KU LEUVEN

Basics of biological chemistry

Assignment

January 2015 Finals

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January 28, 2015

Contents

1 Prof. J. Vanderleyden – dr. H. Steenackers **2**
- 1.1 Chemical reaction equation . . . 2
  - a.) Balance the equation . . . 2
  - b.) Reactants and products . . . 2
  - c.) Lewis structure, VESPR . . . 2
  - d.) Oxidation states . . . 3
  - e.) Mass . . . 3
- 1.2 DNA sequence analysis . . . 3
  - a.) DNA Replication . . . 3
  - b.) Translated Protein . . . 4
  - c.) Mutated exon . . . 4
  - d.) Interactions with antibiotics . . . 4
  - e.) Comparison of error rates . . . 4
- 1.3 tRNA 3D-Structure . . . 4

2 Prof. B. Sels **4**
- 2.1 Biopolymer organisation . . . 4
- 2.2 Chemical structure of proteins and proteins separation . . . 4
- 2.3 Chemical structure of disaccharides . . . 5

3 Prof. D. De Vos **6**
- 3.1 Functional groups . . . 6
- 3.2 Water and oil solubility factors . . . 6

1 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

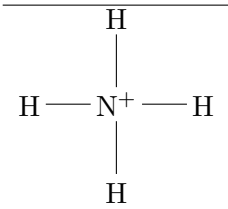
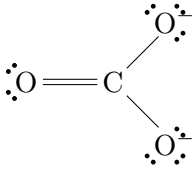
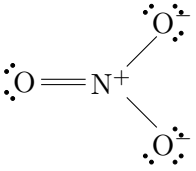
`Q:` Name all reactants and reaction products.
`A:`

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

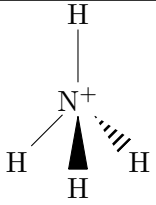
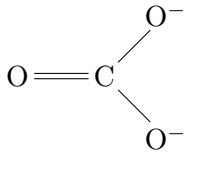
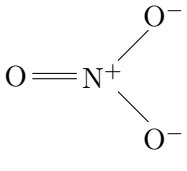
c.) Lewis structure, VESPR

`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 VCIH.

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:

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 Prof. B. Sels

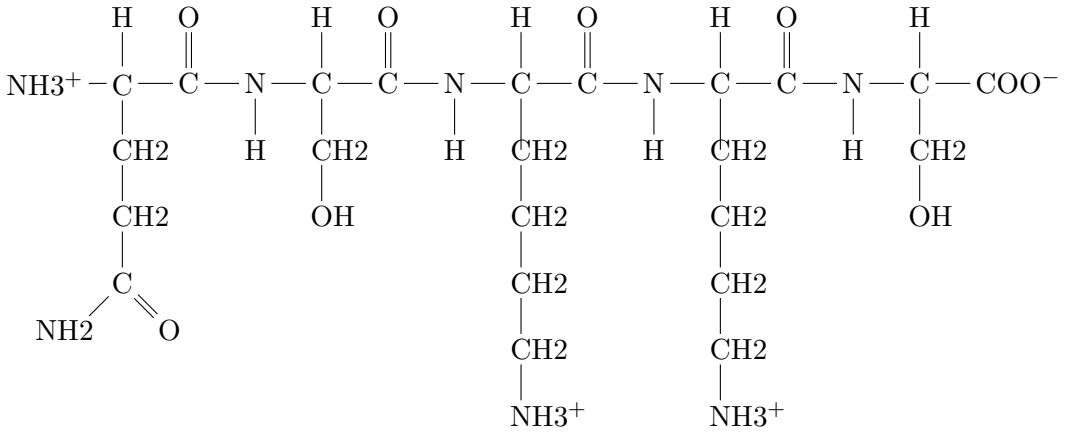
2.1 Biopolymer organisation

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:

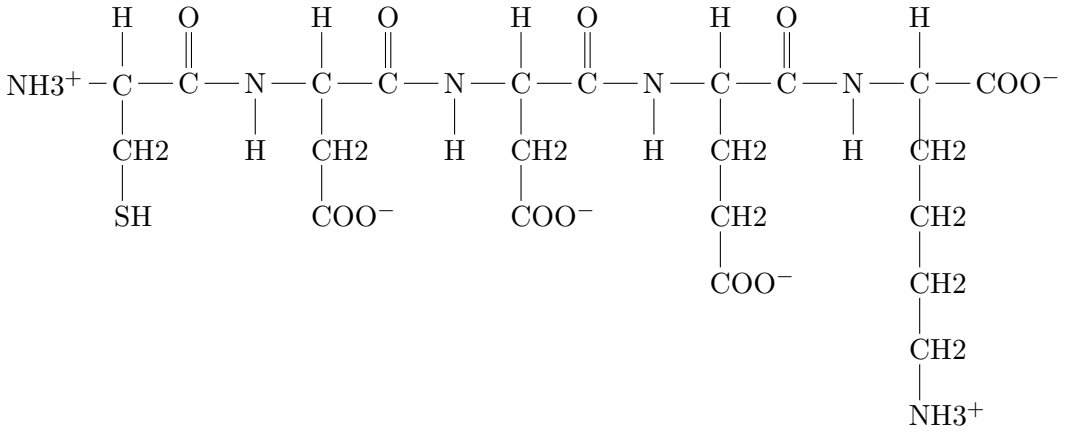
2.2 Chemical structure of proteins and proteins separation

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

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

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

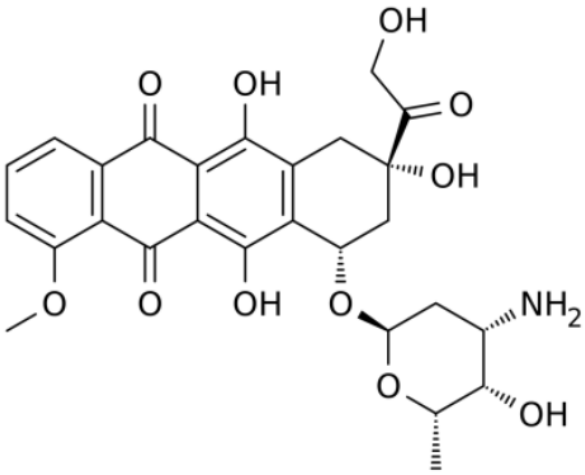
blablabla

- $\beta,\alpha(1\rightarrow2)$glucofructose

blablabla

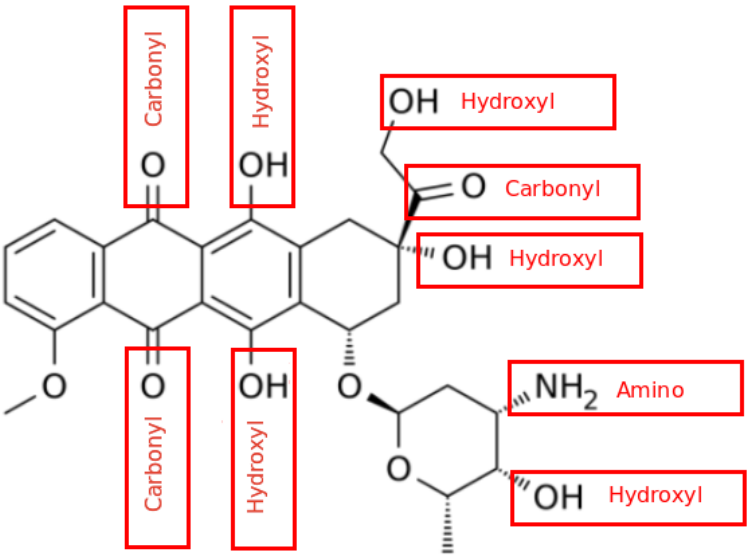
3 Prof. D. De Vos

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)