Gymnasium Muttenz – Matura final exam Chemistry 2024 *(en)*

Classes: 4AB_B *(de)*, 4B *(de)*, 4E_B *(engl.)* **Exam duration:** 4 Hours

Examinators:

Surname: _____ First name:_____

Class: □ 4AB_B □ 4B □ 4E_B

Points: _____ Grade: _____

Dear matura students

Please read the following instructions carefully before you start solving the tasks:

- Make sure you use unambiguous, precise language. In the interest of time, avoid lengthy explanations. Use **technical terms**. Causal relationships should be recognizable as such. Abbreviations that were routinely used in class (vdW, Tb, e-, etc.) are permitted to save time, but must be comprehensible in context.

- Write legibly! Unidentifiable text will not be marked.

- Do not write with a pencil or Frixion, do not use ink eraser, eraser or Tippex - manipulated text will not be corrected. Use a ruler to **cross out incorrect answers**. If there are several answers, it must be clear which text is to be corrected.

- You will be given extra pages for sketching and trying things out, but these will not be marked. **Only the task sheets (containing the exam questions) will be marked**, remember to transfer everything that is to be corrected and assessed to the task sheets! You can always use the back of the previous page, if you run out of space, however, make sure you clearly indicate what question the extra text belongs to.

- For calculations, the **path to the solution must be traceable** and **all units must be indicated for each calculation step**. No points are awarded without a solution, missing units lead to points being deducted. Round to one decimal place.

- An error in multiple choice questions (MC) leads to a deduction of 0.5 points; however, you cannot achieve less than 0 points per task.

- Permitted aids:
o Periodic table (provided)
o Formula and table collection (provided)
o Calculator (bring your own), common reset

- The maximum achievable score is 76.5, with grade 6 already attained at a lower score.

Good Luck! ✾

Formation of ionic compounds (salts) (2.5 P)

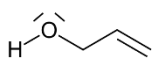
1) Which main group elements are the best «electron thieves», i.e. which main group contains the element with the highest electron affinity when compared to other elements of the same period (periods 2-5)? Give reasons with reference to the atomic structure (Bohr's atomic model, i.e. shell model) and the forces at work. **(2 P)**

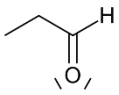
2) It is often falsely claimed that metals *want* to give up their valence electrons in order to achieve a noble gas configuration. The sign (+/-) of which physical quantity proves that this is not the case? **(0.5 P)**

Structure and Properties (4.5 P)

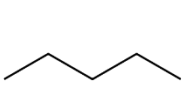
3) Melting and boiling point: Answer the questions and explain your decision with reference to atomic/ionic/molecular structure and the forces at work. Name the relevant forces (if a specific term exists).
   a) Which of these has the higher melting temperature (Tm), RbF or SrF_2 ? **(1.5 P)**

   b) Does Prop-2-en-1-ol or Propanal have a higher boiling temperature (Tb) ? **(1.5 P)**

Prop-2-en-1-ol 

Propanal 

   c) Which has the higher boiling temperature (Tb), Pentane or 2,2-Dimethylpropane? **(1.5 P)**



Pentan

2,2-Dimethylpropan

Kinetics, Thermodynamics and Equilibrium (13 P)

4) Consider the evaporation of water: $H_2O\ (l) \longrightarrow H_2O\ (g)$
   a) This process leads to an increase in entropy of the system and it is endothermic. Both can be determined without looking it up in tables. Explain in 2-3 sentences how. **(2 P)**

   b) Is the process spontaneous: yes / no / depends on conditions? Write down the relevant equation and explain your choice with reference to the signs of the variables it contains. **(2.5 P)**

5) Thermodynamics and chemical equilibrium.
   Correct the following false statement: "In exothermic reactions, the equilibrium lies on the right (on the product side)." No further explanation necessary. **(0.5 P)**

.

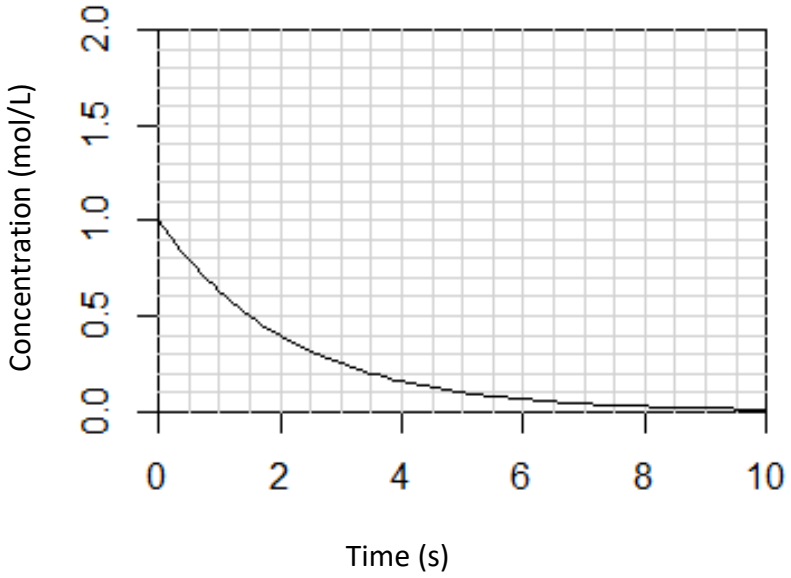
6) Diborane decomposes to monoborane

a) The diagram below shows how the concentration of diborane changes over time, assuming that the reaction runs to completion. Determine the half-life of the reaction. You do not have to show your working. **(0.5 P)**

$t_{1/2}$ = _____ s

b) Add the temporal change of the monoborane concentration $[BH_3]$ to the diagram. **(1 P)**

$B_2H_6 \rightarrow 2\ BH_3$ $\quad [B_2H_6]_0 = 1\ mol/L \quad [BH_3]_0 = 0\ mol/L$



a) Under different reaction conditions an equilibrium is established with the following equilibrium concentrations:

$B_2H_6 \rightleftarrows 2\ BH_3$ $\quad [BH_3]_{eq} = 0.5\ mol/L \quad [B_2H_6]_{eq} = 2\ mol/L$

Formulate the law of mass action for this reaction (to figure out equilibrium constant K) and calculate the value of K. **(1 P)**

K =

b) The values used in tasks a-c) are fictitious: In fact, monoborane (BH_3) is highly unstable and does not exist in detectable amounts under standard conditions. What could be the reason for this instability? One sentence is sufficient. **(0.5 P)**

7) Disturbing a chemical equilibrium
Carbon monoxide and chlorine react to form phosgene; an equilibrium state is established:

$$CO(g) + Cl_2(g) \rightleftarrows COCl_2(g) \quad , \Delta H = -108\,kJ/mol$$

a) Indicate whether the following statements are true (T) or false (F). **(3 P)**

T	F	
□	□	An increase in the concentration of CO leads to a subsequent decrease of Cl_2.
□	□	An increase in the concentration of CO leads to a subsequent decrease of $COCl_2$.
□	□	An increase in the concentration of CO leads to an increase in the value of the equilibrium constant K.
□	□	An increase in pressure leads to a subsequent decrease in the concentration of $COCl_2$.
□	□	An increase in temperature leads to a decrease in the value of the equilibrium constant K.
□	□	An increase in temperature leads to a decrease in the rate of the forward reaction.

b) Evaluate the following claim on a particle level and take a position on it: "If the concentration of Cl_2 is reduced, the forward reaction after the disturbance is slower than the reverse reaction." Why is it correct / incorrect? **(2 P)**

Protolysis reactions (11.5 P)

8) Determine the pH-value.
   a) A solution of 0.5 mol hydrogen fluoride (HF) in 2 L water. **(1 P)**

   b) A solution of 0.5 mol potassium oxide (K_2O) in 2 L water. **(1 P)**
   Hint: Start by setting up the chemical equation.

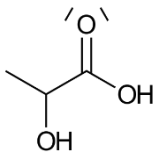
9) Kettles or coffee machines with limescale buildup (dt. Verkalkung) are cleaned with acid descaler. Formulate the reaction equation between lime (calcium carbonate) and an acidic solution. Indicate the aggregation state in each case (solid s / liquid l / gaseous g / dissolved aq). **(1 P)**

$CaCO_3$ (s)

10) Titration and Buffer
   a) What is the name of the glass tube from which the titrant (solution with known concentration) is added to the analyte (solution of unknown concentration) during a titration? **(0.5 P)**

   _____

b) We examine a descaler composed of water and lactic acid. 50 mL of descaler is taken from the bottle and diluted in an Erlenmeyer flask with deionized water to approx. 200 mL. The resulting solution in the Erlenmeyer flask is then titrated with NaOH (aq) 2 mol/L (see titration curve below).
Evaluate the titration. You must show your working, an examiner should be able to follow the steps that lead you to your answer (show not only calculations but also how you work with the diagram) **(3 P)**



Lactic acid

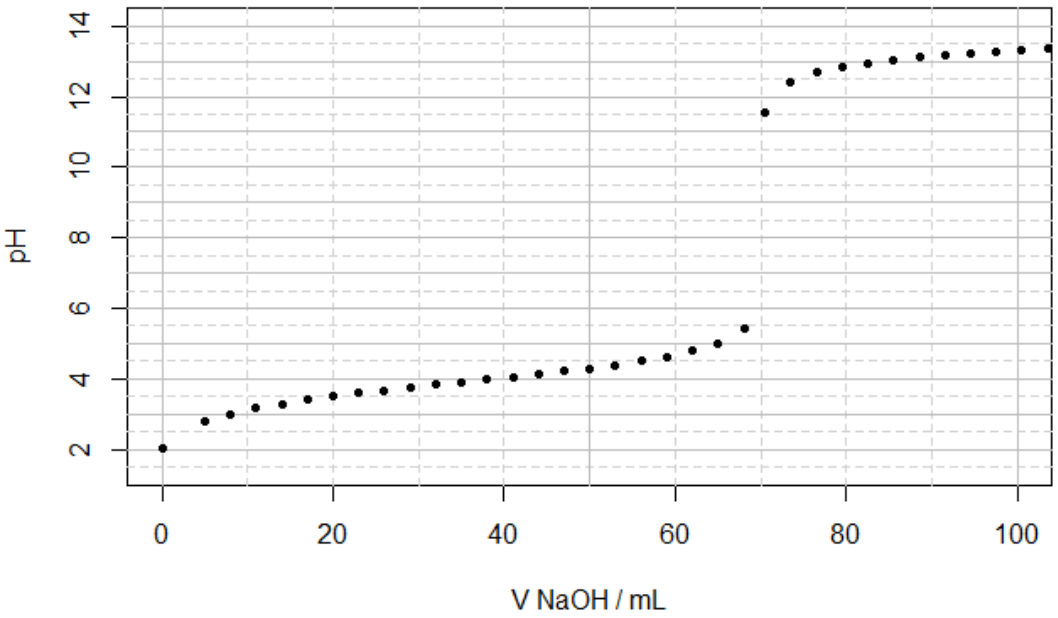
- Use the tangent method to determine the equivalence point.

  V(NaOH) at equivalence point: _____

- Calculate the concentration of lactic acid in the descaler.

- Indicate the half equivalence point in the diagram and determine pK_A of lactic acid..

  pK_A Lactic acid: _____



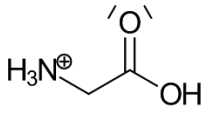
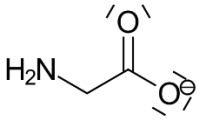
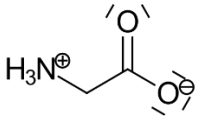
c) When titrating a weak acid with a strong base (as in b), the solution transitions through a buffer region. In what range is the buffer region of lactic acid? What does the titration curve look like in the buffer region? Give an explanation on the particle level for the shape of the curve in the buffer region. **(2 P)**

11) Strength of acidity

Which proton of lactic acid is split off more easily: that of the hydroxyl group (COH) or that of the carboxylic acid group (COOH)? Explain in 1-2 sentences and with a sketch of the relevant conjugate base. **(2 P)**

12) Amino acids

Amino acids are protonated to different degrees depending on the pH value of the solution. The amino acid glycine is shown three times below. Assign the pH values 2, 7 and 12 to the appropriate structure (1 pH value per illustration). **(1 P)**

Glycine			
pH-value of the solution			

Stoichiometry and redox reactions (6 P)

13) Synthesis of calcium phosphide:

$$Ca_3(PO_4)_2 \quad + \quad Al \quad \longrightarrow \quad Ca_3P_2 \quad + \quad Al_2O_3$$

a) Add the missing coefficients to the equation above to balance it **(1 P)**

b) Determine the oxidation numbers of all atoms in the equation above and indicate which atoms are oxidized and which are reduced. **(1.5 P)**

c) Calcium phosphide reacts with water to form toxic monophosphane and calcium hydroxide and it therefore is used in damp environments to control rodent infestations.
What mass of calcium phosphide do you need to produce 17 g of monophosphane? **(2 P)**

$$Ca_3P_2 + 6\,H_2O \longrightarrow 2\,PH_3 + 3\,Ca(OH)_2$$

d) Give an estimate, how the density of monophosphane PH_3 (g) compares to that of air. A rough comparison assuming ideal behavior is required. Indicate what your estimate is based on. **(1.5 P)**

Electrochemistry (7.5 P)

14) Iron nails often are coated in zinc to protect them from corrosion. How does this protection work? Use technical terms in your explanation.. **(1.5 P)**

15) Electrolysis

a) Name the following ionic compounds (systematic name) **(1 P)**

i) $CuBr_2$ _____

ii) $NaNO_3$ _____

b) Formulate the redox reaction of the electrolysis of potassium chloride. **(1 P)**

Electrolysis of KCl (l):

_____

16) A Volta element is assembled by dipping a zinc strip and a copper strip in an aqueous solution of sulfuric acid and connecting them via a multimeter as shown in the illustration below (A multimeter is a device that can measure soltage, current and resistance). The following reaction takes place:

$$2\,H_3O^+ + Zn \longrightarrow H_2 + H_2O + Zn^{2+}$$

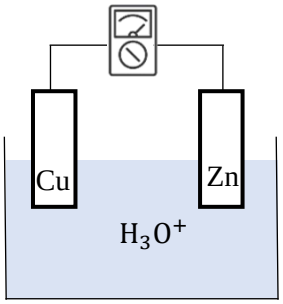
a) Identify the anode, cathode, plus and minus poles (MC, 1 cross/line): **(1 P)**

□ *Cu is the anode, Zn is the cathode* □ *Zn is the anode, Cu is the cathode*
□ *Cu is the plus pole, Zn the minus pole* □ *Zn is the plus pole, Cu the minus pole*

b) In what way do voltage and electrical current depend on the pH-value of the sulfuric acid? Check the right boxes (MC, 1 cross/line) and explain your choices. **(3 P)**
Hint: The strength of electrical current depends on the reaction rate.

The voltage is □ *higher* □ *lower,* *the lower the pH-value is.*
The current is □ *higher* □ *lower,* *the lower the pH-value is.*

Explanation:



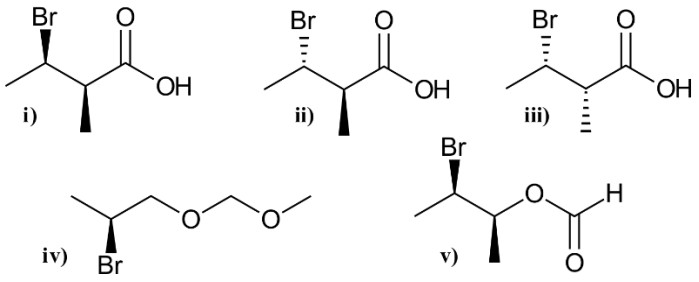
Molecular formulas and nomenclature (4 P)

17) Draw structures of the following molecules. Ensure correct bond angles and use wedge-dash formulas for each non-planar molecule/portion of a molecule. Indicate formal charges, if any are present. Also draw the non-bonding electron pairs. **(4 P)**

NOCl	$CH(NH)NH_2$
4-Propylheptane	*(S)*-3-Methylhex-1-ene

Isomerism (3 P)

18) What type of isomerism exists between the structures i-v) shown below? Indicate which pairs (e.g. i+iii) are constitutional isomers (= structural isomers), which are enantiomers, and which are diastereomers. Some pairs are not isomers. Incorrect answers are deducted. **(3 P)**



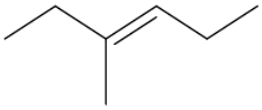
Constitutional isomers: _____

Enantiomers: _____ Diastereomers: _____

Synthesis (9.5 P)

19) Consider the reaction below

a) Draw the reaction product (skeletal formula/Lewis-formula, you can neglect stereocenters) **(1 P)**

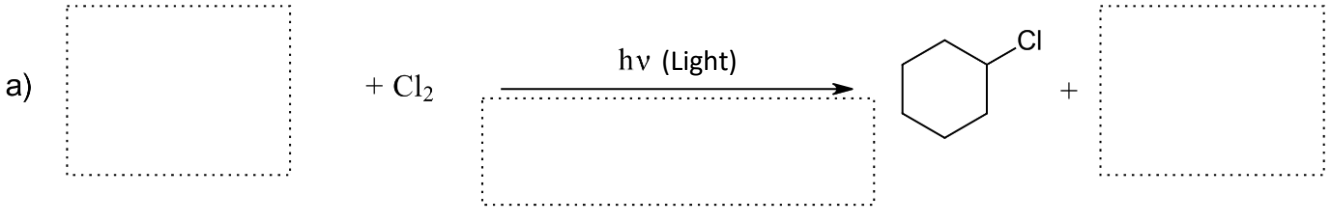


+ HBr →

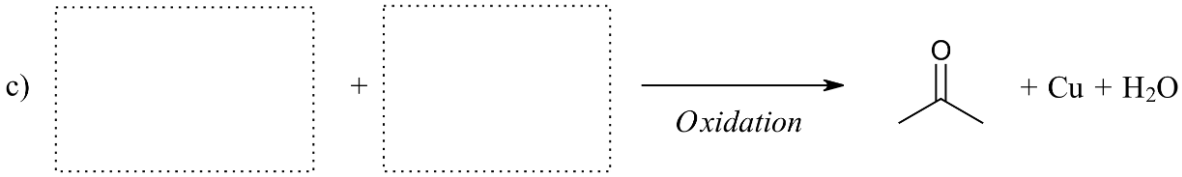
b) Draw the intermediate product (very short lived intermediate step) of the reaction in a) and explain why this particular intermediate product is formed. Use technical terms. **(2 P)**

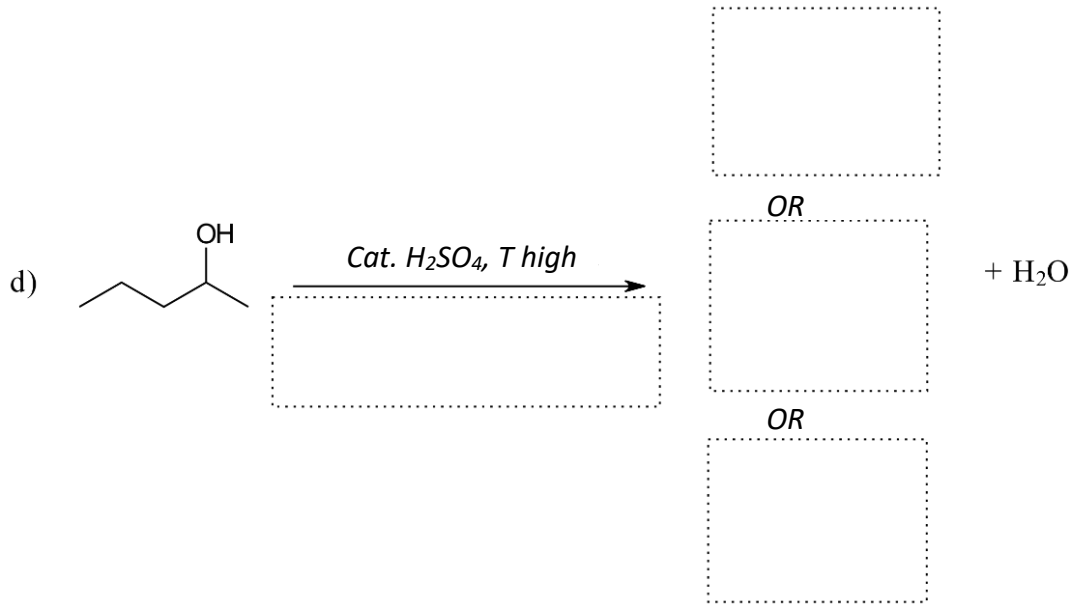
c) What is this type of reaction called? _____ **(1 P)**

d) Fill in the gaps in the following reactions with the appropriate reactants, products and reaction names. **(5.5 P)**

a) 

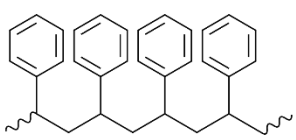
b) 

c) 

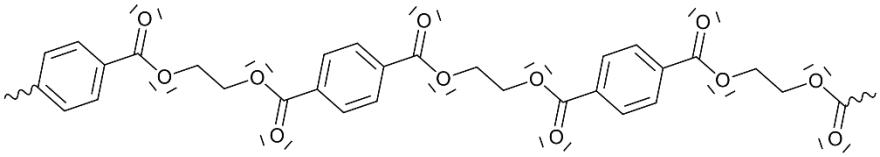
d) 

Polymers (3 P)

20) Consider the two polymers A and B below:



A



B

a) What monomers were the polymers A and B synthesized from, respectively? Draw skeletal structures. **(1.5 P)**

A	B

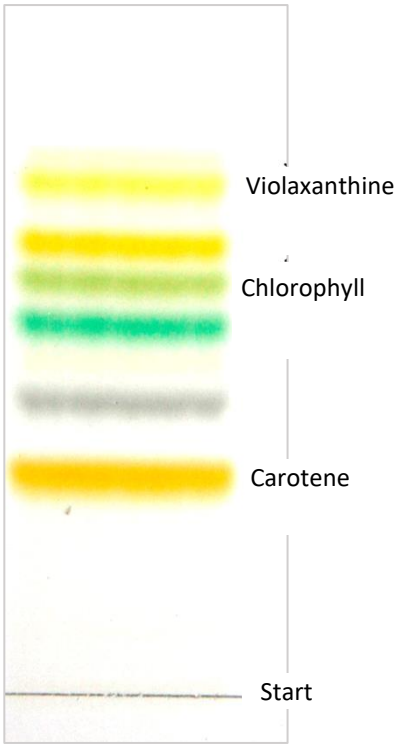
b) Specify the reaction type employed for the production of plastics A and B in each case. **(1 P)**

Polymer A	□ *Radical addition polymerization*	□ *Condensation polymerization*	□ *Cationic subtraction polymerization*
Polymer B	□ *Radical addition polymerization*	□ *Condensation polymerization*	□ *Cationic subtractionpolymerization*

c) Plastics are divided into three categories according to their mechanical and thermal behavior. Judging from the description given below, which category does PLA (polylactic acid) belong to? No further explanation necessary. **(0.5 P)**
PLA is used as a material in 3D printing: It is unwound as filament from a spool, softened in a heated nozzle and applied to the printing plate or model, where the material solidifies again upon cooling.

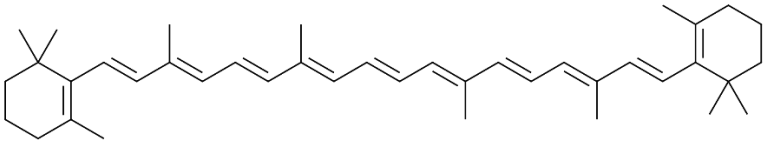
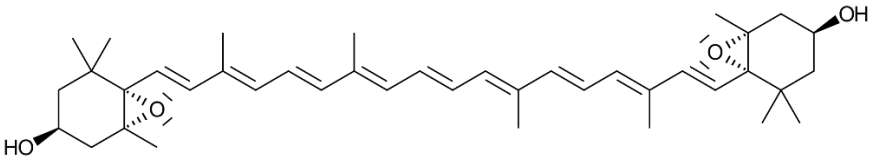
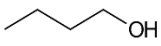
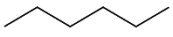
Plastic category: _____

Color, Solubility, UV-Vis-Spectroscopy (8.5 P)

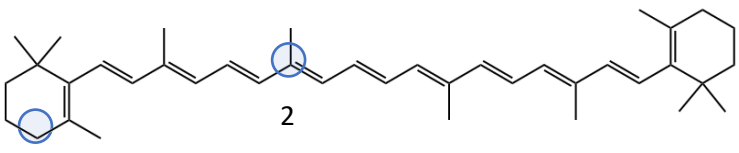


21) You prepared an extract of pigments from spinach leaves and analyzed the extract using thin layer chromatography.

a) Consider the result shown in the figure on the right and the structures of molecules shown below. Which running solvent did you use in this case: Butan-1-ol or hexane? Explain your choice of running solvent in 3-4 sentences with reference to the structures.
(2 P)

Carotene	
Violaxanthine	
Butan-1-ol 	Hexane 

b) What are the hybridizations of the carbon atoms encircled in the structure of carotene below?.
(1 P)



1: _____

2: _____

c) Arrange the following types of electromagnetic radiation in order of <u>increasing</u> energy. **(1 P)**

a. UV lights used in tanning salons (wavelength 300-400 nm)
b. Radiation from an FM radio station at a frequency of 93.1 MHz
c. Radiation from mobile phones (450-2100 MHz)
d. The red light of a LED
e. The yellow light from a streetlamp

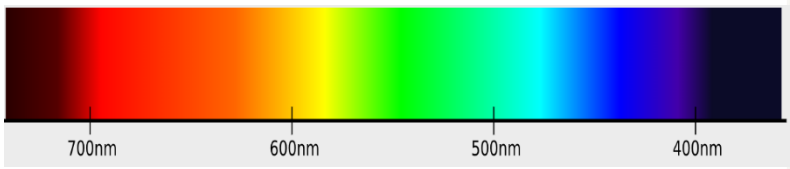
Lowest energy						Highest energy

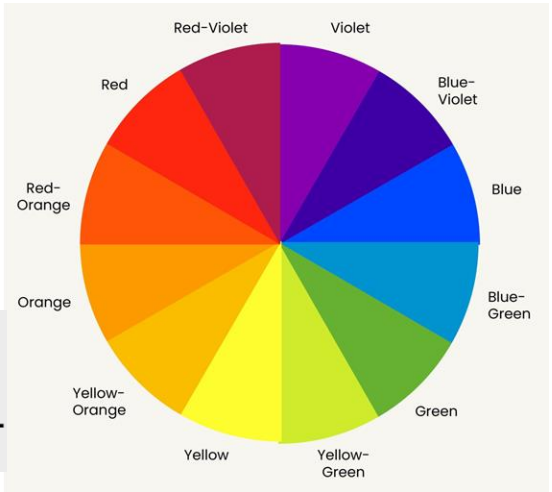
d) What explains the difference in color of carotene (orange) and violaxanthine (yellow). To answer this question, follow the approach outlined below.. **(2.5 P)**

- Identify and mark the conjugated π-systems in the structures of carotene and violaxanthin on the previous page.
- Conjugated π-systems absorb UV photons and photons of visible light. Use the color wheel below to determine which light the two substances absorb.

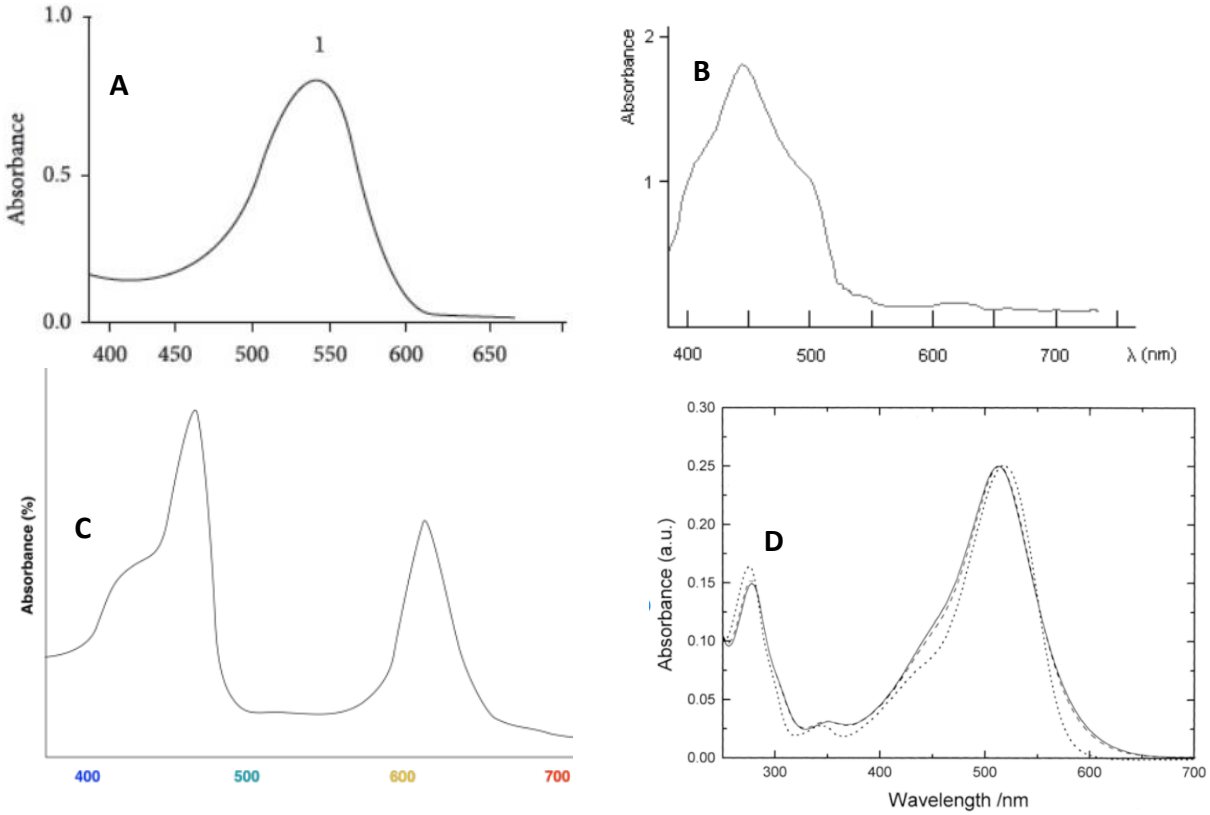
Carotin: _____ Violaxanthin: _____

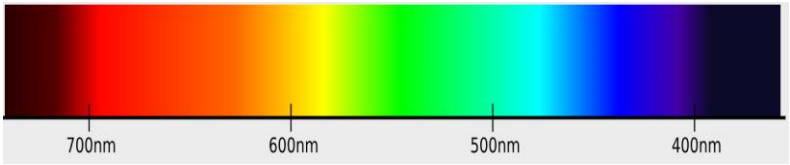
- Now answer the initial question with reference to the differing structures of the two substances.





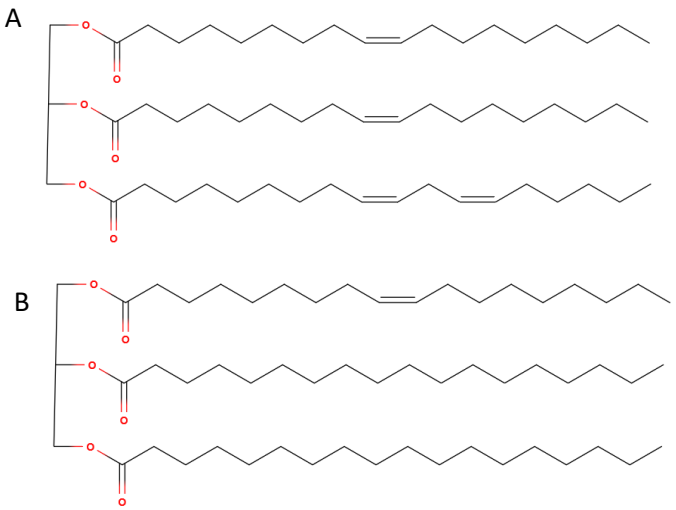
e) You isolate chlorophyll from your extract and record an absorption spectrum with a UV-Vis-spectrometer. Describe what an absorption spectrum shows in general, i.e. what do low or high points in the curve actually mean? Which of the absorption spectra below corresponds to chlorophyll? Explain your choice. **(2 P)**





Lipids (3.5 P)

22) Shown on the right are two triglycerides. A and B



a) Historically, soap is produced through a process called saponification, the alkaline hydrolysis of triglycerides. Draw the products of a reaction of the upper triglyceride (A) with NaOH. You may replace the hydrocarbon chains with the letter *R*. **(1.5 P)**

b) The two triglycerides shown above are the main components of olive oil and pig's fat (essentially bacon). Which is which? No explanation required! **(0.5 P)**

□ A Olive oil, B Pig fat □ A Pig fat, B Olive oil

c) Iodometry: A fat/oil solution is mixed with excess iodine (I_2) and allowed to react. Afterwards some starch is added and the mixture is titrated with thiosulfate solution to reduce I_2 to iodide (I^-). You are asked to perform iodometry on the triglycerides A and B shown above. So, you mix equal portions of A and B with equal amounts of iodine and proceed to titrate with thiosulfate. Which sample would you expect to subsequently require a greater volume of thiosulfate solution for complete reduction of iodine? Explain your choice in 2-3 sentences! . **(1 P)**

d) What marks the endpoint of iodometry (information given in c)? **(0.5 P)**

a. The brown-blue solution turns colorless □
b. The colorless solution turns brown-blue. □
c. The colorless solution turns pink. □
d. The pink solution turns colorless. □
e. The Erlenmayer flask explodes! □