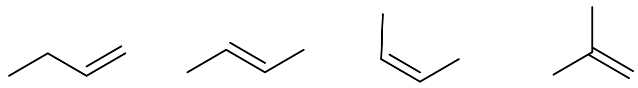
Practice exam questions M&M

P. J. Deuss

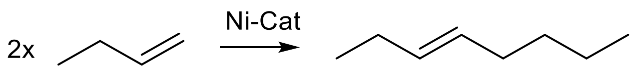
1. Oil refineries produce a fraction that consists of a mixture of butenes shown below together with their boiling points (bp), melting points (mp), water solubility (W_{sol}) and density as a liquid (d_{liquid}).



	A	B	C	D
bp	266.9 K	274.0 K	286.9 K	266.3 K
mp	87.8 K	167.7 K	134.3 K	132.9 K
W_{sol}	insoluble	insoluble	insoluble	insoluble
d_{liquid}	0.62 g/cm^3	0.63 g/cm^3	0.64 g/cm^3	0.59 g/cm^3

a. Name all four components **A-D** of this mixture
b. Indicate what type of isomers components **A**-**D** are.
c. Which of components **A**-**D** is the most stable (the inverse of reactivity of the double bond)
d. Explain the boiling point difference between component **B** and **C** and give a reason why this could is different in the melting point.

The butenes are commonly dimerized to produce plasticizers. An example reaction is shown below. For this reaction the whole mixtures is used to obtain a new mixture that is use for further reactions



During the dimerization reaction, the location of the double bond is also varied by an ongoing secondary isomerization reaction.

e. Provide an additional 10 products (draw the structures) and name them (do not worry about selectivity or stability of the products just make sure the product can be formed by dimerization followed by isomerization).

f. Give 2 reasons why this is a favorable reaction for industry even though a complex mixture of products is obtained (look at feedstock and the products).
g. Use the provided physical properties to explain why butenes are used as a mixture and not as separate components.

h. Why are the products from the dimerization of component **D** more desirable for application as fuel additive after conversion of the alkene to an alkane (hydrogenation) compared to those originating from component **A** by dimerization and subsequent hydrogenation?

Bart Kooi

Exercise 1: Mechanical properties of materials (8 pt)

a. A brass (Cu-Zn alloy) bar, with a diameter of 20 mm, is loaded parallel along its long axis. The diameter of the bar changes 5 μm as a consequence of the loading. Compute the value of the load (in kilograms) that has been put on the bar. Assume that the bar is loaded completely elastic. However, check after the calculation whether this assumption was justified. The yield strength of the brass is 75 MPa, its Young's modulus 97 GPa, its Poisson's ratio 0.34. (4 pt)
b. Describe 2 methods by which a metal (material) can be strengthened. Explain concisely why strengthening occurs. A certain type of defects plays a crucial role. What is the name of these defects; describe their role. (4 pt)

Exercise 2: Electrical properties of materials (10 pt)

Pure copper has at 20 ^{0}C a conductivity of 6.0 10^7 $(\Omega m)^{-1}$. Pure silver has 6.8 10^7 $(\Omega m)^{-1}$.

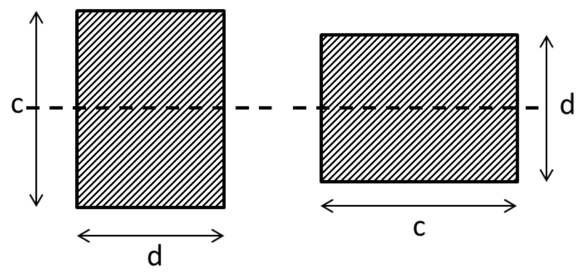
a. Approximately determine the value for the conductivity of Cu at 170 ^{0}C. Explain why the change in conductivity occurs with temperature change. (3 pt)
b. The Cu is alloyed with 2 at.% Ag. Does the conductivity of the alloy becomes worse or better than the one of pure Cu? Explain your answer. (2 pt)
c. Intrinsic GaAs has at room temperature a conductivity of 10^{-6} $(\Omega m)^{-1}$. The mobility of the electrons and the holes is 0.88 and 0.04 $m^2/(Vs)$, respectively. The unit charge e = 0.16 10^{-18} C, Avogadro's number N_{Av} = 6 10^{23} $(mole)^{-1}$ and Boltzmann's constant k = 8.617 10^{-5} eV/K. What is the number of conduction electrons and what is the number of holes at room temperature? (3 pt)
d. Does the conductivity of an intrinsic semiconductor increase or decrease when the temperature is increased? Motivate your answer. (2 pt)

Exercise 3: Materials selection and design (8 pt)

In the figure below a so-called 'Ashby map' is shown, in which the stiffness (Young's modulus E) is plotted versus the density (ρ) for a large number of materials (classes). We want to design an axis of a turbine with a minimum weight. When the axis is loaded in torsion and the design has to be sufficiently stiff, materials with the highest possible value for $E^{0.5}/\rho$ are most suitable. When the axis is loaded in tension, materials with the highest possible value for E/ρ are most suitable. We can choose between aluminum alloys, titanium alloys and steel.

a. How do the performances of the 3 materials compare for torsional loading? Motivate your answer. (2 pt)
b. How do the performances of the 3 materials compare for tensile loading? Motivate your answer. (2 pt)

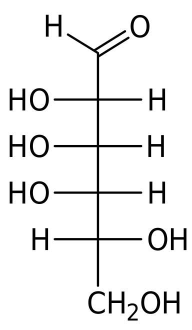
c. The shape factor for bending is defined as $\phi_B^e = 4\pi I_{xx}/A^2$ with $I_{xx} = \int y^2 dA$ with y the distance to the bending axis and A the cross-sectional area. We have two rectangular cross-sections with the same area as shown on the right, where in both cases the bending axis is oriented horizontal as indicated by the dashed line. Calculate (in terms of dimensions c and d) for both shapes first the second moment of area I_{xx} (in principle you can do this with one calculation) and then the shape factors. Which one of the two has a larger shape factor and is thus more efficient? (4 pt)



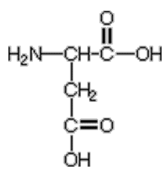
Edita Jurak

1) **Starch and cellulose are two of the main polysaccharides used in various industrial application**
a) **Which are the single unit building blocks of starch and cellulose**
b) **Draw the Fisher projection of the building blocks of starch and cellulose**
c) **What chemical bond is binding the building blocks (please name all the bonds in the corresponding biomasses with full chemical names)**
d) **Describe in detail the 3 step industrial process of converting semicrystaline starch to glucose syrup (think of the original structure, bonds in the structure, enzymes, temperature…)**
e) **By degrading starch and cellulose, fermentable sugars are obtained. Give a definition of fermentable sugars**
f) **Provide two examples of fermentable sugars**
g) **Please draw the Haworth projections (=ring structure) of the alpha D-talose and it's C3 epimer alpha D-idose**

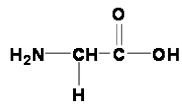
D-talose



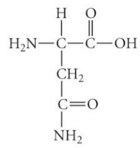
2) **Please connect the following amino acids by peptide bond in correct order: polar-hydrophobic-charged.**



Aspartic acid



Glycine



Serine

3) **Please give a definition of an enzyme and describe how an enzyme works**

4) **Which of the following words/terms go instead of the numbers in bold?**

Vmax, substrate, cofactor, amount, protein, enzyme, Michaelis-Menten kinetics, Km, inhibitor, Vo

The rate of **1** catalysed reaction depends on the **2** of enzyme and the amount of the **3** available. **4** a measure of the affinity of an enzyme for its substrate, and is a parameter unique to each enzyme. With the substrate concentration **5** increases, until enzyme becomes saturated with substrate and reaches **6.**

3. **Encoded sequences.**

a) Write the sequence of the mRNA molecule synthesized from a DNA template strand having the following sequence:

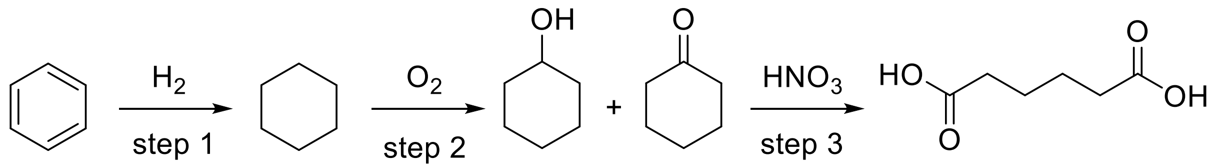
5'-ATCGTACCGTTA-3'

b) What amino acid sequence is encoded by the following base sequence of an mRNA molecule? Assume that the reading frame starts at the 5'end.

5'-UUGCCUAGUGAUUGGAUG-3'

c) What is the sequence of the polypeptide formed on addition of poly(UUAC) to a cell-free protein-synthesizing system?

2. Product **E** is one of the main components of Nylon and is produced from **A** via the steps shown below.



A **B** **C** **D** **E**

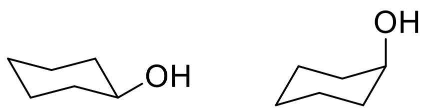
a. Match the following name with the right compound **A**-**E**: cyclohexanol, hexanedioic acid, cyclohexane, benzene, cyclohexanone.

b. In step 1 is exothermic. However, less energy is released then expected compared to the energy released by the hydrogenation (addition of H_2) of three molecules of ethylene. Why is this?

c. Assuming that step 2 gives a 1 : 1 mixture of **C** and **D** and water is released as a side product, rewrite the reaction equation and balance it. What will change in the equation when the reaction is selective for **C**?

d. Step 1 and 2 do not happen spontaneously and simply heating the reaction till a reaction takes place will lead to many side reactions. What is required to have these reaction happen selectively to the desired product.

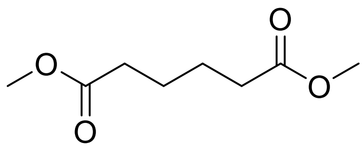
Below, two forms of compound **C** are provided.



form A form B

e. What are these two forms of each other and which of the two is more stable? Explain.

f. Use the Lewis structure of compound **E** and the type of interactions this allows to explain why this compound is water soluble and the compound shown below is not.

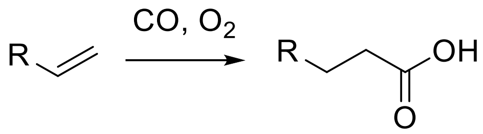


g. To form Nylon from acidic compound **E** an acid additive is required that is a stronger acid. Provide the name and chemical formula of such an acid that is largely available and cheap.

Step 3 is not very selective and generates a lot of side products in the form of nitrate (NO_3^-) and nitrite salts (NO_2^-).

h. Draw the resonance contributors for both the nitrate and nitrite anion as well as the final resonance hybrid.

A more direct route to compound **C** would be via oxidative carbonylation of an alkene (reaction scheme shown below).



i. Balance the reaction equation for R = H (ethylene) and provide atom economy.

j. Provide the E-factor for R = H (ethylene) given that for every 1000 Kg of product 50 Kg of side products are generated. Is that suitable for industrial implementation of the process for this bulk chemical?

k. What oil-derived starting compound that is obtained as a major product steam cracker would be the ideal starting material for a direct route to compound **C**? Draw and name.