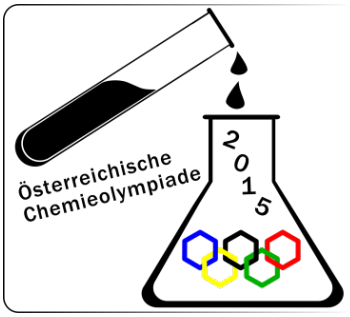
41st Austrian Chemistry Olympiad

National Competition

technologische fachoberschule bruneck



SOLUTIONS

Task 1 **28/ 7.5 points**

Chemistry around a purification plant

1.1. Write balanced reaction equations in ionic form for the single steps as well as for the overall reaction of nitrification.

$NH_4^+ + 1{,}5\ O_2 \rightarrow HNO_2 + H_2O + H^+$ ***1bp***

$HNO_2 + 0{,}5\ O_2 \rightarrow NO_3^- + H^+$ ***1bp***

$NH_4^+ + 2\ O_2 \rightleftarrows NO_3^- + 2\ H^+ + H_2O$ ***1bp***

1.2. Calculate the mass of $Ca(OH)_2$, which is needed hourly to hold a constant pH in the nitrification zone.

$m(NH_4^+) = 1.5 \cdot 10^7 \cdot 2.5 \cdot 10^{-3} = 3.75 \cdot 10^5 g$

$n(NH_4^+) = \frac{m}{M} = 2.083 \cdot 10^4 \triangleq n(Ca(OH)_2)$

$m(Ca(OH)_2) = n \cdot M = 1.542 \cdot 10^6$ g/d $\Rightarrow$ $\mathbf{m(Ca(OH)_2) = 64.25\ kg/h}$ ***2bp***

1.3. Calculate the standard potential of the half cell NO_3^-/NH_4^+

$E^O = \frac{6 \cdot 0.866 + 2 \cdot 0.94}{8} = \mathbf{0.885\ V}$ ***1bp***

1.4. What is the potential of the half cell of 1.3., if the pH is brought to 7.0, while all other concentrations remain unchanged? T = 298 K. Show your calculations.

For: $NO_3^- + 8e^- + 10\ H^+ \rightarrow NH_4^+ + 3\ H_2O$

$E = E^O - \frac{RT}{zF} ln \frac{[NH_4^+]}{[NO_3^-][H^+]^{10}} = 0.885 - \frac{8.314 \cdot 298}{8 \cdot 96485} \ln(10^{-7})^{-10} = 0.368$ V ***2bp***

1.5. Write a balanced reaction equation for the reaction nitrate-methanol in ionic form.

$6\ NO_3^- + 6\ H^+ + 5\ CH_3OH \rightarrow 5\ CO_2 + 13\ H_2O + 3\ N_2$ ***2bp***

1.6. Show by calculation, that NO may disproportionate into N_2 and NO_3^-.

$E^O(NO_3^-/NO) = \frac{0.996 + 1.07 + 0.803}{3} = 0.956$ V ***3bp***

$E^O(NO/N_2) = \frac{1.59 + 1.77}{2} = 1.68$ V

$NO \rightarrow N_2$: 1.68 V and $NO \rightarrow NO_3^-$: -0.956 V give for $NO \rightarrow N_2 + NO_3^-$: 0.724 V

$\Rightarrow$ equilibrium on the right side, NO disproportionates

1.7. What is the lowest pH, at which iron(III) hydroxide will start to precipitate, if the solution contains 10 g/m³ Fe^{3+}? Show your calculations. $pK_L(Fe(OH)_3) = 38.7$

3bp

$10\ g/m^3 = 10\ mg/L \Rightarrow 0.179\ mmol/L\ Fe^{3+}$

$K_L = [Fe^{3+}][OH^-]^3 \Rightarrow [OH^-] = \sqrt[3]{\frac{10^{-38.7}}{0.179 \cdot 10^{-3}}} = 2.23 \cdot 10^{-12}\ mol/L$

$pOH = 11.65 \Rightarrow pH = 2.35$

1.8. Calculate the proportion of amount Fe:P in the above case.

1.5bp

P: $22 \cdot 10^6 \cdot 0.005 = 1.1 \cdot 10^5\ g \Rightarrow 3.552 \cdot 10^3\ mol$

Fe: $250\ kg \Rightarrow 4.476 \cdot 10^3\ mol$

Fe:P = 1.26:1

1.9. Calculate the solubility product of $AlPO_4$ assuming that no protolysis takes place.

1.5bp

$s^* = 96.4\ \mu g/m^3 = 9.64 \cdot 10^{-8}\ g/L$ $\quad M(AlPO_4) = 122\ g/mol$

$s = 7.9 \cdot 10^{-10}\ mol/L$

$K_L = s^2 = 6.24 \cdot 10^{-19}$

1.10.Calculate the solubility of $AlPO_4$ at the pH mentioned.
hint: you may calculate accurately or you may use sensible simplifications. In the latter case you have to prove mathematically, that the simplifications were valid. If you did not get a value in 1.9. you may use $9{,}0 \cdot 10^{-19}$ for K_S.
H_3PO_4: $pK_{A1} = 2.15$; $pK_{A2} = 7.20$; $pK_{A3} = 12.4$;

$[Al^{3+}] = s \quad [PO_4^{3-}] = a \quad [HPO_4^{2-}] = b \quad [H_2PO_4^-] = c \quad [H_3PO_4] = d$ **9bp**

$s = a + b + c + d$ with $a + d \ll b + c$ we have $s \approx b + c$

$K_L = a \cdot (b + c)$

$K_{A2} = [H_3O^+] \cdot \frac{b}{c} \Rightarrow c = [H_3O^+] \cdot \frac{b}{K_{A2}} = \left[H_3O^{+2}\right] \cdot \frac{a}{K_{A1}K_{A2}}$

$K_{A3} = [H_3O^+] \cdot \frac{a}{b} \Rightarrow b = [H_3O^+] \cdot \frac{a}{K_{A3}}$

$K_L = a \cdot ([H_3O^+] \cdot \frac{a}{K_{A3}} + \left[H_3O^{+2}\right] \cdot \frac{a}{K_{A1}K_{A2}}) \Rightarrow K_L = a^2 \cdot ([H_3O^+] \cdot \frac{1}{K_{A3}} + \left[H_3O^{+2}\right] \cdot \frac{1}{K_{A1}K_{A2}})$

$a = \sqrt{K_L \cdot \left(\frac{[H_3O^+]}{K_{A3}} + \frac{[H_3O^{+2}]}{K_{A3}K_{A2}}\right)^{-1}} = \sqrt{6.24 \cdot 10^{-19} \cdot \left(\frac{10^{-5}}{10^{-12.4}} + \frac{10^{-10}}{10^{-12.4} \cdot 10^{-7.20}}\right)^{-1}} = 1.248 \cdot 10^{-14}\ mol/L$

$b = 10^{-5} \cdot \frac{1.248 \cdot 10^{-14}}{10^{-12.4}} = 3.13 \cdot 10^{-7}\ mol/L$

$c = 10^{-5} \cdot \frac{3.13 \cdot 10^{-7}}{10^{-7.20}} = 4.97 \cdot 10^{-5}\ mol/L$

$d = [H_3O^+] \cdot \frac{c}{K_{A1}} = 10^{-5} \cdot \frac{4.97 \cdot 10^{-5}}{10^{-2.15}} = 7.02 \cdot 10^{-8}\ mol/L \quad \Rightarrow \quad a + d \ll b + c$ q.e.d.

$s = b + c = 3.13 \cdot 10^{-7} + 497 \cdot 10^{-5} = 5.0 \cdot 10^{-5}\ mol/L$

Task 2 **27 / 7.5 points**

Thermodynamics and Equilibrium

A. A thermodynamic cycle

2.1. Calculate the efficiency of the machine.

Calculation: ***1bp***

$\varepsilon = \frac{T_{hot} - T_{cold}}{T_{hot}} = \frac{1073 - 508}{1073} = 0.527$

2.3. Calculate the p- and V-values of the points A, B, C, and D, and give a sketch of this thermodynamic cycle using the p-V-diagram at hand (the form of the hyperbolic curves should be estimated).
Mark the geometrical part by shading, which corresponds to the net-work of the system.

Calculation: ***4bp***

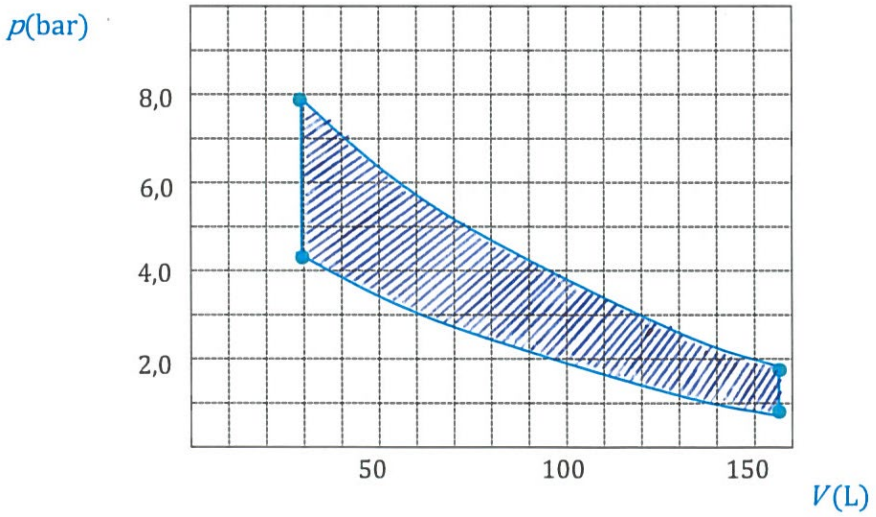
A: $V_A = 30.0\ \text{L} \Rightarrow p_A = \frac{nRT_{hot}}{V_A} = \frac{3 \cdot 8.314 \cdot 1073}{30 \cdot 10^{-3}} = 8.92\ \text{bar}$

B: $p_B = 1.70\ \text{bar} \Rightarrow V_B = \frac{nRT_{hot}}{p_B} = \frac{3 \cdot 8.314 \cdot 1073}{1.7 \cdot 10^{-5}} = 157\ \text{L}$

C: $V_C = 157\ \text{L} \Rightarrow p_C = \frac{nRT_{cold}}{V_C} = \frac{3 \cdot 8.314 \cdot 508}{157 \cdot 10^{-3}} = 0.807\ \text{bar}$

D: $V_D = 30.0\ \text{L} \Rightarrow p_D = \frac{nRT_{cold}}{V_D} = \frac{3 \cdot 8.314 \cdot 508}{30 \cdot 10^{-3}} = 4.22\ \text{bar}$

sketch:



Shaded area = |w| ***3bp***

2.4. Calculate the work of the reversible isothermal expansion at 800°C and the heat which is released to the surrounding of the machine.

Calculation: ***2bp***

$w = 3RT_{hot} ln\frac{30}{157} = -44.3\ \text{kJ}$

$w = 3RT_{cold} ln\frac{30}{157} = -21.0\ \text{kJ}$

2.5. Calculate the final temperature and the final pressure of this adiabatic expansion.

Calculation: **3bp**

$p_1 \cdot V_1^{\frac{C_P}{C_V}} = p_2 \cdot V_2^{\frac{C_P}{C_V}}$ und $\frac{C_P}{C_V} = \frac{5R}{2} \cdot \frac{2}{3R} = \frac{5}{3}$

$p_2 = p_1 \cdot \left(\frac{V_A}{V_B}\right)^{\left(\frac{5}{3}\right)} = 8.92 \cdot \left(\frac{30}{157}\right)^{\frac{5}{3}} = 0.565$ bar

$T_2 = \frac{pV}{nR} = \frac{56500 \cdot 157 \cdot 10^{-3}}{3.8.314} = 356$ K

B. Boudouard's Equilibrium

2.6.What is the molar percentage of CO in the equilibrium mixture at 727°C and 1 bar?

70% **0.5bp**

2.7. Calculate K_P of the reaction at 727°C and a total pressure of 0.80 bar.

Calculation:

$K_X = \frac{0.7^2}{0.3} = 1.63$ pressure of the diagram(!): $K_P = K_X \cdot p_g = 1.63$ **1bp**

2.8. Calculate the percentage of CO at 727°C and a total pressure of 2.0 bar.

Calculation: **4.5bp**

	CO_2	CO
n_0	1	0
Δn	-a	+2a
n_{eq}	1-a	2a
x_{eq}	$\frac{1-a}{1+a}$	$\frac{2a}{1+a}$

$K_x = \frac{(2a)^2 \cdot (1+a)}{(1+a)^2 \cdot (1-a)} = \frac{4a^2}{1-a^2}$ $\Rightarrow$ $K_p = \frac{4a^2}{1-a^2} \cdot 2 = 1.63$

$4a^2 = 0.815 - 0.815a^2$ $\Rightarrow$ $a = \sqrt{\frac{0.815}{4.815}} = 0.411$ mol

$x(CO) = \frac{2 \cdot 0.411}{1+0.411} = 0.584$ $\Rightarrow$ 58.3% CO

C. An Isomerisation

2.9. Calculate the equilibrium constant of the reaction and the composition of the equilibrium mixture at 25°C.

Calculation: **2.5bp**

$K = e^{-\frac{\Delta_R G^O}{RT}} = e^{-\frac{1700}{8.314 \cdot 298}} = 0.50$

$[F6P]_{eq} = x \quad [G6P]_{eq} = 1 - x \quad \Rightarrow \quad K = 0.5 = \frac{x}{1-x} \quad \Rightarrow \quad x = 0.33$

0.33 mol F6P and 0.67 mol G6P

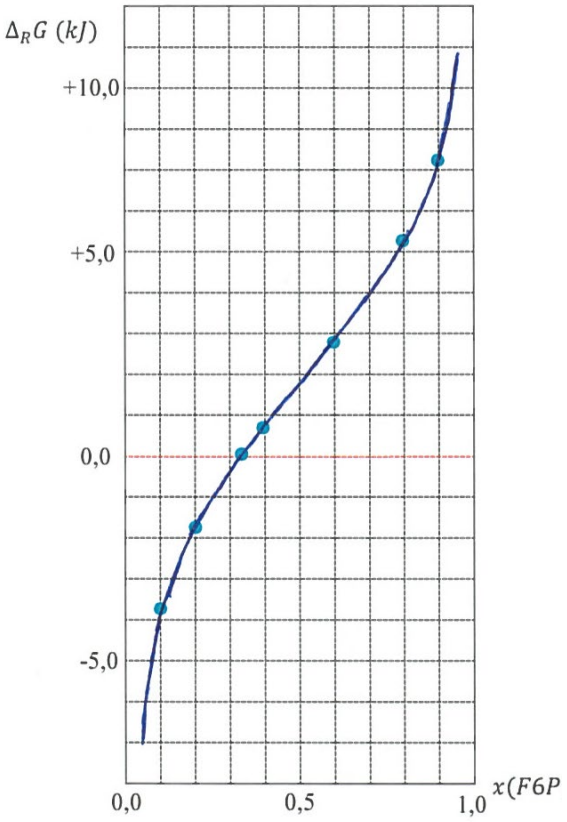
2.10. Calculate the free reaction enthalpy of this reaction $\Delta_R G$ depending on the fraction of fructose-6-phosphat in optional reaction mixtures (at least 6 values), and draw a sketch of this dependency in the given diagram.

$\Delta_R G = \Delta_R G^O + RT ln Q$

$\Delta_R G = \Delta_R G^O + RT ln \frac{x}{1-x}$

$\Delta_R G = 1.7 + 2.48 \cdot ln \frac{x}{1-x}$ kJ

x	$\Delta_R G$ (kJ)
0	-∞
0.1	-3.75
0.2	-1.74
0.33	0
0.4	0.69
0.6	2.71
0.8	5.14
0.9	7.15
1.0	+∞



5.5bp

Task 3 **54/ 15 points**

Three Elements out of the Copper Mine

A. Copper itself

*3.1. Calculate the lattice constant in Angström (*1Å = 100 pm*)*

lattice constant a = 3,70 Å **2bp**

Your calculation:

$$\rho = \frac{m}{V} = \frac{4 \cdot M_{Cu}/N_A}{a^3} = 8.29\ \text{g} \cdot \text{cm}^{-3} \quad \Rightarrow \quad a = \sqrt[3]{\frac{4 \cdot 63.55}{8.29 \cdot 6.0221 \cdot 10^{23}}} = 3.70\ \text{Å}$$

3.2. Calculate the radius of this statistical atom.

calculated radius r = 1.30Å

Your calculation:

$M_{average} = 63.55 \cdot 0.75 + 65.41 \cdot 0.25 = 64.015$ **1bp**

$a = \sqrt[3]{\frac{4 \cdot 64.015}{8.51 \cdot 6.0221 \cdot 10^{23}}} = 3.683$ Å **1bp**

$2a^2 = (4r)^2 \Rightarrow r =$ 1.30Å **1bp**

3.3. Write down the empirical formulae of these two compunds.

A:	CuAu	1bp	B:	Cu_3Au	1bp

B. Copper minerals and the production of copper

3.4. Determine the formulae of the compounds **X** *and* **Y**.

X:	SiO_2	1bp	Y:	Fe_2SiO_4	1bp

Your calculation:

$\frac{53.25}{16} = n \cdot \frac{46.75}{M} \Rightarrow M = n \cdot 14.05$

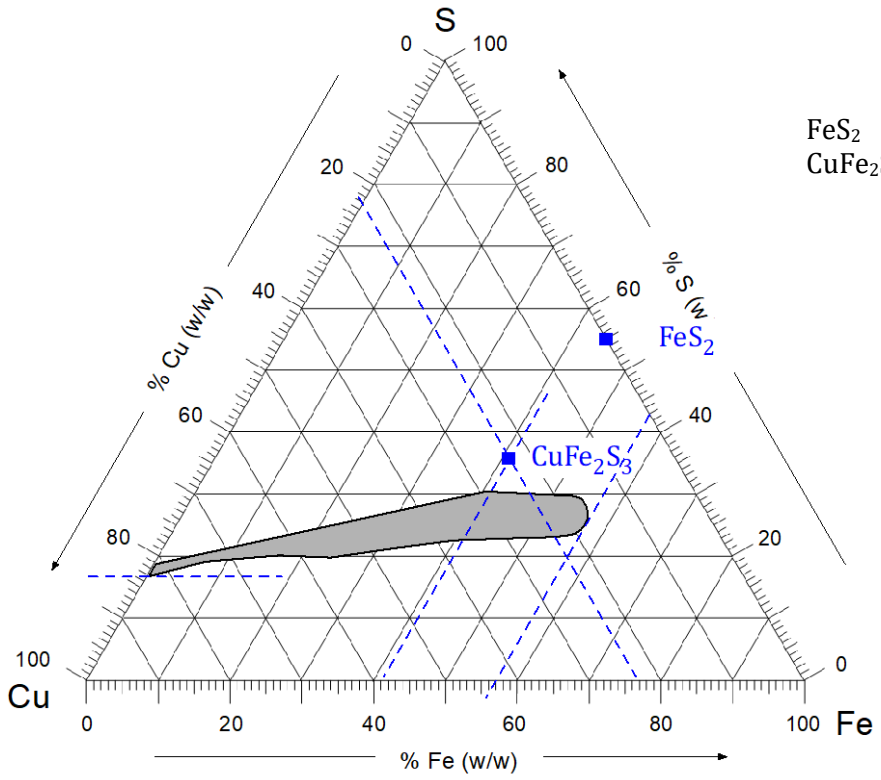
N not possible (NO_2 not difficult to melt)

Si matches → **X** is SiO_2

Y: 31.41% O ... 1.9631 mol ... 4
13.78 % Si ... 0.4906 mol ... 1
54.81% Fe ... 0.9814 mol ... 2

3.5. Give balanced equations for the reactions in steps a. to d.:	
a. $6\ Cu_5FeS_4 + 13\ O_2 \rightarrow 15\ Cu_2S + 2\ Fe_3O_4 + 9\ SO_2$	***2bp***
b. $2\ Fe_3O_4 + 2\ CO + 3\ SiO_2 \rightarrow 3\ Fe_2SiO_4 + 2\ CO_2$	***1bp***
c. $2\ Cu_2S + 3\ O_2 \rightarrow 2\ Cu_2O + 2\ SO_2$	***1bp***
d. $1\ Cu_2S + 2\ Cu_2O \rightarrow 6\ Cu + SO_2$	***1bp***

*3.6. In the empty plot denote the compositons of **pyrite** (FeS_2) (46,5 % Fe) and **cubanite** ($CuFe_2S_3$)(23,4% Cu, 41,1% Fe).*



gray region: Cu-Fe-S- compositions useable for pyrometallurgy

FeS_2 ***3bp***
$CuFe_2S_3$ ***3bp***

3.7. For the Cu-Fe-S-compositions useable in pyrometallurgy denote:

a) the maximum percentage of Fe such a mixture may have *56.5 %* ***2bp***
b) the minimum percentage of S such a mixture must have *16.5 %* ***1bp***

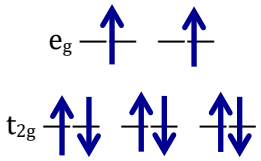
C. Strange copper compounds

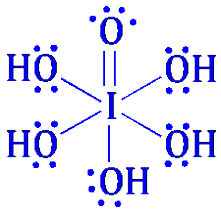
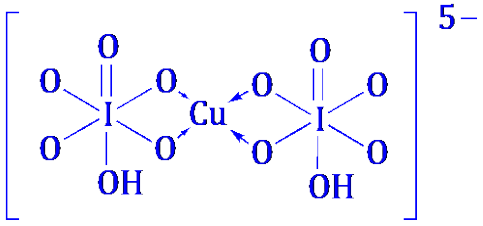
3.8. Give a balanced equation for the formation of potassium hexafluoridocuprate(III).

$6\ KCl + 2\ CuCl_2 + 6\ F_2 \rightarrow 2\ K_3[CuF_6] + 5\ Cl_2$ ***2bp***

3.9. Write down the entire electron configuration for Cu(III) in its ground state.

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$ ***1bp***

3.10. Depict the splitting of the d-orbitals for the complex and tick the right box:	
Scheme of the d-Orbitals:  ***2bp***	☐ diamagnetic **X** paramagnetic ***1bp***

3.11. Draw a Lewis – formula and tick the right box:	
structure of H_5IO_6:  ***2bp***	geometry according to VSEPR ☐ linear ☐ trigonal planar ☐ tetrahedral ☐ square pyramidal **X** octahedral ***1bp***
3.12. Write down the molecular formula of the copper-containing complex anion:	
Formula: $[Cu(O_6IH)_2]^{5-}$ ***2bp***	
Justify by calculation $M(HIO_6^{4-}) = 224$ M(complex with 12.4%Cu) = 63,55/0.124 = 513 → two HIO_6^{4-} needed	
3.13. Propose a structure for this anion:	
 ***3bp***	

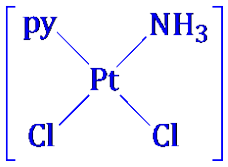
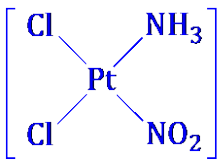
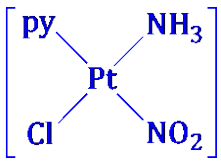
D. Arsenic

3.14. Write down complete, balanced equations for both decays. Denote the nuclids with the appropriate mass numbers.
β^+: $^{74}_{33}As \rightarrow {}^{74}_{32}Ge + e^+ + \nu_e$ ***1bp***
β^-: $^{74}_{33}As \rightarrow {}^{74}_{34}Se + e + \bar{\nu}_e$ ***1bp***

3.15. Calculate the decay constant for the β^+ *decay in* s^{-1}.
β^+: $\lambda_1 = 2.980 \cdot 10^{-7} s^{-1}$ **2bp**
Your calculation: $\lambda = \frac{\ln 2}{\tau} = \frac{\ln 2}{17.77 \cdot 24 \cdot 3600} = 4.5147 \cdot 10^{-7} s^{-1}$ β^+: $\lambda_1 = \lambda \cdot 0.66 = 2.980 \cdot 10^{-7} s^{-1}$

3.16. Indicate the mass number of the Ge-isotope, that gets converted according to the equation given above.
Mass number A = 72 **1bp**
3.17. Calculate the total activity of the sample (β+ and β-) immediately after the irradiation.
activity *A* = 1.80 MBq **3bp**
Your calculation: 0.743 g GeO_2 → 7.101 mmol Ge → 1.946 mmol ^{72}Ge = $1.172 \cdot 10^{21}$ atoms of ^{72}Ge $1.172 \cdot 10^{21} \cdot 3.4 \cdot 10^{-9} = 3.985 \cdot 10^{12}$ atoms were converted $A = N\lambda = 3.985 \cdot 10^{12} \cdot 4.515 \cdot 10^{-7} = 1.80 \cdot 10^{6}$

E. Reactions of square planar platinum(II) complexes

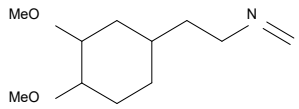
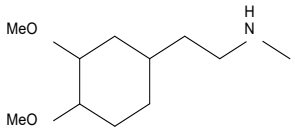
3.18. Indicate which letter stands for which ligand.					
A: Cl^-	B: NO_2^-	C: NH_3	D: py	je *1bp* = **4 bp**	
3.19. Draw configuration formulae for the complexes IV - VI.					
IV  **1bp**		**V**  **2bp**		**VI**  **1bp**	
3.20. How many isomers are possible for complex VI?					
There are ____ 3 _____ possible isomers. **1bp**					

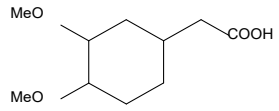
Task4 **15 points**

Synthesis of different drugs

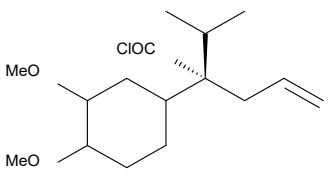
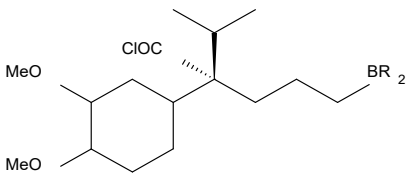
A. Verapamile

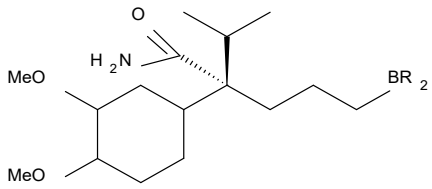
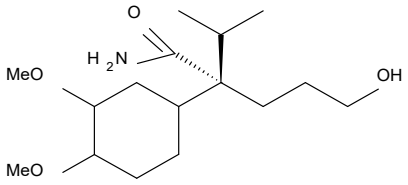
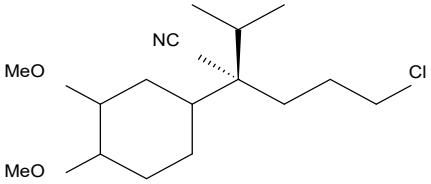
4.1. Write down the absolute configuration of this sterogenic center.
S

*4.2. Draw constitution formulae of **B** and **C** and a possible formula of the reagent a.*	
reagent a: $LiAlH_4$ or H_2/catalyst	***0,5 bp***
B 	***C*** 

*4.3. Draw the constitution formula of compound **D**. Draw a formula of reagent **b** and suggest two conditions of the reaction from **D** to **E**.*	
D 	***b:*** CH_3OH *2 conditions:* H^+, heat

*4.4. Write possible formulae of reagents **c, d, e, f, g** and **h**.*	
c: strong base, NaOEt, LDA etc.	***f:*** CH_2=CH-CH_2Br
d: $(CH_3)_2$CH-Br (I)	***g:*** OH^-, H_2O
e: strong base, NaOEt, LDA etc.	***h:*** H_3O^+

*4.5. Draw constitution formulae of the compounds **I, J, K, L** and **M**.*	
I 	***J*** 

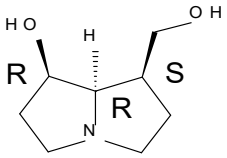
K  	***L*** 
M  	

*4.6. Which type of reaction is meant in the reaction of **M** and **C** to Verapamile?*
What is the reason for adding Et_3N?

nucleophile substitution, S_N2

for capturing HCl, moves the equilibrium to the right.

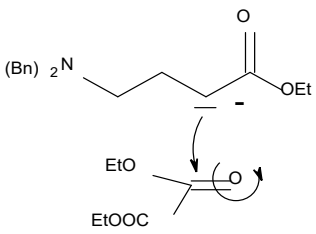
4.7. Assign absolute configurations to the stereogenic centres in the formula above.



*4.8. What is the name of the reaction of **N** with diethyl oxalate?*

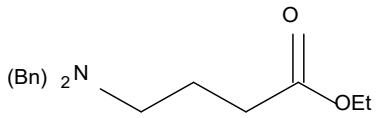
Claisen-ester-condensation

4.9. Draw a mechanism of the 1st step of attack on diethyloxalate.

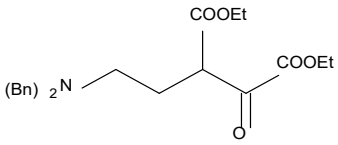


*4.10. Draw constitution formulae of compounds **N, O,P** and **Q.***

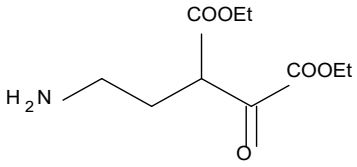
N



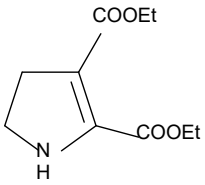
O



P

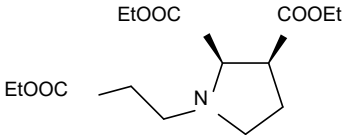


Q

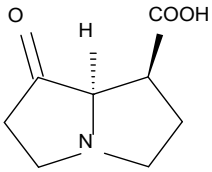


*4.11. Draw steric formulae of the compounds **R, S** and **T** and suggest a possible reagent for **i.***

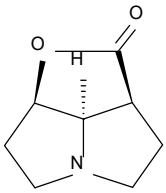
R



S



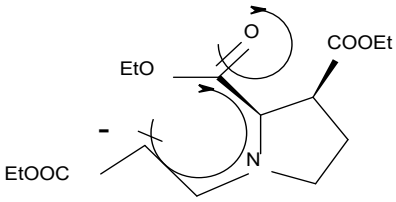
T



Reagenz i:

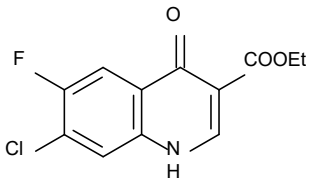
$LiAlH_4$

*4.12. Draw the species which is formed in the reaction of **R** with the base NaH. By using a curly arrow show the attack which finally leads to the formation of the bicyclus.*

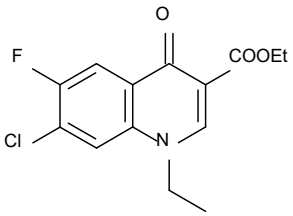


*4.13. Draw constitution formulae of the compounds **W, X, Y** and **Z**.*

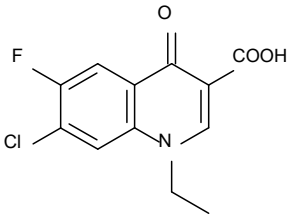
W



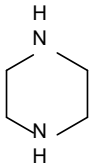
X



Y



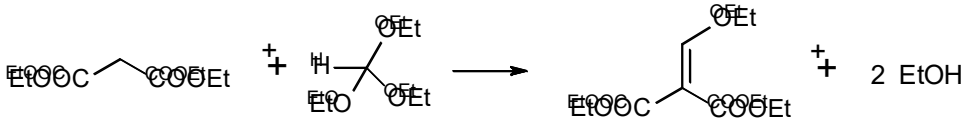
Z:



*4.14. Name the reaction type of the transformation of **V** to **W**.*

elektrophilic substitution, S_E

4.15. Write a balanced equation for this reaction.



Task 5 **25 / 7.5 Punkte**

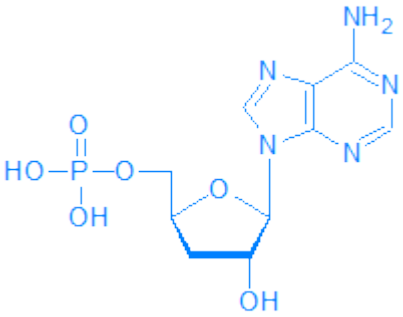
A synthetic nucleoside functions as HI-virustatica

5.1. Name the three building blocks of a nucleotide.

organic, heterocyclic base; saccharide (usual a pentose), phosphoric acid ***1.5bp***

5.2. Design the structure of a 3-Deoxy-"purine nucleotide".

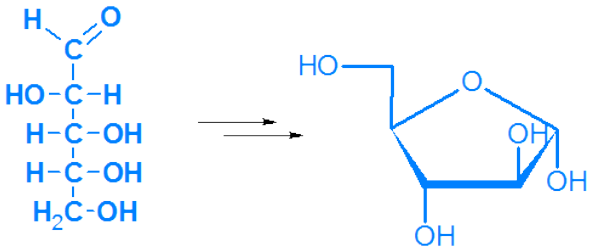
4bp



alternatively: guanine as base and / or 2´ -ester; also di-or triphosphate are correct

5.3. Show the equation leading from the chain form of (2S, 3R, 4 R)-2,3,4,5-Tetrahydroxypentanal to α-D-arabinofuranose. Depict the reactant in Fischer projection and the product in Haworth projection.

3bp



5.4. Name the reaction type leading from the open chain to the ring form.

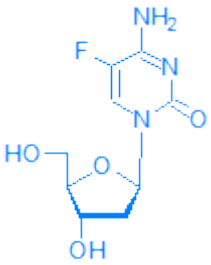
nucleophilic addition (A_N) ***1bp***

5.5. Calculate the sum-formula of A.

$C_{3.67}H_{4.90}O_{1.63}N_{1.22}F_{0.41}$ → $C_9H_{12}O_4N_3F$ ***2bp***

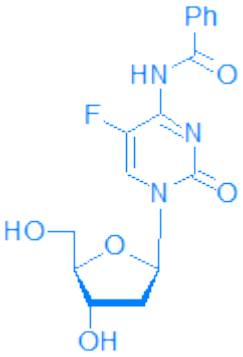
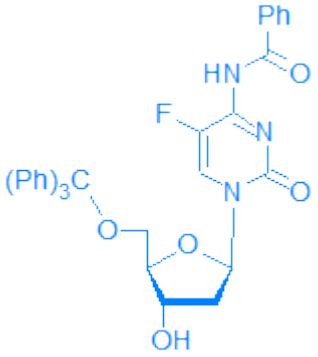
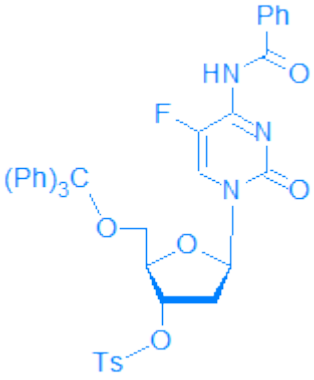
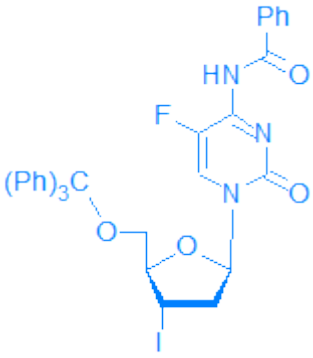
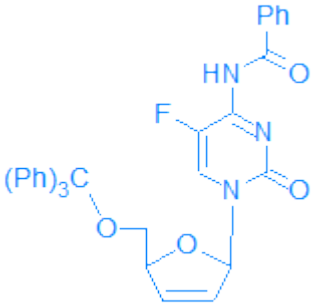
5.6. Design the structure formula of A.

4bp



5.7. Write down the structural formulae of the substances B to G into the boxes. Abbreviate Phenyl with Ph as usual. If the base is not involved in a reaction, use the abbreviation "base".

Use a Guanine-nucleoside with a common sugar with a primary hydroxyl group if you are not able to derive the formula for A.

B: *1bp* 	***C:*** *1bp* 
D: *1bp* 	***E:*** *1bp* 
F: *1bp* 	***G:*** *1bp* 

5.8. Write down the letters t (true statement) and w (wrong statement) in the boxes. Randomly placed crosses lead to a deduction according to the scores.

3.5bp

f	*The absence of the 2´ hydroxyl group causes the way of molecular action.*
w	*The nucleoside analogue G vies competitively with dCTP.*
f	*The nucleoside analogue G vies competitively with CTP.*
f	*The nucleoside analogue G vies competitively with TTP.*
w	*Chain termination at the DNA elongation is the key factor of the inhibitory effect.*
f	*The reverse transcriptase is a DNA-dependent DNA polymerase. This enzyme uses the wrong nucleotide for transcription.*
w	*The reverse transcriptase is an RNA-dependent DNA polymerase. This enzyme uses the wrong nucleotide for transcription.*

Task 6 **25.5/ 7.5 points**

The horse-radish Enzyme

6.1. Using the partial equations, derive a law for the rate of the reaction.

4bp

$$K = \frac{[H_3O_2{}^+]}{[H_2O_2][H_3O^+]} \rightarrow [H_3O_2{}^+] = K[H_2O_2][H_3O^+]$$

$$v = k_2[I^-][H_3O_2{}^+]$$

$$v = Kk_2[H_2O_2][H_3O^+][I^-] = \frac{k_1k_2}{k_{-1}} \cdot [H_2O_2][H_3O^+][I^-]$$

Enzymkinetik

6.2. Write down the unit of K_M..

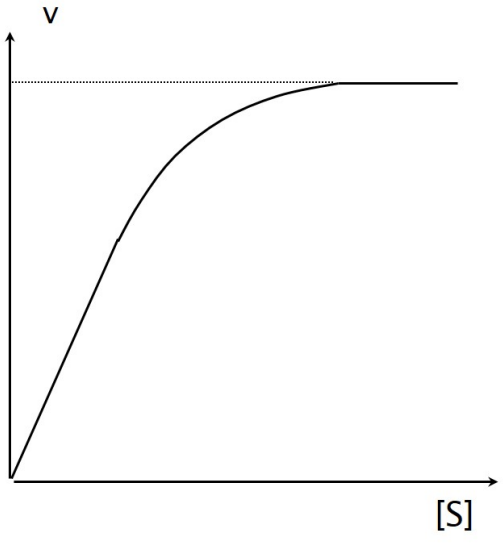
$\text{mol} \cdot \text{L}^{-1}$ ***1,5bp***

6.3. Calculate the maximum rate of this reaction.

$v_{max} = \frac{v(K_M+[S])}{[S]} = 1.50 \cdot 10^{-3}\ mol \cdot L^{-1} \cdot s^{-1}$ ***2bp***

6.4. Draw a graph of eq. 1 by plotting v against [S]. It is not necessary to scale the axes.

3bp



6.6. Show by calculation which condition leads to $v = v_{max}$.

3bp

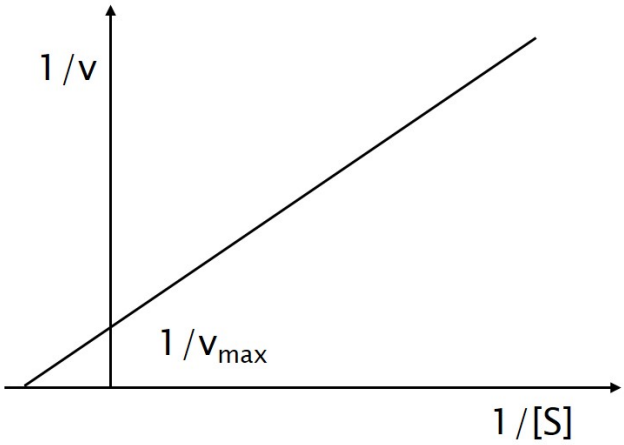
$$[S] \gg [K_M]:\ v = \lim_{[S]\rightarrow\infty} \frac{v_{max}[S]}{K_M+[S]} = v_{max}$$

6.7. A linear transformation of eq. I leads to the equation of Lineweaver and Burk.
Perform a linear transformation of eq. I and show your calculation by forming the reciprocal of the Michaelis-Menten-equation.
Sketch a graph. It is not necessary to scale the axes.
Name the axes and highlight the ordinate axis, when x = 0.
Find an expression for the slope of the function.

5bp

$$\frac{1}{v} = \frac{K_M}{v_{max}} \cdot \frac{1}{[S]} + \frac{1}{v_{max}}$$

$$\frac{\Delta y}{\Delta x} = \frac{K_M}{v_{max}}$$



6.8. Derive the rate law (Michaelis-Menten eq.) and show your calculation step by step (application of the steady state model).

7bp

$$\frac{d[ES]}{dt} = 0 = k_a[E][S] - k_{-a}[ES] - k_b[ES] = 0$$

$$[E_{tot}] = [E] + [ES] \rightarrow [E] = [E_{tot}] - [ES]$$

$$k_a([E_{tot}] - [ES])[S] = k_{-a} + k_b[ES]$$

$$[E_{tot}][S]k_a - [ES][S]k_a = k_{-a} + k_b[ES]$$

$$[E_{tot}][S]k_a = [ES](k_{-a} + k_b + k_a[S])$$

$$[ES] = \frac{[E_{tot}][S]k_a}{(k_{-a} + k_b + k_a[S])}$$

$$[ES] = \frac{[E_{tot}][S]}{\frac{k_{-a} + k_b}{k_a} + [S])}$$

$$[ES] = \frac{[E_{tot}][S]}{K_M + [S])}$$

$$v = [ES] \cdot k_b$$

$$v = \frac{k_b[E_{tot}][S]}{K_M + [S])}$$

$$v = \frac{v_{max} \cdot [S]}{K_M + [S])}$$