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SCHOOL-RELATED CONTENT KNOWLEDGE IN ORGANIC CHEMISTRY – HOW DIFFERENT SCHOOL CURRICULA SHOULD BE CONSIDERED FOR THE DEVELOPMENT OF TASKS

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ABSTRACT

Background:
The professional knowledge of teachers, as described by Shulman (1968) consists of content knowledge, pedagogical content knowledge and pedagogical knowledge. Woehlecke and Massolt et al. (2017) describe the school-related content knowledge (SRCK) as a cross-disciplinary construct. We developed tasks in organic chemistry using their construct. In these tasks often a school context was used. The tasks were evaluated by using a questionnaire and by conducting focus group interviews.

Purpose:
The investigation of how the different school curricula of the federal states in Germany should be considered by the development of new tasks.

Sample/Setting:
The school curricula are examined. Summaries of all topics in organic chemistry were made. The results of the evaluation of the developed tasks were, in combination with the results on the contents of the curricula, used to answer the research questions. The tasks were used for a course in organic chemistry for bachelor students (prospective chemistry teachers).

Design Methods:
Quantitative (questionnaires) and qualitative (focus group interviews and summaries) methods were used.

Results:
The differences between the school curricula of the federal states are significant. These differences should be considered for the development and use of the tasks. The students are focused on their own school biography and the state where they went to school and where they want to be a chemistry teacher. By changing the contexts in the tasks these differences can be positively used for the development of new tasks.

Conclusions/Implications for classroom practice and future research:
The design of the tasks should be changed. One focus should be on the standards for the teacher education. These standards should be made transparent in all chemistry courses.

Keywords: organic chemistry, tasks, seminars, school related content knowledge, school curricula

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1 INTRODUCTION

As a result of the “Qualitätsoffensive Lehrerbildung”, a federal funded project in teacher education in Germany, much research on the professional knowledge of (prospective) teachers is currently conducted. This knowledge was described in 1968 by Shulman as consisting of content knowledge (CK), pedagogical content knowledge (PCK) and pedagogical knowledge (PK). The content knowledge of prospective teachers in the STEM subjects was the topic of several studies in recent years (e.g. Kraus et al., 2008; Riese, 2009; Borowski et al. 2010; Walzer, Fischer, Borowski 2014). Woehlecke and Massolt et al. (2017) describe the school-related content knowledge (SRCK) as a cross-disciplinary construct. It is characterized by the knowledge of concepts, the knowledge of learning processes and the knowledge to adapt complexity meaningfully and anticipatorily. The development of tasks in physics for teaching in university physics courses is described by Massolt and Borowski (2018).

What prospective teachers should know is the responsibility of the university. The KMK (Kultusministerkonferenz – conference of the ministers for the arts and culture – also responsible for education) recommends topics for the teacher education to ensure equal standards in Germany (KMK, 2019). What students at school should learn is also defined by the KMK (KMK, 2004). Here competences which the students should obtain at school are defined. The development of the curricula and which topics these should contain is the task of the federal states (Länder). The MNU (organisation for the promotion of STEM subjects) therefore proposed a list of topics for the teaching of chemistry in secondary school (students aged 10 – 15 years) in order to prevent significant differences in the topics between the federal states (MNU, 2006). However, for the development of tasks in organic chemistry for students acquiring school-related content knowledge in organic chemistry the topics in school chemistry should be known. We therefore analyzed the curricula of all federal states on the topic of organic chemistry and compared the results of this study with the evaluation of the developed tasks and will discuss our results in this paper.

2 RESEARCH BACKGROUND

Massolt and Borowski (2018) developed tasks for tutorial groups in physics by focusing on school-related content knowledge. The goal of their study was to increase the perceived relevance of university content knowledge courses. In the physics courses therefore one of the regular problems was replaced by a problem designed using the construct of SRCK. In these tasks often a school context, for example the description of a problem during teaching at school, is used. The students rated the problems with respect to perceived relevance using a questionnaire. The questions based on the SRCK were perceived as more relevant by the students. Connecting university physics with school physics can therefore increase the perceived relevance of problems.

The use of interesting contexts in teaching chemistry at German schools is described for the construct “Chemie im Kontext” (chemistry in context) by Demuth et al. (2008). As contexts, situations from the real life of the students were used with the goal that the students are more interested in studying chemistry when there is a connection with their daily routine.

For the use in chemistry courses we developed new tasks in organic chemistry (Hermanns, 2019). For this we used the school-related content knowledge construct as published by Woehlecke and Massolt et al. (2017). School situations were used as contexts in these new tasks. By doing so, school knowledge and university knowledge should be bridged. All topics were constructed to be suitable for initiating conceptual specialist knowledge. To evaluate the use of the tasks in our seminars a questionnaire was used. The students (prospective chemistry teachers) should assess the tasks by using a four item Likert scale. One new task was compared with a customary task without any context. The new tasks were evaluated as more relevant for their future work. Two findings are important for this paper: only if the school context was identified as realistic, the relevance was recognized; extracurricular contents were less relevant for the students even if the context was a school situation. The item “for this task I used my school knowledge” was rated very differently; the standard deviation was more or less 1 (depending on the task). For us the following question resulted: Have students a different understanding of “school knowledge” or is their school knowledge different? To further investigate this question, two interviews with groups of two and five students respectively (prospective chemistry teachers) were conducted. In these interviews it became clear that the students understand “school knowledge” as the topics in chemistry they had in school. However, there were also differences in the schools they attended; schools with a focus on STEM subjects taught different topics as schools without such a focus. Important topics for the students in our tasks were, as a consequence, those topics they know from school or expect in their future teaching. Mostly they meant the topics of the curriculum in Brandenburg (one of the sixteen federal states in Germany – its capital is Potsdam).

As a result of the interviews we decided to examine the curricula on organic chemistry of the different federal states (“Länder”). To our knowledge only Ropohl et al. (2014) examined the curricula in recent years. Their analysis was executed in 2007/2008. All chemistry curricula for secondary school (students aged 13 – 15 years) were part of their study. The number of specialist terms was determined. However, no information on the topics is provided. Therefore, we examined all curricula in 2018 in regard to all topics in organic chemistry and for the whole secondary school. The following research questions should be investigated and answered:

1) Are there significant differences between the curricula on organic chemistry?
2) If so, how should the differences be considered for the development of tasks on the construct of SRCK?
3) Is it possible to positively use these differences for the development of the tasks?

3 METHODS AND DATA

All curricula were examined (Curricula of the federal states, 2018). First a summary was made. For this the table of contents of the curricula was adopted. In a second step the same contents (for example alkanes) in the different curricula were identified and summarized (see Supplementary Materials – Tables 1s and 2s). For each content, the federal state in which it was represented in the curriculum, was indicated. Because we are particularly interested in a comparison between Brandenburg and the other federal states, we created a new summary (see Appendix - Tables 1a and 2 a) which we used for answering our research questions. This summary consists of a list of all topics in organic chemistry, the number of states where these topics are taught at school and whether the topics are part of the curriculum in Brandenburg. Each step in creating the summaries was discussed and controlled by both authors. The summaries contain only topics that are specifically mentioned in the curricula.

The data acquired from the questionnaires and interviews (see chapter 2) were, in combination with the summaries, also used to answer the research questions number 2 and 3.

4 RESULTS

We will first present the summary of all topics in organic chemistry (tables 1 and 2). Table 3 shows topics that are not in the curriculum of Brandenburg. Table 4 shows different tasks and the results for the evaluation of these tasks from the questionnaires. Relevant citations from the interviews are shown in table 5.

4.1 The summary of all topics in organic chemistry: a comparison between Brandenburg and the other federal states

For our analysis the topics of the curricula in Brandenburg were summarized. The topics were grouped according to the substance classes, as for example alkanes or carbohydrates. One analysis was made for the students aged 13-15 years and one for the students aged 16-18 years. Because most of our students went to school in Brandenburg (or in Berlin) and want to become a teacher in Brandenburg, they focus mainly on the curriculum of Brandenburg. Therefore we compared the curricula of the other federal states with the curriculum in Brandenburg. In comparison the number of other federal states that also have these topics in their curriculum is given (the curricula of the federal states of Brandenburg and Berlin are the same). Table 1 shows this summary for secondary school (students aged 13 – 15 years). Only the topic “alkanes” is part of the curriculum in all federal states. The other topics are only part of the curricula in some of the states; the topics differ therefore greatly between the states.

Tab. 1
The summary of all topics in organic chemistry in Brandenburg in secondary school (students aged 13 – 15 years) in comparison with the other federal states.

Topic	Number of other federal states with this topic
Alkanes	15
Alkenes	11
Alkynes	11
Alcohols	14
Aldehydes	10
Ketones	10
Carboxylic acids	13
Esters	11
Amino acids	7
Fats	8
Carbohydrates	7
Synthetic materials	12

Table 2 shows this summary for secondary school (fifth and sixth form classes). Here there is also only one topic (synthetic materials) that is part of the curricula of all states. Some of the contents however, as for example “alkenes” are supplementary to the contents shown in table 1; if they are part of the curriculum for the students aged 13-15 years, they are mostly no part of the following curriculum for the students aged 16-18 years. The situation in Brandenburg is summarized in table 3.

Tab. 2
The summary of all topics in organic chemistry in Brandenburg in secondary school (fifth and sixth form classes) in comparison with the other federal states

Topic	Number of other federal states with this topic
Alkanes	7
Alkenes	7
Alcohols	13
Amino acids	13
Organic dyes	13
Carbohydrates	13
Synthetic materials	15
Proteins	14
Soaps, surfactants, laundry detergents	10

Table 3 shows the topics that are not in the curriculum of Brandenburg as well as the number of states which have these topics. Especially the topics in fifth and sixth form classes differ strongly. However, many of the topics that are in the other federal states part of the curriculum for students aged 16-18 years are already part of the curriculum in Brandenburg for the students aged 13-15 years, as alkynes, aldehydes, ketones, carboxylic acids, esters and fats. The focus in organic chemistry is therefore mainly for the students aged 13-15 years. Only one topic (halogenalkanes) is not part of the curriculum.

Tab. 3
The summary of all topics in organic chemistry that are not in the curriculum in Brandenburg in secondary school (in brackets the number of federal states with these topics)

Topics for students aged 13 – 15 years	Topics in fifth and sixth form classes
Halogenalkanes (7)	Alkynes (5)
Carbohydrates (8)	Aldehydes (9)
Synthetic materials (13)	Ketones (7)
	Carboxylic acids (10)
	Esters (9)
	Aromatics (12)
	Ethers (3)
	Halogenalkanes (4)
	Enzymes (4)
	Fats / Fatty acids (11)
	Pharmaceuticals (8)
	Silicons, Siloxanes (5)
	Vitamins (3)
	Structural analysis (4)

4.2 Different tasks and the results for the evaluation of these tasks

For the course "Organic Chemistry I" different tasks for the school-related content knowledge were developed, applied and evaluated. First results on the use of the tasks in the course of 2017-18 are published (Hermanns, 2019). Table 4 shows three representative tasks used in the courses of 2017-18 and 2018-19. The results from the evaluation of the previous course were used for the development of the tasks for this latest course. For our research questions the items "The technical content of the task is important for my future profession", "The school context of the task is clearly recognizable" and "In order to deal with the task, I have to apply my school knowledge" are relevant. Table 4 shows the evaluation of the tasks (for the tasks see Appendix 3).

Tab. 4
Tasks on the school-related content knowledge in organic chemistry and results from the evaluation: the arithmetical mean (in brackets the standard deviation)

	Result evaluation		
Task	technical content	school context	school knowledge
In the laboratory at school[1]	3.83 (0.514)	3.67 (0.686)	2.50 (0.924)
At university[2]	2.62 (0.805)	2.86 (0.727)	1.95 (0.669)
Exam at school[1]	3.59 (0.599)	3.70 (0.618)	2.19 (1.076)

Students used a scale of 1-4, with 1 being "strongly disagree" and 4 being "strongly agree".
[1] course year 2017-18
[2] course year 2018-19

4.3 Citations from the focus group interviews with students on school-related content knowledge in organic chemistry

During the course in 2018-19 two focus group interviews with two and five students respectively were carried out. The students commented on all items in the questionnaire. Representative citations for the relevant items are listed in table 5.

Tab. 5
Citations from the focus group interviews

Citations on the item		
technical content	school context	school knowledge
"The first is that the subject is also discussed in school. So that it's not something that's outside of school knowledge."	"There were tasks, which took place in school. I found it very interesting, because I could think about how I would explain my specialist knowledge to my students."	"For me it is what I had in school already and could explain with my school knowledge"
"I attach it …. where I can still remember the themes we had."	"I´m wondering if that would really happen to me as a teacher."	"I can solve it with what I had only in school".
"To what extent that was relevant in class."	"It was also a bit thinking back what I did at school".	"All I had till my exams in school."
"I try to think back to what the teachers taught us and whether I learned that in school or not."	"Was it there or was it not there".	"Everything I know from school".
"…or if the students could ask a further question out of it."	"Tasks that are not part of the curriculum in Brandenburg are not relevant for school".	"School knowledge is what I acquired at school"

5 DISCUSSION AND CONCLUSIONS

The results will be discussed below with regard to the three research questions. In the conclusions an outlook on further research is given.

5.1 Research question 1: Are there significant differences between the curricula on organic chemistry?

As shown in tables 1 and 2 the differences between the curricula are significant. Only the topics "alkanes" and "synthetic materials" are part of all curricula. Some of the topics that are part of the chemistry lessons for students between 13 and 15 years are not part of the chemistry lessons in fifth and sixth grade (for example in Brandenburg the topics aldehydes and ketones) and vice versa. As mentioned in the introduction, the KMK defines competences which the students should obtain at school. Surely it is possible to obtain such competences by learning different topics, but in our opinion it is, for example, problematic to teach only the topics alkanes and alcohols (without alkenes and alkynes) as in North Rhine – Westphalia and Rhineland-Palatinate. This leaves a gap in the assembling of competences in organic chemistry. For example, the topic "technical synthesis of ethanol from ethene" as a bridge to the topic "alcohols" is not possible in these curricula. However, because our analysis reflects the situation in 2018, it remains to be seen which future changes of the curricula will occur. For now, the differences are significant and should therefore be considered when developing tasks for our students. Because of these differences we can state that there is no universal school knowledge.

5.2 Research question 2: How should the differences between the federal states be considered for the development of tasks on the construct of SRCK?

For teacher education, the answer to research question 1 indicates that it is not possible to just educate prospective teachers for teaching in one federal state. From our focus group interviews however, we know that some of the students expect such a curriculum at university: *"Tasks that are not part of the curriculum in Brandenburg are not relevant for school".* Although the teacher education at university is aimed at all federal states, most of the students at our university are very focused on schools in Brandenburg. It remains to be seen whether this will change during the course of their studies. Further research with master students will therefore be executed in 2019-20. It is a fact that there are differences between the topics for the teacher education defined by KMK (see Supplementary Material; table 3s) and the curricula at school.

For Brandenburg this means that e.g. the topics UV-Vis- and IR-spectroscopy, aromatics, reaction mechanisms and syntheses, heterocycles and polycycles, stereochemistry, synthesis and catalysis, coenzymes and natural products are topics from the KMK-standards (see Supplementary Materials, table 3s), but not part of the curriculum at school. Although the students know and mostly accept that a teacher should know more than his or her students ("*…or if the students could ask a further question out of it")*, they evaluate the contents of our tasks regarding the importance in school: *"to what extent that was relevant in class".* This is in line with the results of the questionnaires. The topic "synthesis of amines", which is not a topic in school but at university, is for the item "The technical content of the task is important for my future profession" rated only with 2.62 (between "is not important" and "is important"). One idea could be to use another context for this topic, which is not located at university but at school. In a comparative design also a topic that is relevant at school should be situated in a university context to find out whether the students are more interested in the context or the content.

But either way, it makes sense to consider the curriculum in Brandenburg for the development of tasks. It also can have an impact on the effectiveness in learning, because the students are more motivated by tasks that they believe to be relevant for their future profession in school, as also stated by Massolt and Borowski (2018). For the overall usefulness of our tasks at universities in other federal states, a new design should be developed as will be discussed below.

5.3 Research question 3: Is it possible to positively use these differences for the development of the tasks?

The differences between the curriculum at university and at schools is not a phenomenon specific for Brandenburg but can be observed for all federal states. Therefore, a general solution for this dilemma is needed. As stated before, the students know in fact that it is necessary to know more than their students at school, as the following citation from the focus group interviews shows: *"to have a better technical understanding than the students".* A Delphi study conducted by us on the SRCK shows, that present chemistry teachers at school are of the opinion that prospective teacher students should learn a lot more than what they need directly at school; they should build up university knowledge in organic chemistry well beyond the school curriculum.

To positively use these differences for the development of the tasks, the following ideas arise: the development of different and replaceable contexts for the tasks: a) a school context if the context is part of the curriculum, b) an university context if the context is part of the curriculum at university and c) a school context at a school with STEM focus or some special STEM course or in one specific federal state if the context is not a part of the curriculum in the federal state where the students are at university and where they see their future as a chemistry teacher. The tasks will be developed in a manner that the contexts can be replaced by the appropriate one in a kind of modular system. By using these three context categories it is also made transparent which contents are represented where.

For the evaluation of the tasks one item should be replaced; in place of the item "The school context of the task is clearly recognizable" the item "The situation in the context is realistic" should be used. This should prevent that the item is rated poorly because the school context is not recognized as being appropriate.

5.4 Conclusions and outlook

We showed in our paper that the curricula of the federal states should be considered for the development of tasks in organic chemistry on the construct of SRCK. However, as discussed before, we think that changes in the design of the tasks can overcome the problems generated from these differences. One focus should be on the standards for the teacher education. These standards were defined by the KMK to ensure that the students can teach chemistry in all federal states and throughout their entire career as a teacher (curricula are subject to regular changes). Because the students rely on their own learning biography (as shown in the focus group interviews) and they therefore often refuse to deal with some topics, these standards and the reasons for defining these standards should be made transparent in all chemistry courses. This can be one method to reduce students' defensive posture to those topics that in their opinion are not relevant. The results of our Delphi study on the SRCK will also be communicated to our students. We hope that the opinion of experienced teachers can help us to explain that it is important to have very good technical knowledge in chemistry if someone wants to become a chemistry teacher. Together with the development of new tasks this should provide assistance for the construction of SRCK in organic chemistry, as SRCK is specifically not school knowledge (see Woehlecke and Massolt et al., 2017). The results of the evaluation on the development of new tasks will be published in due course.

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SUPPLEMENTARY MATERIALS

The supplementary material consists of the following tables: table 1s: Summary of the contents in organic chemistry in secondary school (students aged 13-15 years), table 2s: Summary of the contents in organic chemistry in secondary school (students aged 16-18 years), table 3s: Topics for the teacher education by KMK.

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APPENDICES

Appendix 1:

Table 1a: Topics in organic chemistry in the federal states of Germany (no distinction into type of school) in secondary school (students aged 13 – 15 years)

Topic	Contents	Number of federal states	Brandenburg
Alkanes	properties, chemical formulas, functional group, production, homologous series, isomerism, nomenclature, reactions, environmental relevance, use, deposits	16	yes
Alkenes	properties, chemical formulas, functional group, production, homologous series, detection reaction, nomenclature, reactions, use	12	yes
Alkynes	properties, chemical formulas, functional group, production, homologous series, detection reaction, nomenclature, reactions, use	12	yes
Alcohols	properties, chemical formulas, functional group, production, homologous series, detection reaction, nomenclature, reactions, use, physiological effect	15	yes
Halogenalkanes	properties, production, environmental relevance, use, deposits	7	no
Aldehydes	properties, chemical formulas, functional group, production, homologous series, detection reaction, nomenclature, reactions, use	11	yes
Ketones	properties, chemical formulas, functional group, nomenclature, reactions, use	11	yes
Carboxylic acids	properties, chemical formulas, functional group, production, homologous series, nomenclature, reactions, use, deposits	14	yes
Esters	properties, chemical formulas, functional group, production, use, deposits	12	yes
Amino acids	properties, functional group, nomenclature	8	yes
Fats	properties, production, use, deposits	9	yes

Carbohydrates	structure, properties, production, reactions, use, deposits	8	no
Synthetic materials	structure, properties, structural formula, production, reactions, recycling, use	13	no

Appendix 2:

Table 2a: Topics in organic chemistry in the federal states of Germany in secondary school (no distinction into the type of course) (fifth and sixth form classes)

Topic	Contents	Number of federal states	Brandenburg
Alkanes	properties, chemical formulas, production, functional group, homologous series, isomerism, nomenclature, reactions, structure, environmental relevance	8	yes
Alkenes	properties, chemical formulas, functional group, homologous series, isomerism, detection reaction, nomenclature, reactions, structure	8	yes
Alkyns	properties, chemical formulas, functional group, homologous series, detection reaction, nomenclature, reactions, structure	5	no
Alcohols	importance, properties, chemical formulas, physiological effects, preparation, production, homologous series, isomerism, nomenclature, reactions, structure, use	14	yes
Aldehydes	preparation, properties, functional group, homologous series, detection reaction, nomenclature, reactions, structure, use	9	no
Ketones	preparation, properties, functional group, homologous series, nomenclature, reactions, structure, use	7	no
Carboxylic acids	preparation, properties, functional group, homologous series, nomenclature, reactions, structure	10	no
Esters	importance, functional group, production, nomenclature, reactions, structure, use	9	no
Amino acids	preparation, properties, chirality, detection reactions, nomenclature, structure, deposits	14	yes
Aromatic hydrocarbons	importance, properties, chemical formulas, hazards, mesomerism, reactions, structure, use, deposits	12	no

Ethers	functional group, homologous series, nomenclature, structure	3	no
Halogen hydrocarbons	properties, detection reaction, nomenclature, reactions, environmental relevance	4	no
Enzymes	importance, catalysis, mode of action	4	no
Organic dyes	importance, properties, research, historical development, sustainability, structure, use, deposits	14	yes
Carbohydrates	importance, preparation, chirality, properties, isomerism, detection reaction, nomenclature, reactions, structure, deposits, use	14	yes
Fats / Fatty acids	importance, properties, preparation, structure, reactions, use	11	no
Synthetic materials	properties, chemical formulas, production, sustainability, reactions, recycling, structure, use	16	yes
Pharmaceuticals	importance, research, sustainability, structure	8	no
Proteins	importance, properties, detection reaction, reactions, structure, use, deposits	15	yes
Soaps, Surfactants, Laundry detergents	importance, properties, production, structure, environmental relevance, use	11	yes
Silicons, Siloxanes	importance, research, sustainability, structure	5	no
Vitamins	importance, nutritional balance, reactions, structure	3	no
Structural analysis	IR, MS, NMR, UV/VIS	4	no

Appendix 3:

Task 1: In the laboratory at school

Peter and Janina are on laboratory duty; they are supposed to wipe the shelves in the school's student laboratory because a lot of dirt has accumulated there over time. Janina additionally wipes the chemical bottles with a damp cloth, because she thinks that this is also necessary. In doing so, she first wipes off the labels without noticing it. When she notices it, she can't remember which label belongs to which bottle. One contains butanal and the other propanone.

Help Janina by developing an experiment that allows to distinguish between both substances relatively quickly and explain why Janina gets the information she needs from this experiment so that she can then stick the labels back on the right bottle.

Task 2: At university

Daniel and Josephine meet to solve exam preparation tasks together. They disagree on one task. The task is to make butylamine. Josephine says: “Finally a simple task! All you have to do here is combine butyl chloride and ammonia”. Daniel's not sure. He can vaguely remember the production of amines from ammonia. The professor said something about it in the lecture.

Help Daniel and give him the arguments so that he can solve the problem together with Josephine.

Task 3: Exam at school

A chemistry teacher has set the following task in the secondary school: Formulate the electrophilic addition of hydrogen bromide to 2-methyl-2-hexene in single steps. Name the resulting product systematically according to the IUPAC nomenclature. After the exams are returned there is some agitation in the classroom. Different students are obviously talking about the task. The teacher asks and Marie gives him the following information: Jan gave the product 2-bromo-2-methylhexane and got three points for it. I have given 3-Bromo-2-methylhexane as my product and have not received any points. My product is also the result of electrophilic addition!

Help the chemistry teacher in this situation. What mistake did he obviously make in his task?

Supplementary Materials

Table 1s: Summary of the contents in organic chemistry in secondary school (students aged 13-15 years)

Topic	Contents	Federal states
Aldehydes	properties, chemical formulas, functional group, production, homologous series, detection reaction, nomenclature, reactions, use	1, 2, (2[a]), 3, 4, 6*, 7, 8*, 12, (13), 15
Alkanes	properties, chemical formulas, functional group, production, homologous series, isomerism, nomenclature, reactions, environmental relevance, use, deposits	1, 2, 2[a], 3, (4), 5, 6*, 7, 8*, (9), 10, (11), 12, 13, 14, 15
Carboxylic acids	properties, chemical formulas, functional group, production, homologous series, nomenclature, reactions, use, deposits	1, 2, 2[a], 3, 4, 6*, 7, 8*, (9), 10*, 12, 13, (14), 15
Alkenes	properties, chemical formulas, functional group, production, homologous series, detection reaction, nomenclature, reactions, use	1, 2, 2[a], 3, (4), 6*, 7, 8*, 12, 13, (15)
Alkyns	properties, chemical formulas, functional group, production, homologous series, detection reaction, nomenclature, reactions, use	(1), 2, 2[a]*, 3, (4), 6*, 7, 8*, 12, 13, 15*
Alcohols	properties, chemical formulas, functional group, production, homologous series, detection reaction, nomenclature, reactions, use, physiological effect	1, 2, 2[a], 3, 4, 5, 6*, 7, 8*, (9), 10, 11*,12, 13, 14, 15
Amino acids	properties, functional group, nomenclature	2, 2[a], (3), 6*, 7, 8*, 12, (13)
Esters	properties, chemical formulas, functional group, production, use, deposits	1, 2, 2[a], 3, (4), 6*, 7, 8*, (9), 12, 13, 15
Fats	properties, production, use, deposits	2, (2[a]), 3, (4), 6*, 7, 8*, 12, (13)
Halogenalkanes	properties, production, environmental relevance, use, deposits	2, 2[a], 4, 6*, 7, 8*, 12, 13
Ketones	properties, chemical formulas, functional group, nomenclature, reactions, use	1, 2, (2[a]), (3), 4, 6*, 7*, 8*, 11*, (12), 13*
Carbohydrates	structure, properties, production, reactions, use, deposits	(1), 2, 2[a], 6*, 7, 8*, (9), 12
Synthetic materials	structure, properties, structural formula, production, reactions, recycling, use	(1), (2), 4, 5, 6*, 7, 8*, (9), 10, 11*, 12, 13, 15
Molecular structure	inter- and intramolecular interactions, spatial structure	2, 2[a], 3, 4, 6, 7, 8*, 9, 10, 12, 13, 14, 15
*p*H-indicators	*p*H-determination	1, 2, 2[a], 3, 4, 5, 6*, 7, 8*, 10, 11, 12, 13, 14, 15

notes:

number	federal state / federal states
1	Baden-Württemberg
2	Bavaria: high schools specializing in natural and technical science
2[a]	Bavaria: high schools specializing in language and music or high schools specializing in economy and social studies
3	Berlin + Brandenburg
4	Bremen
5	Hamburg
6	Hesse
7	Mecklenburg-West Pomerania
8	Lower Saxony
9	North Rhine-Westphalia
10	Rhineland-Palatinate
11	Saarland
12	Saxony
13	Saxony-Anhalt
14	Schleswig-Holstein
15	Thuringia

6 → much room for interpretation: „Treatment of everyday relevant hydrocarbon compounds from the energy industry, transport, sports, spare time, diet and hygiene", contents of organic chemistry tends to be treated more in sixth form

8 → a lot of room for interpretation through the formulation of thematic fields, more detailed treatment of the organic chemistry contents in sixth form

9 → much room for interpretation, more detailed treatment of the organic chemistry contents in sixth form

10 → much room for interpretation, more detailed treatment of the organic chemistry contents in sixth form

11 → much room for interpretation, more detailed treatment of the organic chemistry contents in sixth form, there was no curriculum for tenth form class

() No direct mention of the topic in curriculum or the listed contents are less than one third in the curriculum

*Treatment of the topic makes sense in context, but the curriculum is too vague

Only Listing of topics that are in the curriculum in at least five federal states

Topics in the curriculum in less than five federal states:

Proteins: 2, 2[a], 7, 12

Aromatic hydrogarbons: 7

Table 2s: Summary of the contents in organic chemistry in secondary school (students aged 16-18 years)

Topic	Contents	Federal states
Aldehydes	preparation, properties, functional group, homologous series, detection reaction, nomenclature, reactions, structure, use	6^{G}, 6^{LK}, 8, 9, (10^{G}), (10^{LK}), 11, (12^{G}), 12^{LK}, 13^{G}, 13^{LK}, 14, 15
Alkanes	properties, chemical formulas, production, functional group, homologous series, isomerism, nomenclature, reactions, structure, environmental relevance	6^{G}, 6^{LK}, 8, 9, (10^{Ga}), (10^{LKa}) 11, (13^{LK}), 14, 15
Carboxylic acids	preparation, properties, functional group, homologous series, nomenclature, reactions, structure	(2), 6^{G}, 6^{LK}, 8, 9, (10^{G}), (10^{LK}), 11, (12^{G}), 12^{LK}, 13^{G}, 13^{LK}, 14, 15
Alkenes	properties, chemical formulas, functional group, homologous series, isomerism, detection reaction, nomenclature, reactions, structure	6^{G}, 6^{LK}, 8, 9, (10^{LK}), 11, (12^{G}), 12^{LK*}, 14, 15
Alkyns	properties, chemical formulas, functional group, homologous series, detection reaction, nomenclature, reactions, structure	6^{G}, 6^{LK}, (10^{LK}), 11, (12^{G}), 12^{LK*}, 15
Alcohols	importance, properties, chemical formulas, physiological effects, preparation, production, homologous series, isomerism, nomenclature, reactions, structure, use	(2), 3^{G*}, 4^{*}, 5, 6^{G}, 6^{LK}, 8, 9, 10^{G}, 10^{LK}, 11, (12^{G}), 12^{LK}, 13^{G}, 13^{LK}, 14, 15
Amino acids	preparation, properties, chirality, detection reactions, nomenclature, structure, deposits	1^{G}, 1^{LK}, 2, 3^{G}, 3^{LK}, 4, 6^{G}, 6^{LK}, 7^{G*}, 7^{LK*}, 8, 10^{GEO}, 10^{LKEO}, 11, 12^{LK}, 13^{Ga*}, 14, 15^{LK}
Aromatic hydrocarbons	importance, properties, chemical formulas, hazards, mesomerism, reactions, structure, use, deposits	1^{LK}, 2, 4, 6^{G}, 6^{LK}, 8, 9, 10^{G}, 10^{LK}, 11, 12^{G}, 12^{Ga}, 12^{LK}, 13^{G}, 13^{LK}, 14, 15
Chelates	importance, properties, structure, use	1^{LKa}, 3^{G}, 6^{LKa}, (7^{LK}), (10^{Ga}), 10^{LKa}, 12^{LK}, 13^{Ga}, (14), 15^{LK}
Chemical equilibria	application, catalysis, principles, theory	1^{G}, 1^{LK}, 2, 3^{G}, 3^{LK}, 4, 6^{G*}, 6^{LK*}, 7^{G}, 7^{LK}, 9, 10^{G}, 10^{LK}, (14), 15
Enzymes	importance, catalysis, mode of action	2, 4, (10^{Ga}), 10^{LKa}, 15^{LK}
Esters	importance, functional group, production, nomenclature, reactions, structure, use	6^{G}, 6^{LK}, 8, 9, (10^{G}), 10^{Ga}, 10^{LK}, 10^{LKa}, 11, 12^{LK}, 13^{G}, 13^{LK}, 14, 15
Ethers	functional group, homologous series, nomenclature, structure	8, (10^{LK}), 12^{LK}
Organic dyes	importance, properties, research, historical development, sustainability, structure, use, deposits	1^{LKa}, 2, 3^{G}, 3^{LK}, 4, (5), 6^{Ga}, 6^{LKa}, 7^{G}, 7^{LK}, (9), 10^{G}, 10^{LK}, 10^{LKa}, 11^{*}, 12^{LK}, 13^{Ga}, 14

Fats / Fatty acids	importance, properties, preparation, structure, reactions, use	1^{G}, 1^{LK}, 2, 4, (5), 6^{G}, 6^{LK}, 8, 10^{Ga}, 10^{LKa}, (11), 13^{Ga*}, 14, 15
Halogen hydrocarbons	properties, detection, nomenclature, reactions, environmental relevance	6^{G}, 6^{LK}, 8, 10^{Ga}, 10^{LK}, (10^{LKa}), 11
Ketones	preparation, properties, functional group, homologous series, nomenclature, reactions, structure, use	6^{G}, 6^{LK}, 8, 9, (10^{G}), (10^{LK}), 11, 12^{LK}, 14
Carbohydrates	importance, preparation, chirality, properties, isomerism, detection reaction, nomenclature, reactions (e.g. Half acetal formation), structure, deposits, use	1^{G}, 1^{LK}, 2, 3^{G}, 3^{LK}, 4, (5), 6^{G}, 6^{LK}, 7^{G}, 7^{LK}, 8, (10^{Ga}), 10^{GEO}, 10^{LKa}, 10^{LKEO}, 12^{LK}, 13^{Ga*}, 14, 15^{LK}
Synthetic materials	properties, chemical formulas, production, sustainability, reactions (Polymerization, Polycondensation, Polyaddition), recycling, structure, use	1^{G}, 1^{LK}, 2, 3^{G}, 4, 5, 6^{G}, 6^{LK}, 7^{G}, 7^{LK}, 8, (9), 10^{Ga}, 10^{GEO}, 10^{LK}, 10^{LKa}, (11), (12^{G}), 12^{LKa}, 12^{LK}, 13^{Ga}, 14, 15^{LK}
Molecular structure	inter- and intramolecular interactions, spatial structure	6^{G}, 6^{LK}, 8, 10^{G}, 10^{LK}, 10^{LKEO}, 12^{G}, 12^{LK}, 14, 15
Pharmaceuticals	importance, research, sustainability, structure	1^{LKa}, (5), 6^{LK}, 10^{Ga}, 10^{LKa}, 11^{*}, 12^{LKa}, 13^{Ga}, 14
Proteins	importance, properties, detection reaction, reactions, structure, use, deposits	1^{G}, 1^{LK}, 2, 3^{G}, 3^{LK}, 4, (5), 6^{G}, 6^{LK}, 7^{G}, 7^{LK*}, 8, (10^{Ga}), 10^{GEO}, 10^{LKa}, 10^{LKEO}, 11, 12^{LK}, 13^{Ga*}, 14, 15^{LK}
Soaps, Surfactants, Laundry detergents	importance, properties, production, structure, environmental relevance, use	1^{LKa}, 2, 3^{G}, 4, (5), 6^{Ga}, 6^{LKa}, 10^{Ga}, 10^{LKa}, 11, 14, 15
Silicons, Siloxanes	importance, research, sustainability, structure	1^{LKa}, (2), 4, 6^{Ga}, 6^{LKa}, 10^{LKa}
Structural analysis	IR, MS, NMR, UV/VIS	6^{LKa}, (8), (9), 12^{G}, 12^{LK}
Vitamins	importance, nutritional balance, reactions, structure	10^{Ga}, 10^{LKa}, 12^{LKa}, (14)

notes:

number	federal state / federal states
1^{G}	Baden-Württemberg (basic course)
1^{LK}	Baden-Württemberg (advanced course)
2	Bavaria
3^{G}	Berlin + Brandenburg
3^{LK}	Berlin + Brandenburg
4	Bremen
5	Hamburg

6[G]	Hesse (basic course)
6[LK]	Hesse (advanced course)
7[G]	Mecklenburg-West Pomerania (basic course)
7[LK]	Mecklenburg-West Pomerania (advanced course)
8	Lower Saxony
9	North Rhine-Westphalia
10[G]	Rhineland-Palatinate (basic course)
10[GEO]	Rhineland-Palatinate (basic course → category either or) Amino acids and Proteins together one topic
10[LK]	Rhineland-Palatinate (advanced course)
10[LKEO]	Rhineland-Palatinate (advanced course → category either or)
11	Saarland
12[G]	Saxony (basic course)
12[LK]	Saxony (advanced course)
13[G]	Saxony-Anhalt (basic course)
13[LK]	Saxony-Anhalt (advanced course)
14	Schleswig-Holstein
15	Thuringia (contents in basic course and advanced course)
15[LK]	Thuringia (advanced course)

() No direct mention of the topic in curriculum or the listed contents are less than one third in the curriculum

[*] Treatment of the topic makes sense in context, but the curriculum is too vague

[a] Treatment is not prescribed according to curriculum / choice

Table 3s: Topics for the teacher education by KMK (Kultusministerkonferenz – conference of the ministers for the arts and culture – also responsible for education)

Organic / biological chemistry	
Contents in teaching studies for secondary school (students aged 13-15 years)	Extended contents in teaching studies for secondary school (fifth and sixth form classes)
• Aromatic compounds • Fundamentals of metabolism and energy transition • Natural and synthetic macromolecules • Organic dyes and dyeing processes • Selected reaction mechanisms and syntheses • Structure property relations, also in biological chemistry • Substance classes, functional groups • Sustainability as a basic principle of chemical research and production • UV/VIS- and IR-Spectroscopy	• *Greater knowledge of the contents mentioned for secondary school (students aged 13-15 years) and following contents:* • Basics in photochemistry • Biopolymers, coenzymes, natural substances • Heterocycles and polycycles • Reaction mechanisms and intermediates • Stereochemistry, isomerism • Synthesis and catalysis