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Ethics of Chemical Synthesis

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Abstract: 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 harm of living beings. This paper provides for the first time a systematical analysis of moral issues arising from chemical synthesis, based on concepts of responsibility and general morality. Topics include the questioning of moral neutrality of chemical synthesis as an end in itself, chemical weapons research, moral objections against improving material conditions of life by chemical means, and freedom of research. The paper aims at providing both a sound basis for moral judgements of chemistry in a public discourse and a framework for chemists to reflect on the moral relevance of their activity.

Keywords: *ethics of synthetic chemistry, responsibility, utilitarian and nonutilitarian ends of synthesis, chemical weapons research, freedom of research*.

1. Introduction

Like in all other fields of philosophy, chemistry lies on the blind spot of philosophers in applied ethics, too. To be sure, many philosophers are aware of moral issues related to chemistry, such as chemical weapons research, environmental pollution, chemical accidents, unintended bad 'side-effects' of chemical products, *etc.* However, contrary to the public opinion, which tends to equate chemistry with all evils, philosophers seem to be unable to relate these issues to chemistry. Instead, they discuss them in diverse fields such as warfare ethics, environmental ethics, medical ethics, or ethics of technology, without recognizing the common grounds of chemistry. Between public condemnation of chemistry and the philosophers' ignorance of chemistry in applied ethics, the contrast could not be greater. It is overdue to take chemistry seriously also from an ethical point of view and to fill the large gap left by philosophers. What is in need is both a sound basis for moral judgements of chemistry in a public discourse and a framework for chemists to reflect on the moral relevance of their activity.

In the present paper, I focus on moral issues of chemical synthesis. Unlike the knowledge producing activities of other scientists, synthetic chemists also produce new material entities, chemical substances, such that their research activity already changes our material world. In addition, their cognitive product is

synthetic knowledge, *i.e.* knowledge for changing the material world on the substance level. It is exactly that difference in scientific products that makes synthetic chemistry, among all other branches of natural sciences, peculiar in moral matters and from which most moral issues related to chemistry derive. Changing the material world requires different moral reflections than producing ideas about the world because it directly affects material conditions of life – for the benefit or harm of living beings.

Entering new grounds requires some systematical work rather than the discussion of particular issues from particular points of view. To that end, I start with some general ideas of philosophical ethics (Section 2), mainly to clarify the concept of responsibility and to introduce a minimal concept of general morality that, beyond all differences among ethical theories, allows to draw general moral conclusions. Section 3 briefly provides some empirical data about the actual activity of synthetic chemists and their goals. This supports discussing the moral issues of chemical synthesis in two separately fields: the production of new substances as an end in itself (Section 4) and for utilitarian ends (Section 5). The last field is divided up again into two branches, whether the new substances are intended to harm people (*e.g.* chemical weapons, Section 5.1) or to improve material conditions of life (Section 5.2). Since intentions of improvement might be considered as a moral permission per se, particular attention is paid to a systematical analysis of morally justified objections. Based on the concepts of responsibility and general morality introduced in Section 2, for each case I point out both the scope of responsibility of chemists and minimal moral constraints. Finally, I discuss if freedom of research weakens these moral constraints and then suggest a moral foundation of that concept (Section 6).

2. Responsibility and general morality

Despite its ubiquitous use in both ordinary and philosophical discourses, the concept of responsibility is vague and ambiguous such that a preliminary clarification of what I mean by that term is necessary.[1] If *x* is responsible for *y* to *z*, we may distinguish between different types of responsibility according to different instances of *x*, *y*, and *z*. Usually *x* , the subject or agent of responsibility, is an individual person of sound mind. Beside individuals, we also hold corporations, as corporate agents, responsible for something, and it depends on the inner social structure of that corporation if all members share the same responsibility or if certain officials take the main responsibility. Thus, in our case a chemist can be responsible as an individual (*individual responsibility*) and as a member of the chemical community, a chemical society, a company, or any other chemical organization (*corporate responsibility*).

Most frequently, the consequences of *x*'s actions (or omission of certain actions) are the *y* for which *x* is held responsible (*action responsibility*). For these actions it is required that *x* could do otherwise, *i.e.* that *x* has a free choice between options and that the decision is based on *x*'s preferences. Thus, responsibility establishes a causal attribution of events *y* to an agent *x*.[2] There is a difference between past consequences (*retrospective responsibility*) and future consequences (*prospective responsibility*), because only in the former case the consequences are well known, whereas prospective responsibility is necessarily bound to more or less uncertain prognoses of possible consequences of one's actions. Since criminal law is, for practical reasons, largely restricted to retrospective responsibility, prospective responsibility is a particular field of morality and the topic of ethical studies. Besides consequences of actions, we also hold somebody responsible for persons, animals, or certain things, meaning that the agent should take care of their well-being and well-growing (*care responsibility*). Paradigm cases are the responsibility of parents for their children or people's responsibility for their pets.[3] Since the possibility of well-being or well-growing is a sufficient condition that something can become subject to care responsibility, we may also include more abstract things as social structures and knowledge. In this regard, it also makes sense to speak of chemists being responsible for the well-being or well-growing of chemical knowledge considered as a public good.

The *z* in our phrase '*x* is responsible for *y* to *z*' is the institution to which we feel or are made obliged to justify our actions related to *y* in a moral discourse. Note that the English term 'responsibility' derives

from ‘to respond’ in the sense of answering questions about one’s own actions and justifying them in a moral discourse; and *mutatis mutandis* in all major European languages.[4] The institution z may be a single person, a group, a community, a national society, or humanity as a whole; and it may be represented by a group or community leader or a court, depending on its social structure. In addition, the institution may be internally represented by one’s own conscience, which is even required if the institution is not formaly established as it is the case with humanity.[5] Thus, we may once more distinguish between different kinds of responsibility (*single person, group, community, society, and humanity or general responsibility*), and accordingly between different kinds of obligations. These kinds of responsibilities are not necessarily connected with each other. Somebody can feel obliged to justify his or her action before a national court and, at the same time, abrogates any group or general responsibility. For instance, if a company breaks national law, an employee may lose any responsibility to the company and take the cause to court. Or, a soldier killing people in war might feel obliged only to his nation and abrogate responsibility to humanity. The examples also illustrate that in different institutions the rules of moral discourses, their values and kinds of acceptable justifications may considerably differ from each other, to the extent that the same action is praised in the discourse of one institution and blamed in another. I will call such instances of conflicting obligations to different institutions *vertical obligation dilemmas,* and distinguish them from *horizontal obligation dilemmas* that arise from conflicting obligations to the same institution.

It is important to emphasize that, unlike a widespread confusion, holding somebody responsible for something does not yet include a moral judgement about his or her action, since it is still open whether the action is to be blamed or praised. Similarly, taking responsibility for something is not yet a moral self-judgement. Instead, if I take responsibility for something to institution *z*, I declare my willingness and self-obligation to justify my actions in a moral discourse of institution *z*, thereby accepting its standards and possible moral judgements of my actions. Accordingly, if I hold *x* responsible to institution *z*, I want to make *x* obliged to justify his or her actions in a moral discourse of institution *z* and to accept its standards and possible judgements. In such a moral discourse, it may turn out that bad consequences of one’s action were unintentional, unforeseeable, unavoidable, or even the best choice, such that the action will not be judged morally wrong – but that does not exonerate from responsibility. In sum, responsibility is the willingness or obligation to justify one’s actions to an institution and thereby to accept its standards of a moral discourse. Since the general notion of responsibility is not bound to specific moral norms or systems, it is fundamental to all kinds of morality.

That is particularly important if we turn to philosophical ethics. The main field of philosophical ethics is traditionally concerned with the institution humanity as a whole, to be represented in one’s own conscience.[6] Unlike group, community, and society morals, norms and obligations of general morality are addressed to every human being, independent of particular memberships. The problem is only that there is some dissent among philosophers about the exact standards of the general moral discourse, including its norms and obligations. Starting with general responsibility, however, allows ignoring these differences at first before considering different moral judgements according to different moral systems in a second step.

Do we have general criteria to decide whether a sentence ‘*x* is responsible for *y* to *z*’ is true or not? Of course, the causal connection between *x*’s actions and *y* (the causal attribution) is a necessary requirement, but not a sufficient one. If responsibility is the willingness or obligation to accept the standards of a certain moral discourse, x’s public acceptance or abrogation of responsibility for *y* to *z* is the only criterion we have. Can we not hold *x* responsible even if *x* abrogates responsibility? We can say so, but that does not necessarily affects *x*’s willingness and self-obligation to make the sentence true. Instead, holding somebody responsible is a *prescriptive* claim through which we want somebody feel responsible. The question is rather: do we have general criteria to decide whether holding somebody responsible is morally justified or not?

In the cases of group, community, and society responsibility, problems do not arise because accepting the standards of the moral discourse of the corresponding institution is usually part of an explicit or implicit contract (*e.g.* the constitution) that everybody must sign to become a member. Thus, we can turn to the

central question: are there general moral criteria to decide whether holding somebody responsible to humanity is justified or not? In other words, should everybody take general responsibility to humanity? Here, we have neither a contract nor definite standards of a moral discourse, but many different general moral systems. Hence, it comes down to the most general question if everybody ought to accept any general moral system whatsoever. The answer is that every general moral system of obligations, per definition, includes the general claim that everybody ought to accept general morality, because their obligations are addressed to everybody and not only to members of particular groups, communities, or societies. Thus, demanding general responsibility is a common claim of all general moral systems of obligations and norms. If *x* abrogates general responsibility, there is of course no way to convince *x* through general moral arguments, because x thereby rejects any general moral discourse whatsoever. Therefore, abrogating general responsibility is an amoral position that cannot, by definition, be justified by general moral arguments. On the other hand, since holding everybody responsible to humanity is a justified claim in every general moral system, we have the strongest kind of moral justification possible in the realm of ethics.

For the purpose of the present paper, this means that holding chemists, as everybody else, responsible to humanity for the consequences of their actions is, in the strongest possible sense, justified. In the following, I will pick up only one sort of chemical actions, the synthesis of new substances, and analyze possible moral issues from the point of view of general morality.

Before so doing, the concept of a general moral system needs further clarification. A general moral system defines the standards, *i.e.* the values, norms, obligations, and rules of a general moral discourse that somebody accepts by taking responsibility to humanity. Since there is no real moral discourse among all members of humanity, these standards must be theoretically developed, which is done in the field of ethical theory. There is much debate among ethical theoreticians about details resulting in many different general moral systems. Beyond dissent, however, there are some general conditions that every moral system must at least meet in order to be considered a general moral system. In the following, I take three conditions as defining the core of general moral systems for judging and guiding actions. (1) The primary value is the welfare of humanity, the *z* in our notion of general responsibility, including all present and future human beings. (2) All moral norms and obligations must be related to the primary value, such that following these norms may be expected to promote, at least not to reduce, the welfare of humanity. (3) All moral norms and obligations (including general responsibility) must be equally addressed to everybody as both guidelines for and standards to judge actions.

These minimal requirements are necessary to exclude particular interests, pseudo-moral obligations in the name of general morality and to guarantee general responsibility of everybody. Beyond that, there is room enough for specification and extension to cover all major approaches of ethical theory. In particular, it remains open how ‘welfare’ is exactly defined, what particular values it includes, what the particular norms and obligations are, and on what epistemic grounds excactly they can be expected to promote the welfare of humanity.[7] In addition, one may include as a secondary value the welfare of all other living or sentient beings, as variants of ecological ethics do. However, since the present paper aims at general moral conclusions on consensual grounds of ethical theories, instead of presenting my own moral opinions or getting lost in special debates of philosophical ethics, focus will be on minimal requirements, with only occasional references to more far-reaching constraints of particular ethical theories.

3. Chemical Synthesis

Having clarified some general ethical concepts, a closer look at the subject field, *i.e.* chemical synthesis, is necessary before we start the moral discussion. To that end, I refer to results of empirical investigations of what ordinary chemists worldwide are actually doing.[8]

During the past 200 years, the synthesis of new substances has been the main experimental activity of

chemists. Today there are over 3 million chemists worldwide who produce some 570,000 papers a year reporting on some 900,000 new chemical substance (including biosequences, 6 million). Random sample analysis of 300 papers in general chemistry shows that in 75% of the papers the synthesis and characterization of at least one new substance is a central part. Empirical document analysis of the goals of chemical synthesis reveals that nearly half of the papers aim at improving synthetic capacities, such that synthesis is both the means and the goal, *i.e.* an end in itself. Only a quarter of the papers indicate an interest in technological applications of the new substances, either explicitly or implicitly by referring to properties not required for substance characterization. Minor goals include elaborating on classification, finding structural peculiarities, and, to the smallest degree, improving models and theories.

In contrast to a growing rhetorical emphasis on applied research, the actual interest of synthetic chemists in technological applications seems to have been rather constant worldwide, if one refers to the number of patents abstracted by *Chemical Abstracts*. It is true that the number of chemical patents in proportion to the number of all chemical journal papers has slightly been increasing during the past 30 years (Fig. 1), indicating a slightly growing general interest in applied chemistry. However, for synthetic chemistry, there is no significant trend recognizable in the ratio of new substances to new chemical patents, as the ratio has varied around 0.16 during the past 30 years.

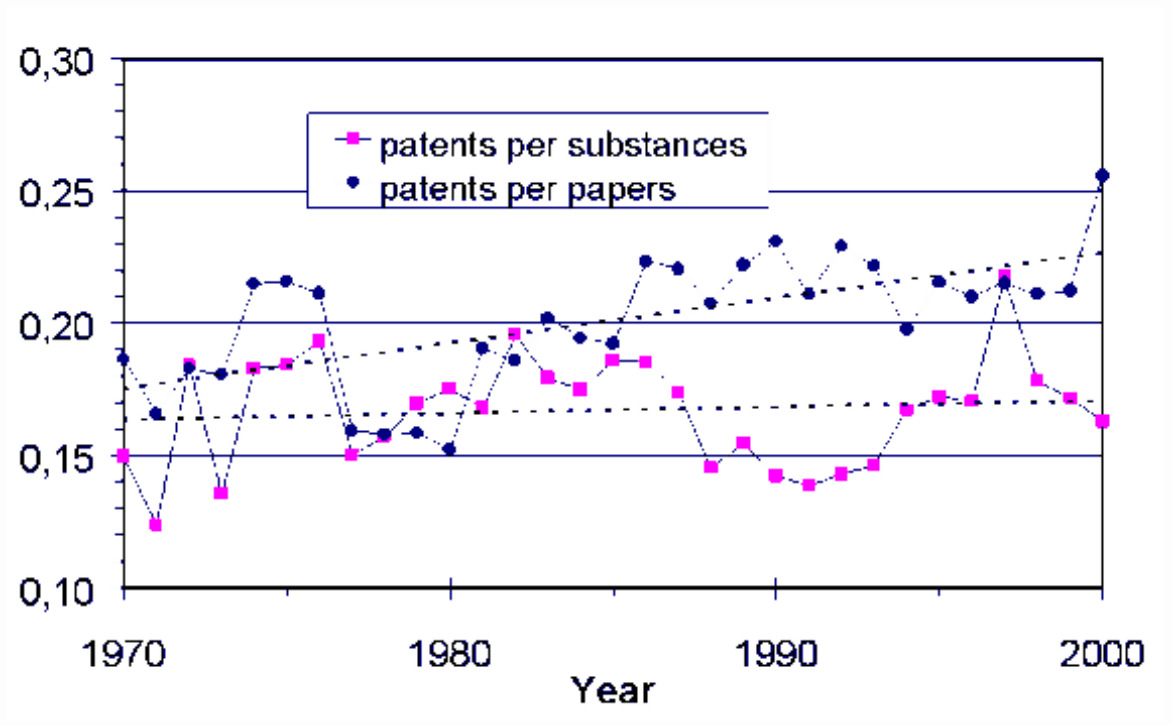

Figure 1: Number of chemical patents per papers and per new substances. Data from CAS 2001 (biosequences excluded.) Linear regression trend lines added.

Thus, for the main part, producing new substances continuously serves improving methods of producing further substances; *i.e.* pure synthetic chemistry for which producing new substances is an end in itself.[9] The second largest part of chemical synthesis aims at technical applications for utilitarian ends. For the purpose of the present paper, this allows to distinguish between two main cases: (1) chemical synthesis as an end in itself, (2) chemical synthesis for utilitarian ends.

4. Chemical synthesis as an end in itself

Since producing new substances is, to the largest part, an end in itself for synthetic chemistry, synthetic chemists might feel obliged to advance the field by both producing new substances and improving synthetic capacities. In this sense, they take responsibility for their synthetic research to the community of

synthetic chemistry. That community may have its own award system and criteria to distinguish between good and bad research, and requiring, for instance, a minimal number of new substances in a paper worth publishing.

Beyond responsibility to the synthetic chemistry community, one would also expect responsibility to the chemistry community as a whole because synthetic chemistry is only a branch of chemistry, albeit that issue has probably never been raised. It is understood that synthetic chemistry contributes to the general skills and knowledge of chemistry, for instance, by producing analytical reagents, developing better understanding of reaction mechanisms, elaborating on chemical classifications, *etc.* In addition, improving synthetic capacities can be instrumental to utilitarian research projects, to be discussed in the next section. Despite such specific contributions, however, it is far from clear whether synthetic chemistry generally helps or hinders a better chemical understanding of the material world.

Chemical knowledge about the material world provides us with an understanding of its chemical components, *i.e.* chemical substances, their properties, and chemical dynamics. If the material world consists of a given set of substances, then synthesis of a new substance changes the material world by adding one more, which is a change of the object of knowledge. It is clear that this is completely different from playing with a box of bricks, because every new substance, despite of its being composed of a small set of chemical elements, constitutes an infinite potential of new and unforeseeable material properties, [10] and even meets strict conditions of novelty.[11] With every new substance, the scope of our knowledge increases by its produceability as well as by some characteristic properties necessary for identifying the new entity.[12] However, since synthesis changes the material world, the gain of knowledge must be compared with the increase of nonknowledge or lack of knowledge, defined by the number of undetermined properties. With every production of a new substance, the scope of nonknowlegde increases tremendously, by the number of undetermined properties of the new substance as well as by all chemical reactivities of the already existing substances with the new one.[13]

Nonknowledge resulting from changing the object of knowledge should be well distinguished from epistemological reflections on the limits of knowledge resulting in the classical idea that ‘the more I know, the more I know that I do not know’. Furthermore, it is also different from the phenomenon that new knowledge sometimes opens up new unexplored perspectives of knowledge, such when, for instance, new reaction mechanisms open up new fields of reactivity studies. The crucial difference is that in synthetic chemistry, it is neither epistemological reflection nor knowledge about the world but the actual change of the material world, *i.e.* the object of knowledge, that results in nonknowledge.[14] Thus, in general, synthesizing new substances produces much more nonknowledge than knowledge, though this might be different in particular cases where synthesis is performed to improve or qualify more general knowledge. Not only is it difficult to reconcile that with traditional views of science as knowledge-producing activity, one might also wonder if synthetic chemists should hold any care responsibility for general chemical knowledge about the material world, considered as a public good.

Beyond academic interest, the production of nonknowledge by the synthesis of new substances is of general concern if the new substances leave, through whatever door, the laboratories and become part of our material environment. Since the chemical complexity of a material system, defined as the number of chemical relations between its components, sensitively depends on the number of chemical compounds, introducing new substances into our environment tremendously increases its chemical complexity, *i.e.* its chemical incomprehensibility. Thus, in real life, chemically produced nonknowledge turns into increased unpredictability of environmental changes induced by the introduction of new substances. At that point, the general moral issue arises, if synthetic chemists, both as individuals and as a community, are generally responsible for any possible environmental harm caused by their new substances. Even if synthetic chemists themselves neither introduce their new substances into the environment nor promote them for commercial usage, their first synthesis of a substance is the crucial causal step for its existence and possible harm caused by that. Since causal relation is exactly the condition of attribution, synthetic chemists, as free creators of new substances, are generally responsible for all possible harms caused by their creations, which does not exclude that others are responsible too. Therefore, chemical synthesis is not a morally neutral activity, as many chemists tend to see it.

Let us take an extreme case: A chemist has produced a new substance for no other reasons than that it was not around before. Now, it turns out that the substance is poisonous, and that somebody steals it (or its recipe) from the laboratory and uses it to harm other people. Again, since the creation of the new substance is a crucial causal step for all possible harm done by using or misusing that substance, our chemist is generally responsible, which does not affect the thief's responsibility.

Those who feel uncomfortable with the last claim should note that holding somebody responsible does not yet include a moral judgement; it is only a prerequisite of a judgement in a moral discourse (Sect. 2). Whether the synthesis is judged morally right or wrong depends on the weight of the moral arguments our chemist can provide in the discourse as well as on the moral principles accepted in that discourse. Let us consider the three main arguments.

First, our chemist could say that being a synthetic chemist requires, by necessity, the production of new substances (*necessity argument*). This argument aims at undermining individual responsibility by refering to social 'forces' that exclude the chemist's free choice between different options. However, it is not necessity but the obligation to the community of synthetic chemists, as well as his wish to pursue a career in synthetic chemistry, that makes him inclined to synthesize new substances. He could do otherwise. Instead of pursuing synthesis as an end in itself, he could work in other branches of chemistry, or even in those fields of synthetic chemistry that aim at improving knowledge or conditions of live, in case of which moral arguments would indeed be possible. Therefore, the necessity arguments does not undermine individual responsibility but points out that, in addition, there is a corporate responsibility of the community of synthetic chemists.

Second, our chemist might say that he could not foresee the harm caused by his creation nor its harmful properties (*knowledge argument*). This is trivially true of all substances, because there are infinitely many possibilities of future usage of a substance and because every substance bears an infinite potential of properties. From that it follows, however, that it is very likely that any new substances can be used to cause harm. Thus, we may expect that our chemist, while being unable to foresee the particular case of harm, knows well about the high probability of possible harm. Therefore, the knowledge argument turns to the contrary and does not help to excuse our chemist.[15]

Third, our chemist could say that he did not intend to cause harm with his creation (*intention argument*). This accepted, it is a matter of moral principles held in the discourse to what degree intentions are weighed in moral judgements. According to one extreme, consequentialism, only the (actual or probable) consequences of one's action play a role in moral judgements, regardless of other intentions. (This is similar to the scientific award system that celebrates discoverers even if the discovery was unintentional and incidental.) The other extreme, judging actions only according to good intentions regardless of their bad consequences, is so naïve that it would be difficult to name any follower.[16] For if good intentions were the only thing that morally matters, nobody would care about the knowledge to foresee the consequences of one's own action, which would undermine the notion of responsibility. Hence, all moral discourses consider consequences and differ only in the degree of how much good intentions can outweigh bad consequences. Thus, the intention argument of our synthetic chemist is incomplete. We need to know his *morally relevant* good intentions of his synthesis in order to consider if they outweigh the unintended bad consequences.

In a general moral discourse, obligations to specific groups or communities are not necessarily general moral obligations. Thus, if our chemist replies that it was his good intention to improve the field of synthetic chemistry by adding one more substance, this is hardly a general moral argument, nor is such an intention necessarily good or bad in a general moral sense. Instead, reference to general values is required. Because in this section we deal with chemical synthesis as an end in itself and exclude general utilitarian ends to be dealt in the next section, references to general values are difficult to find here. The only possible reference would be to knowledge, considered as a general value. As we have seen, however, the synthesis of new substances generally increases nonknowledge much more than knowledge, although that might be different in particular cases. Therefore, our chemist would have serious difficulties

to outweigh the unintended bad consequences of his action by general moral arguments, such that his synthesis would have to be judged morally wrong. In general, producing new substances just because they did not exist before is a morally questionable activity. Since our discussion is not limited to any specific requirement of certain general moral system, the conclusion holds generally.

That moral conclusion does not only challenge individual chemists who synthesize new substances just because they did not exist before. It is also a moral challenge to the whole community of synthetic chemists for which synthesis is actually an end in itself. The fact that the internal norms and obligations of that community are not in agreement with general moral standards shows that the whole community do not recognize their general moral responsibility and wrongly consider their activity as morally neutral. That notwithstanding, it is fully justified (Sect. 2) to hold both individual synthetic chemists as well as the community generally responsible for all possible harm from new substances.

5. Chemical synthesis for utilitarian ends

The second largest part of synthetic chemistry produces new substances because of their usefulness. Saying that something is useful means that it has instrumental value for certain people. Additional information is required as to which people it helps achieve what goods or prevent what evils. In the following, without going into details, I take happiness as the highest good and lack of happiness as the highest evil, from which all other goods and evils may be derived according to various ethical theories. [17] Next we may ask which people are meant and how they count. At the level of general morality, with which I will primarily deal here, every present and future human being equally counts such that usefulness refers to humanity as a whole. This is to be distinguished from usefulness to particular groups such as a national society, the chemical community, a company *etc.* Since these groups need not necessarily share the same interest as humanity, it is evident that the same thing, *e.g.* a chemical substance, can be useful to a certain group but harmful to humanity. In the following, I will first consider utilitarian ends to the detriment of humanity, with emphasis on chemical weapons research. Then I will analyze what moral issues are possible in case of utilitarian ends for the benefit of humanity.

5.1 Utilitarian ends to the detriment of humanity

From the point of view of general morality, *every synthesis of a new substance with the intention to harm or kill people, e.g. a poison as a poison, is morally wrong*. Therefore, since it is justified to hold chemists, as anybody else, responsible to humanity, every chemist involved in such projects as chemical weapons research violates norms of general morality. This claim, as I will show, is a categorical claim without any exceptions and valid in any general moral system. General moral systems can be divided up in two classes, whether they include the interdiction of doing harm to people as a moral principle or not. For the first class, the claim is trivially true. For those systems, which do not explicitly include that principle but allow doing harm if it is outweighed overall by positive effects, *i.e.* variants of utilitarianism, specific arguments are required.

First, however, it is necessary to emphasize the strict distinction between the general moral level and any particular notions of usefulness. For an armaments factory, a new poison developed in its laboratory might be useful. The research chemists in that factory might feel obliged to their employer to engage in poison research. However, neither the commercial interest of a factory owner nor the obligations of employees to their employers affects the general moral obligation to humanity. Such vertical obligation dilemmas cannot be solved by offsetting one obligation against another, as personal interests do not count as general moral arguments. Furthermore, a national society, represented by its government, might consider chemical weapons useful to serve national interests – usually military expansion because no society has an interest in poisoning its own country. Chemists who feel obliged and responsible to their national society might say

that synthesizing a new poison is useful and good. However, that is no general moral claim because it serves only the interest of the nation and neglects the interests of all other human beings who, by their different nationality, can become victims of the poison. The history of warfare research is particular rich of scientists mixing up patriotism with general morality and thereby abrogating general responsibility, while politicians usually do their best to pass obligation to the nation as general moral obligation. In sum, the usefulness of poisons to particular groups or societies in certain situations does not affect their general harmfulness to humanity as a whole, nor does it exonerate from general moral responsibility.

Apart from that, there are situations where doing harm to individuals prevents greater harm to *humanity*. According to utilitarianism, the action that causes less harm ought to be preferred, such that in these situations doing harm is not only allowed but morally demanded. At first glance, utilitarianism seems to undermine our categorical moral claim. However, are there really situations in which the development of new poisons (weapons) is for the benefit of humanity because it prevents greater harm? At least that is what national politicians, from the Manhattan project to the Cold War era, said and continue to say since weapons research, including chemical weapons research,[18] makes up a large if not the largest part of national research budgets of many countries.

The problem of the argument is that it confuses two different kinds of actions: scientific research of a new weapon and the military deployment of any weapon. The two kinds of actions have completely different scopes of consequences and responsibilities, and only the first kind is relevant in the present context. While it might be possible to survey and control the negative consequences, the harm, caused by the single *use* of a certain weapon in a particular situation, it is definitely impossible in case of weapons *research*. The first synthesis of a new poison, like the invention of any other weapon, is the crucial causal condition of all harm caused by everybody's possible use or misuse in all future. All that is to be counted as consequences of weapons research for which the scientist as the creator of the weapon is generally responsible to humanity. In any case, the probable harm done by a new weapon in all future situations is much greater than the probable harm that might be prevented in a single situation. Therefore, utilitarianism does not undermine but strongly support the categorical moral claim that every synthesis of a new substance with the intention to harm or kill people is morally wrong.

To sum it up, the argument is based on two frequently blurred distinctions: (1) between interests of nations and interest of humanity; and (2) between the use of weapons and the inventions of new weapons. While the invention and use of chemical weapons might be in the interest of a nation, and while it might be argued from an utililarian point of view that the *use* of weapons can sometimes be in the interest of humanity, the *invention* of new chemical weapons, like the synthesis of any substance with the intention to harm or kill people, is definitely against the interest of humanity.

5.2 Utilitarian ends for the benefit of humanity

In Section 4, I have dealt with the synthesis of substances without utilitarian interest. Section 5.1 analyzed the synthesis of substances following particular utilitarian interest to the detriment of humanity. Now, what is left is the large scope of synthetic chemistry aiming at the improvement of material conditions of life for the benefit of humanity. In that area, we have the huge fields of medical and agricultural chemistry, and the development of new materials for both daily use and all sorts of engineering such as building, dying, electrical engineering, instrument building, medical prosthesis, *etc*. Unlike the other two groups, the synthetic chemists in that area usually recognize their moral responsibility to humanity and have some moral ideas of the improvement of conditions of life. Thus, it appears that, from a general moral point of view, there is nothing more to say about this group than to praise their activity. Strangely enough, however, the chemists working in that area encounter strong reservation and even hostility in the public. In this section, I will try to give a brief systematic analysis of possible moral issues.

If a new substance can serve to improve certain conditions of life, only two kinds of morally justified objections could be raised. First, the improvement of certain conditions for humanity could be at the

expense of worsening other conditions for humanity (*gain-loss arguments*). Second, the improvement of certain conditions could be wrongly distributed among people or even at the expense of worsening the conditions of other people (*distribution arguments*). Since improvement as such is per definition morally good, there is no other kind of objection against improvements justified on general moral grounds. In particular, saying that improvements are bad simply because they change the *status quo* is but a morally ignorant conservative attitude that deserves no further attention. This is to be well distinguished from conservative attitudes based on gain-loss arguments that we consider now.

5.2.1 Gain-loss arguments

If improvements of certain conditions of life of all people go at the expense of worsening other conditions, a comparison of gains and losses decides whether it is, on the whole, an improvement or worsening. As to improvements by chemical means, typical losses are the unintended bad side-effects on the environment and health of people. Drawing a comparison of gains and losses is easier said than done, however, since there is no simple measure to calculate gains and losses of happiness. People considerably differ in evaluating the various conditions of life. Even if the present generation could reach an agreement, future generations might have different preferences that would be ignored in case of irreversible changes of the environment. Because of these uncertainties, the gains should considerably outweigh the losses in order to count as real improvements.

The issue grows much more complex if we take risks into account. Improvements of certain conditions that are at the expense of unacceptable risks are surely no real improvements. Risk assessment, while being an established field in ethics of technology, is particular intricate in the case of introducing new substances into the environment, and therefore usually neglected. Standard approaches to calculate risks (probability of a damage multiplied by the extent of the damage) are difficult to apply here, because every new substance has an infinite potential of unpredictable properties (Sect. 4), such that risks are unpredictable. Furthermore, there is an unavoidable subjective component of risk assessment, depending on the individual preparedness to take risks. Hence, two people may differ in their moral judgement of a general risk inducing action, without having a superior moral level for ‘objective’ decisions. Combining both aspects explains the peculiar public reservation, sometimes even hysterics, against new ‘chemicals’: many people are less prepared to take *unpredictable* risks even if this comes along with considerable improvements of other conditions. For others, prepared to take such risks, doing without the improvements would be a grave omission and morally wrong. There is no moral solution to the problem other than a political, to say nothing about technocratic decisions.

Even if the decision is democratically legitimized and factories produce and distribute the new substance, it is the ‘fate’ of synthetic chemists, as the creators of new substances, that they never loose responsibility for all consequences of their synthesis (Sect. 4). It should be stressed, however, that taking responsibility in actively working for the improvements of conditions for humanity is praiseworthy, because otherwise improvements would be impossible. Moreover, unlike the groups discussed in Sects. 4 & 5.1, these chemists have good moral arguments in favor of their syntheses as they are intended to improve conditions of life. In a moral discourse, however, good intentions are convincing only if they are not combined with naïvety. To that end, intentions should be based on the full awareness of the entire scope of relevant conditions of life defined by standards of happiness. Since happiness is a psychological category, material conditions, on which chemists are working, are only instrumental to the improvement of psychological states and only part of the game. For instance, improvements of material conditions that cause fear of risk of material damage can considerably worsen conditions of life overall, even if the damage will never happen. Or, material remedies can drive out traditional psychological or social strategies for the improvement of life such that people get dependent on, or even addicted to these remedies and loose their capacity for an autonomous conduct of life. The chemists who are willing to work for the benefit of humanity should be aware of such instances where well-meaning but naïve intentions cause bad effects. If they narrowly focus on small gains and ignore large losses, they have little to reply in a moral discourse.

5.2.2 Distribution arguments

The second group of moral issues concerning the improvement of conditions of life by chemical means refer to the concept of *justice*, of which different ethical views are possible. Up to now, my arguments have been based on consensual grounds of all major systems in philosophical ethics. Now, we are forced to enter the field of dissent and distinguish between different ethical positions. It is easier to explain the issues, if one describes improvement and worsening of conditions of life in terms of distributing goods and evils among people. The concept of justice then defines moral criteria for the distribution of goods and evils.

According to one notion of justice, the equal distribution of goods and evils to everybody is morally demanded such that nobody has an advantage or disadvantage over others. Synthetic chemists, while being only the creator and not the distributor of their substances, might consider this out of scope of their responsibility. However, there are many instances where unequal distribution of goods and evils is incorporated, so to speak, in the intended usage of substances to be synthesized. For example, substances could be intended to improve the luxury needs of a privileged class or society only and, at the same time, cause global environmental harm to everybody (*e.g.*, chlorofluorocarbons used for hairsprays cause global ozone depletion in the stratosphere).

A more far-reaching notion of justice demands that underprivileged or particularly needy people must be favored in the distribution of goods.[19] Inasmuch as synthetic chemists are free to decide in which utilitarian research project they want to work, they are morally demanded to prefer those projects which particularly help underprivileged and needy people. One should note that current economical trends drive global ‘life sciences companies’ into the opposite direction, as they focus research on products for a broad market of rich people, on so-called ‘blockbusters’. For instance, drug research for sexual potency or against obesity pays much more than drug research against serious diseases of small groups. To be sure, obese people are happy about drugs reducing the harm caused by their insensible diet. Thus, gain-loss arguments do not apply here. The chemists who work in such fields should be aware, however, that they might be morally accused of neglecting more serious problems and thereby violating standards of justice. Since nobody can do everything, the charge is rather on the chemical community as a whole.

Finally, if both goods and evils are distributed and the evils include serious harm to some individuals, the moral issue arises if large gains overall justify the sacrifice of few individuals. Many variants of utilitarianism tend to say yes. Nearly all other moral systems include the interdiction of doing harm as a higher principle than the demand of doing well. (This is the old *primum nil nocere* principle from medical ethics.) Or they even have a categorical principle of human dignity that interdicts any purely instrumental use of individuals such as sacrificing individuals for the benefit of humanity. Is that relevant to synthetic chemistry? In my view, this is the most important moral conflict about all technological progress, because what is defined as progress in one moral system is considered regression in another, and *vice versa*. Chemical instances are abundant. A chemical factory may produce goods, *e.g.* medicines, for the benefit of humanity, but does harm to workers and people in the neighborhood in case of accidents. Before new drugs come onto the market, possible negative side-effects are tested first with animals and then with human beings at the risk of doing serious harm. The story of pesticides, say DDT, illustrates that the regular use of chemical products may save the lives of thousands of people at the expense of some being poisoned. It is rather difficult to imagine cases of large gains by chemical means without any losses. The synthetic chemists who subscribe to some variants of utilitarianism feel morally obliged to work for progress according to their utilitarian notion. They fully take responsibility for their research to humanity, as they feel prepared to give good arguments in a moral discourse. However, they should be aware that there are different moral systems and that the actual public moral discourse could have different rules and values judging the same activity as morally wrong. Instead of presenting a solution or going into details, the only point I would like to make here is that there is a fundamental difference in moral systems that underlies cultural debates about technology in general and synthetic chemistry in particular. There is no definite moral solution because there is no external or ‘higher’ moral system, despite the many internal claims to the ‘highest moral’.

6. Conclusion: freedom of research

In public discourses, scientists sometimes refer to ‘freedom of research’ as a license to do what they want. Taking freedom of research as a ‘higher’ value, they reject any claims of particular groups or societies to the control of their research. Now, if it is true that freedom of research is a ‘higher’ value than interests of particular groups, (scientific) communities, or societies, then it must have its justification on the general moral level. In other words, scientists referring to freedom of research as a ‘higher’ value implicitly accept general morality as valid standards of controlling and restricting scientific research. Otherwise, it makes no sense. Hence, the topic ‘freedom of research’ allows summarizing the moral issues of the present paper. Finally, I will argue that freedom of research in synthetic chemistry is morally justified only on the grounds and to the extent of freedom of moral consciousness.

Accepting freedom of research as a higher value than those of particular groups, communities, and societies means accepting it as a value of humanity as a whole. Therefore, every scientists who points to that value as the guidelines of his or her actions, implicitly takes general responsibility to humanity and thereby accepts norms of general morality for the judgement of his or her research (Sect. 2). In Section 4, I have shown that the synthesis of new substances as an end in itself cannot be justified on the grounds of whatever general moral system, unless particular contributions to knowledge of general concern and value are made that outweigh the production of nonknowledge and the risk of unintended harm. Hence, such kind of research cannot be justified by referring to freedom of research, nor is it morally neutral. Instead, it must be judged morally questionable. Furthermore, all those kinds of synthetic research that aim at producing substances to the detriment of humanity, such as chemical weapons research, are to be judged morally wrong (Sect. 5.1). Finally, freedom of research does not justify utilitarian research projects that violate the gain-loss arguments developed in Section 5.2.1, nor does it allow ignoring concepts of justice (Sect. 5.2.2).

Is freedom of research is but a fantasy? Does general morality require utilitarian research to be morally regulated even in the smallest detail? On might object that freedom of research should be taken as an independent principle that keeps scientists free of too much moral rigor. If that should be a moral argument (what else shall it be?) then freedom of research cannot be taken as an morally independent principle but must be justified on general moral grounds. In this regard, one could make some points saying that a too much regulated system is ineffective and that scientific creativity requires some freedom to develop. However, that does not allow scientists to violate fundamental moral norms. The cases where such arguments usually apply are in scientific research that produces knowledge as a public good. Inasmuch as knowledge improves nonmaterial conditions of life of humanity, it is, of course, also morally relevant. The argument hardly applies to synthetic chemistry, however, because first its products are not only ideas but also new substances changing the material world and, secondly, the production of nonknowledge in most cases outweighs the production of knowledge. Therefore, the scope of freedom of research must be sought within the limits of moral constraints on changing material conditions of life, as developed in the previous sections.

Within these limits, the general scope of freedom of research can be defined by the scope of dissent among general moral systems, which is equivalent to the scope of freedom of moral consciousness. Thus, in order to justify freedom of research, we need a moral justification of freedom of moral consciousness. Such a justification must go beyond the particularities of general moral systems and refer to their common ground. All general moral systems demand as a common prerequisite general responsibility of everybody (Sect. 2). That demand is fulfilled only if everybody actually takes general responsibility and feels obliged to a general moral discourse ruled by those moral principles which he or she is actually willing to accept. Therefore, all general moral systems implicitly include concessions to moral tolerance, *i.e.* freedom of moral consciousness, on a meta-level, despite their partial dissent on the level of norms and obligations. Thus, the scope of freedom of research can be justified by the meta-principle of moral tolerance.

As to synthetic chemistry it follows that freedom of research does not affect the moral claims based on common grounds of general morality as developed in the previous sections. The general scope of freedom, defined as the scope of moral dissent, particularly includes the choice among concepts of justice and progress (Sect. 5.2.2). For instance, nobody can be made morally obliged to work for general progress in the sense of utilitarianism, if he or she considers that a regression according to his or her own general moral opinion. On the other hand, if one subscribes to the utilitarian concept of progress, general freedom of research discharges from moral criticism based on different moral views of progress.

Once a decision is made for one or the other general moral system, its particular norms and obligations define one's *personal* freedom of research as the corresponding scope of morally neutral actions. It should be noted that each particular moral system is much more restrictive than the common basis of general morality discussed here. For instance, if the welfare of nonhuman living or sentient beings is to be considered too, as most approaches of ecological ethics do, gain-loss and distribution arguments must be modified accordingly. In synthetic chemistry, this particularly means that also all harm to nonhuman living or sentient beings caused by environmental pollution of new substances is morally relevant, even if no human being is affected.

Finally, since general freedom of research is based on freedom of moral choice, it does not discharge from actually making a choice between particular moral systems. Therefore, chemists, as everybody else, are expected to reflect their moral preferences far beyond the common basis of general morality discussed in this paper.

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Notes

[1] I start with a simplified version of the approach suggested by Hans Lenk ('Über Verantwortungsbegriffe und das Verantwortungsproblem in der Technik', in: H. Lenk, G. Ropohl (eds.), *Technik und Ethik*, Reclam, Stuttgart, 1987, pp. 112-148) and then introduce some modifications, additions, and consequences required for the following sections.

[2] Many philosophical discussions of responsibility deal only with attribution or imputation and thereby ignore the *z* in our phrase. This is because imputation already raises many interesting issues, such as the question of free will and determinism, on which many prominent philosophers have written. In the present context, these metaphysical issues are less important since we can assume that chemists are free to choose among their scientific activities.

[3] From these paradigms, Hans Jonas (*Das Prinzip Verantwortung*, Insel, Frankfurt, 1979) has tried to derive humanity's care responsibility for nature as a whole.

[4] see extra file.

[5] In the Christian tradition, the ultimate institution has been God at the Last Judgement.

[6] Conscience may be briefly defined as the personal capacity to distinguish between morally right and wrong and thus allowing to make moral judgements about one's own actions. In the Christian tradition,

following Jerome and Augustine, God's moral law is revealed in one's conscience, such that the ultimate institution to which one is responsible is God. In moral psychology, conscience results from adopting moral values during one's particular socialization; in Freudian terms, this constitutes the quasi-personal institution of the *Über-Ich*. Apart from the questions of how conscience originates and whether or not a quasi-personal shape, an imagined tribunal, is required, responsibility to humanity requires a level of conscience beyond the values of particular social groups, *i.e.* a capacity to distinguish between right and wrong with respect for humanity. Normative theories in philosophical ethics try to provide guidelines for that from the point of view of impartiality, which corresponds to the principle of universalizability expressed below in requirement 3.

[7] Since the notion of responsibility refers to consequences of one's actions, there is some emphasis on consequentialist reasoning, though nonconsequentialist arguments will ocassionally be considered too.

[8] The following data are taken from J. Schummer: 'Scientometric Studies on Chemistry I: The Exponential Growth of Chemical Substances', 1800-1995', *Scientometrics*, **39** (1997), 107-123; 'Scientometric Studies on Chemistry II: Aims and Methods of Producing New Chemical Substances', *Scientometrics*, **39** (1997), 125-140; and from *CAS Statistical Summery 1907-2000*, Columbus/Ohio, 2001.

[9] *Cf*. also J. Schummer: 'Challenging Standard Distinction between Science and Technology: The Case of Preparative Chemistry', *Hyle*, **3** (1997), 81-94.

[10] *Cf*. J. Schummer: 'Towards a Philosophy of Chemistry', *Journal for General Philosophy of Science*, **28** (1997), 307-336 (316); 'Epistemology of Material Properties', in: *Proceedings of the 20th World Congress of Philosophy, Boston/MA, USA, August 10-16, 1998*, Boston 1999 [http://www.bu.edu/wcp/Papers/TKno/ TKnoSchu.htm].

[11] *Cf*. J. Schummer, *Realismus und Chemie. Philosophische Untersuchungen der Wissenschaft von den Stoffen*, Königshausen & Neumann, Würzburg, 1996, chap. 6.6.

[12] For details about the properties of new substances that chemists actually determine, see J. Schummer: 'The Impact of Instrumentation on Chemical Species Identity', in: P. Morris (ed.): *From Classical to Modern Chemistry: The Instrumental Revolution*, London 2001 (forthcoming).

[13] *Cf*. J. Schummer: 'Coping with the Growth of Chemical Knowledge. Challenges for Chemistry Documentation, Education, and Working Chemists', *Educación Química*, **10** (1999), 92-101.

[14] The only way to interpret the synthesis of new substances as the exploration of unknown, but preestablished, fields would be by replacing the physical space with the chemical space, which is topologically defined by all chemical relations between all *possible* substances (see my *Realismus und Chemie*, *op. cit*., chap 5.2.7).

[15] By analogy, one might argue that, due to the infinite potential of properties, there is also a probability that a new substance may turn out to be useful some time. While this is undeniable, it is also true that three quarters of synthetic chemists do not care about any probably useful properties, as they determine only properties required for substance characterization (see the empirical studies quoted above). Furthermore, referring to a probability of unintended usefulness is neither a moral argument that might excuse from actual harm caused by the substance, nor does it reveal a rational or scientific attitude; rather it seems to be mocking of the large scale scientific search for useful substances (see next Section). The fuss made about the later found useful properties of buckminsterfullerene and cubane (2 out of several million substances produced in the past few years) suggests that many chemists actually feel a lack of justifying synthesis as an end in itself.

[16] Philosophers might probably think of Kant here. However, his ethical approach does not judge actions (neither by consequences nor by intentions) but moral maxims for actions according to his ideal of

a rational will expressed in his categorical imperative. *E.g.* "Die Ethik giebt nicht Gesetze für Handlungen (denn das thut das *Ius*), sondern nur für die Maximen der Handlungen." (*Metaphysik der Sitten*, AA, vol. VI, p. 388) Moreover, Kant's judgement of maxims (whether or not they are acceptable as general laws) includes the consideration of *consequences* of their possible implementation as general laws, as his fourth example in his *Grundlegung zur Metaphysik der Sitten* (AA, vol. IV, p. 423) makes undoubtedly clear.

[17] For more details and various approaches, see the papers in *Glück und Ethik*, ed. J. Schummer, Königshausen & Neumann, Würzburg, 1998.

[18] It should be noted that chemical research of new toxic substances for possible warfare use has never been prohibited by international conventions, which makes prohibition by any national law very unlikely. Following the vague *Geneva Protocol of 1925* and the equally vague *Convention of 10 April 1972*, eventually we have now the detailed *Chemical Weapons Convention*, effective since 29 April 1997 and signed, ratified, or acceded by 174 states as per 12 February 2001. (For the full text and details, see the web site of the Organization for the Prohibition of Chemical Weapons http://www.opcw.org/). The conventions prohibits "the development, production, stockpiling and use of chemical weapons" and provides for the first time powerful tools to supervise the obedience to the convention. However, since the definition of a chemical weapon combines both the toxicity of a substance and a quantity consistent with warfare purposes (Art. II, § 1 a) the production of small quantities is allowed and needs no declaration. In addition, "purposes not prohibited under this convention" explicitly includes "research" without any specification of the aims of research (Art. II, § 9 a/c). Furthermore, because the convention actually refers only to a list of well-known toxic substances, it does not cover research of new substances. In sum, chemical weapons research, in the sense of searching for and synthesizing new toxic substances for possible warfare use, is not prohibited by international or national law and still calls for moral regulation.

[19] Despite some differences, favoring of needy people follows from both utilitarianism and the most famous modern counter-approach, John Rawl's *A Theory of Justice* (Oxford UP, 1971). Philosophers might miss further concepts of distributive justice. I omit the idea of favoring people according to their moral merits because that is a circular concept in ethics (*cf.* W.K. Frankena, *Ethics*, Prentice-Hall, Englewood Cliffs, 1963, p. 40). Furthermore, for the utilitarian idea of favoring people according to their ability to use the goods for the benefit of humanity, I do not see any instance directly relevant to synthetic chemistry.

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