The Role of Chemistry in Organic Chemistry, Toxicology, and Chemical Engineering

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Introduction:

From the perfume you wore to last night's dinner to the plastics that you recycle to the air we breathe, chemistry is a significant part of everyone's daily-lives. Many products that most people use and our everyday activities usually have some correlation to chemistry. Dealing principally with substance properties, chemistry is known to be a branch of natural sciences, the natural laws that describe these changes and the changes they undergo.[1] Chemistry plays a crucial role in various fields, such as chemical engineering, toxicology and organic chemistry.[2] For all three of these careers, chemistry serves as a backbone for individuals who choose to pursue them. In the United States, there are many careers that are chemistry-based. For chemical engineers, chemistry, physics and mathematics are involved with the process of creating valuable products from raw materials. They work across various industries such as energy, food production and pharmaceuticals, and their contributions are critical for solving global problems such as pollution and sustainability. Toxicology focuses on the harmful effects of chemicals on living organisms. The work includes assessing products that many use on a daily basis and making sure they are safe, as it plays a major role in public health. Organic chemists work on carbon-containing compounds - the building blocks of life. They work with the development of new materials, technologies and drugs. Organic chemists often work with precision and creativity, collaborating with other scientists in various fields, making their work essential for modern advancements in science.

My personal interest in chemistry began a few years ago when I first entered high school. I knew that I wanted to pursue a career in medicine, which I later found out involved a lot of chemistry. To learn more about the sciences involved in medicine, I chose to reach out to a professor at Clemson University who ended up giving me a position in his lab as a student researcher. Currently, as I am working in this position, I have the opportunity to research various chemistry related topics, such as halogens, natural polymers, and backgrounds related to the creation of microfluidic chips for ischemic strokes. Although I am looking to pursue a career in medicine, I have been considering other careers that are chemistry-based, and I wanted to learn more about the ones that involved more chemistry and research. The following text will explore the specific chemistry-based careers: Organic chemist, toxicologist and chemical engineer, discussing their education, occupational information, chemistry involvement, history and applications.

[1] "What Is Chemistry?," What is Chemistry? - Dept of Chemistry - University of Idaho, accessed July 4, 2024, https://www.uidaho.edu/sci/chem/undergraduate/what-is-chemistry.
[2] Azubuike faith, "30 Careers in Chemistry," Medium, December 6, 2023, https://medium.com/teach-chemistry/30-careers-in-chemistry-22795b3952c0.

Organic Chemists:

Organic chemistry is the study of properties, structure, reactions, composition, and preparation of carbon-containing compounds. Organic chemists create and explore molecules and compounds.[3] They spend their time synthesizing compounds and developing new ones.[4] Some reactions that Organic chemists might work with include substitution reactions and elimination reactions. In substitution, there are two different kinds of reactions: SN2(concerted mechanism - strong nucleophile - attacks from the backside to kick out leaving groups) and SN1(stepwise mechanism - the loss of the leaving group - leading to the intermediate carbocation - the nucleophile attacks after). The difference between the both is that SN2 has a strong nucleophile, while SN1 has a weaker nucleophile.[5] SN2 is a fast reaction with a stronger nucleophile, while SN1 is slower than SN2, due to it being a stepwise reaction.

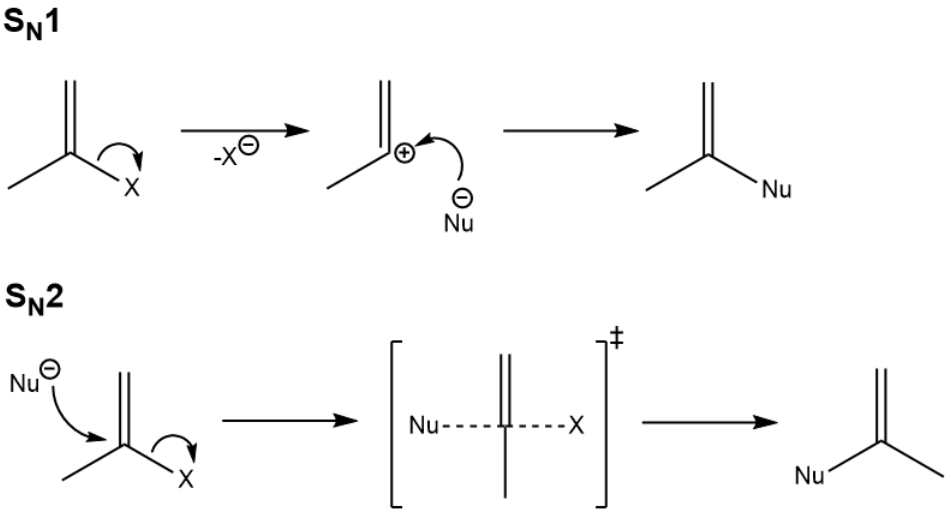

Figure 1: The SN1 and SN2 reactions. Acid-catalyzed Ester Hydrolysis. Large. Pearson.https://www.pearson.com/channels/organic-chemistry/exam-prep/asset/71738d09.

To pursue organic chemistry, most have a bachelors in chemistry, biology or physics and specialize in organic chemistry in a masters or doctorate level. Organic chemists who have higher level degrees typically fall within the top-earner range(Figure 2).[6] Organic chemists are also currently in high demand, so pursuing higher education can make a candidate more considerable. To develop this career further, most do fellowships

[3] Advanced Chem Tech, "What Is the Study of Organic Chemistry?," Advanced ChemTech - Providing Various Fine Chemicals in Louisville, KY, June 29, 2022, https://www.advancedchemtech.com/what-is-the-study-of-organic-chemistry/.
[4] "Organic Chemistry," American Chemical Society, accessed July 4, 2024,
[5] Ashenhurst, James. "Identifying Where Substitution and Elimination Reactions Happen." Master Organic Chemistry, March 21, 2024. https://www.masterorganicchemistry.com/2023/01/18/where-will-substitution-elimination-reactions-occur/.
[6] *How to become an organic chemist | Academic Invest*. (n.d.).https://www.academicinvest.com/science-careers/chemistry-careers/

like post-doctoral research to have more advanced training.[7] Some classes in a curriculum could be sciences, physics, biology and organic and inorganic chemistry.[8] Organic chemistry is known to be very challenging, and a very complicated field. When it comes to salaries, the more education one has, the higher their pay range can be as an organic chemist.

National Annual Average:

Education:	**Ranges:**	**Annual Salaries:**	**Hourly salaries:**
Associates and Under	Low Range	$52,370	$25/hr
Bachelors	Average	$77,860	$37/hr
Masters or Doctorate	High Range	$125,450	$60/hr

Figure 2: Data from unknown, "How to become an organic chemist", onlinedegree.com

Highest Education Among Organic Chemists:

Degrees:	**Percentage:**
Less than High school	0.1%
High School	0.3%
College	2.7%
Associates	4.4%
Bachelors	54.3%
Masters	19.7%
Doctorate	18.4%

Figure 3: Data from unknown, "How to become an organic chemist", onlinedegree.com

Organic chemists have the opportunity to pursue many different careers, such as academia(researchers and professors), industrial(process chemists, product developers, etc.) and government roles(regulatory agent, etc.). They are professionals who work in biotechnology, pharmaceuticals, and environmental sciences. They use many medicinal chemistry techniques for improving patient outcomes and creating advanced medical treatments. For example, they contribute to the use of polymers used in medical devices and product durability.

[7]Organic chemist: What is it? and how to become one? | ziprecruiter, accessed July 4, 2024, https://www.ziprecruiter.com/career/Organic-Chemist/What-Is-How-to-Become.
[8]"How Hard Is Organic Chemistry?: 24HourAnswers Blog," 24HourAnswers, accessed July 4, 2024, https://www.24houranswers.com/blog/113/How-Hard-is-Organic-Chemistry#:~:text=While%20organic%20chemistry%20is%20a,school%20to%20switch%20their%20major.

They also work with reducing environmental impact, creating green solvents and biodegradable plastics. They also work with designing efficient fuel cells or energy sources, contributing to cleaner energy alternatives. Some responsibilities that organic chemists have are testing products to ensure public safety; conduct experiments to understand concepts; report statistics of lab experimentation; train lab technicians; provide reports to agencies; analyze compounds and research; create proposals for grant money; design new organic substances; develop products and more.[9]

Friedrich Wöhler synthesized biological compound urea with "The Wöhler synthesis". Yielding ammonium cyanate, silver or lead cyanate was mixed with ammonium nitrate. "Wöhler, however, discovered that the end product of this reaction is not ammonium cyanate, but urea, a biological compound. Berzelius had to concede that $(NH_2)_2CO$ and NH_4OCN were isomers".[14] Before this discovery in 1828, chemists believed that organic substances couldn't be formed with 'vital force' in animals or plants. "The Wohler synthesis" has helped.[14]

Toxicology:

Toxicology is an area of science that works with harmful effects of substances, chemicals and situations that could involve humans or animals. Toxicologists work with chemicals to explore and determine if they are harmful.[10] Some chemicals and substances that toxicologists generally work with are cocaine, alcohol, marijuana and prescription drugs.[11]

A lot of the time, when toxicologists use substances and chemicals, they are working with toxicology tests. The BIO-RAD test(Figure 5) looks for traces of illegal substances, drugs and more from testing DNA. Students and employees may need to be tested due to school or company policies. Medical professionals can request and order treatments for substance abuse or to help keep track of recoveries. A toxicology test can determine the presence of drugs.[12,13]

[9] 7 jobs for organic chemists (with salaries) | indeed.com, accessed July 4, 2024, https://www.indeed.com/career-advice/finding-a-job/jobs-for-organic-chemists.
[10] "Toxicology." National Institute of Environmental Health Sciences. Accessed July 1, 2024. https://www.niehs.nih.gov/health/topics/science/toxicology#:~:text=What%20is%20toxicology%3F,%2C%20animals%2C%20and%20the%20environment
[11] "Toxicological Profiles," Centers for Disease Control and Prevention, May 3, 2024, https://www.atsdr.cdc.gov/toxprofiledocs/index.html.
[12] "Toxicology Tests: Purpose, Procedure Results," WebMD, accessed July 1, 2024, https://www.webmd.com/mental-health/addiction/what-is-a-toxicology-test.
[13] Tox/seeTM protocol sheet, accessed July 2, 2024, https://www.bio-rad.com/sites/default/files/webroot/web/pdf/cdg/literature/C244_Toxicology.pdf.

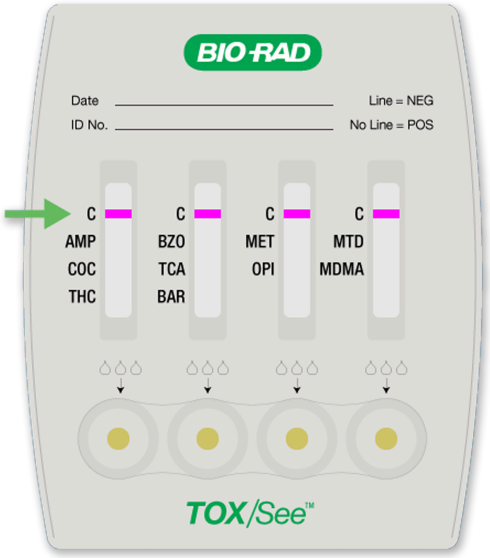

Figure 5: A Urine drug test image, (*TOX/See step-by-step guide*, medium, BIO-RAD,, https://www.bio-rad.com/sites/default/files/webroot/web/pdf/cdg/literature/C244_Toxicology.pdf)

Therapeutic Index:

One of the equations that toxicologists work with is the common way to calculate the toxicity of a drug. "The common method used to derive the TI is to use the 50% dose-response points, including TD50 (toxic dose) and ED50 (effective dose).[14]

$$TI = \frac{\textit{toxic dose}}{\textit{dose for therapeutic response}} = \frac{TD50}{ED50}$$

Figure 6: TI formula image, (*Determining the safety of a drug*, medium, TOXTutor,https://www.toxmsdt.com/25-determining-the-safety-of-a-drug.html#:~:text=The%20common%20method%20used%20to,of%203%20(Figure%201).)

"For example, If the TD50 was 200 and the ED50 was 20 mg, the TI would be 10"[22].

$$TI = \frac{TD50}{ED50} = \frac{200}{20} = 10$$

Figure 7: TI example formula, (*Determining the safety of a drug*, medium, TOXTutor,https://www.toxmsdt.com/25-determining-the-safety-of-a-drug.html#:~:text=The%20common%20method%20used%20to,of%203%20(Figure%201).)

[14] "Welcome to Toxtutor," Toxicology MSDT, accessed July 1, 2024, https://www.toxmsdt.com/25-determining-the-safety-of-a-drug.html#:~:text=The%20common%20method%20used%20to,of%203%20(Figure%201).

Deriving TI from doses ED50 and TD50 may be misleading, regarding the drug's safety in relation to the slope of the dose-response curves for toxic and therapeutic effects. In order to control and regulate this deficiency, the term, “The Margin of Safety” is often used by toxicologists to denote the safety of a drug.[16]

Examples(Therapeutic Index):

TD50:	**ED50:**	**TI:**
200	20	10
300	10	30
450	50	9
1500	50	30
75	25	3

Figure 8: Data from Anwitha Kandula(Southside High School)

The graph(figure 9) shows the relationship between toxic dose responses and effective dose responses. The toxic dose responses remain below TD50, while the shaded area represents the doses where the substances produce effective dose responses. The slope of the graph represents how the doses increase in response to the toxic or effective dose. Low doses have the potential of being effective without producing toxicity due to the differences in the slopes and thresholds. Although most patients have the potential of benefiting from high doses, it is offset by the probability that toxicity will occur.[22]

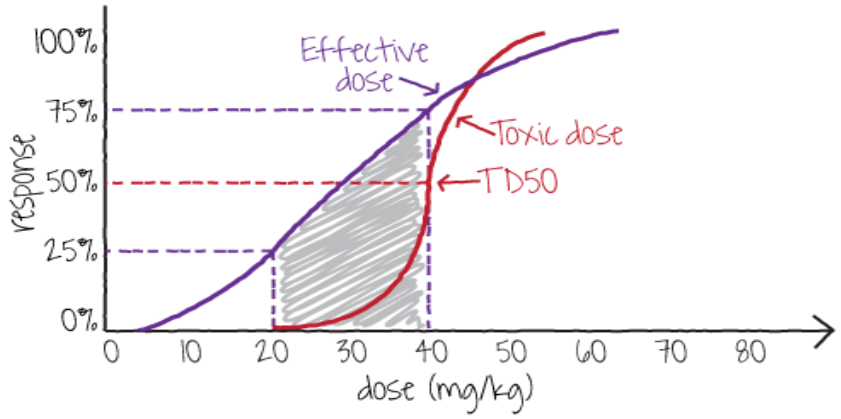

Figure 9: MOS Graph image, (NLM, *Determining the safety of a drug*, medium, TOXTutor, https://www.toxmsdt.com/25-determining-the-safety-of-a-drug.html#:~:text=The%20common%20method%20used%20to,of%203%20(Figure%201).)

Using the slopes for each curve, the toxicity of various substances can be compared. For certain substances, a small increase in a dose can cause a large increase in the response, which can be seen in how

steep toxicant A's slope is(Figure 10). For other substances, larger increases in a dose is required to create the same increase in response, which can be seen through toxicant B's shallow slope.[16]

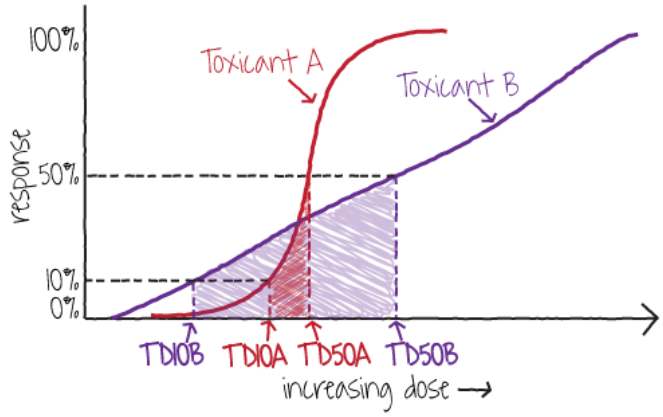

Figure 10: MOS Graph image (NLM, *Determining the safety of a drug*, medium, TOXTutor, https://www.toxmsdt.com/25-determining-the-safety-of-a-drug.html#:~:text=The%20common%20method%20used%20to,of%203%20(Figure%201).)

There are many different types of toxicologists. A forensic toxicologist focuses on testing during an autopsy for compounds, conducting scientific tests on tissue samples and bodily fluids to identify chemicals and drugs in the body. They are usually looking for the presence of toxins from biological samples.[15] Forensic toxicologists usually perform tests on labs, using samples collected from forensic pathologists during a crime investigation or autopsy.[16]

Analytical toxicologists work in labs to measure, identify and detect drugs, and other harmful chemicals in bodily fluids for the treatment, prevention and diagnosis of poisoning.[17] The main role for them is to diagnose poisoning, analyzing tissues to understand toxins and drugs like amphetamines, cocaine, opiates, and cannabinoids".[18]

Clinical toxicologists research the prevention and treatment of diseases caused by drugs, toxins and chemicals, working on envenomations, such as snake bites, scorpion stings and spider bites[21];"Marine toxins such as ciguatera poisoning, paralytic shellfish poisoning, tetrodotoxin and many others".[19] Clinical

15 "Forensic Toxicology," National Institute of Justice, accessed July 2, 2024, https://nij.ojp.gov/topics/forensics/forensic-toxicology#:~:text=Forensic%20toxicology%20is%20the%20analysis,is%20above%20a%20harmful%20level.

16 "Forensic Toxicologist," ExploreHealthCareers.org, May 6, 2024, https://explorehealthcareers.org/career/forensic-science/forensic-toxicologist/#:~:text=Forensic%20toxicologists%20perform%20scientific%20tests,or%20by%20crime%20scene%20investigators.

17 NHS choices, accessed July 2, 2024, https://www.healthcareers.nhs.uk/explore-roles/healthcare-science/roles-healthcare-science/life-sciences/analytical-toxicology.

18 "Analytical Toxicology," SlideShare, February 4, 2014, https://www.slideshare.net/slideshow/analytical-toxicology/30801685.

19 Scitechnol.com, "About Medical and Clinical Toxicology," Medical and Clinical Toxicology | List of High Impact Articles | PPts | Journals | Videos, accessed July 2, 2024, https://www.scitechnol.com/scholarly/medical-and-clinical-toxicology-journals-articles-ppts-list.php#:~:text=Envenomations%2C%20such%20as%20snake%20bites,botulism%2C%20scombroid%20poisoning%20and%20more.

toxicologists work with comprehensive and high levels of care for patients and people who come into contact with their substances, drugs and other threatening agents.[21]

The minimum requirement for this occupation is a bachelors in a science. However, it would be beneficial to pursue a masters or doctorate, as toxicology is a competitive and high-in-demand field, as it may show employers skills related to efficiency and proficiency in work. In graduate degrees, students typically focus on a chosen area, expanding their knowledge and skills. Toxicologists typically go through training periods during their degrees or after graduating. During undergraduate and masters degrees, most students do internships, apprenticeships or shadowing to gain experience in the field. After graduating with their doctorate, some candidates enter a post-doctoral fellowship. These fellowships can last for long periods of time and can allow toxicology fellows to conduct research, learn from professionals and gain training. Certifications can help toxicology students advance in their careers and gain employment, even though they are mostly voluntary. The American Board of Forensic Toxicology offers various certifications with different eligibility levels.[20]

Some skills that toxicologists need for their career are organization skills - toxicologists often work on large projects and need to collect multiple samples at a time, managing and recording experiments; Analytical skills - Toxicologists perform tests that require interpretations of good results; Time management - toxicologists often have to complete an assortment of tasks in restricted time frames; Communication - Toxicologists are working with other scientists or people who work within toxicology, so it is important for them to be able to communicate well with others. They have to give presentations to other peers, colleagues, bosses and the public; Mathematics - Oftentimes, toxicologists have to make mathematical computations based on a study or research factor(s).[23]

The salary that toxicologists earn can vary due to their education and work background. The highest paying industries are development, manufacturing and research. The BLS estimates a 17% increase in medical scientists' employment between now and 2030.[21]

Toxicologists Salary in the United States(Annual):

Percentage:	**Salary:**
10%	$57,115
25%	$70,836

20 How to become an organic chemist | Academic Invest. (n.d.). https://www.academicinvest.com/science-careers/chemistry-careers/how-to-become-an-organic-chemist

21 Salary.com. (n.d.). Toxicologist salary | Salary.com. https://www.salary.com/research/salary/benchmark/toxicologist-salary

50%	$85,907
75%	$103,745
90%	$119,986

Figure 11: Data from Salary.com

Poisons have been prominent since 331 BC and hunters would dip their arrows into them. Mithridates VI Eupator, the ruler of Pontus tried to protect himself using them from assassinations, studying them using prisoners and discovering a universal antidote: mithridate. He took 50 tablets a day, causing his immunity when he, failed trying to commit suicide after loosing to the Roman Empior, eventually causing his death by a sword. In modern times, workers are protected with safety guidelines and measurements. Toxicologists also work in environmental pathology pollutants to prevent similar poisonings.[22]

Chemical Engineering:

Chemical Engineering is the production and manufacturing of products through a chemical process, including designing equipment, systems and processes for refining raw materials and for mixing, processing and compounding chemicals. Chemical engineers typically work in large manufacturing plants where they work to minimize costs while increasing productivity and product quality. Many industries use chemical engineering to develop their products and earn proficient outcomes, such as biomedicine, electronics, technology, military, environmental and aerospace. Some of their responsibilities are conducting research into improved manufacturing processes, estimating production costs, planning and designing equipment, optimizing and monitoring the production process and incorporating safety procedures for working with dangerous chemicals.[23]

Another type of equation they work with is a reaction kinetic. Optimized reaction conditions and designing reactors is very crucial for understanding the rates of chemical reactions. Mathematical modeling using reaction rates is what chemical modeling usually involves with differential equations, which are eventually used to determine the optimal reactor design parameters and optimal reaction conditions. For designing heat equipment, heat exchangers, distillation columns, reactors and other equipment, equations like

22 Hyden, M., & Cartwright, M. (2024b). Mithridates' Poison Elixir: fact or fiction? *World History Encyclopedia*. https://www.worldhistory.org/article/906/mithridates-poison-elixir-fact-or-fiction/

23 "Chemical Engineering," American Chemical Society, accessed July 3, 2024, https://www.acs.org/careers/chemical-sciences/areas/chemical-engineering.html.

Fourier's law of heat conduction, Ficks law of diffusion and Navier-Stokes equations are very fundamental for the process.[24]

For example, chemical engineers design reactors, as they use principles of thermodynamics and reaction kinetics to design reactors that optimize the yield and selectivity of chemical reactions. They use and develop catalysts to enhance selectivity and reaction rates, making processes more efficient. Chemical engineers use Process Flow Diagrams(PFDs) to create detailed diagrams of chemical processes that include heat exchange, separations and reactions. They use energy balance equations to perform balanced energy balance calculations to ensure efficiency and management in chemical processes.[25]

In the Nernst equation, the “E” stands for the reduction potential, the “E^0” is the standard potential, the “R” is the universal gas constant, the “T” is the temperature in kelvin, the “z” is the ion charge, the “F” is the faraday constant and the “Q” is the reaction quotient. Chemical engineers use this formula for the cell potential of an electrothermal cell, calculated under non-standard conditions.[26,27]

$$E = E^0 - \frac{RT}{zF}\ln Q$$

Figure 12: The Nernst Equation. (*Cadence*, ,https://resources.pcb.cadence.com/blog/2020-nernst-equation-example-for-electrochemical-systems-design)

The ideal law of gas is related to macroscopic properties of ideal gasses. The variable “P” is pressure, the variable “V” is volume, the variable “n” is the amount, the variable “R” is the ideal gas constant and the variable “T” is temperature. This is used to demonstrate the relationship between volume, pressure and temperature for gasses.[28] The operation of a hot air balloon is a real-life application regarding the ideal law of gas, as the balloon will rise and fall in relation to the temperature of the air inside its envelope.[29]

24 Dudukovic, M. P. (2010). Reaction engineering: Status and future challenges. Chemical Engineering Science, 65(1), 3–11. https://doi.org/10.1016/j.ces.2009.09.018

25 “School of Science,” Chemistry or Chemical Engineering – What Is the Difference? | Science at Rensselaer, accessed July 3, 2024, https://science.rpi.edu/programs/undergrad/bs-chemistry/Chemistry%20or%20Chemical%20Engineering%20%E2%80%93%20What%20Is%20the%20Difference%3F.

26 Todd Helmenstine, “Practice Using the Nernst Equation with This Chemistry Sample Problem,” ThoughtCo, November 6, 2019, https://www.thoughtco.com/nernst-equation-example-problem-609516.

27 “Nernst Equation Explained (Practical Example Included),” PalmSens, accessed July 3, 2024, https://www.palmsens.com/knowledgebase-topic/nernst-equation/#:~:text=A%20typical%20use%20for%20Nernst,the%20potential%20across%20a%20cell.

28 Kevin M. Tenny, “Ideal Gas Behavior,” StatPearls [Internet]., May 6, 2024, https://www.ncbi.nlm.nih.gov/books/NBK441936/#:~:text=The%20ideal%20gas%20law%20is,%2C%20and%20Gay%2DLussac's%20laws.

29 “Physics,” StudySmarter UK, accessed July 3, 2024, https://www.studysmarter.co.uk/explanations/physics/further-mechanics-and-thermal-physics/ideal-gases/#:~:text=One%20illustrative%20example%20of%20the,causing%20the%20balloon%20to%20ascend.

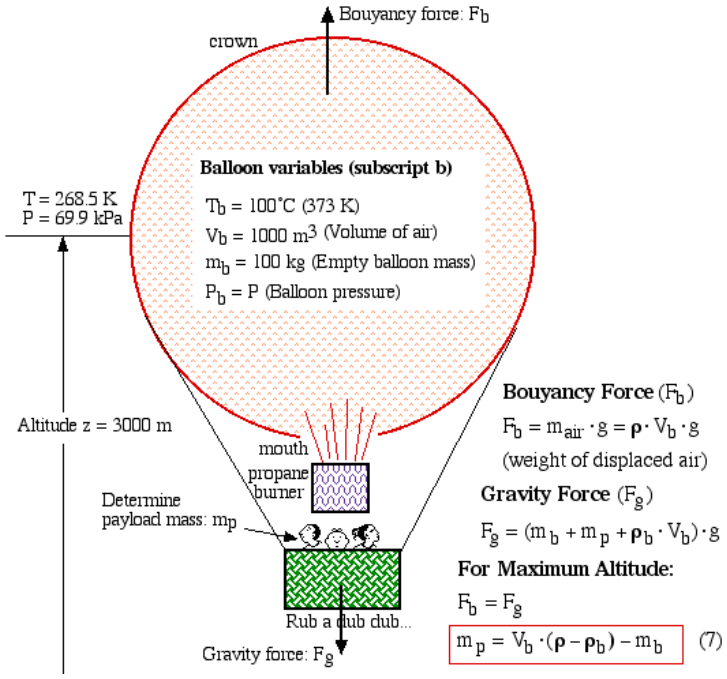

Figure 13: An example of a hot air balloon using the ideal gas equation. (Photograph by Isreal Urieli, *Chapter 2: Pure Substances*, https://people.ohio.edu/trembly/mechanical/thermo/Intro/Chapt.1_6/Chapter2b.html).

Oftentimes, when chemical engineers are working for environmental, electronical, biomedical, medical, aerospace and military fields, they use films, biocompatible materials and strong fabrics, fibers and adhesive.[30] For example, when working with oil refining and petrochemicals, some hydrocarbons that chemical engineers work with are benzene, xylene, toluene and ethylene. They design and work in pharmaceuticals and biotechnology where they work with active pharmaceutical ingredients such as ibuprofen, penicillin and acetaminophen. They work with food and beverages where they use food additives such as monosodium glutamate, citric acid and ascorbic acid.[31]

Becoming a chemical engineer can take a lot of hard work because of its extensive course load and demanding work field. It is challenging because it requires intense studies in sciences.[32] Some important qualities are community skills, analytical skills, math skills, problem-solving skills, research skills, design

30 "Professional Training Courses London: London Training Excellence," Professional Training Courses | London Training Excellence, accessed July 3, 2024, https://www.londontfe.com/blog/what-chemicals-are-involved-in-chemical-engineering-.

31 Advanced Chem Tech, "Do Chemical Engineers Create Products?," Advanced ChemTech - Providing Various Fine Chemicals in Louisville, KY, February 21, 2022, https://www.advancedchemtech.com/do-chemical-engineers-create-products/.

32 1. Nicholas Student et al., "Is a Mechanical Engineering Major Difficult?," CareerVillage, August 29, 2023, https://www.careervillage.org/questions/771782/is-a-mechanical-engineering-major-difficult#:~:text=It%20is%20a%20field%20that,in%20this%20field%20of%20work.

skills, science skills and creativity.[33,34] These are skills that are important for chemical engineers to develop new ideas; understanding concepts from different perspectives; design processes and equipment; classifying, experimenting, measuring, observing and inferring on various subjects and topics; solving problems with methods and formulas and more.To become an engineer, one needs a bachelor's degree in chemical sciences or engineering. It is common for most people to study engineering first and pursue a masters degree in chemical engineering.[35] The benefits of a masters can be higher pay.[39]"According to job posting data, chemical engineers with a bachelor's degree earn a median annual salary of $96,100".[36]

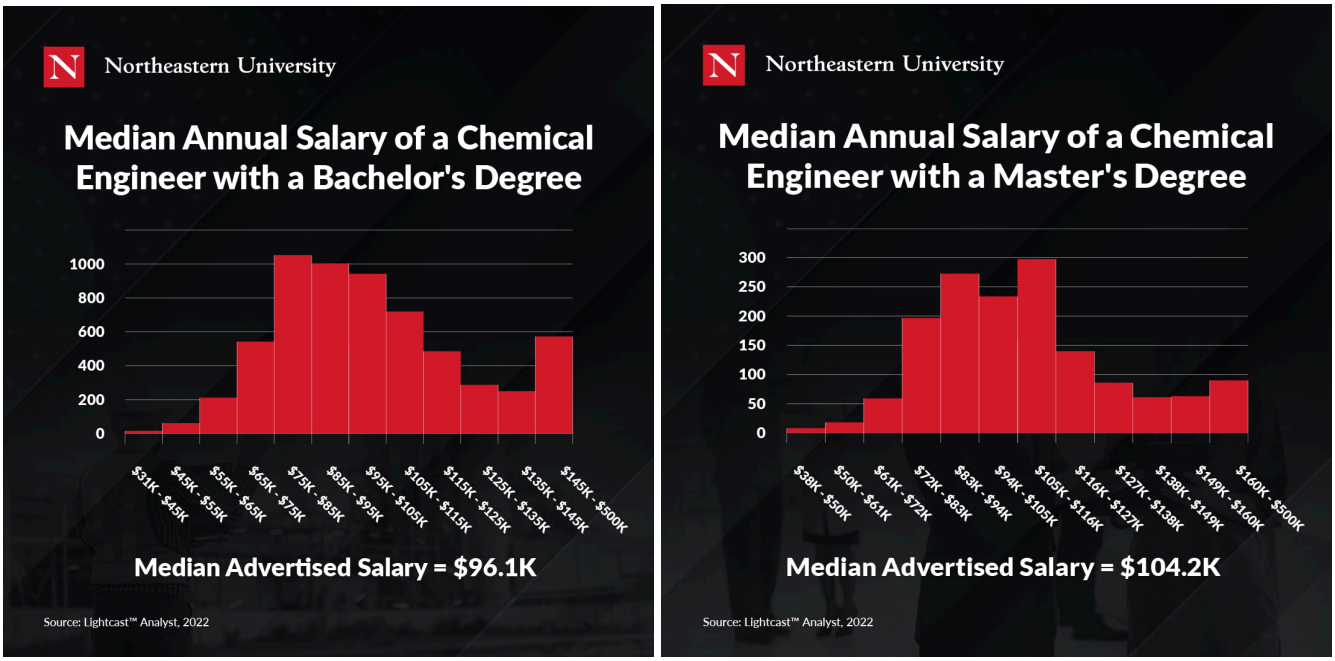

Figure 14: Median Annual salary for chemical engineer degrees(Bachelors and Masters),(Northeastern University's Master Science in Chemical Engineering Program, Lightcast Analysis 2022, https://graduate.northeastern.edu/resources/reasons-to-get-a-masters-in-chemical-engineering/#:~:text=Increase%20Your%20Earning%20Potential,in%20chemical%20engineering%20can%20help).

Pursuing a masters degree gives students the opportunity to develop in-demand industry skills such as product development, chemical engineering, process development, data analysis and process engineering.

33 Important chemical engineer skills and how to improve them | indeed.com, accessed July 3, 2024, https://www.indeed.com/career-advice/resumes-cover-letters/chemical-engineer-skills.

34 "Chemical Engineers," U.S. Bureau of Labor Statistics, April 17, 2024, https://www.bls.gov/ooh/architecture-and-engineering/chemical-engineers.htm.

35. "Study Chemical Engineering, Why & How to Study," Chemical Engineering degrees | course guide - Complete University Guide, accessed July 3, 2024, https://www.thecompleteuniversityguide.co.uk/subject-guide/chemical-engineering#:~:text=for%20Chemical%20Engineering.-,What%20Chemical%20Engineering%20degrees%20can%20you%20study%3F,MEng%20(Master%20of%20Engineering).

36 Kate Gibson, "4 Reasons to Get a Master's in Chemical Engineering," Graduate Blog, March 30, 2023, https://graduate.northeastern.edu/resources/reasons-to-get-a-masters-in-chemical-engineering/#:~:text=Increase%20Your%20Earning%20Potential,in%20chemical%20engineering%20can%20help.

Gaining work experience is another benefit of pursuing a masters degree, as most students who graduate with only a bachelor's degree are more likely to struggle to find employment due to their lack of skills and experience.

In the 19th century, George E. Davis is known as the Father of Chemical engineering and its original founder. Based on his 1887 lectures, Handbook of Chemical Engineering, was the first text to organize chemical engineering principles. It was first established in the UK and originated from evaporation and fermentation. It evolved to a production of chemicals and consumer products. The Industrial Revolution relied on labor-intensive limited production, but the industrial revolution created an efficient shift in the industry. Today, chemical engineers are significant for addressing global problems.[37]

Conclusion:

This report includes information about the careers - organic chemists, toxicologists and chemical engineers. A deep understanding of these careers was conducted to present potential future careers. For organic chemists, valuable insights have been gained regarding skills with other chemical related topics. It was significant to learn more about what organic chemists do, as most know them to primarily test chemicals. They explore and create molecules and compounds, using various concepts like SN2 and SN1. For toxicologists, they often work with anything living to study substances and chemicals. They analyze urine tests and work with drug usage. Most students major in chemistry during their undergraduate, as toxicology is not a common degree. Toxicology is present in several historical eras. For chemical engineers, they use various equations that work with flows of fluids and cell potentials like the Ideal Law of Gas formula, which operates a hot air balloon temperature rise and fall. Within the next decade, most of these careers are likely to change. In chemical engineering, many advancements can be made with manufacturing using AI and machine learning, creating smart features with an optimization of chemical production. They might work with instilling renewable energy sources with chemical processes to lessen carbon footprints. Nanotechnology might become further developed with materials and catalysts, using chemical engineering applications. In toxicology, many analytical advancements will be made with the implementation of proteomics, genomics and metabolomics. In vitro silicon methods might assist with more ethical and accurate testing of animals. For organic chemists, within the next decade, greener chemistry and sustainability might become a major advancement. The use of

37 The History of Chemical Engineering | NEWENGINEER. (2021, January 13). NewEngineer. https://newengineer.com/blog/the-history-of-chemical-engineering-1506258

biomimetic catalysis and enzymes might enhance the efficiency of chemical transformation, while reducing environmental impact.

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