Introducing Intellectual Property in an Undergraduate Chemistry Curriculum

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Abstract: An exercise that introduces undergraduate chemistry majors to concepts associated with intellectual property is outlined. The assignment includes an introduction to the terminology associated with starting a company based on intellectual property and to nondisclosure agreements. After this, the students write a draft patent application. With over 150,000 United States patents issued annually, the role of intellectual property is prominent and becoming increasingly important in current corporations and in the formation of new businesses, as well as in government and academic settings.

Discussion

Intellectual Property or the idea of owning an idea is at the root of our industrialized society [1–6]. Holding a patent on the synthetic route to an anticancer drug, a large-scale synthetic polymer process, or the logic behind a successful software package can make a small company an investor's dream. Large corporations can prosper or wither with the intellectual property they develop and own. Negotiations between nations (i.e., the U.S. and China) often involve intellectual-property rights to patents and copyrights. Despite the fact that approximately 160,000 United States Patents are issued every year, chemistry majors routinely go through undergraduate curriculums with no exposure to the basic ideas behind intellectual property.

The author has had two different experiences with patent applications. The first came at Los Alamos National Laboratory where an idea and results were provided to the in-house patent attorneys. The next contact with patents was two-and-a-half years later when a copy of the patent arrived in the mail (Manning, T. J.; Palmer, B. A.; Hof, D. E. Closed Inductively Coupled Plasma Cell. U.S. Patent 4,968,142, Nov 6, 1990.). At VSU, a primarily undergraduate institution, another successful idea surfaced and the inventor was involved in the many details and logistics. This included interacting with patent attorneys, presenting to a newly formed intellectual property committee, and dealing with the University President, the Vice President of Academic Affairs, and the Director of Grants and Contracts, as well as with the state-wide Board of Regents. Although the author didn't foresee intellectual property development when he started his undergraduate research group, he did find substantial support from the upper levels of the administration at VSU as well as at the state level. Since this initial project, the author has filed two additional patent applications, one in the area of nanotechnology (Novel Method to Synthesize Fullerenes, filed 1998) and another in natural product discovery (Natural Products from Humic Substances, filed 2001). The 1998 filing had two VSU undergraduates as co-authors. In addition to several publications and a range of talks, one of the students gave a presentation at the United States Senate entitled "Commercializing Undergraduate Research."

In this exercise students are introduced to some of the ideas, phrases, and Web sites associated with writing a draft patent application. This exercise will not be a complete coverage of intellectual property, but serves to familiarize the student with some of the basics. Chemistry students often have a range of career choices possible. In addition to working in industry as a bench chemist, entering professional programs (medical, dental, pharmacy, etc.), and graduate school, students now regularly pursue advanced studies in patent law, enter MBA programs, or become involved in start-up companies.

This exercise was carried out in a senior-level instrumental analysis course. It was explained to the class that most of the chemical instrumentation we use is or was covered at some time by patents. Each technique had a point of origin, and a patent was probably filed on the technique. The patent protected the company and prevented others from copying and selling the technique for an extended period of time. In this work we chose to build on some past undergraduate research conducted at VSU in nanotechnology and ozone generation. Specifically, the author patented a novel ozone generation process that was subsequently licensed to a small company and is currently under development under the auspices of a Small Business Innovative Research (SBIR) contract. This patent (Manning, T. J. Apparatus and Method for Generating Ozone. U.S. Patent 6,022,456, February 8, 2000.) was distributed as a model for the students to use in writing their abbreviated patent. Any technical patent could be chosen as a model. Second, undergraduates working in this laboratory have conducted research on the synthesis of nanostrucutres. From this experience, a simple device was put together and presented to the class as a novel method of generating carbon nanotubes. The instructor could choose any device, instrument,

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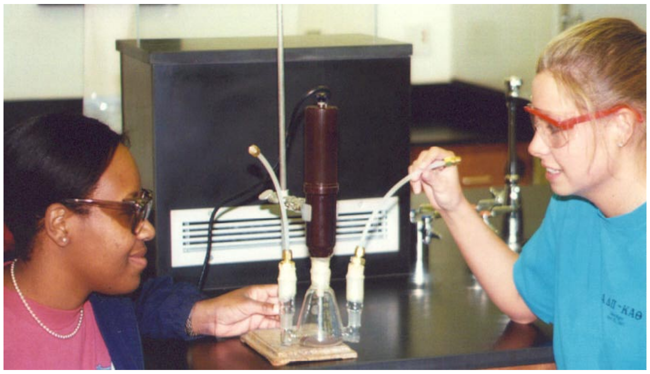

Figure 1. Two students look at the experimental setup that contained a high voltage discharge and a reaction vessel that produced nanotubes. They were told that their small start-up company had designed, built, and demonstrated the device for nanostructure synthesis. In undergraduate research projects, students have used this simple system to produce nanostructures from metal/hydrocarbon mixtures, ozone from oxygen/nitrogen/argon mixtures and amino acids from ammonia/methane/water mixes.

or even software for the students to describe in their patent application.

The class was presented with the following scenario. Working in their garage, they just discovered a new method to make carbon nanotubes. The instrumentation is easy to build (low capital cost), easy to maintain (no service contracts), and produces an array of nanostructures. Their goal is to patent the idea so that their small company can build a prototype and either start manufacturing it or license the technology. They have to review the United States patents already granted to ensure their device is novel and write a draft patent application that will require minimal tweaking by the patent attorney (to keep those fees down!). The company might seek venture capital, a Small Business in Innovative Research (SBIR) contract, or a Small Business Association loan to raise money for its short-term survival. The part-time laboratory technician that works for the company has signed a confidentiality agreement so that they do not tell the competition about the invention.

The exercise is outlined using a topic in nanotechnology, an area in which the authors have conducted research. Other exercises in biochemistry (vaccine for HIV), synthetic organic chemistry (synthesis of bryostatin), analytical separations (separation of fullerenes by thin-layer chromatography), physical chemistry (hydrogen storage for batteries), environmental chemistry (ozone generation), inorganic chemistry (superconductor synthesis), materials chemistry (producing thin films of diamonds), and computational chemistry (new software logic) are outlined. Prelaboratory questions for each of these areas are suggested, references for faculty and students are given, and a potential topic is provided.

Figure 1 shows the device that the students were asked to describe in their patent application. A Tesla coil was arced to an iron-filing/organic-solvent mix. The students had already read the classic papers by Kroto et al. [8], Krastchmer et al. [9], and Ijima [10] that describe the synthesis of fullerenes and nanotubes. From this reading, they had some understanding of what a carbon nanotube is; how they are produced by an electrical arc; and the potential applications of nanostructures in electronics, medicine, etc. The students were told that the following experimental parameters were successful in producing the carbon nanotubes *but* that these parameters (i.e., solvent, frequency, voltage, etc.) could be varied, producing different levels of the tubular carbon structures.

a. The discharge has a potential between 10 and 50 kV.
b. It discharges at 0.5 MHz.
c. The solvents tested were octane or cyclohexene.
d. The metal used is iron filings.
e. The atmosphere is nitrogen.
f. The ratio of iron to solvent is approximate 1:1 by volume.
g. It was switched on for 48 hours.
h. IR, UV–vis, and Raman techniques were used to spectroscopically analyze the product, but they did not provide definitive qualitative identification of the material.
i. The product was analyzed by high-resolution transmission electron microscopy (HRTEM) for definitive identification.

Before beginning to write the patent, students were given two exercises. First, a nondisclosure agreement (NDA, Supporting Material 1 found in s00897010508b.pdf) was handed out. We discussed the role of NDAs, or confidentiality agreements, in various aspects of industrial, academic, and government research. The first part of the assignment is to read the NDA and identify five points that both parties must follow in the agreement. Second, we briefly reviewed some terminology, concepts, and people that can impact patents and small businesses. As part of the laboratory write-up the students were asked to write a few sentences on each topic. They were allowed to use any source (Web, library, faculty, etc.) to obtain the information. The topics were

a. venture capital,
b. IPO,
c. angel,
d. business plan,
e. SBIR contract and federal agencies (list all 7),
f. can you patent software?
g. going public,
h. spin-off company,
i. SBA loan,
j. blue-chip stock,
k. incorporation,
l. copyright,
m. royalty and license,
n. NASDAQ,
o. trademark,
p. SBDC (Small Business Development Center)
q. Dow Jones,
r. SEC,
s. Harold Greenspan,
t. NYSE,
u. PCT (Paris Cooperative Treaty),
v. location of USPTO,
w. assignee versus inventor,
x. active versus inactive patent,
y. length of review (once submitted, how long?),
z. provisional patent.

After these exercises were discussed, students were given a copy of a patent, and its general form was reviewed. The importance of writing broad claims was emphasized and several examples related to the device presented were discussed. For example, we discussed that claiming the solvent was cyclohexene and the metal used was iron filings limited our protection because another researcher might show that using hexane and zinc gave the sample experimental results and then start to market a similar device. In the sections called "Background of the Invention" and "Summary of the Invention," they might give specifics of the experiment, but in the "Claims" section, it was recommended that they include *any* organic solvent and *any* transition metal with the knowledge the claims might be negotiated with the United States Patent and Trademark Office (USPTO) examiner.

The class than went to the United States Patent and Trademark Office Web site [7] and searched this database for patents issued that are related to the synthesis of nanostructures. Specifically they were told to include between five and ten existing patents in their report. The students were instructed to sketch the experimental setup and use a two-dimensional illustrator such as the draw command in Microsoft Word or PowerPoint to produce their final illustration. They were to include an abstract, a three-to-four paragraph description of their invention, and at least five claims. Students were told not to try to match the body of the patent in length but to concentrate on the claims section. Supporting Material 2 (s00897010508b.pdf) contains a student's final patent application that was submitted at the completion of the exercise.

Listed below are eight additional topics of current importance that could be used for this type of student exercise in a range of upper-level chemistry classes.

1. Materials Chemistry: Thin Films of Diamond. Polycrystalline diamond thin films can be grown using chemical vapor deposition (CVD). In a low- pressure environment, carbon atoms are deposited via sublimation onto a substrate to form the solid. Techniques such as atomic force microscopy (AFM), scanning tunneling microscopy (STM), and scanning electron microcopy (SEM) are used to characterize the surface. Optical techniques such as infrared spectroscopy and Raman spectroscopy can also be used to confirm diamond synthesis. Diamond has a tremendous ability to resist heat (high thermal conductivity) and has been incorporated into a range of applications from jet engines to computer chips. Diamond is also resistant to electrical damage from radiation, leading to applications in satellites, oil wells, nuclear power plants, and other locations that experience high radiation levels. The students can use any source to answer the prelaboratory questions including the library, the Web, or references provided.

Prelaboratory Questions

1. What is the thermal conductivity of diamond and how does it compare to other pure elements (include Si, Fe, Cu, arsenic)?
2. What is CVD and how does it work? Provide background on instrumentation (pumps, chamber, etc.) and the chemistry behind the sublimation process.
3. Describe three applications of diamond thin films.
4. Describe the following forms of pure carbon: diamond, graphite, exfoliated graphite, reticulated carbon (RVC), carbon aerogels, and highly organized pyrolytic graphite (HOPG).

Review Articles and Books

1. *Handbook of Industrial Diamonds and Diamond Films;* Prelas, M. A.; Popovici, G.; Bibelow, L. K., Eds. Marcel Dekker: New York, September 23, 1997.
2. Stanishevsky, A. Fabrication of Submicron Structures in CVD Diamond by Focused Ion Beam. *Journal of Superhard Materials* **1998,** *20,* 4.
3. Delclos, S; Dorignac D.; P. F.; Silva, F.; Gicquel, A. Ultra-High-Resolution Electron Microscopy of Defects in the CVD Diamond Structure. *Diamond Relat. Mater.* **1998,** *7* (2–5), 222–227.

Related Patents

1. Shates, S. C. Process for Depositing Diamond and Refractory Materials. U. S. Patent 5,749,966, May 12, 1998.
2. Ulczynski, M. J.; Reinhard, D. K.; Asmussen, J. Process for Depositing Adherent Daimond Thin Films. U.S. Patent 5,897,924, April 27, 1999.

Suggested Topic

You have discovered that by using carbon aerogels (15-to-20-nm spheres of solid carbon) as the starting material in a CVD chamber, you can cover a surface with a very uniform diamond coating that is 10-nm thick. You have routinely covered silicon wafers and stainless steel surfaces with areas measuring several square centimeters with minimal pretreating. You believe your process can easily be scaled up. Carbon aerogels can be made by thermally decomposing fluorinated graphite (C_1F_1) at high pressure (50 atm) and temperature (600 °C). No scientists have conducted research using aerogels as the precursor or starting material and you are prepared to file the patent.

2. Biochemistry: HIV Vaccine. The HIV virus has captured the public's attention and there is global hope for a cure. According to the U.S. Center for Disease Control and Prevention in Atlanta, GA, there were 688,200 reported cases of AIDS in this country, through 1998, and 410,800 deaths. The disease has decimated Africa and swept through Asia. The race for an answer has been given top priority at several pharmaceutical companies. AIDSVAX is a vaccine that raises the antibody response in the body. VaxGen (Brisbane, Calif.) has cloned a form of the protein (GP-120) that is found on the HIV virus. Once it is injected and the body begins developing antibodies to the actual GP-120 protein, an immunity to HIV may result. This drug is currently in Phase III clinical trials.

Prelaboratory Questions

1. What is GP-120? Describe its role with the HIV virus.
2. Provide background on the different strains of HIV.
3. Briefly describe how to clone a protein.

Review Articles and Books

1. Beardsley, T. AIDS Moonshot? Under President Clinton's Command, Researchers Step Up the Search for an

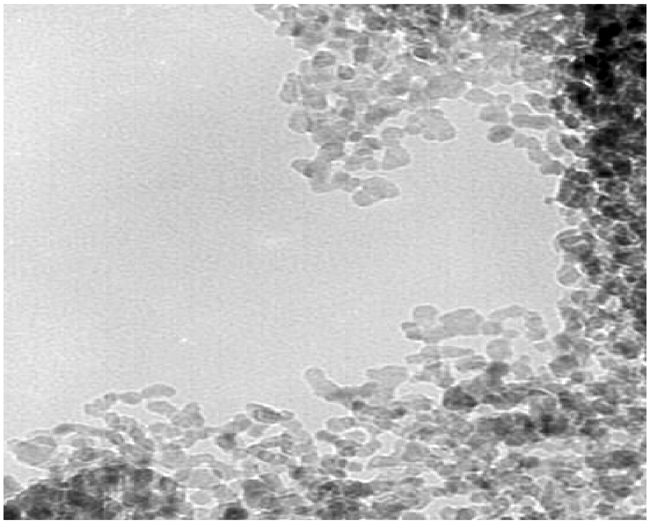

Figure 2. High-resolution transmission electron micrograph (× 500,000) illustrates carbon aerogel (10–15 nm) material.

http://www.sciam.com/explorations/aids/060297beardsley.html.

2. Rakowiczszulczynska E.; Mcintosh, D G. Mechanisms of Cancer Growth Promotion by HIV-I Neutralizing Antibodies. *Cancer J.* **1995**, 8 (*3*), 143–149.

3. Mollace, V.; Colasanti, M. HIV Coating GP-120 Glycoprotein-Dependent Prostaglanddin-E(2) Release by Human Cultured Astrocytoma-Cells is Regulated by Nitric-Oxide Formation. *Biochem. Biophys. Res. Commun.* **1994,** 203 (*1*), 87–92.

4. Bulterys, M. Preventing Vertical HIV Transmission in the Year 2000: Progress and Prospects—A Review. Placenta **2001,** 22 (*supp A*), S5–S12.

5. Beck, E. J. Miners, A. H. The Cost of HIV Treatment and Care—A Global Review. *Pharmacoeconomics* **2001,** 19 (*1*), 13–39.

6. Voelker, R. Med *News & Pers.* **1999,** 282 (*21*), 1992–1994.

Related Patents

1. Chang, T.-W.; Fung, S. C.; Sun, C. R.-Y.; Chang, N. T.; Kim, Y. W. Immunoconjugates Which Neutralize HIV-1 Infection. U.S. Patent 5,834,599, November 10, 1998.

2. Chang, T.-W.; Fung, S. C.; Sun, C. R.-Y.; Chang, N. T.; Sun, B. N.-C.; Sun, C. R. Y. Chimeric Monoclonal Antibodies Which Neutralize HIV-1 Infection and Their Applications in Therapy and Prevention for AIDS. U.S. Patent 5,981,278 or AIDS, Nov. 9, 1999.

Suggested Topic

Learning from the GP-120 approach, your laboratory has cloned another protein, dubbed XY-123. It raises the antibody level to three times that produced by GP-120. In your patent you propose a mechanism (see article reference 2) based on experimental data and present your antibody results.

3. Computational Chemistry: Software. Software has transformed all areas of chemistry, including data acquisition and analysis and calculations involving various aspects of quantum mechanics. Large software companies, such as Microsoft, regularly patent various aspects of their software as "processes," "methods," "systems," etc. Specifically, they are seeking intellectual property rights to the logic behind their programs. They may patent anything from new font types to novel ways to store data.

Prelaboratory Exercise

The instructor should pick a single review article in computational chemistry (see below) and ask students to write a summary of the article.

Review Articles and Books

1. Young, D. *Computational Chemistry: A Practical Guide for Applying Techniques to Real World Problems;* Wiley-Interscience: New York, 2001.

2. Profeta, S., Jr. *Kirk-Othmer Encyclopedia of Chemical Technology*, Supplement 315, John Wiley & Sons: New York, 1998.

3. Greene, N. Review of Computational Tools for Toxicity and Metabolism Detection. *Abstracts of Papers, Part 1,* 220th Meeting of the American Chemical Society, Aug 20–24, 2000, Washington, DC; American Chemical Society: Washington, DC. paper U281.

4. Zeng, J. Mini-Review: Computational Structure-Based Design of Inhibitors That Target Protein Surfaces. *Combinatorial Chem. & High Throughput Screening* **2000,** *3* (5), 355–362.

5. Taylor, P. A Computational Chemistry Primer. http://www.sdsc.edu/GatherScatter/GSwinter96/taylor1.html (accessed Aug 2001).

6. An online text on computational chemistry: http://www.biochemistry.bham.ac.uk/osmart/course/os_molf.html

Related Patents

1. Schmidt, J. M. Computational Method for Designing Chemical Structures Having Common Functional Characteristics. U.S. Patent 5,699,268, December 16, 1997.

2. Schmidt, J. M. Computational Method for Designing Chemical Structures Having Common Functional Characteristics. U.S. Patent 6,219,622,April 17, 2001

3. Chen, C.-C.; Barrera, M.; Ko; G.; Osias, M.; Ramamathan, S. Tremblay, D. Polymer Component Characterization Method and Process Simulation Apparatus. U.S. Patent 5,687,090, November 11, 1997

4. Isaacs, N. W.; Lapthorn, A. J.; Harris, D. C.; Grootenhuis P. D. J. Three-Dimensional Glycoprotein Hormone Structure Representation Using a Computer. U.S. Patent 5,864,488, Jan. 26, 1999

Suggested Topic

If a piece of software has a novel or unique logic and a potentially broad application, the pursuit of intellectual property rights should be considered. With your recently developed software a total molecular volume (nm^3), a shape (sphere, rod, etc.), an empirical formula (i.e., $C_xH_yN_zO_aS_b$), the number and type of functional groups (i.e. 3 carbonyls, 1 primary amine, etc.), and the desired solubility (mg/L) in water is entered; the program will return all possible structures. Using this program, a wide number of molecular structures can be designed for specific targets. The program might have upper limits for size and molar mass but the logic behind the software is unique and revolutionary. Your patent application will center on this logic.

4. Inorganic Chemistry: Superconductor Synthesis. Superconductors are materials that conduct electricity with no loss of power and no heat generated. Their current and potential applications include medical (MRI, biotechnical engineering), electronics (SQUIDs, transistors, Josephson Junction devices, circuitry connections, etc.), industrial (magnets, sensors and transducers, magnetic shielding, etc.), power generation (motors, generators, energy storage, transmission, fusion reactions, transformers and inductors, etc.), and transportation (magnetically levitated vehicles, etc.). Superconductors are typically broken into two types: Type I (very pure lead, mercury, tin) and Type II ($Y_1Ba_2Cu_3O_7$ (T_c = 90 K), $HgBa_2Ca_2Cu_30_{8+x}$ (T_c=133 K), $Bi_2CaSr_2Cu_2O_9$, etc.).

Prelaboratory Questions

1. Define a Type I and Type II superconductor.
2. Define superconductivity and T_c. Why would a room temperature superconductor have a tremendous impact on our society?
3. What is a Josephine junction? A SQUID?
4. Assign one review article (#1 or 2 below) and ask students to summarize (instructors choice).

Review Articles and Books

1. Khurana, A. Superconductivity Seen Above the Boiling Point of Nitrogen. *Physics Today* **1987,** *40,* (4), 17–23.
2. Ginzburg, V. L. Superconductivity: The Day before Yesterday, Yesterday, Today, and Tomorrow. *J. Supercond.* **2000,** *13* (5), 665–677.
3. Gabovich, A. M.; Voitenko, A. I. Superconductors with Charge- and Spin-Density Waves: Theory and Experiment (review). *Low Temperature Physics* **2000,** *26* (5), 305–330.
4. Tsuei, C.; Gupta, A.; Trafas, G.; Mitzi, D. Superconducting Mercury-Based Cuprate Films with a Zero-Resistance Transition Temperature of 124 Kelvin. *Science* **1994,** *263,* 1261–1263.
5. Pan, S. H.; Hudson, E. W.; Lang, K. M.; Eisaki, H.; Uchida, S.; Davis, J. C. Imaging the Effects of Individual Zinc Impurity Atoms on Superconductivity in $Bi_2Sr_2CaCu_2O_{8+d}$. *Nature,* **2000,** *403* (Feb 17), 746–750.
6. Hudson, E. W.; Pan, S. H.; Gupta, A. K. Ng, K.-W.; Davis, J. C. *Science* (July 2), **1999,** *85,* 88–91.

Related Patents

1. Li, Q.; Michels, W. J; Parrella, R. D.; Riley, G. N., Jr.; Teplitsky, M. D.; Fleshler; S. High Performance $(Bi,Pb)_2Sr_2Ca_2Cu_3O_y$ Composites. U.S. Patent 6,188,920, February 13, 2001.
2. Burns, M. J.; de la Houssaye, P. R.; Garcia, G. A.; Russell, S. D.; Clayton, S. R.; Barfknecht, A. T. Method for Making a Monolithic Integrated High-T_c Superconductor–Semiconductor Structure. U.S. Patent 6,165,801, Dec. 26, 2000.

Suggested Topic

Building on reference 5 (Pan et al., above), your laboratory has discovered that by replacing Sr with Ba (in $Bi_2Sr_2CaCu_2O_{8+d}$) and adding a Nd impurity (in place of zinc), the T_c was raised to a remarkable 290 °C. Write a patent for your new material.

5. Organic Chemistry: Bryostatin Synthesis. Bryostatin ($C_{47}H_{68}O_{17}$, 905 g/mol) is a strong anticancer drug in Phase II and Phase III clinical trials at over a dozen U.S. Medical Centers. It is extracted from the marine animal bryozoa, a millimeter-sized creature that lives in saltwater colonies that grow in size to 1 to 2 ft. The problem with extracting the molecule is that the yields are very low. During one collection in the Gulf of Mexico, the National Cancer Institute extracted less than 2 oz of bryostatin from fourteen tons of bryozoa. In order for the molecule to be widely used, a simple synthetic route must be identified. At least 30 flavors or structures of bryostatin have been identified but all share the bryophan ring.

Prelaboratory Questions

1. Briefly describe the animal bryozoa.
2. What is a bryophan ring? (include structure)? What is the "flavors" of bryostatin; provide the structure for three of them.
3. Camptothecin, Topotecan, 9AC, and CPT-11 are four natural products. What do they have in common? Briefly describe a current application.
4. Aspirin, quinine, taxol, morphine, and digoxin all have their roots as natural products. What is the natural source of each?
5. Why is it desirable for a natural product to have some water solubility?

Review Articles and Books

1. Zonder, J. A. Shields, A. F. A Phase II Trial of Bryostatin 1 in the Treatment of Metastatic Colorectal Cancer. *Clin. Cancer Res.* **2001,** *7* (1), 38–42.
2. Newman, D. J. Bryostatin: from Bryozoan to Cancer Drug. In *Bryozoans in Space and Time;* Gordon, D. P.; Smith, A. M.; Grant-Mackie, J. A., Eds.; National Institute of Water and Atmospheric ResearchF: Wellington, NZ, 1996; pp 9–17. (See http://www.civgeo.rmit.edu.au/bryozoa/bookform.html.)
3. Newman, D. J.; Cragg, G. M. The Influence of Natural Products upon Drug Discovery. *Nat. Prod. Rep.* **2000,** *17* (3), 215–234.
4. Gschwend, J. E.; Fair, W. R. Bryostatin 1 Induces Prolonged Activation of Extracellular Regulated Protein Kinases in and Apoptosis of LNCaP Human Prostate Cancer Cells Overexpressing Protein Kinase C Alpha. *Mol. Pharmacol.* **2000,** *57* (6), 1224–1234.
5. Prendiville, J.; Crowther, D. A. Phase-I Study of Intravenous Bryostatin-1 in Patients with Advanced Cancer. *Br. J. Cancer* **1993,** *68* (2), 418–424.
6. Varterasian, M. L. Mohammad, R. M. Phase I Study of Bryostatin 1 in Patients with Relapsed Non-Hodgkin's Lymphoma and Chronic Lymphocytic Leukemia. *J. Clin. Oncol.* **1998,** *16* (1), 56–62.

Related Patents

1 Blumberg, P. M.; Szallasi, Z.; Pettit, G. R. Method of Treating Cancer Using C-26-Modified Bryostatin. U.S. Patent 6,060,505, May 9, 2000.

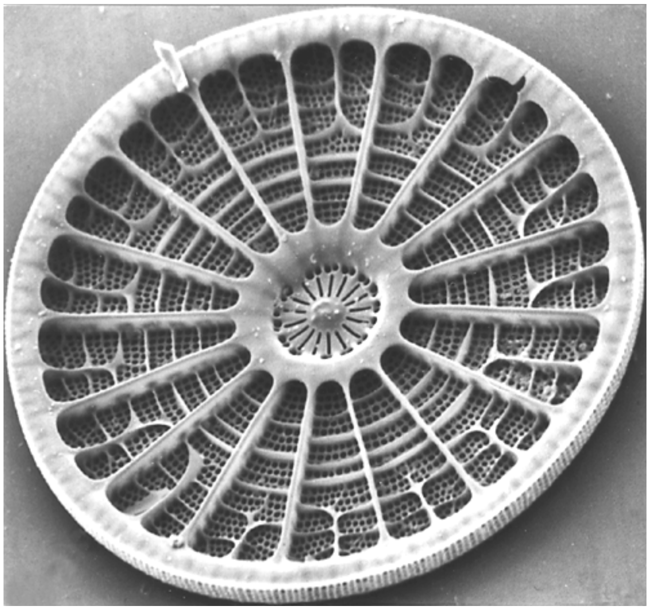

Figure 3. The diatom, *Arachnoidiscus sp.*, is proposed as part of a stationary phase for TLC separation of fullerenes in the student exercise.

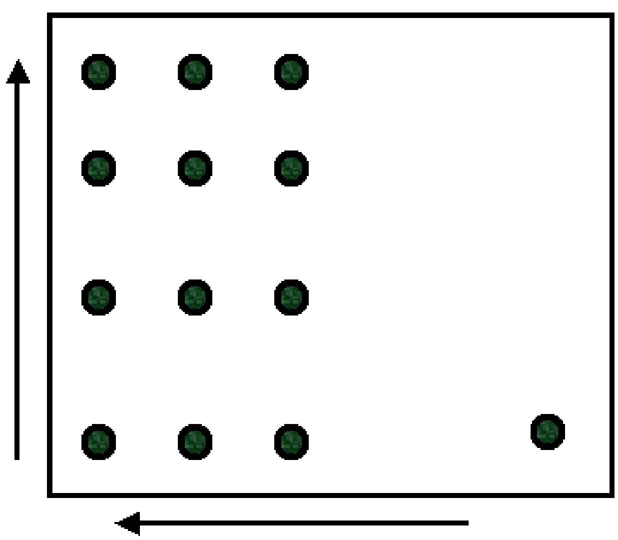

Figure 4. The original spot separated into three fullerene components (*x* axis). Subsequently, these components were further separated into hydrogenerated fullerenes ($C_{60}H_{36}$, $C_{70}H_{36}$, $C_{84}H_{36}$), endohedral fullerenes (NaC_{60}, NaC_{70}, NaC_{84}), and unsubstituted fullerenes (C_{60}, C_{70}, C_{84}, left most column). This separation was achieved with your newly discovered silica/diatom matrix on a 2-D plate.

2. Demspey, E. C. Method of Using PKC Inhibiting Compounds to Treat Vascular Disease. U.S. Patent 6,228,843, May 8, 2001.

Suggested Topic

While bryostatin has been found in the filter feeder bryozoa, you have found that a bacterium actually makes a precursor, which is an open bryophan ring. Bryozoa takes this open ring structure and simply closes it via a single-step reaction. Your patent will center on producing the bacteria on a large scale in an aquaculture environment in order to produce the opened bryophan ring. Your novel one-step synthesis will involve closing the ring to form bryostatin I, which is extracted, in bulk, from the bacteria tanks.

6. Analytical Chemistry: Separation of Fullerenes by TLC. Fullerenes are spherical allotropes of carbon, which were discovered in 1985 at Rice University. There are various forms of carbon-cage molecules including C_{60}, C_{70}, C_{76}, C_{84}, C_{96}, and C_{112}. Typically, their analysis involves separation on a LC column. You have found that a novel substrate for the TLC plate, comprised of a derivatized silicate combined with the exoskelton of a diatom, can separate the various spherical allotropes when run in a two-dimensional mode. This approach allows you to easily separate and analyze not only for the pure fullerenes, but also for some exohedral structures ($C_{60}H_{36}$, $C_{70}H_{36}$, etc.) and endohedral structures (NaC_{60}, NaC_{70}, etc.), simultaneously. The compounds produce dots that are reddish-brown in color and are easily seen with the naked eye.

Prelaboratory Questions

1. Describe the Kraschmer method to synthesize fullerenes.
2. What is a diatom? Where do they live? What is their exoskeleton made of?
3. Looking at an image of a diatom, propose why it might make for a good stationary phase for chromatography, particularly size exclusion chromatography (SEC).
4. Describe how two-dimensional TLC works. Include a diagram of a 2-D TLC plate.
5. Describe several different exohedral and endohedral fullerene structures that have been synthesized.

Review Articles and Books

1. Litvinova L. S. J. Planar Thin-Layer Chromatography of C_{60} and C_{70} Fullerenes. *J. Planar Chromatogr-Mod TLC* **1997,** *10* (1) 38–43.
2. Mohammad A. 22 Years Report on the Thin-Layer Chromatography of Inorganic Mixtures—Observations and Future Prospects. *J. Planar Chromatogr-Mod TLC* **1996,** *9* (5), 318–360.
3. Ahmad J. Use of Alumina as Stationary-Phase for Thin-Layer Chromatography of Inorganic and Organometallic Compounds. *J. Planar Chromatogr-Mod TLC* **1996,** *9* (4), 236–246.
4. Touchstone, J. C. New Developments in Planar Chromatography. *LC-GC* **1993,** *11* (6), 404–405.
5. Mohammad A. 35 Years of Thin-Layer Chromatography in the Analysis of Inorganic Anions, *Sep. Sci. Technol.* **1995,** *30* (19). 3577–3614.

Related Patents

1. Haas, J. S.; Kelly, F. R.; Bushman; J. F.; Wiefel, M. H.; Jensen, W. A. Hand Portable Thin-layer Chromatography System.U.S. Patent 6,096,205, Aug. 1, 2000.
2. Armstrong, D. W. Bonded Phase Material for Chromatographic Separations. U.S. Patent 4,539,399, September 3, 1985.

Suggested Topic

You believe your new stationary phase for two-dimensional TLC is novel and very useful to scientists and engineers doing work with fullerenes. It provides a relatively inexpensive

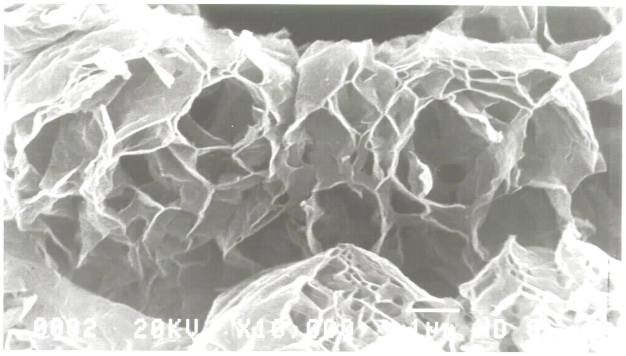

Figure 5. Exfoliated graphite as a storage medium for hydrogen for fuel. Individual sheets of graphite are pulled apart increasing surface area for H_2 adsorption.

method to analyze various analogs of fullerenes. You can show, theoretically, that the separations are very predictable. Your discovery is ideal for a small company in that the TLC plates are very easy to produce in a reproducible manner. You decide to file a patent on the media.

7. Physical Chemistry: Electrochemical Cell. Hydrogen (H_2) offers several advantages, currently realized and futuristic, as a fuel. It is abundant and can undergo both electrochemical and combustion reactions with oxygen producing energy and nontoxic byproducts (i.e., H_2O). One of the technological restrictions involved in its use is storage. For example, storing hydrogen for use as a fuel in a vehicle would involve either a heavy metal tank at high pressure or a battery that would be exceedingly massive. If a material was developed that could adsorb H_2 at a 8 to 10% mass ratio (H_2 to C), it would be a revolutionary breakthrough for the environmentally friendly fuel.

There are several forms of graphite including highly organized pyrolytic graphite (HOPG), RVC, carbon whiskers, and exfoliated graphite. EG (see below) is a form of graphite whose sheets are separated, lowering the density of the material and significantly increasing the surface area. Scientists have been investigating the potential role of carbon nanotubes as an adsorption material but the potential for the economical large-scale production of nanotubes is remote. EG can be made by a variety of methods including soaking graphite dust in Br_2 or heating it in a concentrated HNO_3 solution. The existing methods produces an EG that puffs open above 130 °C, but collapses below these temperatures making its potential for operation not likely at ambient conditions. You have developed a new procedure to produce EG that stays puffed or exfoliated under ambient conditions. Its production is outlined in reference 1 below.

Prelaboratory Questions

1. Hydrogen can be used to generate energy with oxygen through combustion and electrochemistry. Describe, using reactions and equipment diagrams, how each is achieved.
2. You have a single sheet of graphite that is 1 cm^2 and hydrogen is adsorbed onto its surface on both sides. Assume there are two hydrogen atoms per carbon atom (top, bottom). What is the mass of graphite? What is the mass of hydrogen adsorbed? What is the mass percent of hydrogen on this two-dimensional storage cell? (Hint: you'll need to find the graphite bond lengths)
3. If you have a single walled carbon nanotube that is 2.2 nm in diameter and the carbon-carbon bonds have the same bond distance as graphite, estimate the number of carbons needed to make a single ring of the nanotube.
4. Use the number of atoms per ring you just calculated in #3. If the nanotube is hydrogenerated (each carbon atom switched from sp^2 to sp^3 hybridization), the bond distance changes to the average bond distance found in diamond. What is the new nanotube diameter?

Review Articles and Books

1. Manning, T.; Mitchell, M.; Stach, J.; Vickers,T.Synthesis of Exfoliated Graphite from Fluorinated Graphite Using an Atmospheric-Pressure Argon Plasma, *Carbon* **1999,** *37* (1999), 1159–1164.
2. Wronski, Z. S. Materials for Rechargeable Batteries and Clean Hydrogen Energy Sources. *Int. Mater. Rev.* **2001,** *46* (1), 1–49.
3. Baddour-Hadjean, R. Meyer, L. An Electrochemical Study of New $La_{1-x}Ce_xy_2Ni_9$ ($0 <= x <= 1$) Hydrogen Storage Alloys. *Electrochim. Acta* **2001,** *46* (15) 2385–2393.
4. Yin, Y. F. Molecular Simulations of Hydrogen Storage in Carbon Nanotube Arrays, Langmuir, **2000,** *16* (26), 10521-10527.
5. Talapatra, S, Gases Do Not Adsorb on the Interstitial Channels of Closed-Ended Single-Walled Carbon Nanotube Bundles. *Phys. Rev. Lett*. **2000,** *85* (1).
6. Bauschlicher, C. W. Hydrogen nd Fluorine Binding to the Sidewalls of a, (10,0) Carbon Nanotube. *Chem. Phys. Lett*. **2000,** *322* (3–4), 237–241.

Related Patents

1. United States Patent #6,113,673, Loutfy et al., September 5, 2000, Gas storage using fullerene based adsorbents
2. United States Patent #5,916,642, Chang, June 29, 1999, Method of encapsulating a material in a carbon nanotube

8. Environmental Chemistry: Ozone Generation for Water Treatment. Ozone (O_3) has found, on an international basis, wide-spread application in many areas, including treating wastewater and drinking water, bleaching in the pulp industry, disinfecting, treating swimming pool water, etching materials, removing odors, and treating aquarium water. In most cases it is the combination of its strong reduction potential, its favorable environmental characteristics (O_2 is the residue), and the relative speed of its reactions with chemical and biological species that have increased its applications. The study of ozone formation in various types of discharges and plasmas has been an ongoing endeavor of scientists and engineers. Ozone (O_3) is a strong oxidizing agent that is produced in an electrical discharge. It is made from pure oxygen (O_2) with the most critical steps in the synthesis being

$$O_2(g) + e^- \rightarrow 2O(g) \qquad (1)$$

$$2O(g) + 2O_2(g) \rightarrow 2O_3(g) \qquad (2)$$

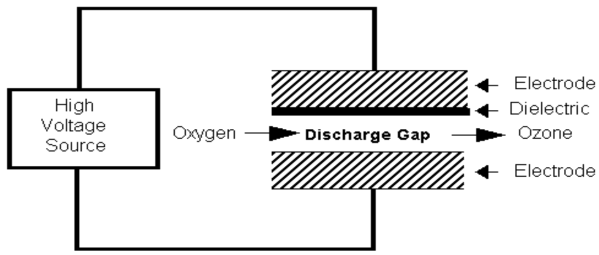

Figure 6. A simplified diagram of a corona discharge (CD) produces electrons in a discharge (also called arc or plasma) that breaks the O_2 double bond. The CD is commonly used to produce ozone for a range of applications including water treatment.

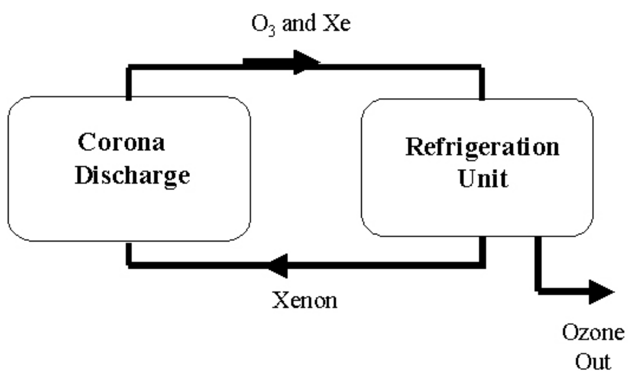

Figure 7. O_3 and xenon are separated by boiling point allowing the low ionization potential of Xe to be used economically to dramatically increase the production of ozone using significantly lower power.

Increasing the electron density of the discharge or plasma increases the ozone production. UV light sources, from the sun (ozone production in the stratosphere) to light bulbs, can also break the oxygen-to-oxygen double bond to produce atomic oxygen, but are not efficient for large scale production.

Review Articles and Books:

1. Rice, R. G. Ozone in the United States of America–State of the Art. *Ozone: Sci. Eng.* **1999,** *21* (2), 99–118.
2. Matsumoto, N.; Watanabe, K. Footprints and Future Steps of Ozone Applications in Japan. *Ozone: Sci. Eng.* **1999,** *21* (2):127–138.
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6. Manning, T. Production of Ozone in an Electrical Discharge Using Inert Gases as Catalysts. *Ozone: Sci. Eng.* **2000,** *22* (1), 53–64.
7. Manning, T.; Hedden, J. Gas Mixtures and Ozone Production in an Electrical Discharge. *Ozone: Sci. Eng.* **2001,** 23 (2), 95–103.

Suggested Patents

1. Manning, T. Inert Gases as Catalysts for Ozone Production. U.S. Patent 6,022,456, Feb 2000.
2. Yokimo, T.; Kobayashi, J.; Nakatsuka, S. Apparatus and Method for Generating High Concentrations of Ozone, U.S. Patent 5,370,846, Dec. 6, 1994.

Suggested Topic

Xenon has the lowest ionization potential of the nonradioactive inert gases; thus it will produce a discharge or plasma with the highest electron density of any inert gas. As mentioned above, increasing electron density will allow a discharge to produce more ozone.

Xenon is quite expensive and could not be used in a continuous-flow process. Like Xe-arc light bulbs, if used in a static mode, its potential in ozone production could be realized. Using a modified corona discharge, you have found a novel method in which you can easily recycle xenon in the discharge. Specifically, you separate ozone from xenon via boiling point and return xenon to the discharge. Your patent application will outline this system.

Conclusion

While this work was originally done as part of an instrumental analysis class, it can be introduced into the chemistry curriculum in a variety of ways, including:

Instrumental Analysis. The class is given the same topic and each student writes their own patent application, or each student in the class is given a separate topic and they write their own application. This might lend itself to individual presentations and, in addition to learning about patents students are introduced to a range of modern chemical topics.

Advanced Chemistry Classes. Other upper-level classes (advanced organic, inorganic, etc.) or senior seminars could utilized topics outlined here or develop their own.

Special Topics. If a faculty member is comfortable with writing patents, a special topics class could be developed that centered on intellectual property development for chemists.

The topics are defined but are also subject to refinement for two reasons. First, this forces the students to do some investigation on their own, either through the literature or by discussions with the instructor in order to develop a proper mental image for their "invention." Second, it gives the students some creative freedom to define the specifics of their process or instrument.

When the instructor is using an exercise of this nature for the first time, the following approach is recommended. Pick a single topic for the whole class from the instructor's interest or training and spend some time researching it. Pick one or two patents in the field and two or three relatively short papers for the students to read. Using either a drawing (for a reaction, software etc.) or a simple device (for instrumentation), provide the students with some type of visual aid. After reviewing patents and papers and outlining the form of United States patents, give the students one week to work on the exercise. After the first submission, make recommendations for improvements and return to the students giving them another week to make corrections.

Whether students are considering a career in patent law, research and development, management, pharmacy, or medicine, various aspects of intellectual property will likely confront them in their professional lives. While undergraduates may often be able to take elective business classes, these offerings are typically economics, accounting, marketing, and finance and do not address intellectual property (particularly with a technical twist!). While students may have additional questions when the exercise is complete, they have been introduced to a range of important concepts ranging from confidentiality in the workplace to writing a patent application.

This exercise grew from the author's experience of winning a U.S. Patent and subsequently licensing it and from student questions about various career options, including patent law. The student response to the exercise was very positive, and two of the six students expressed a strong desire to pursue patent law, a career they were only vaguely familiar with before the exercise.

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Supporting Material. A sample of a nondisclosure agreement (NDA), and a student's final patent application that was submitted are available as an Adobe Acrobat PDF file (http://dx.doi.org/10.1007/ s00897010508b).

Appendix

Intellectual Property and Technology Development in the Smaller, Non-Research Intensive University. Intellectual Property within Academe, particularly the smaller, non-research intensive university, has only recently been a topic of serious conversation. Fifty years ago the university expected, generally, to do some research and educate young people to take their place in the world. Today that expectation has evolved into many mutations and interpretations. The university still educates and still does research but it may do a great deal more, particularly in the area of technology transfer, innovation and the impact of all of this on the interpretation of intellectual property. Today Universities play an entirely new role in technological innovation by licensing inventions and discoveries to industry and, even to faculty-owned businesses.

With these changes has come a need to have a policy addressing directly the concept of intellectual property and the rights and responsibilities of all members of the academic community related to this concept. Developing such a policy in a non-research intensive institution where the need may be only dimly perceived is challenging. The staff of grants and contracts, working with external awards, frequently is the first point of awareness regarding the need for a policy regarding Intellectual Property. In such cases, it is important to bring into the awareness circle upper level administrators and research faculty as well as some non-research faculty. A wide representation is crucial to obtaining the best possible policy that matches the culture of the institution and that the entire academic community will accept.

A working committee, charged with the task of developing a policy, would be wise to work with sister schools within their region and even, the nation. Many schools now have well thought-out, well-managed Intellectual Property policies and it seems appropriate to begin with what already exists. Of course, care needs to be taken at every step to obtain permission for use of any policy terminology, format or wording that the committee selects to put into their working model. This development stage can well take from three months to a year or more. Length of time is often directly related to the amount of dissemination of information about the policy and the work of the committee. More information will mean it takes more time, but in the end, this sharing of information will make for a better policy and one that is more widely accepted.

Once the committee has completed its task the policy can be presented to the chief administrator, in the case of Valdosta State University, the policy was presented to the President. The President was requested by the committee to accept this policy as an "Interim" policy. After reviewing did accept the policy, it was accepted as the "Interim" Intellectual Property Policy. This gave tme for review by the Faculty Senate to thoroughly review it. This process tool approximately 14 months but when brought before the full Senate for final discussion, it was accepted almost without discussion.

As a final step the policy was presented to the governing Board of Regents of the University System of Georgia for review and acceptance. The policy was accepted, with minor amendments, and a commendation for the language within the policy indicating that all new faculty would be asked to sign a statement accepting this policy as a part of their employment terms.

Having an Intellectual Property policy is one thing. Developing full faculty 'buy-in' for that policy requires full dissemination to all faculty and staff and a continuing effort to inform faculty and staff about the policy. Frequently faculty, and staff as well, do not realize the many ways that such a policy can impact their intellectual and academic careers. An uninformed faculty may take a very negative view of such a policy. However, faculty who have worked with an Intellectual Property Committee will frequently have very positive responses. The public relations work never ceases, as the policy becomes a part of the fabric of the academic community.

As the policy is accepted and begins to have an impact on the academic community activities such as technology transfer and licensing of innovation or discoveries begin to emerge. When technology transfer or licensing become topics of discussion, someone within the academic community must step forward to learn what the terms mean and how such things can be accomplished. The best advice is probably the simplest. Ask the people who are doing it and learn everything you can about the processes from those institutions that already have moved into this sector. Good attorneys, knowledgeable in technology transfer, are crucial for such tasks as filing patent applications. But nothing can help a novice in the field more than talking to the people in other academic institutions that have been doing this for years and really know what is involved in developing a licensing agreement, filing a patent or any of the other questions that evolve.

Developing a good solid policy is interesting and challenging but learning about and the ins and outs of technology transfer is a fascinating, intellectually stimulating activity. This is the challenge and the reward for bringing policies and practices into being that help the non-research intensive university meet the demands and opportunities of changing expectations within the academic community.

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