C I A!

Challenging **I**nvestigations in **A**rt forgery

30th of April 2015

Challenge 2

Country:

Team:

Lab safety rules

- Lab coats and safety goggles must be worn all times in the laboratory.
- Eating and drinking is strictly prohibited in the laboratory.
- Disposable gloves are provided and should be worn while working with chemicals.

General instructions

- On completion of your work all papers including scribbling paper must be handed in. NOTHING must be taken from the laboratory.
- All results must be entered into the answer sheet (coloured paper).
- Graphs must be handed in together with the answer sheet.

Only the final answer sheet (coloured paper) and the supplemented graphs will be assessed!

Task A: 92 Marks

Task B: 92 Marks

Task C: 92 Marks

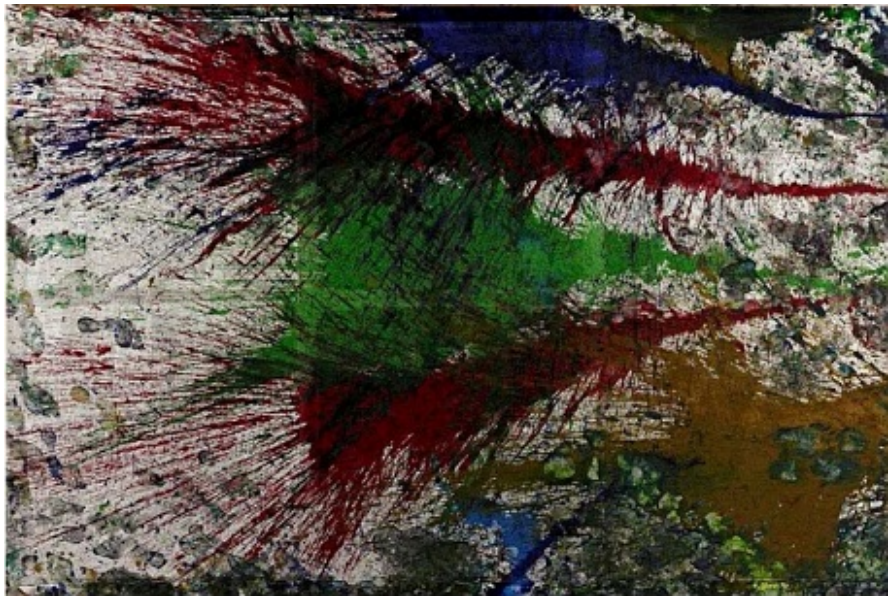
Task D: 06 Marks

Task E: 24 Marks

You have **4 hours** to complete Challenge 2.

The Story

A burglary has been committed in a villa in Klagenfurt. During a vehicle inspection near the house a painting resembling the work of the Austrian actionist artist Hermann Nitsch was found in the trunk of a parked car. Nitsch is famous for using animal blood in his work and has always been under fire for that. After a consultation with the artist himself the painting was identified as forgery, although blood has been identified as a constituent in the colours, so further investigations have to be conducted.



Source: *www.strabag-kunstforum.at/artcollection/kuenstlerinnen-und-kuenstler/?kid=30*

The circle of suspects specialising in faking modern pieces of art has been limited to three persons. At least one of the suspects is known for using animal blood as paint, so the person who faked the painting might be among them.

In order to identify the art forger, investigations concentrate on:

- The painting itself.
- The car where the painting was found.
- The three artist studios (including the garden area and close surroundings).

At all three places different pieces of evidence were secured that - together with the evidence from the car should help identify the perpetrator. Materials and pieces of paintings stem from the three studios that have been secured at earlier investigations. However, during the transport some of the pieces of evidence were mixed up due to badly sealed containers. Luckily the three paint and canvas samples were labelled properly.

As part of this challenge, you as an up-coming science team are asked to investigate the present evidence using basic and straightforward methods and make a joint decision from which studio the painting has come from.

Use the following hints:

- Your own investigation results and measurements.
- The collected pieces of evidence.
- The description of the artist studios and of the surrounding areas.

Information on the artist studios:

The artist studio at the Lake Woerthersee

A quartz-gravel road leads from the main street to the parking space of the premises. Within a few minutes the lakeside can be reached from the artist studio, the way leading through an alder swamp, partly covered with rush. Recently, an introduced aquatic animal has caused fauna and flora problems in the lake. On one hand it competes with rare endemic species for food sources, on the other hand it serves as a food source for ducks.

The artist studio in the forest

The old building, situated close to an old granite quarry, is made up of sandstone. Although the location of the studio is very quiet, the artist has planted a yew tree hedge to screen it from the neighbouring land plot. He sells honey from his own production on the farmer´s market in Klagenfurt and fir trees from his own plantation at the Christmas market; this is additional income for him.

The artist studio at the sea

It is situated in a picturesque location on limestone at the Mediterranean Sea coast. The distance to the beach is only about 100 m, and the beach is lined with typical beach flora. However, the invasive neophyte *Mesembryanthemum crystallinum* is increasingly becoming a threat.

TASK A

In Task A it is possible to use jokers, but marks will be deducted.

Material:

- You will receive five bags with reference samples:
  Bag Forest: from the studio at the edge of the forest of Viktring, a part of Klagenfurt (1, 2, 3)
  Bag Lake: from the studio and from garden at the banks of the Lake Wörthersee (4)
  Bag Sea: from the studio at the Mediterranean coast (5, 6, 7)
  Bag Car: from the car where the painting was found (8, 9, 10)
  Bag Mix: from all three studios, the content of which has accidentally been messed up (11, 12, 13, 14)
- Microscope slides
- Black paper as pad for the slide
- Cover slips
- Microscope
- Diluted hydrochloric acid labeled as "HCl"
- Silver nitrate solution labeled as "$AgNO_3$"
- Magnesia sticks
- Razor blade
- One piece of elder marrow
- Petri dishes
- Bunsen burner (on central lab bench)
- Forceps

1. Assignments to be done with the pieces of evidence in the bags

1.1. Which pieces of evidence from Bag Mix belong to which putative location?
Write the appropriate numbers of the pieces of evidence from Bag Mix in the table next to the corresponding studio location.

⇨ *Answer sheet*

1.2. Systematic criteria assignment: Identify the pieces of evidence from Bag Lake, Bag Forest, Bag Sea, Bag Car and Bag Mix and enter the numbers found on the pieces into the appropriate blanks in the tables "Systematic criteria 1" and "Systematic criteria 2"!

⇨ *Answer sheet*

The more precise the systematic assignment is done, the more marks can be achieved. **Watch out!** Some pieces of evidence can be assigned to one and the same organism.

2. Mesembryanthemum crystallinum

Leaves and stems of *Mesembryanthemum crystallinum,* a succulent plant from the family of Aizoaceae (fig-marigold family or ice plant family), were found in the car.

Mesembryanthemum crystallinum shows the following characteristics:

- As an adaptation to its environment it can undergo a stress-induced switch from C3 metabolism to CAM (**crassulacean acid metabolism)** as a consequence of salt or drought stress.
- *Mesembryanthemum crystallinum* is commonly known as 'ice plant' due to its leaves, stem, buds and seeds that are covered with epidermal bladder cells filled with liquid. Thus, the plant appears as if it is fully covered with small frozen dewdrops. The epidermal bladder cells serve as a storage reservoir for some compounds, such as NaCl, which regulates the water balance.
- Crystals can be found in the vacuoles.

The investigators found different subspecies of *Mesembryanthemum crystallinum* at each artist´s location*:*

- within the vegetable garden at the lake
- as indoor plant at the forest studio
- as a proliferating neophyte in the vicinity of the studio at the seaside

On initial observation the plants cannot be distinguished from each other. They all look very similar. However, subspecies can clearly be distinguished from one another according to the following criteria:

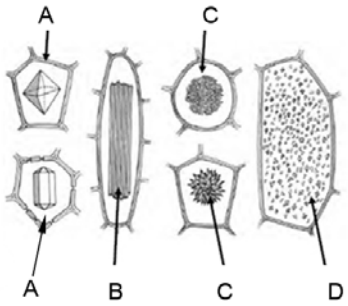
- Shape of the embedded crystals
- Material of the embedded crystals
- Capability of NaCl storage within the epidermal bladder cells
- Optical properties of the bladder cell liquid ➔ **Task C**

Location	**Plants**	**Shape of crystals**	**Material of crystals**	**NaCl in bladder cell liquid**	**Optical activity**
Lake studio (vegetable garden)	*Mesem bryanthemum c. subsp.zzz*	Druse	Calcium carbonate	Storage of NaCl	Optical activity
Forrest studio (indoor plant)	*Mesem-bryanthemum c. subsp. yyy*	Needle-shaped crystals (Raphides)	Calcium oxalate	No storage of NaCl	No optical activity
Sea side studio (invasive neophyte)	*Mesem-bryanthemum c. subsp.xxx*	Needle-shaped crystals (Raphides)	Calcium oxalate	Storage of NaCl	Optical activity

For the investigation it is important to determine which studio the plant found in the car comes from. Use the characteristics mentioned in the table above for your investigations. The following experiments should help you to answer this question!

2.1. Shape of the embedded crystals

Make a cross section of the plant´s leaf. (Take a leaf at least 2 cm long.) If you need instructions ask a laboratory assistant. Be aware: In doing so, you will use up one joker and have 2 marks deducted. With the help of a microscope, look for embedded crystals in the cross section of the leaf. Identify the shape of crystals present in that plant!



Possible crystal shapes:

A. Single crystals
B. Needle-shaped crystals in bundles (Raphides). If the cells are destroyed they can fall apart into single crystal needles.
C. Crystal druses - asteroidal aggregates of crystals
D. Crystal sand

2.1.1. Fill in the appropriate letters into the answer box! ⇨ *Answer sheet*

2.2. Distinction between Calcium oxalate- and Calcium carbonate

You have to work very carefully in doing this experiment!!

Step 1: Add one drop of diluted hydrochloric acid onto in a new microscopic slide.
Step 2: Place a new thin cross section on the drop of hydrochloric acid.
Step 3: Cautiously place a cover slip on top of it.
If you have liquid coming out from below the slip, remove it with tissue without wetting the slide or slip any further. Take care that your skin does not come into contact with diluted hydrochloric acid!
Step 4: Investigate whether the crystals react with the hydrochloric acid. For observation use the 10x objective. Monitor your experiment carefully and patiently; this reaction can take up to 10 minutes.

2.2.1. Tick the result of your investigation in the Table "Reaction of crystals"
⇨ *Answer sheet!*

2.2.2. The conclusion of your investigation.
Choose the appropriate letter and write it into the answer box! ⇨ *Answer sheet!*

E: The crystals are made of calcium carbonate F: The crystals are made of calcium oxalate.

2.3. Investigation of NaCl in bladder cells.

Analysis of chloride ions

You must wear gloves!
Step 1: Place the glass slide on the black paper.
Step 2: Carefully (do not squeeze the bladder cells) take one leaf of *Mesembryanthemum crystallinum* and cut it off with the razor blade.
Step 3: Take the side of the leaf with the bigger bladder cells and put it face down on the glass slide. Gently press the leaf on the glass to make the bladder cells burst so that they leave some fluid film on the glass.
Step 4: Add 1-2 drops of readily prepared $AgNO_3$ (silver nitrate) on the fluid film
Step 5: Observe and investigate the reaction!

2.3.1. Tick the appropriate conclusion in the table "Analysis of chloride ions"
⇨ *Answer sheet!*

Analysis of sodium ions

Step 1: Carefully take a magnesia stick and let one end touch the (big) bladder cells of another leaf. Hold the magnesia stick in place to draw up some fluid. The flame test must only be carried out at the designated bench in the laboratory!
Step 2: Ask a laboratory assistant to help you with the Bunsen burner. Ensure you use a working flame and not the safety flame.
Step 3: Hold the magnesia stick with the probe into the flame for up to one minute.
Step 4: Carry out the flame test at least twice. Let the magnesia stick cool in between, snap off the end carefully (Caution! It might still be HOT) and repeat steps 1 and 3.
Investigate the reaction!

2.3.2. Tick the appropriate conclusion in the table "Analysis of sodium ions"!
⇨ *Answer sheet!*

2.3.3. The flame test for sodium can be tricky. Which of the mentioned mistakes can have an effect on the result? **Tick the appropriate answers in the table "Possible sources of error during flame test".** ⇨ *Answer sheet!*

2.4. The results from the investigation of *Mesembryanthemum* from the car

2.4.1. Summarize your results from your investigation in the checklist "*Mesembryanthemum*"!
⇨ *Answer sheet!*

2.4.2. Write the correct name of the plant (subspecies!) found in the car into the answer box!
⇨ *Answer sheet!*

3. Graphical presentation of epidermal cells and cells of the stomata.

Draw a professional sketch of a surface section of about 20 epidermic cells with cells of stomata in plane view! For observation use the 10x objective ⇨ Coloured paper on the *Answer sheet!*

Prepare a surface section of the leaf. If you need instructions ask a laboratory assistant. Be aware: In doing so, you will use up one joker and have 2 marks deducted.
Pay attention to the correct labelling and provide all relevant scientific information with the sketch!

4. Crude examination of the small stone from the car

Recall what you might know about hardness of stones and which of the materials might show visible effects when they come in contact with hydrochloric acid.
The following materials are provided:

- Water
- A glass plate = Microscope slide
- A dropper bottle with diluted hydrochloric acid

Carry out relevant experiments to find out whether the stone could be quartz, granite or limestone!

4.1. Tick the appropriate answers! ⇨ *Answer sheet!*

4.2. Result of crude determination: Write the appropriate letter into the answer box!
⇨ *Answer sheet!*

A = quartz B = lime C = granite

5. Bag from the Car

After having finished all the practical experiments, it should be possible to match the pieces of evidence from the car to the forger's art studio.

5.1. Tick from which studio the pieces of evidence found in the car might be!

⇨ *Answer sheet*

Watch out! The number of piece of evidence labeled with number 10 has to be entered in the table "systematics 1" as well!

6. Who is responsible for the art forgery?

After your investigation you should be able to identify the fraudulent.

6.1. Tick the most likely location, the fraudulent painting could come from. ⇨ *Answer sheet!*

7. Plant metabolism

After the practical work you will have to answer some theoretical questions about plant metabolism.

7.1. Fill in the appropriate numbers in the table "Plant metabolism"! ⇨ *Answer sheet!*

1 = appropriate statement 0 = not applicable!

TASK B

At your laboratory station, you will find samples from three different artist studios. As an expert chemical analyst you have been asked to help determine the origin of the found painting by analysing paint and canvas samples acquired at the artists' studios.

Introduction

1. Investigation of paint samples

Haemoglobin, a component of blood, can be detected through tests, and would indicate the presence of blood in the paint. Haem is a component in the centre of the haemoglobin, a large protein responsible for the red colour of blood.

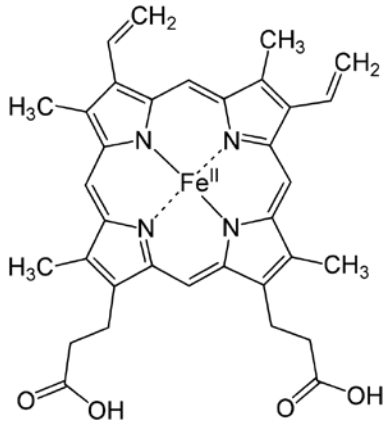


Fig.1: Structure of the haem complex

In order to detect haemoglobin unambiguously three tests must be conducted.

1.1. Detection with luminol

In this forensics test, haemoglobin catalyses the reaction of luminol, resulting in the appearance of luminescence.

The luminol is dissolved in a basic solution, to which hydrogen peroxide is then added. The addition of the hydrogen peroxide causes the oxidation of luminol. In this reaction, a peroxide anion is formed. Then a nitrogen molecule splits off due to the catalysing function of the haem complex and an exited amino phthalate appears. Light is emitted, thus restoring the energetic ground state.

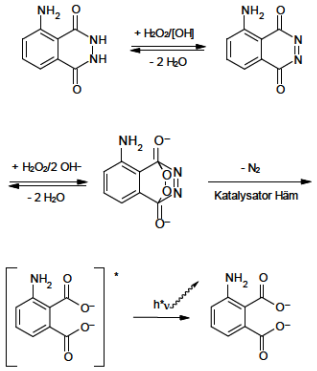


Fig. 2: Reaction of luminol and hydrogen peroxide with haem as a catalyst in alcaline solution

Since this reaction is not only catalysed by haem, but also by all peroxidases, this reaction is not specific to blood.

1.2. Detection of iron

One feature of the red blood-pigment haemoglobin is that it contains an iron(II)-ion, which can be detected with classical analytical reactions.

In order to successfully perform the detection of iron, the haem complex (see Fig.1) has to be destroyed by an oxidising acid. In this process Fe(II) gets oxidised to Fe(III). Fe(III) can now be detected on a spot plate with three different colour reactions.

$Fe^{3+}(aq.) + 3\ SCN^{-}(aq.) \leftrightarrow Fe(SCN)_3(aq.)$ (red) (exemplary equation for this equilibrium)

$4\ Fe^{3+}(aq.) + 3\ K_4[Fe(CN)_6](aq.) \leftrightarrow Fe_4[Fe(CN)_6]_3\ (aq.)$ (Prussian Blue) $+ 12\ K^{+}\ (aq.)$

$Fe^{3+}(aq.) + 3\ NaOH(aq.) \leftrightarrow Fe(OH)_3$ (brownish precipitate) $+ 3\ Na^{+}(aq.)$

Since any red colour could contain iron, one more test must be performed in order to be absolutely sure that the samples contain blood.

1.3. Teichmann test

Haem reacts with Teichmann's reagent (concentrated ethane acid and sodium chloride) to chlorhaemin, which forms typical crystals. For this reaction to occur, ethane acid must first be boiled to rupture the red blood cells. Then the haem complex separates from the globin and the chloride from Teichmann's reagent causes the crystallization of hardly soluble chlorhaemin (see Fig.3)

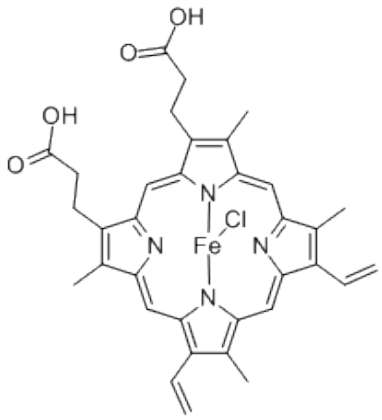


Fig.3: Structure of chlorhaemin complex

In order to definitively determine where the painting originates from, not only the paint, but also the workshop's surroundings must be taken into account.

2. Investigation of canvas

Analysis of the found painting has shown a significant amount of chloride on the canvas. Since one of the workshops is close to the sea, this could be the explanation. However, you should find out whether for some reason canvas samples from other workshops also show this contamination.

Chloride can be extracted from the canvases of the respective workshops and can be determined with thin layer chromatography.

In chromatography, a mobile phase passes through a stationary phase that contains the samples. Thus the components of the samples become separated.

In thin layer chromatography the relation of how far a certain substance travelled and how far the mobile phase travelled is defined by the retardation factor (Rf-value). This value is characteristic for each compound under given chromatographic conditions.

$$Rf - value = \frac{distance\ start{-}middle\ of\ the\ spot}{distance\ start{-}end\ of\ mobile\ phase}$$

List of materials	List of chemicals
• Pen, paper, envelope • Calculator • Permanent marker, pencil, sharpener • Ruler • 6 test tubes, 15 mL (Falcon) • 3 bottles with snap-on caps • 3 glass rods (short) • 9 Pasteur pipettes • Dark box • Spot plate • 3 beakers 100 ml • Heating plate • 3 microscope slides with cover slips • Microscope • TLC-plate with silica gel 60 F254 Merck • Piston pipette 2 µL (adjustable) • Piston pipette 1000 µL (adjustable) • Pipette tips (white, blue) • Container for used tips • Paper towels • Test tube rack • Scotch tape • TLC chamber (in the fume hood, labelled with national flag) • UV-lamp (1 in each room)	• Ultrapure water • Luminol solution (0.1 g luminol (5 Amino 2,3 Dihydro 1,4 Phthalazindion) and 5 g sodium carbonate in 100 ml pure water) labelled ”Luminol“ • 3 % hydrogen peroxide solution labelled “H_2O_2.3 %“) • Nitric acid 2M, labelled “HNO_3“ • Ammoniumthiocyanate (10 %) labelled “NH_4SCN“ • Potassium hexacyanoferrate (10 %) labelled “$K_4[Fe(CN)_6]$“ • Sodium hydroxide solution 2 M labelled “NaOH“ • Teichmann reagent (ethane acid 100 %, 0,1 % NaCl), labelled “Teichmann“ • Mobile phase acetone, *n*-Butanol, ammonia 25 %, water (65 + 20 + 10 + 5) in the TLC-chamber in the fume hood • Chloride-reference solution 1 %, labelled “Cl 1 %“ • Methanolic silver nitrate solution (1 %), labelled “$AgNO_3$“, one in each fume hood • 3 paint samples dissolved, labelled “S1“(Studio lake), ”“S2“(studio sea), ”S3“(studio wood) • 3 canvas samples ”A“(studio lake), ”B“(studio sea), ”C“ (studio wood)

Instructions:

1. Investigation of paint samples

1.1. Detection with luminol

- Label 3 bottles with snap-on caps S1L, S2L and S3L
- Transfer 1 mL of the samples S1-S3 into the respective bottles and add 1 mL ultrapure water each.
- Add five drops of the luminol solution (labelled “Luminol”) to S1L and put it into the dark box.
- Add five drops of the hydrogen peroxide solution (labelled “H_2O_2 3 %”) to S1L and observe.

Repeat for the other two bottles.

1.1.1. Record your observations in the table.
Fill in the table. Write **"P"** for a positive test and **"N"** for a negative test. ⇨ *Answer sheet!*

1.1.2. What colour do you observe?
Tick the appropriate answer**.** ⇨ *Answer sheet!*

1.1.3. What is the reason for the colour?
Tick the appropriate answer**.** ⇨ *Answer sheet!*

1.2. Detection of iron with the spot plate

- Label three 15 mL Falcon test tubes with S1 Fe; S2 Fe and S3 Fe.
- Label another three 15 mL Falcon test tubes and three beakers with S1 Fe/HNO_3; S2 Fe/HNO_3 and-S3 Fe/HNO_3.
- Transfer 2 ml of the samples S1 to the test tubes labelled "S1 Fe and S1 Fe/HNO_3". Repeat for the other samples.
- Fill the Falcon test tubes labelled "S1Fe/HNO_3-S3Fe/HNO_3" with nitric acid (labelled "HNO_3") up to the 10 mL mark and transfer the contents into the respective beakers.
- Heat the samples in the beakers at 150°C for approximately 15 minutes.
- Allow the samples cool to room temperature.
- Using a Pasteur pipette, add the samples to the spot plate four times each, according to the following table.
- Add the detection reagents according to the table.

	Sample	Sample + NH_4SCN	Sample + $K_4[Fe(CN)_6]$	Sample + NaOH
S1 Fe				
S1 Fe/HNO_3				
S2 Fe				
S2 Fe/HNO_3				
S3 Fe				
S3 Fe/HNO_3				

1.2.1. Show the finished spot plate to the laboratory assistant who will take a photo.
Laboratory assistant's signature ⇨ *Answer sheet!*

1.2.2. Which of the samples contain Fe(III)? Record your findings in the table.
Fill in the table. Write **"P"** for a positive test and **"N"** for a negative test. ⇨ *Answer sheet!*

1.2.3. Based on the tests you have conducted so far, which sample(s) might contain blood?
Fill in the table. Write **"P"** if you assume it contains blood and **"N"** if you assume it does not.
⇨ *Answer sheet!*

1.3. Detection of haemoglobin with Teichmann test

- Label three microscope slides with S1-S3
- Warm up the first microscope slide on the heating plate (at around 80°C). In order to do so, put the slide on the edge of the plate, so that the labelled side of the slide is not on the plate.
- Add one drop of sample S1 to the slide with a Pasteur pipette and wait until it dries.
- Then add a second drop over the first drop and wait till it dries.
- Cover the spot with a cover slip.
- Add Teichmann's reagent (labelled "Teichmann Reagens") carefully, so that the solution is drawn under the cover slip. The spot **must** be completely covered.
- As soon as you see bubbles, take the slide off the heating plate.

Repeat for samples S2 and S3.
Let each slide cool for about 15 minutes.

Investigate the results on your slides under the microscope. For observation use the 10x objective.

1.3.1. Which samples contain Teichmann crystals?
For reference, use the picture of what Teichmann crystals look like next to the microscope.
Fill in the table with **"P "** if it contains Teichmann crystals or **"N"** if it does not contain them.
⇨ *Answer sheet!*

1.3.2. Show one sample that contains Teichmann crystals to the laboratory assistant.
Get the laboratory assistant's signature for confirmation. Put the labelled slides into the envelope and make sure that you hand it in with the answer sheet. ⇨ *Answer sheet*

2. Investigation of canvas - detection of chloride with thin layer chromatography

Go to the TLC-chamber, which already contains the mobile phase, in the fume hood. Do not take the chamber out of the fume hood.

- Add 1 mL of ultrapure water to each of the test tubes with the canvas samples A-C.
- Mix thoroughly in order to extract potentially present chloride.
- Draw a fine line with a pencil 2 cm above the bottom edge of the TLC-plate. The silicate gel layer must not be damaged.
- With the 10 µL piston pipette, put 2 µL of each solution from test tubes A, B and C as well as from the chloride reference solution (labelled "Cl 1%") on the line.
- Put the plate into the TLC-chamber and close it.
- Run the TLC till the mobile phase has travelled about 6 cm (this will take around 25 minutes).
- Take the plate out of the TLC-chamber and mark the end of the mobile phase.
- Let the chromatogram dry.
- Lay the plate onto the protective pad and spray with silver nitrate (labelled "$AgNO_3$").
- Observe under the UV-lamp.

2.1. Calculate the Rf-value for chloride. ⇨ *Answer sheet*
Attach the chromatogram to your answer sheet in the space provided.

2.2. In which of the samples have you found chloride?
Fill in the table. Write "**P**" for a positive test and **"N"** for a negative test. ⇨ *Answer sheet*

2.3. Summarize your findings.

2.3.1. The origin of the painting can only be a studio where blood is used.
Tick **"yes"** or **"no".** ⇨ *Answer sheet*

2.3.2. The origin of the painting can only be a studio with an increased concentration of chloride.
Tick "**yes"** or "**no".** ⇨ *Answer sheet*

2.3.3 Based on your findings, which of the studios might the painting originate from?
Fill in the table. Write **"P"** if the studio is possible and **"N"** if the studio is not possible.
⇨ *Answer sheet*

3. Theoretical assignment

3.1 Tick the appropriate answers. ⇨ *Answer sheet!*

3.2 At a 40-fold magnification a crystal appears to be 2 cm long. How big is it in reality?
⇨ *Answer sheet!*

Task C

It is your task to find the studio (forest, sea, lake), where the painting has been forged, by measuring different physical quantities. You should compare properties of the painting with characteristic properties of the confiscated materials from the studios. In the three studios different samples of texture were found, labeled A, B, C, D and E. A texture labeled P was collected from the car.

1. Measurement of the wavelength of a laser

Firstly, you will need to determine the wavelength of the laser. This measurement will be done by diffraction on a grid.

Materials:

- stand
- laser with clothes peg
- grid (300 lines per mm)
- black paper
- ruler
- pencil

Assemble the equipment for your experiment according to Fig. 1.1.

SWITCH ON THE LASER ONLY WHEN IT IS POINTING TOWARDS THE FLOOR OR THE SCREEN!!

NEVER LOOK INTO THE DIRECTION OF THE LASER BEAM!!!

Non-observance can be harmful!

Misuse can lead to disqualification!

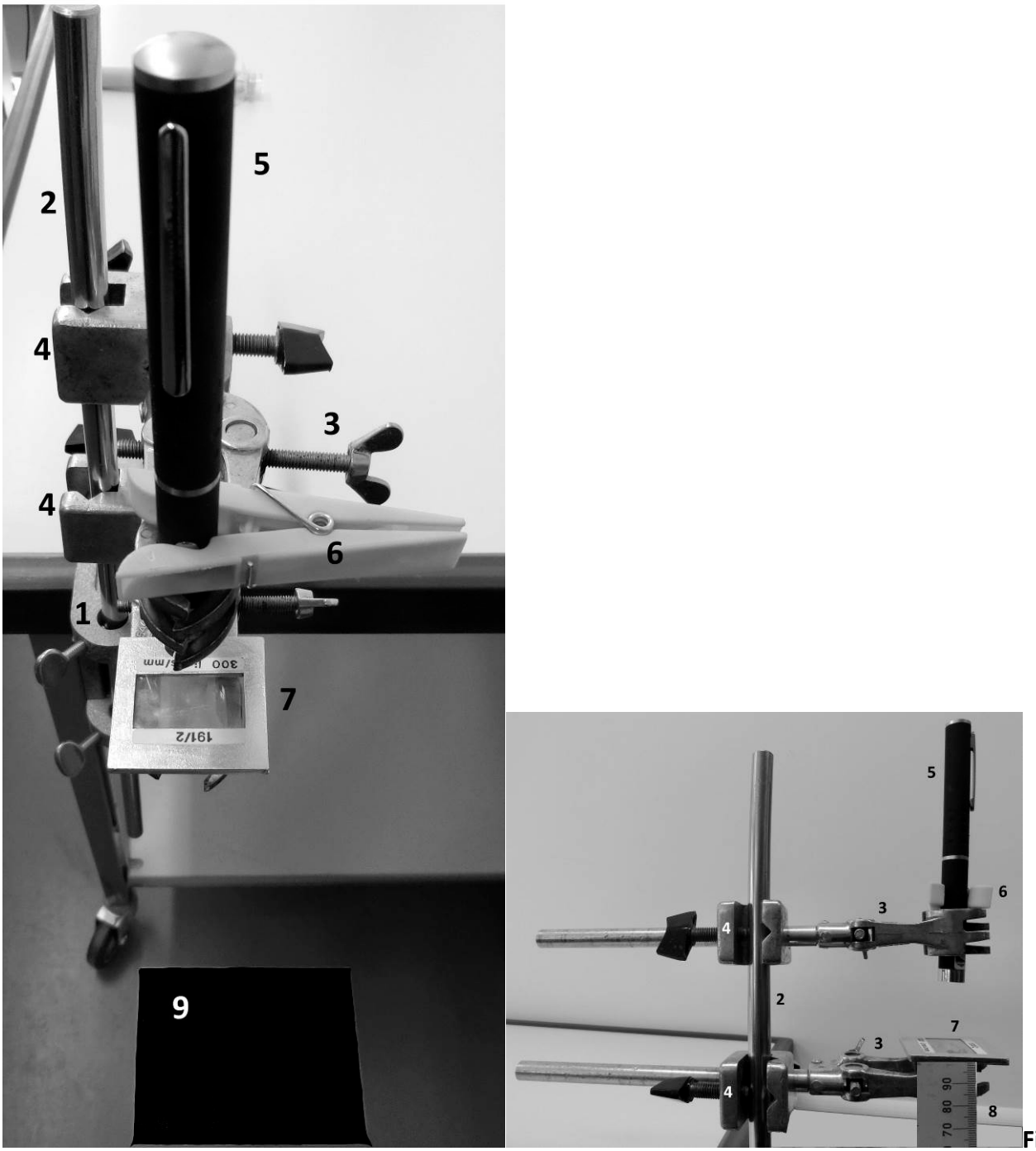


Fig. 1.1: Measuring device: 1) table clamp, 2) stand, 3) clamp, 4) clamp socket, 5) laser pointer, 6) clothes peg, 7) grid 300/mm, 8) ruler, 9) black paper on the floor.
left: view from above; right: side view

The grid should only be placed on the lower clamp, not fixed!

Be careful that the laser beam is vertically directed to the floor and that all optical components are oriented perpendicular to it.

Procedure:
The laser must only be switched on when taking measurements!

Switch on the laser with the clothes peg. Find a position of the black paper on the floor such that the 0th and 1st order maxima are visible on the paper. Mark these spots with the pencil on the paper. Turn off the laser.

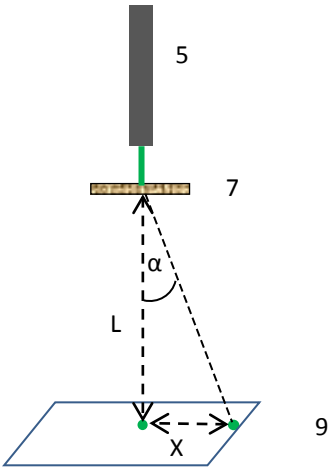


Fig. 1.2: Principle of the measurement

The general formula for the maxima of diffraction is:

$$sin\alpha_n = \frac{n \cdot \lambda}{d} \qquad \textbf{(formula 1)}$$

n: number of the maximum
λ: wavelength of the light
d: grating constant

1.1. Measurement of the angle

Measure the distance from the grid to the floor (L), Put the black paper on the table and measure the distance between the two marks on the black paper (X).

Calculate the angle α between the 0th and 1st order maximum! (Fig 1.2)
Write the formula and the result on the answer sheet. ⇨ *Answer sheet*

1.2. Grating constant

The grating constant is defined as the distance between two lines on the grid.

Determine the grating constant d, i.e. the distance between two lines on the grid. Give the answer in the unit of metre. ⇨ *Answer sheet*

1.3. Wavelength of the laser

Make a transformation on formula 1 in order to determine the wavelength. Write the resulting formula on the answer sheet. ⇨ *Answer sheet*

Calculate the wavelength of the light for the 1st maximum (n = 1) using your measured values. Specify the wavelength of the laser in metre and nanometre. Write the solution ⇨ *Answer sheet*

2. Investigation of textures

Five textures have been confiscated from the studios. Determine characteristic properties of these textures and compare them with the sample found in the car.

Material

- Laser with support
- Plastic tube to clamp the texture, rubber ring
- textures A, B, C, D, E (from the studios)
- sample P from the car
- ruler
- black paper

Procedure

Mount a plastic tube below the laser. The light outlet of the laser should be within the tube. The laser beam should be in the middle of the tube (make some short checks, but remember to switch off the laser). The texture should be mounted on the lower end of the tube one after the other. Fix the textures gently with the plastic ring. The textures should be mounted tightly, so that it is flat and unruffled. **(Fig. 2.1)**

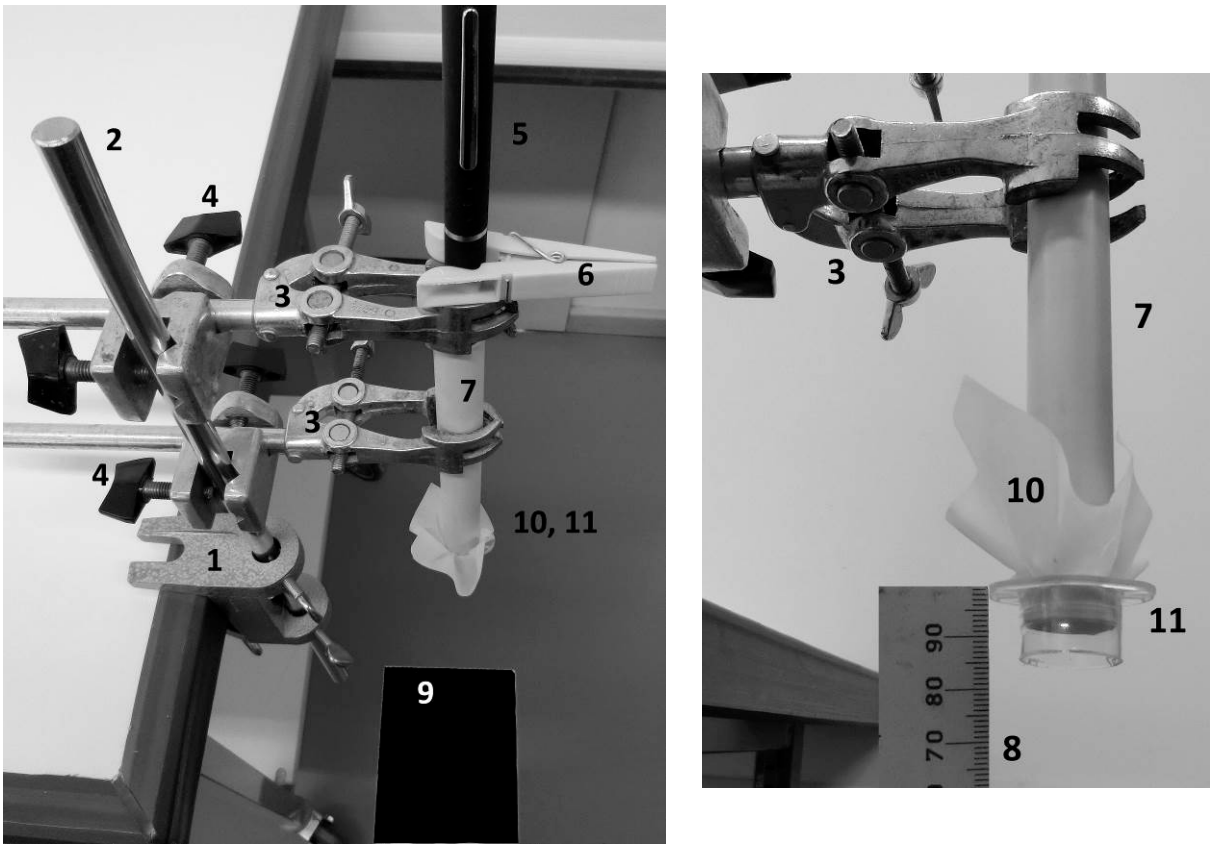


Fig. 2.1: Measuring device: 1) table clamp, 2) stand, 3) clamp, 4) clamp socket, 5) laser pointer, 6) clothes peg, 7) plastic tube, 8) ruler, 9) black paper, 10) + 11) texture and plastic ring.
left: view from above; right: side view

Attention: Since a texture is more complex than a grid, also the diffraction pattern is more complex. X gives the distance between two bright spots at the center (as indicated in Fig. 2.2).

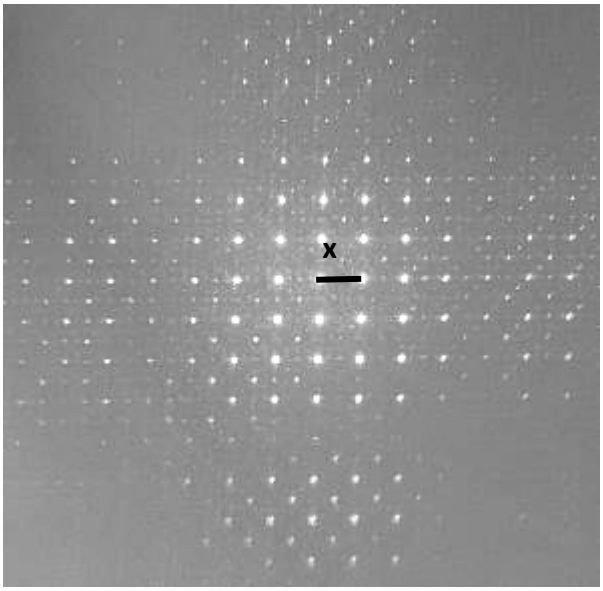


Fig. 2.2: Characteristic diffraction pattern of a texture, distance X.

Measure the distance L (texture – black paper). Switch on the laser and mark two adjacent spots on the black paper. Perform the measurement for each texture three times. Shift the paper between each measurement and mark the two adjacent spots again. Switch off the laser and measure the distance X with the paper on the table.

2.1. Determination of the diffraction angel of textures A - E

Follow the above procedure for each texture A-E.

Insert the values of L and X in Table 2.1a ⇨ *Answer sheet*

Calculate the respective diffraction angles α in degrees and insert them in the table 2.1a. ⇨ *Answer sheet*

Calculate the mean value and the standard deviation. Insert the mean value and the standard deviation in Table 2.1b. ⇨ *Answer sheet*

Standard deviation: You have three values, x_1, x_2 and x_3, and the mean value x_m. The standard deviation σ can be calculated by the following formula:

$$\sigma = \sqrt{\frac{(x_m - x_1)^2 + (x_m - x_2)^2 + (x_m - x_3)^2}{3}}$$ **(formula 2)**

2.2. Diagram: textures (A – E) – diffraction angle

Draw a diagram on a millimeter paper showing the dependence of the angle on the different textures. The standard deviation should be shown with error bars. Paste the diagram into the answer sheet. ⇨ *Answer sheet*!

2.3. Possible forger studios

Investigate sample P from the car in the same way. Insert the diffraction angle in Table 2.3. Perform again three measurements and calculate mean value and standard deviation. ⇨ *Answer sheet*!

Textures A and D were confiscated from the studio in the forest, textures C and E came from studio at the sea and textures A, C and D were found in studio near the lake.

In which studio could the forgery leading to probe P have taken place? Insert your result. ⇨ *Answer sheet*!

3. Identification of a fluid

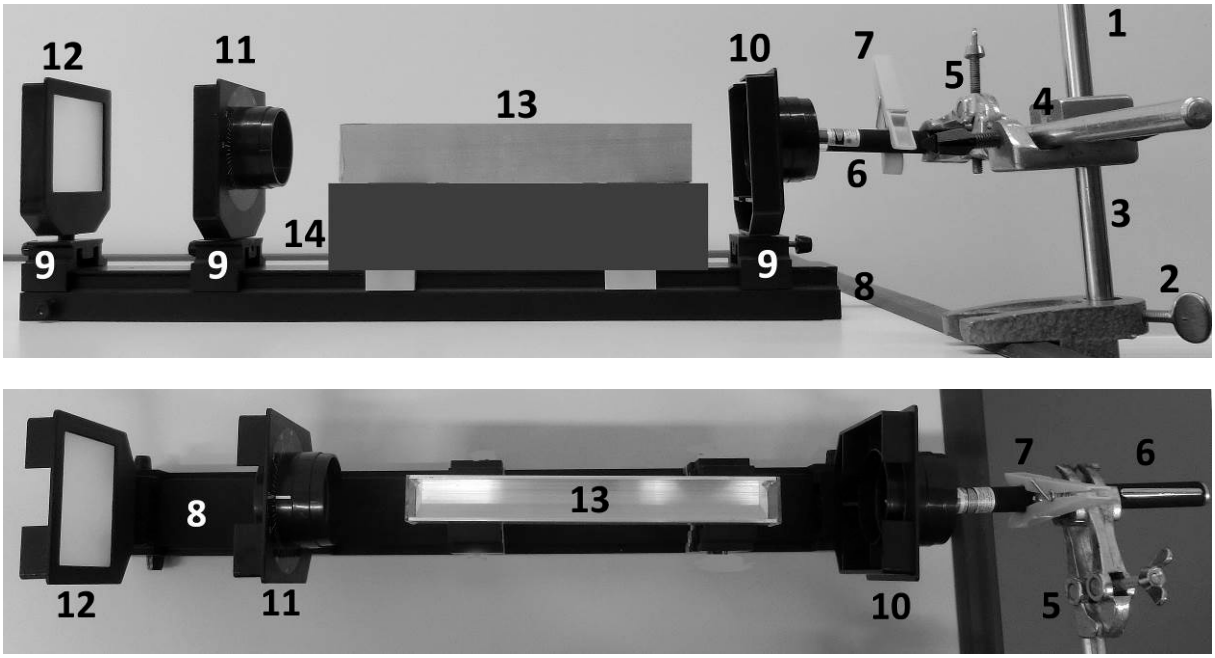
Plants found in the trunk of the car have to have their origin in the vicinity of the studio of the forger. These plants store a typical fluid in small cysts, which shows optical activity. Optical activity means that the plane of polarization of polarized light is rotated while traversing the fluid. This property can be qualitatively and quantitatively determined with crossed polarization filters. For this purpose, the fluid must be filled in a long cuvette that has to be placed between the two filters.

Material

- Laser with support
- Optical bench with two polarization filters and a screen
- Samples of fluid A, B, C for calibration
- Double-faced adhesive tape
- Cuvettes
- Measuring cylinder

Procedure

Assemble the equipment for your experiment as shown below in **Fig. 3.1.**



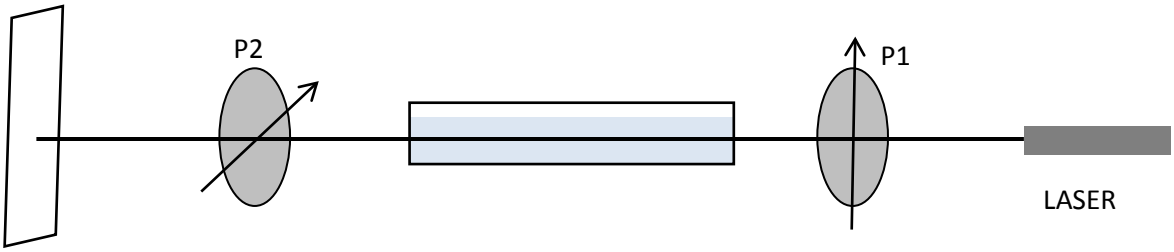


Fig. 3.1 – Measuring device: 1) stand, 2) table clamp, 3) stand, 4) socket, 5) clamp, 6) laser pointer, 6) clothes peg, 7) plastic tube, 8) optical bench, 9) rider for optical bench, 10) mounted polarization filter P1 (polarisator), 11) mounted polarization filter P2 (analysator), 12) screen, 13) cuvette, 14) support bracket for the cuvette.

Adjust the different parts in the following way: All optical components including the empty cuvette have to be aligned along the optical axis. The polarization filter should be oriented such that the white mark points 90 degrees to the right (see **Fig. 3.2**). This filter should stay in this position during the entire experiment!

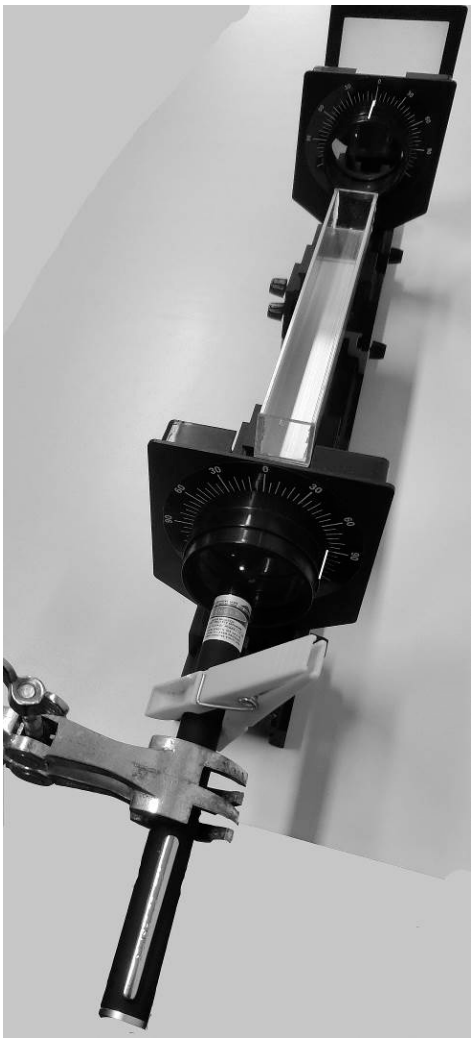


Fig. 3.2 – Adjustment of the polarization filters. The filter in the foreground is close to the laser.

Switch on the laser. Rotate the polarization filter near the screen, until the green point at the screen vanishes or reaches its most dimmed colour. The pointer of this filter should be oriented to 0° or close to it. This orientation is the zero reference mark for the following measurements.

In order not to shift the cuvette unintentionally, it can be fixed with a double-faced adhesive tape.

Principle of measurement

A measurement of the optical rotation is performed in the following way: Fill the fluid into the cuvette. The green point on the screen may or may not appear. If the green point is visible the fluid is optically active and if there is no green point visible the fluid is optically inactive.

Now rotate the filter near the screen to the right (with regard to the direction of the beam), until the green point disappears or becomes very dim. The angle between the zero reference mark and the new position is the rotation angle α.

Do not forget to reestablish the original position of the zero reference mark of the analysator before the next measurement.

3.1. Adjustment of the experiment

Write down the value of the zero reference mark! ⇨ *Answer sheet*

3.2. Which fluid shows optical activity?

One of three given fluid samples (A, B, C) is optically active. You need to determine which one?

Fill sample A into the cuvette. Investigate in the described way, whether the fluid is optically active or not. Insert your result in the answer sheet. Dispose the fluid into the appropriate jar. Clean the cuvette with water and repeat the experiment with samples B and C.

Insert your result in the table 3.2! ⇨ *Answer sheet*

Before you continue, your result has to be confirmed by a lab assistant on the answer sheet!

3.3. Measurement of the optical activity of different concentrations

In the following measurements use the fluid that is optically active. It is the fluid stemming from the plants, which have been found in the vicinity of the studio.

Fill the fluid again into the cuvette. Determine the angle of rotation as before explained. This fluid originally has a concentration of 50 g/100 ml. Dilute the solution with water with the help of a measuring cylinder to the concentrations of 25, 12.5 and 6.25 g/100 ml.

Measure the respective rotation angles. Write the results in the **Table 3.3a**. ⇨ *Answer sheet*

The measurement of the angle has to be done three times for each concentration!

Calculate the mean value and the standard deviation. Insert the values in **Table 3.3b**.
⇨ *Answer sheet*

3.4. Set up of a calibration graph for the optical rotation

Draw a diagram on a millimeter paper, in which the rotation angles α are plotted in relation to the concentration. ⇨ *Answer sheet*

Use again the mean values and **insert also the standard deviations as error bars**. Paste this diagram into your answer sheet.
Theoretically, a linear function is expected. Draw the corresponding straight line of best fit!

3.5. Determination of the specific rotation angle

The specific rotation angle $[\alpha]$ is a characteristic property of a dissolved substance. It is independent of the concentration and of the length of the cuvette. It allows for the identification of dissolved substances.
The specific rotation angle can be determined by the following formula

$$[\alpha] = \frac{\alpha}{l \cdot c} \cdot 100 \qquad \textbf{(formula 3)}$$

α rotation angle of the solution in degree

$[\alpha]$ spezific rotation angle in degree·ml·/ (dm·g)

l length of the cuvette in dm

c concentration of the solution in g / 100 ml

Measure the length of the cuvette in decimetre (between the inner sides of the glass ends).

Calculate the specific rotation angle for each of the different concentrations using the mean values from Tables 3.3b.

- Insert the values in **Table 3.5**
- Insert also standard deviations. You can calculate these from the corresponding values of Table 3.3b by using formula 2. ⇨ *Answer sheet*

3.6. Diagram: Specific rotation angle in relation to the concentration

Draw a diagram on a millimetre paper with the mean values of the specific rotation angles in dependence of the concentrations. Insert also the standard deviations. Draw a straight line of best fit. Paste the diagram into the answer sheet. ⇨ *Answer sheet*

3.7. Interpretation of the results

Tick the appropriate answers in Table 3.7 ⇨ *Answer sheet*

3.8. Determination of the substance

3.8.1 Write the value for the specific rotation angle for the solution from 3.2.
⇨ *Answer sheet*

3.8.2 Using Table 3.8 select the substance that has a rotation angle closest to your result. Tick the appropriate answers in Table 3.8a! ⇨ *Answer sheet*

Tabelle 3.8

material	**range of rotation angle [α] degree**	**studio**
fructose	85 - 120	forest, sea
glucose	42 – 62	Sea
saccharose	56 – 76	Lake
tartaric acid	5 – 15	Forest
ascorbic acid	15 - 35	forest, sea

3.9. Identification of the studio

Table 3.8 shows which kinds of materials (first column) were found in the vicinity of the different studios (third column).

Which studio can be the basis of the forgery? Insert your result! ⇨ *Answer sheet*

TASK D

1. The investigator team's conclusions

Which are possible places of origin of the faked painting? Summarize your results as a team in the table "Investigator team's summary" to help you come to a common statement in the table "Conclusion"!

1.1. Fill in "Y" (appropriate statement) or "N" (not applicable/incorrect) in the table.
⇨ *Answer sheet!*

1.2. Indicate your common statement in the table "Investigator team's conclusion" with an "X" in the relevant field!! ⇨ *Answer sheet!*

TASK E

1. Facts about....

After you finished your individual work, your team will finally have to answer some tricky questions. It might be necessary to discuss each of them.

1.1. Tick the appropriate statements in the table „Facts about…."! ⇨ *Answer sheet!*