KU LEUVEN

Basics of biological chemistry

# Assignment

January 2015 Finals

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# Contents

# 1 Questions from Prof. J. Vanderleyden – dr. H. Steenackers

## 1.1 Chemical reaction equation

Consider the following reaction: $(NH_4)_2CO_3 + Zn(NO_3)_2 \rightarrow NH_4NO_3 + ZnCO_3$

### a.) Balance the equation

$(NH_4)_2CO_3 + Zn(NO_3)_2 \rightarrow 2\ NH_4NO_3 + ZnCO_3$

### b.) Reactants and products

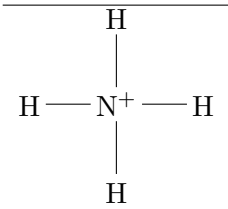
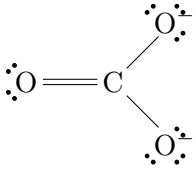
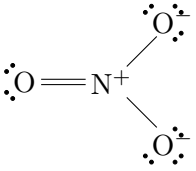
`Q:` Name all reactants and reaction products.
`A:`

- $(NH_4)_2CO_3$ : Ammonium carbonate
- $Zn(NO_3)_2$ : Zinc nitrate
- $NH_4NO_3$ : Ammonium nitrate
- $ZnCO_3$ : Zinc carbonate

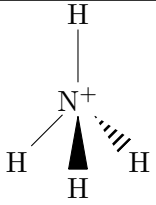
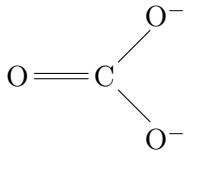
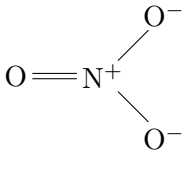
### c.) Lewis structure, VESPR

`Q:` Construct the Lewis structures of the polyatomic ions you recognize and predict their molecular structure using the VSEPR theory.
`A:`

- Lewis Structure of the ions:

| Ammonium | Carbonate | Zinc | Nitrate |
|---|---|---|---|
|  |  | $Zn^{2+}$ |  |

- Molecular structure prediction:

| Ammonium | Carbonate | Zinc | Nitrate |
|---|---|---|---|
|  |  | $Zn^{2+}$ |  |

### d.) Oxidation states

`Q:` Determine the oxidation state of all the atoms in all the compounds. Is this an oxidation-reduction reaction?
`A:` Ammonium Carbonate and Zinc Nitrate (the reactants) are very soluble in water and will thus move freely. The Zinc and Carbonate ions will then precipitate.

- Zn has an oxidation state of 2: $Zn \rightarrow Zn^{2+} + 2\ e^-$
- $(CO_3)$ has an oxidation state of 4: $(CO_3)^{2-} + 2\ e^- \rightarrow CO_3$

### e.) Mass

`Q:` How many grams of ZnCO3 can be prepared from 400g Zn(NO3)2 by using sufficient(NH4)2CO3?
`A:` Let's start by computing the molecular weight of the 2 reactants:

**Molecular weigth of $\mathbf{Zn(NO_3)_2}$** 189.36 g/mol

**Molecular weigth of $\mathbf{(NH_4)_2CO_3}$** 96.09 g/mol

Given that there are 400g of $Zn(NO_3)_2$, we can calculate the number of moles of reactant (and ignore that of $(NH_4)_2CO_3$ since it is in excess):

**Moles of $\mathbf{Zn(NO_3)_2}$** 400 g / 189.36 g/mol = 2.11237 moles

From this last figure, we can infer that the number of moles of $ZnCO_3$ will be 2.11237. Given the molecular mass of $ZnCO_3$, we can compute the amount of $ZnCO_3$ produced to be: 2.11237 mol * 125.3889 g/mol = 264.8678 g.

## 1.2 DNA sequence analysis

The following diagram shows part of a template DNA strand, with sections X,Y and Z being the exons of a gene:

```
5'                        3'
GTA GGT TGT ATC GAT GGT CAT
---     -------         ---
 X         Y             Z
```

### a.) DNA Replication

`Q:` What is the corresponding sequence on the new daughter strand made from the given parent strand during replication?
`A:` Given the principle of base pairing, we can determine the daughter sequence to be (here in the 3' to 5' direction):

```
5'                        3'
GTA GGT TGT ATC GAT GGT CAT
CAT CCA ACA TAG CTA CCA GTA
3'                        5'
```

### b.) Translated Protein

`Q:` What polypeptide sequence will be synthesized from the given template DNA? Give a short overview of the different processes (and enzymes) involved in the synthesis of polypeptides from template DNA. Where in the cell do these processes take place?
`A:` The synthesized polypeptide will consist of the amino acids `Val-Cys-Ile-His`. Since it is mentioned that exons are present, we can assume the translation will take place with the eukaryotic machinery. It will consist of the following stages:

- Transcription: In the nucleus, the RNA Polymerase II will be recruited and will bind to the promoter of the gene. It will produce, by moving in the 5' to 3' direction, a pre messenger RNA which will be identical to the DNA template sequence (with the exception that Uracyl will be used instead of Thymine, and also the addition of a 5' CAP). That messenger RNA will then be processed by the spliceosome, which will remove the introns, and a Poly-A tail will also be added at the 3' end of the mRNA. The mRNA is then ready to go outside of the nucleus to be translated.
- Translation: the mRNA leaves the nucleus and passes through the reticulated ER where it will be captured by a ribosome that will either bind to the ER or not. It will then start scanning for a start codon in the mRNA. From that point on, the synthesis of a polypeptide will be accomplished by reading 3 base pairs at a time and pairing these 3 with the correct tRNA. After that, the polypeptide will either be processed further and sent to the golgi apparatus, or will remain in the cytosol.

### c.) Mutated exon

`Q:` What polypeptide sequence will be synthesized if the ATC in exon Y is mutated to TTC? What polypeptide sequence will be synthesized if the ATC in exon Y is mutated to ATG? Which of those substitution mutations is likely to be more harmful? Why?
`A:` Here are the new sequences with mutated exons:

- TGTATC -> TGTTTC : the resulting polypeptide will be `Val-Phe-His`
- -> ATG : the resulting polypeptide will be `Val-Met-His`

The second

### d.) Interactions with antibiotics

`Q:` Which steps in polypeptide synthesis are affected by resp. the macrolide antibiotics and the tetracycline antibiotics?
`A:`

### e.) Comparison of error rates

`Q:` The error rate in RNA synthesis is much higher than the error rate of DNA replication. What is the origin of this difference? Motivate why this is not a serious problem.
`A:`

### 1.3 tRNA 3D-Structure

Q: All tRNA molecules have a particular 3D-structure. Which functional groups and which chemical bonds/interactions contribute to this particular structure? Why is this particular structure of importance for the biological function?
A:

## 2 Questions from Prof. B. Sels

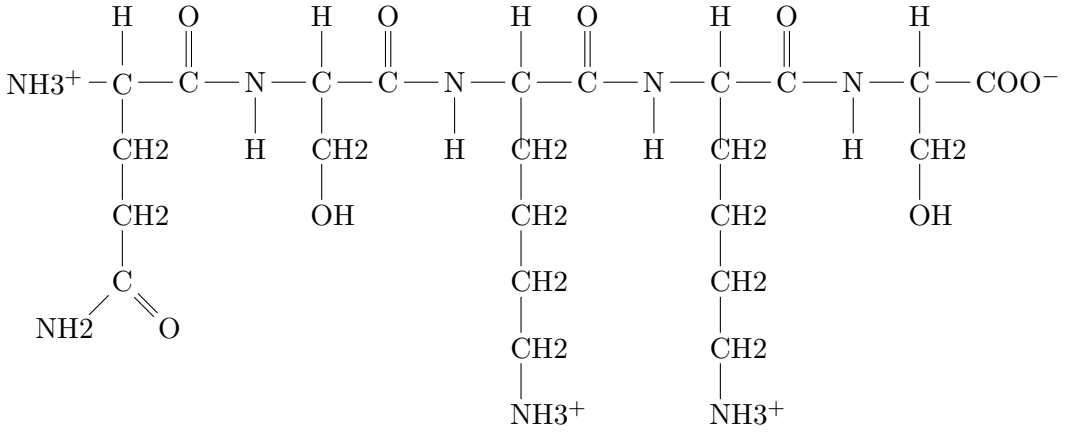
### 2.1 Biopolymer organisation

Q: The course and the textbook systematically organize four important biopolymers mainly according to their chemical structure. Attempt a complete reorganization of the various biopolymer structures (and subfamilies!) according to the following three physiological functions: energy, structure, and communication. Explain the physiological function of each biopolymer type with regard to its chemical structure and/or physical properties.
A:

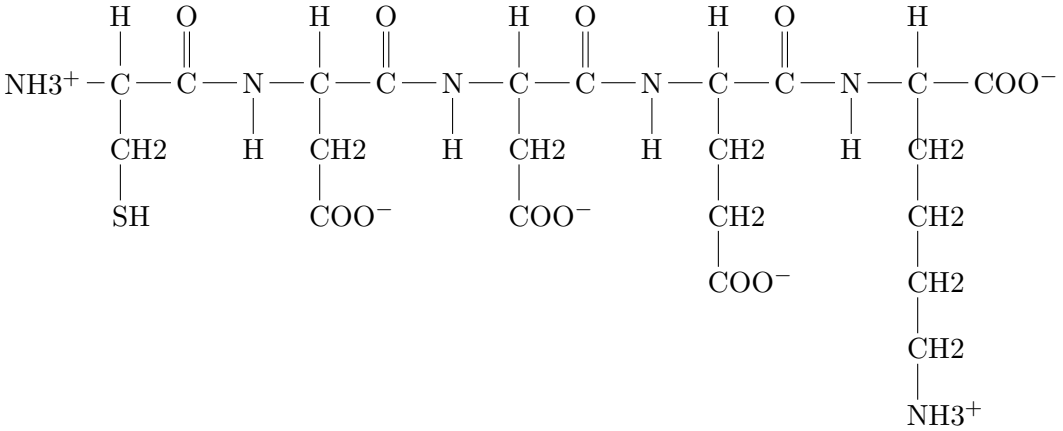
### 2.2 Chemical structure of proteins and proteins separation

Q: Draw the chemical structure of the following two oligopeptide structures, a) Gln-Ser-Lys-Lys-Ser and b) Cys-Asp-Asp-Glu-Lys, determine its net charge in physiological conditions. How would you separate the two peptides ?
A: These are the chemical structures of:

- Gln-Ser-Lys-Lys-Ser




- Cys-Asp-Asp-Glu-Lys



Under physiological conditions (ie, pH around 7.35), these would be the net charge on each polypeptide:

- Gln-Ser-Lys-Lys-Ser: net charge is +2
  $\overset{\oplus}{\text{NH3}}-\text{Gln}-\text{Ser}-\overset{\oplus}{\text{Lys}}-\overset{\oplus}{\text{Lys}}-\text{Ser}-\overset{\ominus}{\text{COO}}$
- Cys-Asp-Asp-Glu-Lys: net charge is -2
  $\overset{\oplus}{\text{NH3}}-\text{Cys}-\overset{\ominus}{\text{Asp}}-\overset{\ominus}{\text{Asp}}-\overset{\ominus}{\text{Glu}}-\overset{\oplus}{\text{Ly}}-\overset{\ominus}{\text{COO}}$

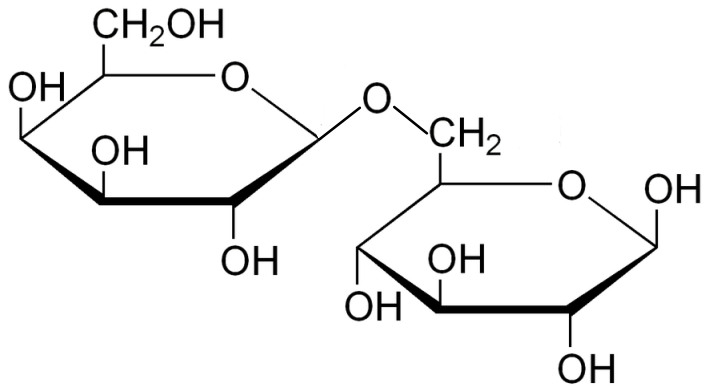
Separation of both proteins can thus be achieved by ion exchange chromatography since they both have a distinct charge.

### 2.3 Chemical structure of disaccharides

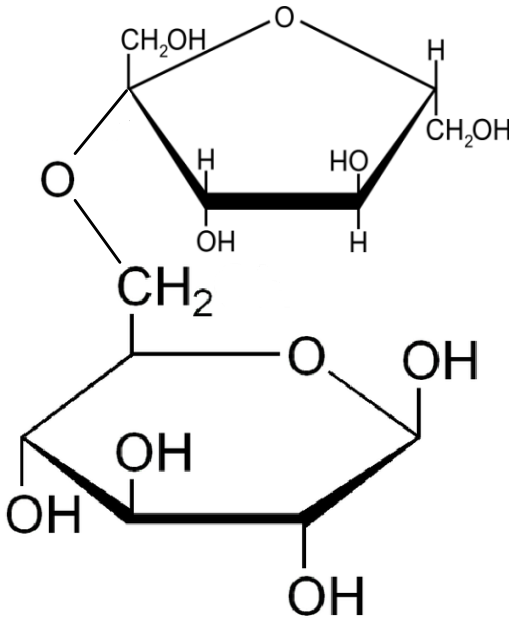
`Q:` Draw the chemical structure of the following disaccharides: a) the $\beta$-anomer of $\alpha(1\rightarrow6)$galactoglucose and b) $\beta$,$\alpha(1\rightarrow2)$glucofructose.
`A:` These are the chemical structure of:

- $\beta$-anomer of $\alpha(1\rightarrow6)$galactoglucose

Beta anomers have a cis relationship between the $CH_2OH$ group on the $C_1$ and the OH group on the $C_6$. This helps us determine the structure of the monosaccharides galactose and glucose. The polymerisation is achieved through an $\alpha$ binding between the $C_6$ of the Galactose, and the $C_1$ of the glucose molecule, giving the following molecular structure:

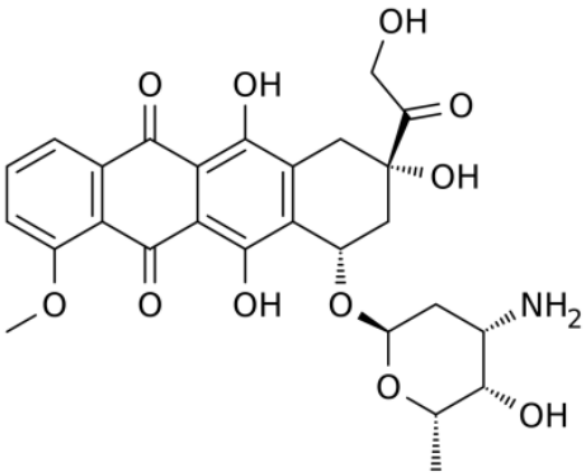



- $\beta$,$\alpha$(1→2)glucofructose



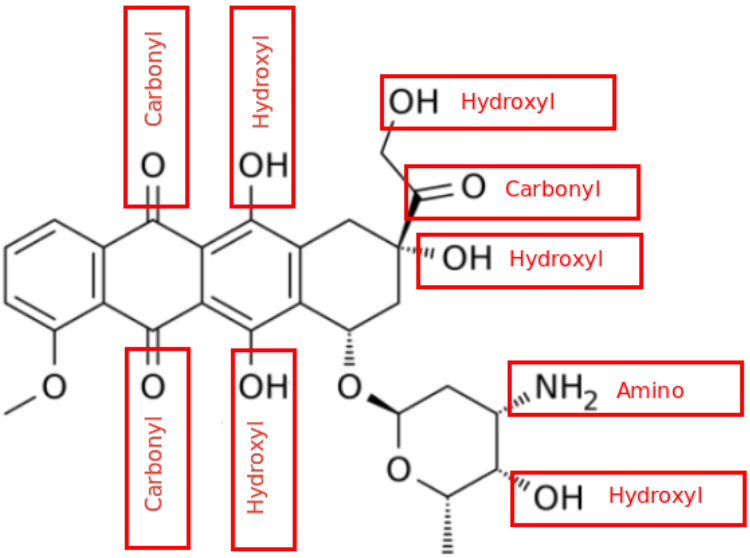

## 3 Questions from Prof. D. De Vos

Considering the following molecule:




### 3.1 Functional groups

Q: Name all functional groups
A: See annoted figure below




### 3.2 Water and oil solubility factors

Q: Indicate which groups make the molecule rather water-soluble than oil-soluble
A: The following groups can partake in hydrogen bonds with water molecules and increase the solubility of the molecule in water :

- Hydroxyl groups (5 of them)
- Carbonyl groups (3 of them)

- Amino group (1 present)