The ethics of synthetic chemistry: Myths and reality.

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Abstract

The products of chemical synthesis, it is claimed, "are new substances that change our material world for the benefit or harm of living beings" (Schummer, 2001 p. 103). It is also claimed that chemists are to be held especially responsible, in comparison to other professionals, for their products (Schummer, 2001). But how different is synthetic chemistry from engineering or applied science so that one can justifiably speak of a difference in ethics? It has been claimed that the difference as regards ethics lies in the fact that for engineers the public welfare and safety are very important while for chemists public safety isn't of special interest. Chemists are free to trade safety and welfare with other interests (Davis, 2002). I will argue that it is neither an easy decision nor an ethically neutral one to engage in such trade offs. It has also been claimed that one can distinguish between chemical synthesis as an end in itself and chemical synthesis for utilitarian ends (Schummer, 2001). I will argue that the dividing line between chemical synthesis as an end in itself and chemical synthesis for utilitarian ends is not always clear. My view is that synthetic chemistry does not differ radically from other disciplines, which implies that the ethical responsibilities of chemists don't differ radically from those of other scientists.

Introduction

Synthetic chemistry has been in the center of attention lately. The products of synthetic chemistry may be both beneficial and harmful. These two considerations are sufficient for society to blame chemists for the bad effects of their products and to turn them in to the black sheep of the scientific community. They are also sufficient for philosophers who come to wonder whether the ethical responsibilities of chemists differ radically from those of other scientists. My view is that synthetic chemistry does not differ radically from other disciplines, which implies that the ethical responsibilities of chemists don't differ radically from those of other scientists. In this paper I will develop my position by examining, first (Part I), what chemical synthesis consists in, how different it is from other branches of chemistry and engineering - this branch of chemistry is not exactly like other branches of chemistry or other natural sciences, nor is it exactly like applied sciences or engineering - and what we mean by the phrase

"synthetic process". I will continue in Part II to examine what it means to "assign responsibility" and whether chemists are especially responsible in comparison to other professionals for the products of their research. In conclusion, I will try to analyze how chemists should respond to crucial ethical issues since there is no discussion of that issue in the literature on ethics and chemical synthesis. There are certainly accounts of what the ethical problems related to chemical synthesis society and environment are. But there is no discussion of how to answer questions such as: "how should the chemists deal with this kind of issues?", "Do they have to stop composing substances?" How can they continue to compose and still be accepted by society? In Part III I will try to answer these questions by discussing the ethical problems posed by chemical synthesis and addressing them from the chemist's rather than society's point of view.

Part I: Chemical Synthesis – Definition and Framework

It has been claimed that: "unlike other branches of science, the scientific products of synthetic chemistry are not only ideas but also new substances that change our material world for the benefit or the harm of living beings" (Schummer, 2001 p. 103). That is taken to be the main difference between chemistry and other natural sciences. From the production of the first synthetic substance, benefits are accompanied by harms. Plastic made life easier but polluted the environment, synthesis made possible the creation of drugs as well as the creation of chemical weapons. And always it is the synthetic chemists the ones who take the blame.

In an effort to explore how different the ethical responsibilities of synthetic chemists are compared to the responsibilities of practitioners of other disciplines, I have, first, to explore how different synthetic chemistry is from other branches of chemistry and other sciences. To this end, I will try in this part, to explicate what we mean by the words synthesis and synthetic process and, furthermore, how and under what circumstances those procedures take place.

Synthetic chemistry is obviously different from other branches of chemistry. In food chemistry, for example, scientists examine properties of substances that can be found in milk, flour and other kinds of food. In synthetic chemistry, however, scientists do not just examine; they create. Synthesis gives to chemistry a dimension that is closer to engineering and to the applied sciences than to natural sciences. We can say that a synthetic chemist is

like a molecule engineer. A chemist forms a compound from simpler compounds or elements, like an engineer builds a bridge from simpler elements.

But what exactly is synthetic chemistry? Synthetic chemistry is a branch of chemistry that focuses on the deliberate manufacture of pure compounds of defined structure and/or the development of new chemical reactions for this purpose (glossary - nature.com)¹. It is true that synthesis is the artificial building of a chemical compound, by the union of its elements or from other suitable starting materials (dictionary - biology-online.org). But do the products of synthesis always change our known material word? Sometimes a synthetic process develops new chemical reactions for the composition of a known substance: a substance that may already exist in nature, a substance that may have been isolated from a plant or an animal and has some kind of usable properties. Most of the time the purpose of that kind of synthesis is the cheap, quick and in high purity industrial production of the substance. Those kinds of products do not change the material world (unless purity by itself becomes a problem or the vast production of some substance affects the equilibrium).

It has also been claimed that the moment a substance is first synthesized, a step into the unknown has at the same time been made (Jacob & Walters, 2005). But to what degree is this true? Often the products of synthetic chemistry are new substances similar to natural ones or already known artificial ones. Synthetic processes have more or less the same pattern: chemists are familiar with a substance which has some useful properties and it is known from previous scientific research they have done themselves or performed by other scientists². Chemists think that changing its structure, that substance can have more properties, be more effective, or equally effective but cheaper for industrial production. To do that, they consider first, research already published to gather information related to similar processes. Usually they start from a known compound and they create a new substance by adding one or more groups of molecules to that compound, or by changing the position of one or more groups of molecules in another position from that of the known compound. Because of the way science is practised in our days, synthetic chemists must be pretty certain about at least some things of the synthesis. Most of the time, only some steps of the procedure are new, the impurities and some properties of the product may also be unknown, but many other things are known from published journals, concerning similar attempts, such as, details about the reaction process, the techniques and the instruments that must be used. So, the whole process is not an absolute step into the unknown.

If what I said is true, then synthetic process is not a complete step into the unknown. Synthetic processes do not simply produce new artificial substances, but also substances that already exist using artificial means. Research in synthetic chemistry appropriates pure scientific knowledge and makes use of techniques, experiments and observations just like research in any other field of natural science. The only difference is the creation of a product, the new substance. This side of synthesis differs from the other branches of chemistry but it is very similar, as I said before to the applied sciences and engineering. Like an engineer who builds a machine to be used as an automobile, a synthetic chemist builds a substance to be used as a drug. Like biotechnology research aims, among other things, to make an organism produce a protein that no living organism had ever before produced, synthetic process aims, among other things, to create a brand new pure substance that never existed before in nature. Both engineers and biotechnologists have to face, along with synthetic chemists, the possibility of unexpected bad consequences of their products. The engineers have to face a possible fall of a bridge because of a deficiency that hadn't been anticipated. The biotechnologists, the possibility that modified vegetables may cause illness, and synthetic chemists have to face the possibility of an impurity of a substance to cause, for instance, environmental pollution. Are professionals responsible for the consequences of their products? Do they have to take the blame? Are synthetic chemists especially responsible in comparison to other professionals for the products of their research? I will explore this dimension in the next part of this paper.

Part II: The assignment of responsibility

Most people will argue that the main difference between synthetic chemistry and engineering lies in the fact that the product of a synthesis may have unknown and unexplored bad consequences. For example, a pesticide may produce a substance that can cause cancer. But does this occur only when it comes to synthetic products? Let's take, for example, a computer-engineering product, the Internet. That is a good product; as the pesticide helps farmers, Internet helps the whole world. It makes possible the distribution of information and helps people communicate with each other. As the pesticide may have bad consequences, the Internet may also have bad consequences. Could the creators of the Internet have imagined that their product would help the distribution of illegal material and assist criminals to seduce and use other people, most of the time children, for their pleasure? It may have crossed their mind but on the balance that was insignificant compared to their invention. These things are facts known to everybody. And the consequences some times are tragic. Unknown and unexplored bad consequences may also occur when other engineering and scientific products are used. Are there any reasons that make chemists, in situations like the one I described above, especially responsible for the effects of their products in comparison to engineers and other scientists? To answer this question, let's consider the concept of responsibility.

We can follow Casey (1971) and distinguish three senses of responsibility so as to analyze the conditions under which we can assign responsibility to someone:

Responsibility (1):

In this sense a person can be responsible for something, can be held responsible or admit responsibility. To be responsible (1) for something is to be blamed for it. This sense of responsibility is connected with praise and blame. Responsibility (2):

This sense of responsibility implicates the duty or obligation to do or prevent something; it is attached to a particular role or profession. It concerns responsibilities prescribed to a profession. Neglecting a duty or obligation arising out of this sense of responsibility may result to responsibility $(1)^3$.

Responsibility (3):

Responsibility (3) is the causal sense of responsibility. For example, a heavy rain is responsible for the slippery road. Responsibility (3) is, by itself, insufficient for praise and blame, and hence for such moral notions as 'holding someone responsible'. (Casey, 1971)

The sense of responsibility in relation to the synthetic chemical research, which I attempt to explore in this part of the paper, is responsibility (1). Under what conditions synthetic chemists must be held responsible for the consequences of their products? In general, someone is responsible (1) for something if and only if:

- a. His/ her actions (or omissions) are responsible (3) for it.
- b. The outcome has some importance in terms of what he/ she might be expected to do; in general, that means that he/ she acted in a certain context and didn't carry out a certain pattern of responsibilities (2) that a certain context required.
- c. The conditions are normal (i.e. no excusing conditions). This means that the agent had the choice to act in a way that wouldn't lead to the undesirable outcome. (Casey, 1971)

As we see here, there are three conditions that have to be satisfied in order to assign responsibility (1) to someone, that is, to blame someone for an outcome. The first condition is connected with responsibility (3). To satisfy condition 1, the actions of an agent must have a causal connection to the outcome⁴. The second condition is tied to

a certain role or occupation. In order to be satisfied the actions of an agent must contain some kind of negligence of a duty or obligation-giving rise to responsibility (2). This means, in other words, that the agent acting in a professional context didn't act as a professional i.e. didn't take under consideration professional ethics while acting. For example, doctors are neglecting their responsibilities (2) when they can help a patient but they let that patient suffer or even die. The last condition has to do with the circumstances obtaining when the actions of an agent that lead to a specific outcome took place. In order for this condition to be satisfied, normal conditions must obtain⁵.

So, after the above clarifications in relation to responsibility, when are chemists responsible (1) for the consequences of their products? To answer this question I have to examine when the conditions I mention above are satisfied. The first condition is clearly satisfied. The actions of the agent –chemist - have a causal connection with the outcome- effects of the product. The creation of a substance – action – is responsible (3) for the effects of the product. If the chemist for example hadn't composed a pesticide, it couldn't have caused cancer. The creation of the pesticide is responsible (3) for the illness. So the first condition is satisfied. Before I move on to the second condition, it is important to examine the third condition first⁶. I will take conditions as normal when research is conducted freely and in full consciousness. Only under these circumstances does the third condition make sense and it is satisfied. What is important now is the evaluation of the second condition. When is the second condition satisfied? As I said, in the previous paragraph this condition is connected to the professional responsibilities (2) of chemists and of course to the ethics of chemistry. In order to examine whether the second condition is satisfied we have to examine whether chemists conduct ethical research. Did the chemist do something unethical during the composition of the pesticide? Was there something that she/he should have done as a professional scientist and she/he hasn't? In a few words the second condition is satisfied only when chemists neglect their professional responsibilities (2) and act unethically.

It is obvious that chemists must take the blame for the bad consequences of their products only when they have conducted unethical research during the composition of the synthetic product. Which means that we have to examine when is research ethical. Research is ethical only when it is conducted based on specific standards of conduct and based on proper ethical reasoning. Professional ethics describes a framework of standards of conduct and values. Scientists have the obligation to respect and follow the standards of ethical conduct their profession requires. The principles that constitute the framework of the professional ethics of chemists have been chosen taking into consideration the purposes of the particular science and the obligations that every chemist has towards

society, the particular discipline, the environment and the scientific community. These principles are: objectivity, integrity, honesty, carefulness, openness, freedom, credit, education, social responsibility, legality, opportunity, mutual respect, efficiency, and environmental protection. (Resnik, 1998, the chemist's code of conduct)⁷.

When chemists conduct synthetic research within the framework of the principles I mentioned above and, furthermore, when they use ethical reasoning to resolve ethical issues and dilemmas they come across, synthetic chemists conduct ethical research. When, for example, they consider the safety of society and environment, when they are objective and honest with the result of their research and they publish everything they know about the substance they have created, then they have conducted ethical research and can not be blamed because the second condition is not satisfied. We can say that chemists are responsible (1) and worthy of blame for the effects of a product when, for example, they hide known impurities or properties that can cause harm. The same thing we can say about engineers who hide on purpose a fault that a machine has, and about biotechnologists who hide undesired results of the use of their products.

But is there something in the synthetic research that can change the way we evaluate the second condition? As we said, the second condition can be satisfied only when chemists act unethically as professional scientists. Synthetic chemistry isn't exactly like other branches of chemistry it is more like engineering and applied science. Is there something in the way synthetic research is conducted that is not captured by the professional ethics mentioned above and which contributes to satisfying the second condition?

It has been claimed that one can distinguish between chemical synthesis as an end in itself and chemical synthesis for utilitarian ends. According to that claim the synthesis of a new substance just because that substance didn't exist before in nature – as an end in itself, is a morally questionable activity (Schummer, 2001). Schummer (ibid.) claims that when chemists compose just because they can, the gain of knowledge goes along with the lack of knowledge. Lack of knowledge is defined as the undetermined properties and all chemical reactivities of the new substance with the already existing ones. If that claim is correct then the second condition I mentioned above is satisfied, because in that case chemists conduct unethical research⁸. Chemists have a professional responsibility to serve the public interest and welfare and to advance scientific knowledge (The chemist's code of conduct), when they conduct synthesis as an end in itself they neglect their professional responsibilities (2). First of all, their research does not advance knowledge because most often the production of non – knowledge is greater than the gain of

knowledge. Second of all, they don't seem to care about the public interest since they compose only because they can, and not because they hope that what they produce might be useful to society.

I have some reservations regarding the distinction between synthetic chemistry as an end in itself and for utilitarian ends. First of all, modern scientific research does not allow the scientist the luxury to compose a substance without having any clue about what that substance is going to be. No university, institute or company is going to spend time and money just to allow a synthetic chemist to compose something without caring for its use or properties. And second of all, even if such a dividing line existed it has been claimed that synthesis as an end in itself has as a result substances with undetermined properties. That means that we don't know all the properties of the substance. So is it possible a substance that has been synthesized as an end in itself to have some usable properties? Since we don't know all its properties, of course it is, unless there is a time limit between the time of the composition of a substance and the time of the discovery of its usable properties. So we can't say for sure that synthesis as an end in itself has as a result substances without useful applications. Furthermore, is it possible for a substance, which has been synthesized to benefit humanity, to also have some undesirable properties and cause harm? Of course it is; the case of Agent Orange is one well-known example. To conclude, it is hardly possible to distinguish synthetic process as an end in itself and for utilitarian ends, because there's no way to know from the beginning of a synthesis all the possible properties and uses of the new substance. So the claim that the chemical synthesis can be distinguished, at least in that way, is unfounded, and because of that, synthetic research as a process is not a morally questionable activity, unless the synthetic chemist acts unprofessionally - unethically.

Could synthetic research, which concerns weapons, be considered unethical or unprofessional? Compared to the research that concerns drugs, it seems it could be. *Prima facie*, that kind of research is unethical because it doesn't serve the public interest and welfare. But if we consider all the sides of those lines of research we may see conflicts between ethics and self-interest and between different ethical, legal, political, religious or institutional obligations that some times result in considering those research processes as ethical and fully professional. We shall talk further about this kind of cases in the next, third part, of the paper. To conclude this second part: should synthetic chemists engaged in this kind of research be held especially responsible, in comparison to other professionals, for their products? I have found no argument to support that claim. Chemists are not the only scientists engaged in that kind of research, other scientists and engineers work in the field of weapons as well. Each one of them under certain circumstances may take the blame for specifically unethical conduct.

Part III: The Ethical Problems

I have argued that synthetic chemists cannot be held especially responsible for their products in comparison to other professionals. Yet, because synthetic chemistry, as a process, combines engineering, natural sciences and applied sciences, synthetic chemists frequently face complex ethical problems. In general, during the process of chemical research, in whichever field this research is conducted, the ethical issues that chemists often face are, more or less, common. Most of them have to do with the way research is conducted, where for example, the management of data can lead to dishonesty in research. Others arise from the process of publication of the data, for example, whether conflicts of interest may lead to biased publication. Some ethical issues also derive from the concept of intellectual property: to whom does the scientific knowledge belong? Finally, ethical issues may spring from the funding of research. In synthetic chemistry another source of ethical problems that arise during the research process in other branches of chemistry. So synthetic chemists must consider and weigh deferent prospects in order to solve such ethical problems or make an ethical choice when they face an ethical dilemma, which arises from the product of their research.

Synthetic chemistry is a field that society disapproves of. Most people connect this field of research with the production of chemical weapons and with all environmental or health hazards caused by plastics, pesticides and by what people general call 'chemicals'. Because of that, chemists are the scientists who take the blame. It's a fact that the field of synthetic research is intensively questioned. Chemical weapons can have tragic consequences if there are going to be used, plastics and pesticides already have caused severe environmental and health problems. Those facts are sufficient to give society the right to think the worse of synthetic chemistry research and turn chemists into the black sheep of the scientific community. The ethical dilemmas synthetic chemists face have two sides: on the one side there is the benefit of society and the protection of the environment and on the other there is synthetic research and the benefit of scientific knowledge. What should the chemists weigh, and how can they deal with the ethical dilemmas they face?

Many people would agree that limiting/restricting synthetic chemical research could be a possible solution. This implies that chemists should stop conducting research in that field. But is this an ethical solution? Should chemists refuse or avoid research in the field of synthesis? In such a case, we have violation of the scientific value of

freedom. Science should be free. According to Resnik (1998): 'Scientists should be free to conduct research on any problem or hypothesis. They should be allowed to pursue new ideas and criticize old ones' (Resnik, 1998 p.59). Given this value, the limitation of research is not acceptable. Because of that, an ethical dilemma arises. The conflict between social responsibility for the advancement of public welfare on the one hand, and the responsibility for the defense of freedom that is necessary for the advancement of science and scientific knowledge.

Let us examine more carefully and in more detail the above dilemma. It is true that the field of synthetic chemistry has negative aspects and the scientists involved in such research seem to be violating the ethics of science. But are there only bad consequences from synthetic research? If we think open mindedly, we will discover that there are other sides of the matter that have not been considered. Plastics, for example, are a very important part of synthetic chemical research and it is unquestionably true that by offering them synthetic chemists benefited humanity. Their discovery changed the known world and gave much potential to human beings. Plastics, for example, are indispensable in nearly every technological achievement. So, the research in the field of polymeric materials has offered, and continues to offer, important and necessary products for the evolution and welfare of mankind. If research in the field of polymers were to stop or to be restricted, further progress and improvement of everyday life may not occur.

As regards now research in chemical weapons, it may be said that they don't seem to offer anything good to society. But if we consider the scientific practice we can say that the chemistry of chemical weapons in many cases does not differ that much from that of drugs. A substance that is an excellent weapon can also have some good applications in research related to drugs. The same thing may occur for substances that result from other kind of researches. As I have argued above, a synthetic process is not an absolute step into the unknown since specific properties of a substance can be known in advance. Its uses, then, cannot all be unforeseen. Because of that, if we limit synthetic research, it may inhibit the advancement of the science of chemistry. We may prevent the production of a chemical weapon, but it is also possible that research, which could have led to the development of a drug, could be passed over as well. So, because of the nature of synthetic chemistry we cannot blame in advance the research that takes place in that field.

It has been claimed that the difference as regards the ethics of chemistry and the ethics of engineers lies in the fact that for engineers the public welfare and safety are very important while for chemists public safety isn't of special interest. Chemists are free to trade safety and welfare with other interests (Davis, 2002). That's not true; chemists acting as professionals do not just trade off in an ethical neutral territory. From what has been said above it is obvious that ethical issues, which arise in the context of synthetic chemical research, cannot be seen as black and white. The dilemma between freedom of research and social responsibility cannot be resolved in a neat and simple manner. The decision about which research will be performed and to what degree it will be pursued demands from chemists to be familiar with ethical reasoning, so that they can reach the right ethical decision. Synthetic chemists should weigh different factors in order to make an ethical decision. They should consider questions like: what should they care for in their research? Should they care for public safety or for he advancement of knowledge? Should they choose freedom of research or social responsibility? In order to make such decisions synthetic chemists should always search for the positives as much as for the negative consequences of research; they should analyze the arguments that are for and against one position. They should also evaluate and take under consideration the values that characterize the profession of chemists and finally to make a choice that is based on the best arguments. That means that even if a particular research is assumed by many to cause the greatest possible harm, it can still be conducted as long as it is supported by the most cogent arguments. Ethical reasoning is as necessary for the support of scientific research as it is for the achievement of the goals of science.

Conclusion

Synthetic chemistry is a field of chemical research enveloped in myths. According to those myths synthetic chemists are most of the time unethical professionals because they don't care for the consequences of their products, and only some times do they produce something useful to mankind. Environmental pollution and the cause of disease are in general the consequences of their research. Chemists of course because of that should be held especially responsible for the outcome of the use of their products. Is this true? There is a grain of true in every myth, as the saying has it. It is true that synthetic products have caused, from time to time, harm to humans, environment and animals. But beyond that, synthetic chemistry does not cease to be a branch of science. Synthetic chemists are professionals. As I argued in this paper synthetic chemists have the uniqueness to combine different sides of different sciences, natural sciences, engineering and applied sciences. Sometimes they face unique ethical issues, but that does not mean that synthetic chemistry is so different from every science it combines; neither does it mean that synthetic chemists should be held especially responsible for the products of their research. I have found no evidence to support this claim. Like every other professional, synthetic chemists make choices during their

research. If their choices are unethical, then they should be held responsible for those choices, but not more than any other professional who makes unethical choices as well⁹.

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¹ Synthetic processes take place in organic, inorganic and industrial chemistry. Those who are engaged in organic chemistry compose using mostly organic molecules, those who are engaged in inorganic chemistry compose using mostly inorganic molecules and finally those chemists in industrial chemistry compose using combinations of molecules.

 2 Having useful properties means that the substance has some kind of interaction with other molecules or reacts toward certain conditions in a way that leads to the assumption that that substance can be used for the creation of certain goods (e.g. a drug).

³ 'Responsibility (1) is to be distinguished from the sense of 'responsible' in which a man has, or takes on, or accepts a responsibility. For instance as a doctor I accept, or take responsibility towards my patients' (Casey J. 1971, p. 178)

⁴ For example, the action of the sudden opening of a door may be responsible (3) for hitting a passer-by. The opening of the door caused the hitting. There is a causal connection between the action and the outcome. That kind of connection between action and outcome must somehow exist.

⁵ For example, during a war we cannot blame a soldier for killing, because war isn't a normal situation.

⁶ J. Schummer (Schummer J. 2001), in order to contend that the creation of a new substance is a crucial causal step for any unexpected outcome of its use, and so to prove the chemist's general responsibility, uses as an example the extreme case of someone stealing a poisonous synthetic substance and using it to harm other people Starting from that point, in relation to the third condition, I have to say that I can't consider a condition normal if it involves the stealing of a dangerous substance, or the use of violence. In such circumstances the third condition is not satisfied. I do not consider this example an example of scientific research normally conducted.

⁷ Those principles do not differ radically from the principles that constitute the framework of standards of ethical conduct in other sciences.

⁸ The second condition in order to be satisfied requires that the chemist has acted in the context of scientific research and didn't carry out the certain pattern of responsibilities (2) that that certain context required.

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