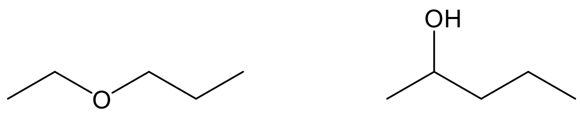
Model answers of the mock exam 2023-M&M

Question 1 (12 points)

The molecular formula $C_5H_{12}O$ belongs to a certain group of organic compounds. Two structural isomers of molecules that are described by this molecular formula are given below.



1 **2**

a) Give the names of **1** and **2** according to the IUPAC naming rules. (2 p)

1-ethoxypropane (1 p) (ethyl propyl ether = 0.5 p)
2-pentanol (or pentan-2-ol) (1 p)

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b) Are **1** and **2** chiral? Why (not)? (2 p)

1: no – no asymmetric carbon (1 p)
2: yes – it contains an asymmetric carbon center, i.e., four different substituents (1 p)

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c) Some of the physical properties of **1** and **2** are listed in the table below. Explain the differences in boiling point and solubility (in water). If you have a mixture of both, how could you separate them? (4 p)

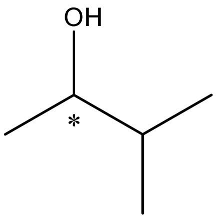
Compound	1	2
T_m (°C)	-172	-73
T_b (°C)	62	119
Density ($g\ ml^{-1}$)	0.739	0.812
Solubility in H_2O ($g\ L^{-1}$)	< 1	45

Boiling point: 2 can form H-bonds with each other, while 1 not (only weaker van der Waals interaction). Stronger interactions = higher boiling point (1.5 p).

Miscibility: 2 can form both donor and acceptor H-bond with water, while 1 can only function as an acceptor. Furthermore, 2 is more polar than 1. More interactions and higher polarity of 2 = better solubility (1.5 p).

Separation: via distillation (boiling point) or extraction (solubility) (1 p)

d) Another compound with the same molecular formula would be 3-methylbutan-2-ol. Draw its structure using the bond-line method. Indicate its chiral center(s). (2 p)



(2 p)

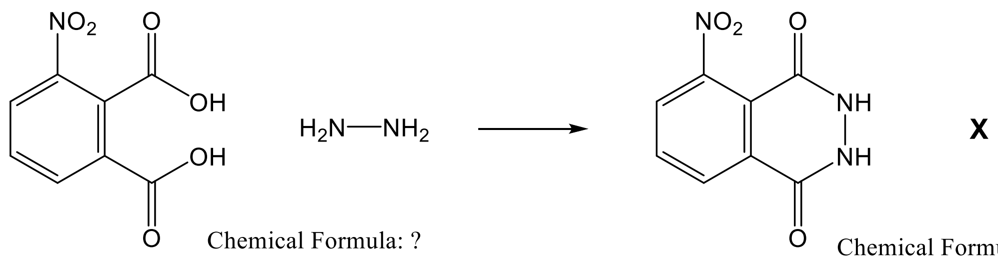
e) Give the structures of two more constitutional isomers. (2 p)

Molecular formula $C_5H_{12}O$ gives many possibilities. For example: 1-pentanol (1 p), 3-pentanol (1 p), 2-methylbutan-2-ol, methoxybutane, etc.

Question 2 (12 points)

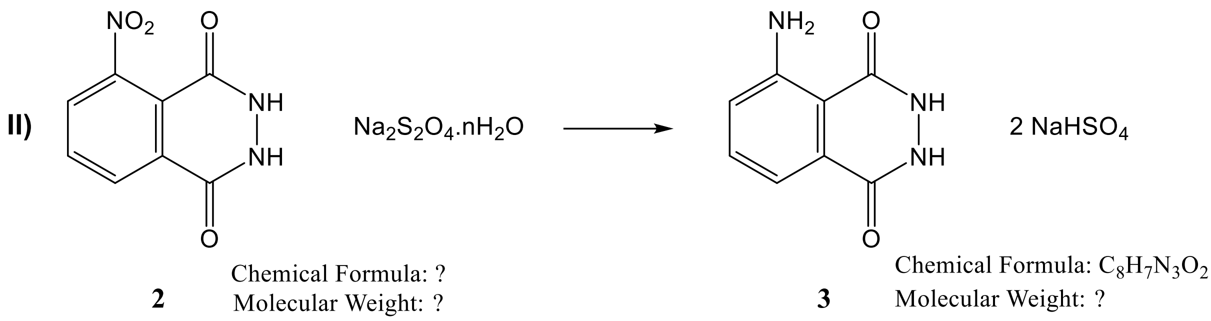
Luminol is a chemiluminescent compound, meaning that it emits blue light when undergoing a specific chemical reaction, in this case an oxidation. You may have encountered it in crime series, where the investigator sprays a solution of both luminol and oxidant in the area of interest. The iron that is present in blood catalyzes the oxidation. Luminol (compound **3**) can be synthesized via a two-step reaction, starting from 3-nitrophthalic acid (compound **1**). The product of reaction I (compound **2**) is subsequently treated with sodium dithionite ($Na_2S_2O_4$) to finally give luminol. For some of these compounds the molecular weights and/or chemical formulas are already given.

I)



1 Chemical Formula: ? Molecular Weight: 211.13 g mol^{-1}

2 Chemical Formula: ? Molecular Weight: ?



a) For reaction I, give the atomic composition of compound “**X**” (2 p)

Before: $C_8H_9O_6N_3$ (total)
After: $C_8H_5O_4N_3$ + X
Difference: X = H_4O_2 (1 p) = 2 H_2O (1 p)

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b) In reaction II, sodium dithionite ($Na_2S_2O_4$) is used as a so-called hydrate, meaning that the salt contains *n* molecules of water. Determine the value of “*n*”. (2 p)

Before: $C_8H_5O_4N_3$ + $Na_2S_2O_4.nH_2O$ = $C_8H_5O_8N_3Na_2$ + n H_2O (0.5 p)
After: $C_8H_7O_2N_3$ + 2 $NaHSO_4$ = $C_8H_9O_{10}N_3Na_2$ (0.5 p)
Difference: H_4O_2 = 2 H_2O. n = 2. (1 p)

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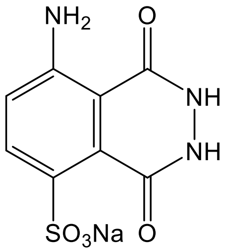
c) Starting with 5.62 g of 3-nitrophthalic acid (**1**), how much luminol (**3**) (in g) can be obtained at 100% conversion? (4 p)

1: 5.62 g = 0.0266 mol (1 p)
3: 0.0266 mol at 100% conversion (1 p)
3: $C_8H_7N_3O_2$ = 177.17 g mol^{-1} (1 p)
So in total 0.0266 * 177.17 = 4.72 g (1 p)

It turns out that reaction II is incomplete (starting from 7.30 g of **2**), and furthermore, an undesired side-product is formed (compound **4**). The reaction mixture consists of 1.23 g **2**, 3.50 g **3** and 2.67 g **4**.



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Chemical Formula: $C_8H_6N_3NaO_5S$
Molecular Weight: 279.20 g mol^{-1}

d) Calculate the conversion of **2**. (4 p)

2: $C_8H_5O_4N_3$ = 207.15 g mol^{-1} (0.5 p)
Before reaction: 7.30 g of 2 = 0.0352 mol (0.5 p)

After reaction: 1.23 g of 2 (0.00594 mol), 3.50 g of 3 (0.0198 mol) and 2.67 g of 4 (0.00956 mol). Convert everything to moles. (1 p)

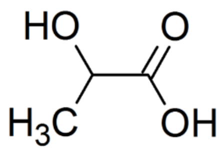
Conversion = [amount of 2 reacted] / [initial amount of 2] * 100% = (3 + 4) / $[2]_0$ * 100% (1 p)
Or: X = ($[2]_0$ – 2) / $[2]_0$ * 100 %

X = (0.0198 + 0.00956) / (0.0352) * 100% = 83% (1 p)

Short method (mass): X = m_t / m_{t0} = (7.3 – 1.23) / 7.3 = 83%)

Question 3

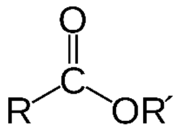
Polylactic acid is made by polymerizing the monomer lactic acid. During this reaction a carboxylic acid group reacts with an alcohol group.



(a) What is the name of the bond that is formed upon reaction of a carboxylic acid and an alcohol?

ester

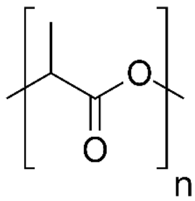
(b) Draw the general structure of this bond.



(c) Which class of polymerizations does this polymerization fall into?

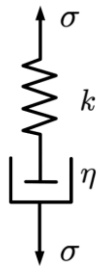
polycondensation

(d) Draw the molecular structure of polylactic acid.



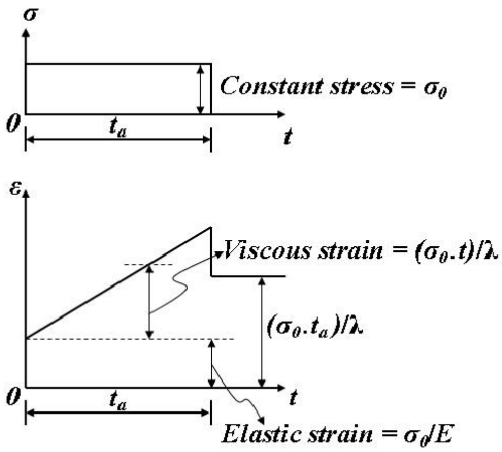
Question 4

Viscoelasticity of polymers can be modelled with springs and dashpots. In this question we assume the polymer to behave according to the model shown below; a purely viscous damper (with viscosity η) and a purely elastic spring (with spring constant k) connected in series. At t = 0 we apply a constant stress (σ) to the polymer. This stress is removed at t = 100s.



(a) Draw the stress as a function of time from t = 0 till t = 100s.

(b) Draw the strain as a function of time from t = 0 till t = 100s.



Question 5

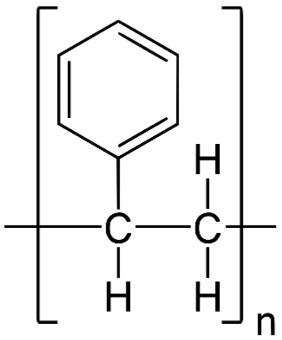
You are given two plastic cups and asked to hit it with a hammer.

(a) Which one is more likely to shatter, a glass made from polystyrene or a polypropylene glass? Explain why.

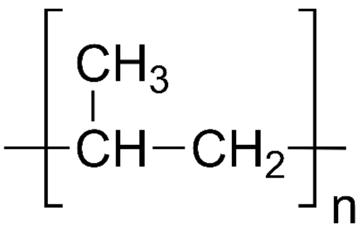
Polystyrene, because it is in its glassy state (below Tg).

(b) Draw the molecular structure of polystyrene and polypropylene.

Polystyrene:



Polypropylene:



Question 6

1. There are five types of nitrogenous bases, four of which are found in the DNA molecule. These are:

A. Adenine, thymine, guanine, uracil
B. Adenine, uracil, guanine, cytosine
C. Adenine, thymine, cytosine, guanine
D. Adenine, uracil, phosphate , ribose

2. How many carbons are present in the diterpene farnasene?

A. 10
B. 5
C. 15
D. 12

3. The alpha-helical structure of a protein is stabilized mainly by …?

A. Hydrogen bonds
B. Disulphide bonds
C. Glycosidic bonds
D. None of these

4. A membrane lipids contains …. fatty acid side chains.

A. 1
B. 2
C. 3
D. None

5. The melting point of a fat with many unsaturated fatty acids is ……. than/to a fat with only saturated fatty acids.

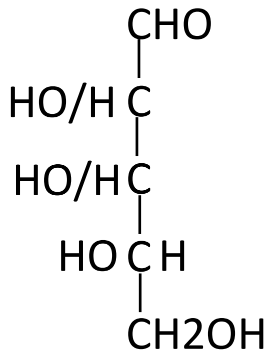
A. Higher
B. Lower
C. Equal
D. Similar

6. What is the correct order, going from high to low bond strength?

A. C-C covalent bond > hydrogen bond > ionic interaction
B. Ionic interaction > C-C covalent bond > hydrogen bond
C. Ionic interaction > hydrogen bond > C-C covalent bond
D. Hydrogen bond > Ionic interaction > C-C covalent bond

Question 7

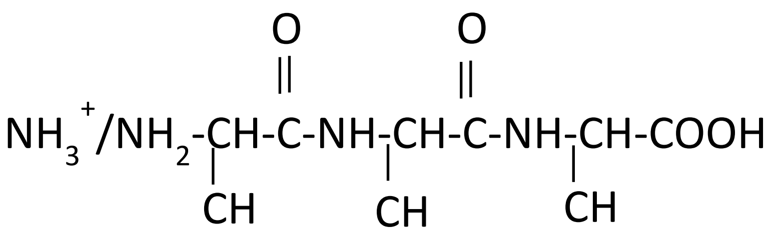
Please draw the Fisher structure of
A. the L-isomer of a C5 aldehyde sugar



B. the C3 epimer of the same sugar. OH on C3 on other side as in 1A.

Question 8

the tripeptide of alanine.



Question 9

Model answers:

a) Plastic deformation implies that crystal planes will be sliding with respect to each other. This sliding of crystal planes occurs via movement of dislocations.

b) When a pure metal is alloyed (with e.g. another metal), then the yield strength always increases, because the alloying elements will make the movement of dislocations more difficult and thus increases the stress level at which dislocations start to glide and thus increases the yield strength. Although pure Cu has a lower yield strength than pure Ni, still adding Cu atoms to nickel will initially (certainly for 5 at.%) increase the yield strength compared to the one of pure nickel.

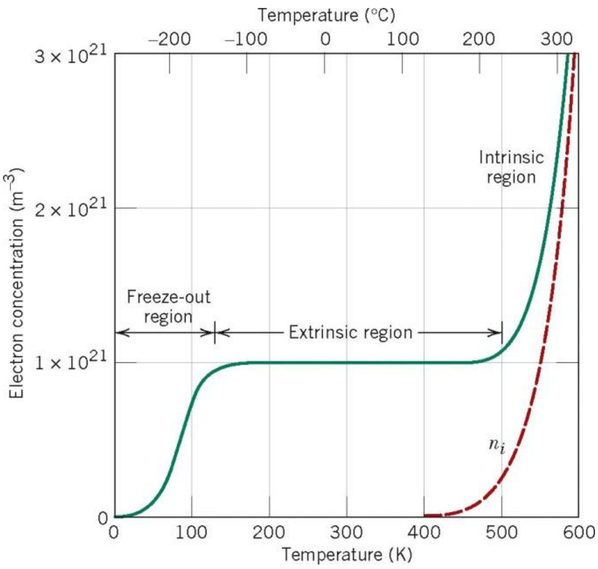
c) At the corners of rectangular windows high stress concentrations would occur and then cracks can easily develop from these corners even when the nominal load is rather low. For round windows the stress can be nicely distributed and no stress concentrations occur and this is much more safe.

Question 10

Model answers:

a) For p-type doping we need elements with 1 electron less than Si in the valence band, i.e. from column III of the period table, i.e. B, Al, Ga, In.

b) See graph on the right which holds for n type semiconductor. For p-type the vertical axis does not hold for (free) electrons, but for holes. The conductivity is directly proportional to the concentration of free charge carriers. Therefore, the behavior seen in this graph also dominates the temperature dependence of the conductivity. (The conductivity is also directly proportional to the mobility of the free charge carriers which is extremely high at low temperature and continuously decreases at higher temperatures. However, this has a much weaker effect on the overall conductivity than the concentration of free charge carriers.)



c) The bandgap of semiconductors is of similar energy as that provided by light (photons). Therefore, shining light on a semiconductor electrons can be excited from the valence band to the conduction band and generates free charge carriers, both free electrons and holes, that can conduct electricity. Hence, the resistivity of the semiconductor reduces.

Question 11

Model answer:

(1) In case of bending the optimum shape is the I profile or rectangular hollow section where the height (in y direction) is larger than the width (in x-direction); see figure on the right. (This is the optimum shape, because most material is as far as possible from the bending plane parallel to the x-axis.)

(2) In case of torsion, which is the same as twisting, the optimum shape is a hollow circular cross section; see figure on the right. (This is the optimum shape, because most material is as far as possible from the point of rotation around which torsion/twisting occurs.)