverage in class.

**Skip.** We will skip some sections or topics. Those who are going on to take university-level organic chemistry may want to read these sections, since they will almost always be on topics that will be covered there. However, you are free to do this at your own pace, even after the course is over. I am happy to discuss "skipped" material with you, or to look at written work.

In Ch 3, we will skip: Sect 9. An overview of skipped sections(s) is later in the handout.

**Advanced.** Some topics may be noted as advanced. A key feature of many "advanced" topics is that they depend on you knowing the basic material. You are responsible for topics I mark as "advanced"; however, they will be covered very lightly on tests. It is much more important that you learn the basic material than that you worry about the advanced material. Those who are doing well, of course, should try to do most of the "advanced" topics.

In Ch 3, the following topics are "advanced":

On p 75 he introduces IUPAC naming of branched alkyl groups. This is more difficult and lower priority. Make sure you are doing ok with the basics (pp 73-74) before tackling this.

In Sect 4, the basic ideas are important: free rotation about single bonds; multiple conformations; conformations that have large groups far apart are favored. However, you are not responsible for the terminology of the conformations, or the artistic methods used to show them, such as Newman projections.

Other things that are "advanced" may be noted below under the general Notes for the Ch.

**Additions.** I may assign certain sections, from the background chapters or elsewhere, that are particularly relevant to the current Ch. For Ch 3, I noted such additional assigned reading above, under “Also read: Background chapters”.

**Essays:** not assigned. (However, you may often find these of interest.)

### **Notes**

You should become comfortable with the idea of isomers. Ch 3 introduces skeletal (constitutional, structural) isomers (p 70, butane vs isobutane) and geometric (cis-trans) isomerism, a type of stereoisomerism (Sect 5). Review Sect 1.11 for an introduction to isomers, a major general idea. (More kinds of isomers in Ch 4 & 6.)

Be sure to distinguish isomers and conformations. Isomers are distinct chemicals; conformations are different shapes of the same chemical. See my Glossary web page for an elaboration.

**You should know:** The names of the n-alkanes with 1-10 C (first half of Table 3.1). Note that, after a few “common” names, the prefix indicates the chain length.

Fig 3.1 introduces the classification of C atoms as primary, secondary, etc. These terms will come up several times during the course, in various contexts. I have posted a web page that covers all the various meanings of primary (etc) you will encounter during the course. As noted there, the meanings vary, and are not all easily predicted. I hope the web page will help you see the big picture -- what is consistent and what is not. You are responsible for each use of the terms as we get to the appropriate chapter.

Sect 3.3. Nomenclature. Focus on naming and drawing compounds, not on memorizing rules. Let the rules emerge from your practice. We will build on this topic throughout the course.

p 72. Terms such as “parent chain” or “main chain” are used while discussing nomenclature. For now, these refer to the “longest continuous chain of C’s”. It is really a bit more complicated than that, so be alert that you will need to modify your understanding of these terms in later chapters.

On p 73, he introduces R to designate an alkyl group. For example, ROH is a general formula for an alcohol, with an -OH group. However, R is not always used consistently in organic chemistry. Sometimes it is used more generally to refer to “an organic group” (not necessarily alkyl). This can be confusing to beginners, and sometimes you may want to ask about R. However, when R is used, it is usually not important exactly what R is.

**You should know:** The common names for small branched alkyl groups, p 74.

I will emphasize IUPAC names, because they are “logical.” However, many common organic chemicals have “common” (or “trivial”) names. It’s good to learn some of these, because they are widely used (unfortunately), but I won’t require it.

[Example, from general chemistry... “dihydrogen monoxide” (a very logical name) is often called “water” -- a name that conveys no information unless you have specifically memorized it.]

We will not discuss IUPAC naming of multi-ring compounds, such as those shown near the bottom of p 79. (It's not in the book.)

p 80. In naming organic chemicals, the position of a group or feature is usually indicated by a number telling which C the group is attached to. In some cases the number is omitted; singly substituted cycloalkanes are one type of example (e.g., methylcyclohexane). See my web page on “Omitting numbers” for a discussion of when you can omit the number. This page may be more useful later; I suggest you refer to it whenever you are tempted to omit the number.

Sect 6. Important ideas, following on Sect 4. Note that the ring prevents free rotation. We will emphasize 6-rings (6-membered rings), which are among the most common in both organic and biochemistry. Such rings are quite flexible, and rapidly interconvert among the various conformations. I strongly encourage you to play with models, to see what terms such as chair, axial, equatorial mean. With models, you should be able to see that axial positions alternate up/down -- and are crowded. Emphasize that cis/trans and axial/equatorial refer to distinct issues, and there is no simple relationship between them. See my web page “Rings: Showing cis/trans and axial/equatorial relationships” for guidance on keeping these two different issues straight. As with Sect 4, we will try to avoid getting bogged down in art work; for example, I will provide you with “chair” templates on a test.

Sect 7. Review electronegativity (Sect 1.3), polar bonds (Sect 1.4), and intermolecular forces (Sect 2.1).

Tables 3.2-3 show data such as boiling points (BP) and density for some compounds. Similar tables are found throughout the book. You should recognize the trends in such data, and the reasons for the trends. Coupled with “common knowledge” about some common chemicals, these trends will help you make useful predictions.

Interestingly, such trends are more uniform for BP than for MP. The BP involves a change from a state with intermolecular interactions to one without such interactions. Thus predictions based on such interactions are easy to apply. The MP involves a change between two states both of which have intermolecular interactions. The net effects can be more complex than expected.

Sect 8. Ordinary combustion of organic compounds is the uncontrolled and complete (or near complete) oxidation by O<sub>2</sub>, as exemplified by the equation at the bottom of p 87. We assume you are familiar with this from intro chem. We normally write and balance the equation showing idealized complete oxidation; the incompleteness has important pollution implications, but is usually small. For some practice writing and balancing combustion equations, see the page of supplemental questions, attached at the end of this handout. Test 1 almost always contains a question of this type.

Sect 10 does not depend on Sect 9, which we skip. This section extends your world of naming organic compounds to include halogen substituents. Good practice; no new principles.

You should learn the general geometry and bond angles that are typical in various types of organic compounds. He covers this in Sect 1.7. For Ch 3, all we need is that C with 4 atoms attached has tetrahedral geometry, with nominal bond angle  $109.5^\circ$ . You are also encouraged to read about the orbital model of how C forms bonds, in Sect 1.8. For Ch 3, all we need is  $sp^3$  hybrid orbitals. Orbitals, including hybrid orbitals, is an “advanced” topic. It is most useful for us when discussing double bonds (Ch 4) and aromatic compounds (Ch 5).

⇒ There is a summary list of all the functional groups on p 19. You are not responsible for these until each one comes up (in its own chapter). However, they get mentioned from time to time, and you can treat this table as open book reference for now.

Reaction summary (p 94). This will be a useful feature in many of the chapters, but this one is not too helpful. The reactions it does include are ones we are skipping. More importantly, it omits a major reaction discussed in the chapter, which is ???

### **“Suggested” problems**

This section is a guide to some problems that I think are more important or helpful. I encourage you to do “most” of the problems, but this list will help you set some priorities.

Note that there is a written assignment for Ch 3, at the top of this handout. Those problems are a subset of the ones listed here. Feel free to turn in any others that you have trouble with, or questions about, or otherwise just want some feedback on.

In general, you should always do the in-chapter problems as you go through the chapter.

For Ch 3, all of the problems are good, with the following notes:

The “Explorations with Molecular Models” are very nice. I encourage you to do at least some. If you do not have models, try to improvise and do some basics, or use my models before or after class. Priority: #1, 6, 7, 11.

7-10, 13-14 & 17-18 are on an “advanced” topic. I do hope you will try some of these.

25-28 are on an advanced topic.

43-46 are on the skipped section.

47-52 are fairly general questions, which do not critically depend on the specific sections they are listed for. Give them a try.

We will not discuss spectroscopy. Most chapters will contain questions such as #53; skip.

You may want to work on some problems from Ch 1-2, as needed.

For more practice on names and structures, try doing problems such as #11-18 backwards. For example, take the names in the answers to #11, and try to write the structures, which are in the question.

A supplemental page of problems on combustion is attached. You should know the basics of combustion from your general chem background -- but some students are rusty. So I have provided a few problems; the answers, at the bottom, give some explanation. Since this is a chapter on alkanes and cycloalkanes, I have asked you to figure out what the chemical is in some questions.

### **Errata**

(Most come from students. Please let me know if you do not agree with book answers, or if you have other suspect points from the text or handouts. As new errors are reported, I will include them in the Errata list file, linked to the Updates page, and include them in upcoming handouts.)

### **Ch 2**

p 62 #1. Model shown is for the wrong compound. The correct compound is pentane,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$ . For a picture of the correct model, see p 95 #5.

### **This Ch**

p 82, Problem 3.6. Answer given is incorrect. The ring O is missing. That is, the answer should be the same as the structure given in the question, except for switching the orientation of the two groups at lower left.

p 98, #29b. Answer given is not the most “fully condensed” formula, as was requested. Replace the two methyl groups by simple lines. (His answer is a quite proper formula. It is just not the best answer to what was asked.)

⇒ To help you organize... The following three sections of the handout (Overview of skipped section(s); Further reading; Computer resources) are all “optional”. When you are doing your final review, there should be nothing in these sections that you are responsible for. I will try to follow this format in all the chapter handouts. Please let me know if I get something in the wrong place.

### **Overview of skipped section(s)**

Some notes, for those who want to explore these sections on their own...

- Sect 9. This section discusses one type of reaction of alkanes, halogenation. The reaction proceeds via free radicals. Note that the more reactive halogen ( $\text{Cl}_2$ ) is less selective; this should “make sense”. There is also a brief discussion of the physical properties of haloalkanes, which introduces the idea that large atoms are “polarizable”. The essay on p 92, which is not assigned, also involves free radical reactions.

**Further reading**

I hope you find it useful to at least browse this section, which will explore a wide range of issues. You are not responsible for the content, and certainly not expected to read the articles.

There are two web pages listing more articles. One is a page of “Old articles”, which used to be in chapter handouts. Some of these, even when too old to include here, are still worth noting. The other is a page for articles on “medical topics”. This will let me shorten some handouts, but still allow me to note a wide range of interesting articles.

For information about using the UC Libraries, including the electronic resources, see the “Library Matters” page at the web site. That page also includes information about doing searches of the scientific literature, to find articles on a topic that interests you. Major topic areas there include: UC Berkeley library; electronic journals; journal articles; Medline searches; citation searches.

H Petroski, Why ‘The pencil’? *Amer Sci* 88:114, 3/00. A delightful article on one major use of one form of carbon. The author is an engineer, and a regular columnist in *American Scientist*. In this article, he is promoting his book. The book uses the development of a common object to discuss the broad issues of product development, especially from an engineer’s viewpoint. More about the book is at my web page “Books: Suggestions for general reading”. (Did you know that Henry David Thoreau played an important part in the fledgling American pencil industry?)

S Gupta, A victim of truth. *Nature* 407:677, 10/12/00. We will mention Wöhler’s synthesis of urea in class, as part of the history of organic chemistry. This “Millennium Essay” is an historical perspective on the notion of a vital force, and how Wöhler’s work affected that idea. The Dec 14 issue of *Nature*, p 767, contains some follow-up correspondence. There are two items; the one by Toby is particularly interesting, in that it questions whether the cyanate that Wöhler used was truly inorganic.

C Hall et al, Hydrocarbons and the evolution of human culture. *Nature* 426:318, 11/20/03. First of a series of articles in a *Nature* Insight feature on hydrocarbon reservoirs. There are several articles, on a range of biological, geological and societal issues concerning fossil fuels. One article is on gas hydrates; also see Bohannon (2008). Also see Computer Resources, below.

M Golombok, Steam hydrocarbon cracking and reforming. *J Chem Educ* 81:228, 2/04. Discussion of major industrial processes. Cracking produces smaller hydrocarbons, such as ethylene; reforming produces  $\text{CO} + \text{H}_2$ , a mixture commonly known as syngas. A key point is that the two reactions are rather similar, but with different conditions so that one is controlled by kinetics and the other by equilibrium. (The author is from Shell Oil.)

R Coontz & B Hanson, Not so simple. *Science* 305:957, 8/13/04. This is the introductory article to a feature section, “Toward a Hydrogen Economy”. The use of hydrogen as a fuel has

been much in the news, and has even become a political issue. This series of articles is an excellent introduction to the issues of using H<sub>2</sub> as a fuel. The most common news stories deal with how nice H<sub>2</sub> is as a clean-burning fuel. However, what limits its use -- and will likely continue to do so -- is any practical way to make it economically. Although there are many worthwhile lines of research on hydrogen, its widespread use as a fuel is not imminent.

G W Gribble, Natural organohalogens: A new frontier for medicinal agents? *J Chem Educ* 81:1441, 10/04. The antibiotics chloramphenicol and vancomycin are examples of natural halogenated compounds already known to be useful in medicine. This article broadly reviews the range of halogenated compounds found in Nature. Many are found among the marine organisms, and this diversity has not been extensively tapped. The article includes a brief discussion of the relatively uncommon fluoro compounds, and the recent work on how F is incorporated. Also see Muller et al (2007).

M El Eid, Astrophysics: The process of carbon creation. *Nature* 433:117, 1/13/05. News, about recent work measuring the rate of a key process [fusion of three  $\alpha$  (alpha) particles (He nuclei)] that makes C in stars.

F Rojo, Specificity at the end of the tunnel: Understanding substrate length discrimination by the AlkB alkane hydroxylase. *J Bacteriol* 187:19-22, 1/05. Commentary. The first step in metabolizing alkanes, carried out by some microbes, is (most commonly) oxygen-dependent hydroxylation. This article discusses some of the biology of this reaction; some of the enzymes may be useful industrially. (For a different approach to oxidizing a hydrocarbon, see Beal et al, 2009.)

Z Shao et al, A thermally self-sustained micro solid-oxide fuel-cell stack with high power density. *Nature* 435:795, 6/9/05. This could be a step toward a small fuel cell suitable for uses such as powering laptop computers. It includes a good discussion of the issues involved in making the fuel cells practical.

A A Raghoebarsing et al, Methanotrophic symbionts provide carbon for photosynthesis in peat bogs. *Nature* 436:1153, 8/25/05. Methane is an interesting molecule of biology, being both produced and consumed by microbes. Both processes are involved in the ecology of peat bogs. Bacteria make methane, and much of it is consumed by mosses, with the help of symbiotic bacteria. The bacteria convert the methane to CO<sub>2</sub>, which is used by the photosynthetic mosses.

R Hoffmann, Old gas, new gas. *Amer Sci* 94:16, 1/06. "Cornell University Nobel laureate in chemistry Roald Hoffmann takes a studious look at methane, the gas we use to heat our homes. Apparently its structure is the only simple thing about it. Methane on Earth has not one source, but many." A delightful essay.

M A Ubeda & R Dembinski, Fluorous compounds and their role in separation chemistry. *J Chem Educ* 83:84, 1/06. Our common knowledge of fluorinated organics probably is restricted to Teflon and perhaps Freons. This article expands on that, with an emphasis on the properties of fluorinated solvents.



D E Canfield, Biochemistry: Gas with an ancient history. *Nature* 440:426, 3/23/06. News. "Researchers persist in tackling our ignorance of what life was like way back in Earth's history. Evidence of methane production in ancient microbial ecosystems now emerges from 3.5-billion-year-old rocks."

P F McMillan, Solid-state chemistry: A glass of carbon dioxide. *Nature* 441:823, 6/15/06. News. "Carbon is unusual in its family of elements because it has gaseous oxides. But under high pressure, carbon dioxide forms crystalline solids and can become a glass - so revealing the chemical family resemblance."

J Zheng et al, Ultrafast carbon-carbon single-bond rotational isomerization in room-temperature solution. *Science* 313:1951, 9/29/06. How free is the "free rotation" in ethane? Seems that it takes about 10 ps for ethane to rotate between two of the equivalent "staggered" conformations. This is in good agreement with theory.

R G Bergman, Organometallic chemistry: C-H activation. *Nature* 446:391, 3/22/07. In Ch 3, we discuss the difficulty of doing useful controllable reactions on alkanes. In fact, there has been some progress in developing catalysts that allow some control of such reactions. However, there is still little of practical use. The Q&A format of this article makes it a nice introduction to the topic.

K Muller et al, Fluorine in pharmaceuticals: Looking beyond intuition. *Science* 317:1881, 9/28/07. Review. Prozac and Lipitor are examples of well-known drugs that contain F. This article discusses the properties of F-containing compounds, and the prospects for making new useful F-drugs. Also see Gribble (2004), which focuses on natural organohalogens.

D M Jones et al, Crude-oil biodegradation via methanogenesis in subsurface petroleum reservoirs. *Nature* 451:176, 1/10/08. There is circumstantial evidence that petroleum can get converted to methane, although the details remain unclear. Here they explore this process. They suggest that the likely major process involves the conversion of microbially-produced CO<sub>2</sub> and H<sub>2</sub> back to CH<sub>4</sub>. They speculate on whether stimulating such a process might be a good way to get enhanced oil recovery -- by converting it to a gas, which is more easily harvested. A news story about this work is listed on my page of Internet Resources for Organic/Biochem, under Alkanes.

G Proskurowski et al, Abiogenic hydrocarbon production at Lost City Hydrothermal Field. *Science* 319:604, 2/1/08. Some hydrocarbons can be formed from CO<sub>2</sub> by geochemical (non-biological = "abiogenic") processes. Here, they provide evidence that such abiogenic processes contribute substantially to one particular deposit of hydrocarbons (on the Mid-Atlantic Ridge). It is unlikely that these processes are major contributors to our reserves of "fossil fuels", though there is some debate on that point. The discussion of abiogenic hydrocarbons, especially methane, is also relevant in the exploration of Mars (Lefevre & Forget, 2009).

P W May, Materials science: The new diamond age? *Science* 319:1490, 3/14/08. News. Si is the basis of our modern world of semiconductor electronics. Why not C, its family member? Because the common form of C, graphite, is a good conductor. However, the less common form of C, diamond, is a semiconductor, and could potentially form the basis of the type of

controlled electronics systems we associate with Si. There are major technical hurdles in making diamonds of satisfactory quality. This news story discusses the challenges, and the limited progress so far.

J Bohannon, Energy: Weighing the climate risks of an untapped fossil fuel. *Science* 319:1753, 3/28/08. News. A report on a meeting on the “Vulnerability and opportunity of methane hydrates”. The plus is the potential of these methane deposits as an energy source; the minus is the possibility that they will release this greenhouse gas to the atmosphere. This article is a very brief and superficial introduction, but perhaps it is a good place to start on this exciting subject. (For more background on this topic, see my Old Articles web page. Also see Hall et al, 2003.)

B Vastag, EPA feels heat over flame retardant. *Nature* 452:513, 4/3/08. News. PBDE = polybrominated diphenyl ether. PBDEs are used as flame retardants. They are now controversial, with mounting evidence of toxicity. This short news item introduces both the science and the politics of this ongoing story.

F Raulin, Planetary science: Organic lakes on Titan. *Nature* 454:587, 7/31/08. News. The Cassini spacecraft has now provided evidence for ethane in the lakes on the Saturnian moon Titan. Earlier, Cassini had shown that there is methane in the lakes. Titan is the only solar system body other than the Earth known to have lakes.

R N Perutz, Chemistry: A catalytic foothold for fluorocarbon reactions. *Science* 321:1168, 8/29/08. News. Fluorocarbons are quite inert. A corollary is that there is a disposal problem. We learned this when the common fluorocarbon refrigerants proved to be persistent atmospheric pollutants. The article here discusses the development of catalysts to promote degradation of fluorocarbons.

G Etiope & P Ciccioli, Earth's degassing: A missing ethane and propane source. *Science* 323:478, 1/23/09. “Natural gas seepage contributes far more methane, ethane, and propane to the atmosphere than formerly realized.”

R E R Nisbet et al, Emission of methane from plants. *Proc Royal Soc B* 276:1347-1354, 4/09. In 2006 a group reported that plants make methane. A lot of methane -- enough to suggest that plants were major contributors to our global methane budget. This was a surprising finding, since it was inconsistent with our understanding of how methane is made. The paper explored how this might occur, with no clear conclusions; in the absence of any reasonable mechanism, many were skeptical. Since the initial report, others have examined this; results varied, but the emerging consensus was that the initial report was either wrong or exaggerated. This report by Nisbet et al offers a new view. They show that the plants lack any known pathway for making methane. Importantly, they report that plants serve as efficient conduits of methane from the soil, via transpiration. Thus they really do emit methane, but it is not their own production. This proposal makes sense, and accommodates the variable results obtained by others. Is this the last word? Let's see. My web page of Org/Biochem Internet Resources includes a link to a news story on this work for this chapter.

E J Beal et al, Manganese- and iron-dependent marine methane oxidation. *Science* 325:184, 7/10/09. The common route of consumption of hydrocarbons is aerobic, with direct oxidation

by O<sub>2</sub> (cf Rojo, 2005; also see Raghoebarsing et al, 2005). Anaerobic utilization of hydrocarbons also occurs; in fact, such anaerobic processes are now recognized as major parts of the overall carbon budget. The early work on anaerobic oxidation emphasized the role of sulfate as the oxidant. The work discussed here shows the role of metal oxides as the oxidant.

F Lefevre & F Forget, Observed variations of methane on Mars unexplained by known atmospheric chemistry and physics. *Nature* 460:720, 8/6/09. "Recent observations of methane on Mars suggest that methane concentrations are locally enhanced and change with the seasons. However, methane has a photochemical lifetime of several centuries, and is therefore expected to have a spatially uniform distribution on the planet. Here, using a global climate model of Mars with coupled chemistry reveals that photochemistry as currently understood cannot explain these variations in Martian methane." They suggest that the Martian surface is exceptionally harsh, leading to a very short lifetime for methane -- and other organics. Also see Proskurowski et al (2008).

E J Dlugokencky et al, Observational constraints on recent increases in the atmospheric CH<sub>4</sub> burden. *Geophysical Research Letters* 36:L18803, 9/17/09. Methane is an important greenhouse gas, with both manmade and "natural" contributions. Its concentration is much lower than for CO<sub>2</sub>, but its effect per molecule is much more. There have been some odd variations in the rate of accumulation of methane in the atmosphere; these are probably short term fluctuations, but are not well understood. This article discusses some of the issues, and some recent observations.

M Albrecht, Carbenes in action. *Science* 326:532, 10/23/09. News. Carbenes are chemicals with divalent carbon; the simplest member of the family is CH<sub>2</sub>. These are highly reactive chemicals; this article discusses some recent advances in carbene chemistry.

C Martin et al, Methane mitigation in ruminants: from microbe to the farm scale. *Animal* 4(3):351-365, 3/10. Ruminant animals, such as cows, carry out anaerobic digestion of cellulose in a stomach compartment called the rumen; they commonly emit substantial quantities of methane as part of this process. The methane emission represents a cost to the farmer (food not being fully consumed); it is also recognized as an issue of global warming, since methane is a significant greenhouse gas. Thus there is motivation to understand the methane emission, and reduce it if possible. This article is a good overview of the issues, which include nutrition, metabolism and microbiology. The bottom line is that no reliable methane control is currently available, but work continues.

### **Computer resources**

All Internet resources listed in class handouts are listed, with live links, on the page of Internet resources for Introduction to Organic and Biochemistry at the course web site: <http://bbruner.org/>

The "General" section of that page has links to sites for a range of organic chem and biochem courses, both at the introductory and regular university levels. Some of the intro sites may be particularly useful for those who would

like more materials at the basic level. Other materials, for this and my other courses, are also available at the web site.

**Cycloalkanes** (cis, trans; axial, equatorial). Dr. Phil Bays (St. Mary's College, Indiana) has a good set of practice problems on stereochemistry. The structures are clear, and the questions appropriate. Instant feedback.

News story about the microbes that make methane in the La Brea tar pits: **Researchers Learn Why Tar Pits Are Bubbly.**

On a lighter note... the **Periodic Table According to Organic Chemists**, from D R Anderson, University of Colorado at Colorado Springs.

My page on **Writing, drawing and viewing chemical formulas** points to some free programs that may be useful to you both during the course and for your personal use outside the course. These include:

- **RasMol**, a program for viewing molecular structures. I encourage you to give it a try early in the course, with some small molecules, so you have some experience with it by the time we get to proteins (Ch 15).
- **ChemSketch** and **ISIS/Draw**, programs for drawing organic chemical structures. These are useful for drawing structures for word processing documents. Further, the structures you draw can be converted to files that can be viewed as 3D models. Many students find it fun to try this -- drawing your own structures and converting them to 3D models. Both programs will name structures that you draw.

My page **Rings: Showing cis/trans and axial/equatorial relationships** discusses these particular aspects of cyclohexane rings.

Other pages at my web site that have been mentioned for Ch 3: Library Matters; Terms: Primary, Secondary, Tertiary, Quaternary; Glossary; Omitting numbers; Books: Suggestions for general reading. The web site also contains a periodic table, current through element #118, on the Download page; that page also contains ChemFormula, a macro to help you format chemical expressions in Microsoft Word.

Also see the web page section on Energy resources.

I would appreciate feedback on whether or not any of these resources are helpful. Also, let me know if you find other sites that might be helpful or interesting to the class.