

Name: _____

9th grade chemistry

Organic chemistry



by Janne Valtonen 2019

The basics

The goal of this booklet is to provide material for content-language integrated students studying English-language chemistry according to the Finnish basic education curriculum. It follows the structure of the text book Ilmiö¹, divided into three sections:

1. Basics of organic chemistry
2. Applied organic chemistry
3. Free-to-choose topics

Each chapter entails a short theory-building section and tasks in the form of *assignments* for theoretical and *experiments* for hands-on group effort. After each chapter, the student assesses how they did in the section via an online form, accessed via a clickable QR code. The form also supports summative self-assessment after studying each of the three sections.



Furthermore, at the back of the booklet, you will find lab report templates to be used at your leisure.

Assessment

The curriculum specifies a set of criteria you need to meet in order to achieve the level of *good* performance (grade 8). As they are many in number, it is possible to not see the wood for the trees.

Some goals described in the curriculum	An example of good performance
Oppilas osaa asettaa omia tavoitteita pienten kokonaisuuksien osalta ja työskennellä niiden saavuttamiseksi.	Managing your study schedule successfully. Optimizing time consumption: only putting in effort where it counts.
Oppilas osaa käyttää kemian keskeisiä käsitteitä oikeassa asiayhteydessä ja yhdistää niitä toisiinsa sekä osaa kuvata, miten kemian osaamista tarvitaan kestäväen tulevaisuuden rakentamiseksi.	Being able to balance between the realms of natural language ("baking <i>pulla</i> ") and chemistry terminology ("incurring a Maillard reaction.").
Oppilas osaa kuvata aineen rakennetta ja kemiallisia ilmiöitä malleilla tai kuvauksilla sekä osaa käyttää aineen ominaisuuksien, rakenteiden ja aineiden muutoksien keskeisiä käsitteitä, ilmiöitä ja malleja tutuissa tilanteissa.	Being able to predict possible outcomes in a given scenario, e.g. pitting an alcohol and a carboxylic acid together.
Oppilas osaa työskennellä turvallisesti, tehdä havaintoja suunnitelman mukaan sekä osaa käsitellä, tulkita ja esittää tutkimusten tuloksia niin suljetuista kuin avoimistakin tutkimusongelmista yhteistyössä muiden kanssa.	Conducting experiments in collaboration with the other group members while following oral, visual, and written instructions given by the teacher and the group. Being able to reproduce meaningful observations by using own words, chemical symbols, and drawn models.
Oppilas osaa hakea tietoa erilaisista tietolähteistä, valita joitakin luotettavia tietolähteitä sekä osaa ilmaista ja perustella erilaisia näkemyksiä kemialle ominaisella tavalla.	Using the book as source material. Being able to discern what information can be trusted while studying a topic, e.g. the chemistry of pharmaceuticals.

¹ [Ilmiö Kemia](#); Ikonen, Kariniemi, Ojala, Tuomisto; SanomaPro; 2019

Carbon and carbon compounds

Did you understand?

1. Name the two categories chemical compounds are classified into.
2. Define organic chemistry.
3. If an organic compound, for instance wood, breaks up under oxygenless conditions, what substance is released?
4. List the five *allotropes*, or forms, of carbon encountered in nature.
5. In a combustion reaction of carbon, which are the two compounds that can be released?
6. What does the phrase *carbon cycle* signify?

7. Reading comprehension. Read the intercept and answer the questions below.

Grafeeni on yhden tai muutaman atomikerroksen paksuinen, lievästi aaltoileva hiililevy (tai -kalvo). Se on kuusirenkaisten hiiliatomien muodostamaa verkkoa. Luonnossa esiintyvä hiilen allotrooppi grafiitti muodostuu todella monista päällekkäin olevista grafeenikerroksista.

Grafeenia onnistuttiin valmistamaan ensimmäisen kerran vuonna 2004. Suurin osa grafeenista valmistetaan repimällä grafiittia. Kun grafiitti saadaan revittyä grafeeniksi, hiilen pinta-alan suhde tilavuuteen kasvaa huimasti. Näin valmistettu grafeeni on yleensä laadukasta. Toinen valmistusvaihtoehto on muodostaa grafiitista ensin hapon avulla oksidoitua grafeenia (GO), joka sitten pelkistetään grafeeniksi.

Grafeenia pidetään tällä hetkellä maailman mekaanisesti vahvimpana materiaalina. Grafeeni on myös niin tiivistä, ettei se läpäise edes vetyatomeja, jotka ovat atomeista pienimpiä. Sen avulla voidaan estää kosteutta tai kaasuja tunkeutumasta materiaalin sisään.

Yhden atomikerroksen paksuinen grafeeni on osin metalli, osin puolijohde. Kahden tai kolmen atomikerroksen paksuinen grafeeni on pelkästään puolijohde. Grafeeni johtaa sähköä paremmin kuin yleisesti käytössä oleva pii.

Grafeenia voidaan käyttää parantamaan polymeerien lujuutta ja lämmönkestävyyttä. Käytännön sovelluksia varten atomin paksuisia grafeeniverkkoja laitetaan sopiva määrä päällekkäin toivotun vahvuuden saavuttamiseksi. Aiemmin polymeerien ominaisuuksia on yritetty parantaa grafiitilla, mutta tulokset eivät ole olleet merkittäviä. Nykyään polymeerien ominaisuuksia voidaan parantaa myös nanoputkilla, mutta grafeenilevyjen tuottaminen on helpompaa ja halvempaa.

- a. How is graphene different from the other allotropes of carbon?

- b. Explain in your own words why a graphene coating repels moisture.

- c. How does the thickness of a graphene sheet affect its properties?



Hydrocarbon compounds

... or compounds consisting of hydrogen and carbon only.

Experiment

Which elements does the gas in the burner consist of?

Use the templates at the back of this booklet to log your findings.



Naming based on IUPAC rules

The logic behind naming rules is to ensure that each compound has one and only one name that is used worldwide. For this reason, the International Union of Pure and Applied Chemistry IUPAC has issued the following principles.

The basis of the name is a prefix that tells the amount of carbon atoms in a hydrocarbon molecule. The suffix depends on the structure of the molecule.

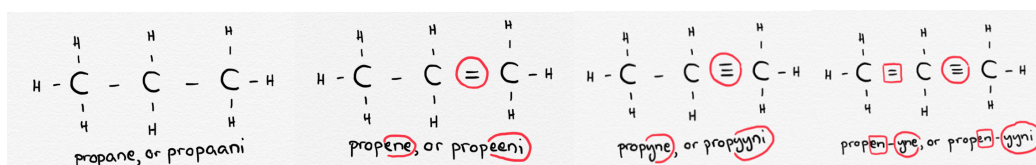
# of carbon atoms	Finnish prefix	English prefix
1	met-	meth-
2	et-	eth-
3	prop-	prop-
4	but-	but-
5	pent-	pent-
6	heks-	hex-
7	hept-	hept-
8	okt-	oct-
9	non-	non-
10	dek-	dec-

Branchless

C-C bonds	Finnish suffix	English suffix
single only	-aani	-ane
at least one double	-eeni	-ene
at least one triple	-yyini	-yne

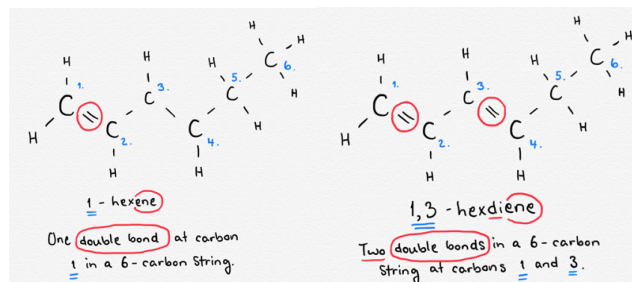
Fancy vocabulary: Hydrocarbon compounds with single carbon-carbon bonds only are called *alkanes*, those with double carbon-carbon bonds *alkenes*, and those with triple carbon-carbon bonds *alkynes*. Furthermore, alkanes are said to be *saturated*, and alkenes and alkynes to be *unsaturated* in the case of a single multiple bond and *polyunsaturated* in the case of several multiple bonds.

Spot the mistake. The three-carbon alkane, alkene, and alkyne, and the polyunsaturated molecule.



Assignment. Draw and name the two-carbon alkane, alkene, and alkyne.

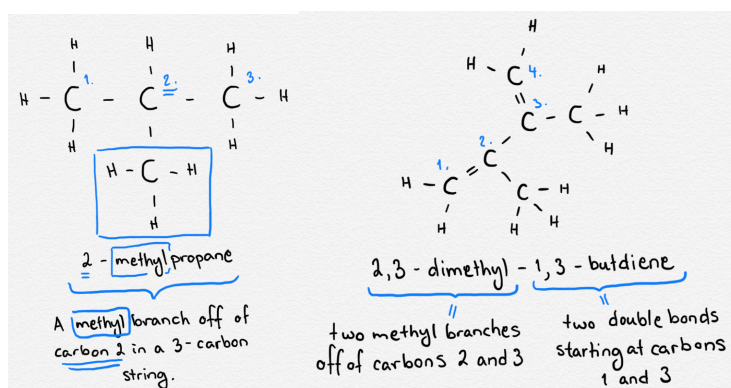
Example. Six-carbon unsaturated and polyunsaturated alkenes.



Assignment. Draw and name the four-carbon alkenes (four in total).

Branched

First, identify the longest string of carbon atoms in the molecule so that the branches are as short as possible and so that the main string contains as many multiple carbon-carbon bonds as possible. Then, name the carbon branches using the regular prefixes and the suffix *-yl* (*-yyli* in Finnish). If the molecule has several identical branches, indicate their amount with the prefixes *di-*, *tri-*, and so forth.



Fancy vocabulary: A branch that can be thought to replace a hydrogen molecule in a hydrocarbon molecule is called a *substituent*.

Assignment. Draw the structural formulae and write the chemical formulae of the following.

a. ethane

b. ethene

c. ethyne

d. 2-butene

e. pentane

f. 1-pentyne

g. 2-methylbutane

h. 2,3-dimethyl-1-penten-4-yne



Alcohols

... or hydrocarbons with a *hydroxylic group* -OH as a substituent.

Naming. Hydrocarbon prefix with suffix *-ol* (*-oli* in Finnish).

Assignment. Read the chapter and take notes as a group.

Experiment

How does the water concentration of an ethanol solution affect its combustibility? Design an experiment as a group and get it approved. Use the templates at the back of this booklet to log your findings.

Caution! The burning match should not linger in the solution.

Fancy vocabulary. An alcohol with only one hydroxyl substituent is called *monohydric*.
An alcohol with a hydroxyl substituent at each carbon atom is called *polyhydric*.

Assignment. Draw and identify the three-carbon and the five-carbon polyhydric alcohol.

Assignment. Choose five tasks.



Carboxylic acids

... or hydrocarbons with a *carboxylic group* -COOH as a substituent.

Naming. Hydrocarbon prefix with suffix *-anoic acid* (*-aanihappo* in Finnish).

Assignment. Study carboxylic acids as a group.

a. State the general definition for an acid in chemistry.

b. State the general definition of a weak acid in chemistry.

a. Draw the structural model of a one-carbon carboxylic acid molecule. Name it.

Assignment. Draw the structural formulae of the following.

a. ethanoic acid

b. propanoic acid

c. ethanedioic acid (or *oxalic acid*, with a double carboxylic group)

Experiment

How does the amount of carbon atoms in a carboxylic acid molecule affect the pH of a 10-percent solution of the acid?

Use the templates at the back of this booklet to log your findings.

Assignment. Where can the following carboxylic acids be encountered? Describe.

a. methanoic acid

b. ethanoic acid

c. butanoic acid

d. oxalic acid

Assignment. Choose five tasks.



Esters

... or products of a reaction between an alcohol and a carboxylic acid.

Did you understand? Refresh your memory first.

- State the definition of an alcohol.

- State the definition of a carboxylic acid.

Example. Artificial pear scent.

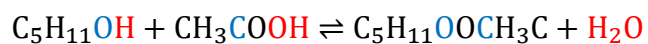
- Draw a pentanol molecule next to an ethanoic acid molecule so that the hydroxyl and carboxylic groups face each other.

- Connect the two molecules by cleaving the constituents of a water molecule out of the structural formulae.

Naming. Alcohol prefix with suffix *-yl*, connected to the carboxylic acid prefix with the suffix *-anoate* (*-yyl*i and *-aatti* in Finnish, respectively).

Example. In the previous example:

pentanol + ethanoic acid \rightleftharpoons pentylethanoate + water



Assignment. Draw the structural formulae and name of the products of the reactants.

a. ethanol + methanoic acid ()

b. butanol + ethanoic acid ()

c. butanol + butanoic acid ()

Did you understand?

a. What do you need to create an ester?

b. What applications do esters have?

Assignment. Choose five tasks.

Experiment Create pentylethanoate (1 : 3) and propylethanoate (2 : 3).
Use the templates at the back of this booklet to log you findings.

Caution! The catalyst, sulphuric acid, is a highly corrosive strong acid.

"Acid to water, all is well. Water to acid, what an accident!"

"Ensin vesi, sitten happo, muuten tulee käteen rakko!"



Revision 1

You may only proceed beyond this revision section once you take the test on the first chapters:

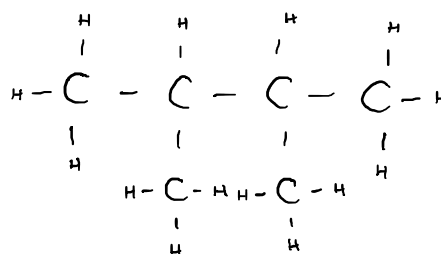
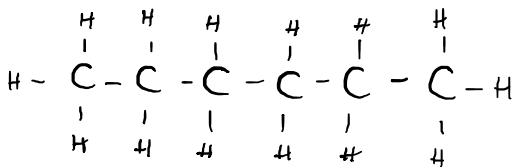
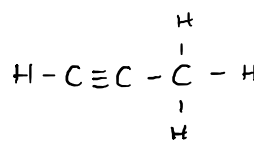
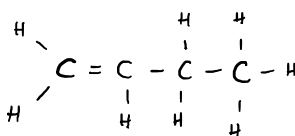
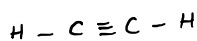
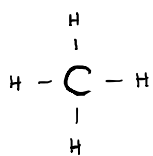
- carbon and its allotropes
- hydrocarbons; alkanes, alkenes, and alkynes
- alcohols
- carboxylic acids
- esters and esterification



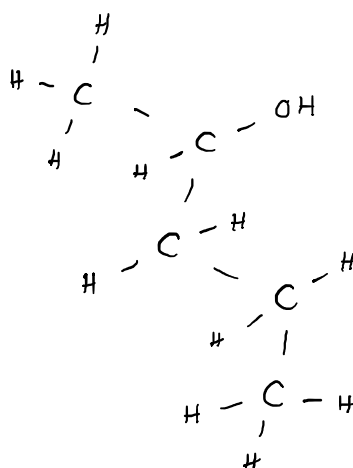
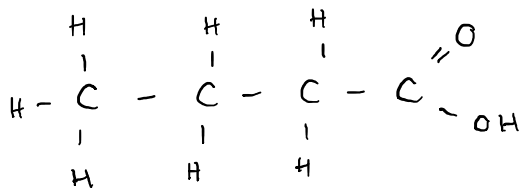
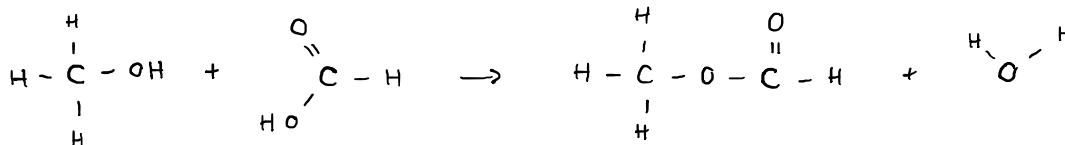
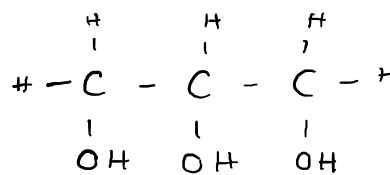
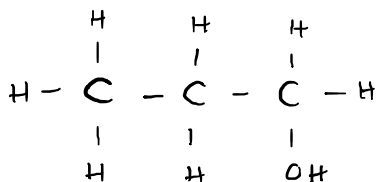
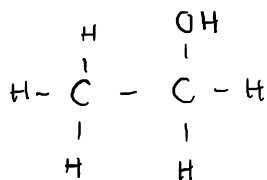
Use the following task battery, the tasks in the book, to your advantage.

Fill in the summative part of the assessment form before the test.

R1 Name the following hydrocarbon molecules and write their chemical formulae.



R2 Circle and name the functional groups of the following molecules. Identify them.



Proceed beyond this point only after taking the first test!

Experiment Design and carry out an experiment to indicate glucose and fructose:

- a. in non-diet soda
- b. in a water solution of potato flour
- c. in a water solution of potato flour one group member has spat in a while before

Use the templates at the back of this booklet to log you findings.

Did you understand?

a. Draw the structural formula for a lactose molecule.

b. Use the formula to explain the sweet taste of many low-lactose dairy products.



Proteins

... or chains of bonded molecules with functional groups -NH_2 and -COOH .

Assignment. Study proteins as a group.

a. List animal-based food items rich in protein.

b. List plant-based food items rich in protein.

c. List human body parts consisting mainly of protein.

Fancy vocabulary. The substituent -NH_2 is called the *amine group*.

Assignment. Map out the chemical composition of a protein as a group.

- a. Draw an example of the structural formula of an amino acid.

- b. Draw two 2-aminopropanoic acid molecules (amine group as a substituent in the middle carbon atom of a propanoic acid molecule) so that the amino group of one faces the carboxylic group of the other.

- c. Connect the two molecules by cleaving the constituents of a water molecule out of the structural formulae.

Fancy vocabulary. The bond formed in the previous example is called a *peptide bond*.

Experiment Design and carry out an experiment to indicate protein in egg white.
Use the templates at the back of this booklet to log you findings.



Fats

... or esters of glycerol and three long-chain carboxylic acids.

Did you understand? Refresh your memory first.

a. Draw the structural formula of glycerol.

b. State the definition of a carboxylic acid.

c. Describe the process of an alcohol and a carboxylic acid forming an ester.

Fancy vocabulary. An unbranched carboxylic acid with four or more carbon atoms is called a *fatty acid*.

Assignment. Map out the chemical properties of a molecule of butter.

a. Draw three butanoic acid molecules next to a glycerol molecule so that the carboxylic groups each face a hydroxylic group of the glycerol molecule.

b. Connect the butanoic acid molecules to the glycerol through esterification.

Following the naming logic of the IUPAC name for this butter molecule is *glyceryl tributanoate*.

Did you understand? Refresh your memory again.

a. Draw the structural formula of a saturated hydrocarbon, of an unsaturated hydrocarbon, and of a polyunsaturated hydrocarbon. Name the molecules.

b. Draw two examples of the possible structural formulae of 2-pentanol: one that is curved and one that is straight.

Fancy vocabulary. Two molecules sharing a molecular formula are said to be *isomeric*. The butene molecules in the previous example are said to be *cis-trans isomeric*, with the curved one being *cis* and the straight one being *trans*.

Assignment. Describe both the macroscopic and microscopic properties of

a. animal-based fats, and name the exceptions

b. plant-based fats, and name the exceptions



Assignment. Scan the QR code, read the article, and answer the questions.

a. Explore the reasons why trans fats can be found in food items.



b. According to the European authorities, what is the daily intake of trans fats considered to pose a health risk?

c. According to the article, the production process of margarine changed radically in Finland in the 1990, consequently leading to a sharp decrease in trans fat intake in the nation. Name and explain the new method.



Did you understand? Choose five tasks.

Reactions of nutrients

Assignment. Study *denaturation* and *coagulation* of proteins as a group.

- a. How can denaturation and coagulation reactions be observed in the context of cooking an egg on a frying pan?

- b. In the previous example, the denaturation is due to heating. State six other factors with examples.

Assignment. Study *gelatinization* of polysaccharides as a group.

- a. How is gelatinization related to cooking potatoes on boiling water?

- b. How does gelatinization affect the consistency of berry jam?

Assignment. Study *rancidification* of fats as a group.

- a. Which carboxylic acid and alcohol esterify to yield butter?

- b. How is rancidification related to the previous esterification reaction?

Assignment. Study *Maillard reactions* of proteins and carbohydrates as a group.

a. Under which conditions and between which reactants can a Maillard reaction occur?

b. State a catalyst and an inhibitor for a Maillard process.

Experiment

Experimental test. Follow the teacher's instructions.

Use the templates at the back of this booklet to log you findings.

Revision 2

You may only proceed beyond this revision section once you take the test on these chapters:

- carbohydrates
- amino acids and proteins
- fats
- denaturation, coagulation
- gelatinization
- rancidification
- Maillard reactions



Use the task batteries in the book to your advantage.

Fill in the summative part of the assessment form before the test.

Proceed beyond this point only after taking the second test

Freestyle 1:

... or a topic you get to choose among the following to flex your organic chemistry skills.

◦ Fuels ◦ Polymers ◦ Nanotechnology ◦ Pharma ◦ Sweeteners ◦ Detergents ◦ Ecotoxicology ◦

Freestyle 2:

... or a topic you get to choose among the following to flex your organic chemistry skills.

◦ Fuels ◦ Polymers ◦ Nanotechnology ◦ Pharma ◦ Sweeteners ◦ Detergents ◦ Ecotoxicology ◦

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.

Lab report

Topic and hypothesis

Goal for the experiment

Equipment and substances

Conducting the experiment

Assess your input and the output

In my opinion, my input was poor/satisfactory/good/excellent.

We worked poorly/satisfactorily/well/excellently as a group.