SwissChO

Practical SwissChO 2018

CONSTANTS AND FORMULAE

Avogadro constant	$N_A = 6.022 \cdot 10^{23}\ \text{mol}^{-1}$	Ideal gas law	$pV = nRT$
Universal gas constant	$R = 8.314\,\text{J mol}^{-1}\ \text{K}^{-1}$	Gibbs energy	$G = H - TS$
Faraday constant	$F = 96\,485\,\text{C mol}^{-1}$	$\Delta_r G^0 = -RT \cdot \ln(K) = -nFE^0_{\text{Zelle}}$	
Planck constant	$h = 6.626 \cdot 10^{-34}\ \text{J s}$	Nernst equation	$E = E^0 + \frac{R \cdot T}{z \cdot F} \cdot \ln\left(\frac{c_{\text{ox}}}{c_{\text{red}}}\right)$
Speed of light	$c = 2.998 \cdot 10^{8}\ \text{m s}^{-1}$	Energy of a photon	$E = \frac{h \cdot c}{\lambda}$
Temperature	$0\,°\text{C} = 273.15\,\text{K}$	Lambert-Beer law	$A = \log\left(\frac{I_0}{I}\right) = \epsilon \cdot c \cdot L$

For the calculation of equilibrium constants all concentrations, refer to the standard concentration $1\,\text{mol dm}^{-3} = 1\,\text{mol L}^{-1}$. If not stated otherwise in a task, consider all gases ideal throughout this test.

Periodic Table

1 H 1.008																	2 He 4.003
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.30											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.96	43 Tc –	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57–71	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po –	85 At –	86 Rn –
87 Fr –	88 Ra –	89–103	104 Rf –	105 Db –	106 Sg –	107 Bh –	108 Hs –	109 Mt –	110 Ds –	111 Rg –	112 Cn –						

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 140.24	61 Pm –	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
89 Ac –	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np –	94 Pu –	95 Am –	96 Cm –	97 Bk –	98 Cf –	99 Es –	100 Fm –	101 Md –	102 No –	103 Lr –

PROBLEM 1 - DOUBLE TITRATION OF A SOLUTION CONTAINING HCL AND $CACL_2$ 25 POINTS

1. There has been an accident with $1\,\mathrm{liter}$ of a solution S_0 containing HCl. Some grains of $Ca(OH)_2$ have been unwillingly added to it. There was no change in the total volume. The resulting solution, containing now HCl and $CaCl_2$, is called S_1 and is now going to be analyzed.

2. Transfer $20\,\mathrm{mL}$ of the solution S_1 into a $250\,\mathrm{mL}$ Erlenmeyer flask using a pipette. Add $100\,\mathrm{mL}$ water with a graduated cylinder, a few drops of the indicator Phenolphtalein and a magnetic stirrbar to the Erlenmeyer flask.

3. Fill the burette with a $0.1\,\mathrm{M}$ NaOH solution (The exact concentration is given on the volumetric flask). Titrate the solutions in the previously prepared Erlenmeyer flask. A color change from colorless to faint pink indicates the end of the titration. Repeat this titration at least three times. Do not dispose the solutions in the Erlenmeyer flasks, as they will be used later on.

4. Fill your data as well as calculated values into the following table and calculate the number of moles of NaOH consumed in the titration.

Titration	V(NaOH) [mL]	n(NaOH) [mmol]
1		
2		
3		
4		
5		
Average		

5. Add a few drops of a $1\,\mathrm{M}$ H_2SO_4 solution into the Erlenmeyer flasks from the previous task. The faint pink color should disappear. In case the color persists, add further drops until a colorless solution is obtained. Add $1\,\mathrm{mL}$ of a $4\,\%$ solution of K_2CrO_4 into each Erlenmeyer flask using a plastic pipette. **Take care, Cr(VI) compounds are toxic as well as carcinogenic. Immediately inform the supervisors in case of any spills or exposures!**

6. Fill your burette with a $0.1\,\mathrm{M}$ $AgNO_3$ solution (The exact concentration is given on the volumetric flask). Titrate the pale yellow solution with $AgNO_3$. The solution becomes milky, because of the appearance of a white precipitate of AgCl:

$$\mathrm{Ag^+ + Cl^- \rightarrow AgCl}\ (s) \tag{1}$$

The titration is finished when a brownish-red color, due to the formation of silver chromate Ag_2CrO_4, persists:

$$2\ \mathrm{Ag^+ + CrO_4{}^{2-} \rightarrow Ag_2CrO_4}\ (s) \tag{2}$$

Repeat this titration at least three times.

7. Fill your data as well as calculated values into the following table and calculate the number of moles of Ag^+ which are consumed during each titration.

Titration	$V(AgNO_3)$ [mL]	$n(AgNO_3)$ [mmol]
1		
2		
3		
4		
5		
Average		

8. Perform the following calculations:

a) Write down the equation of the reaction going from S_0 to S_1.

b) Write down the equation of the titration by NaOH.

c) Calculate the number of moles of H^+ ions derived from the first titration.

d) Calculate the number of moles of Cl^- ions derived from the second titration.

e) Calculate the number of moles of Cl^- due to HCl, and then these from $CaCl_2$.

f) Calculate the concentration of HCl in S_1.

g) Calculate the concentration of $CaCl_2$ in S_1.

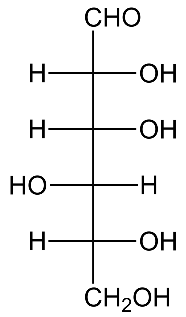
h) Calculate the concentration of HCl in S_0.

i) Calculate the mass of $Ca(OH)_2$ which was added to S_0 for transforming it into S_1.

PROBLEM 2 - STUDY OF FEHLING'S REACTION **15 POINTS**

1. Fehling's reaction occurs when a solution containing Cu^{2+} ions is mixed with a solution of a reducing sugar, like glucose $C_6H_{12}O_6$. In presence of a strong base and at elevated temperatures, the following reaction takes place:

$$\mathrm{RCHO} + 2\ \mathrm{Cu^{2+}} + 5\ \mathrm{OH^-} \rightarrow \mathrm{Cu_2O} + 3\ \mathrm{H_2O} + \mathrm{RCOO^-} \tag{3}$$



Glucose, $C_6H_{12}O_6$

2. Add $20\,\mathrm{mL}$ of the solution labeled *Fehling A*, a Cu^{2+} solution, into a $250\,\mathrm{mL}$ Erlenmeyer flask. Add $20\,\mathrm{mL}$ of the solution labeled *Fehling B*, containing NaOH and sodium potassium tartrate, into the same Erlenmeyer flask. Mix the solution thoroughly.

3. Weigh in $200 - 220\,\mathrm{mg}$ ($\pm 1\,\mathrm{mg}$) of glucose $C_6H_{12}O_6$. Write down this value, and add the sugar into the Erlenmeyer flask containing the *Fehling* solutions. Add $50\,\mathrm{mL}$ of distilled water into the Erlenmeyer flask. Stir the mixture using a stir bar, until a homogeneous solution is obtained. Heat the solution to a boil on the hot plate. A brownish precipitate Cu_2O appears. After $2\,\mathrm{minutes}$ of boiling, remove the Erlenmeyer flask from the hotplate, and cool to room temperature. Remove the stir bar from the flask.

4. Weigh a filter paper which is subsequently going to be used for the filtration of the precipitate. Write down this value as you will need it for the calculations. Add the filter paper into a Buchner filter, and filter the precipitate. Wash the filtrate twice, using $20\,\mathrm{mL}$ of distilled water. Dry the precipitate for $2\,\mathrm{minutes}$ on the vacuum.

5. Transfer the filter paper with the precipitate onto a watch glass, and dry the Cu_2O at $80\,°\mathrm{C}$ for $1\,\mathrm{hour}$ in the oven. **Write your initials on the watch glass, so it is easily recognizable!**

6. While waiting, answer the following questions:

a) The equation (3) contains the simplified formula RCHO for the formula of glucose. The letter R defines a group of atoms C, H and O, with the general formula $C_xH_yO_z$. Determine the values of x, y and z.

b) Draw the skeletal formula of the acid RCOOH which formed by the oxidation of glucose, using the developed formula of glucose (See above).

c) Explain why we have obtained the ion $RCOO^-$ and not the acid RCOOH in the equation (3).

d) The equation (3) is a redox equation. Write down the two corresponding half-equations.

7. After one hour, remove the filter paper from the oven without burning yourself. Weigh the filter paper with the precipitate, which should be dry. Calculate the mass of the precipitate Cu_2O by the difference to the initial mass of the filter paper.

Indicate:

e) the mass of the initial sample of glucose $C_6H_{12}O_6$.

f) the number of millimoles n_1 of glucose contained in this sample.

g) the final mass of the Cu_2O obtained.

h) the number of millimoles n_2 of Cu_2O obtained.

8. These two numbers n_1 and n_2 should be equal according to equation (3). Now the experiment shows that $n_1 < n_2$. This means that a fraction of glucose has not reacted according to (3) but has been used in another reaction producing more than 1 equivalent of Cu_2O. This new reaction can be formulated as:

$$C_6H_{12}O_6 + 4\ Cu^{2+} + 8\ OH^- \rightarrow C_6H_{10}O_7 + 2\ Cu_2O + 5\ H_2O \tag{4}$$

The important difference between these two equations is that 1 mol of glucose produces $1\,\mathrm{mole}$ of Cu_2O in one reaction but $2\,\mathrm{moles}$ in the other reaction. Let's consider that a moles glucose react according to (3) and produces a moles of Cu_2O and that b moles of glucose react according to (4) producing $2b$ moles of Cu_2O. It follows that $n_1 = a + b$.
The total number of moles of Cu_2O is given by $n_2 = a + 2b$. Calculate a and b from your measured weights. Then calculate the proportion p of glucose molecules that have reacted according to (3).

Viel Erfolg!

Bonne chance!

Buona fortuna!

Good luck!