The 3rd Olympiad of Metropolises

Chemistry

Grading Scheme and Answers to Practical Problems

September 4, 2018

Moscow, Russia

Question	a	b	c	d	e	f	Total
Points	4	4	10	2	28	2	50
Result							

Task 1. Multicolor chromium

a. Write down equation of the reaction proceeding and the formula of the complex particle formed.

$K_2Cr_2O_7 + 3C_2H_5OH + 8HCl = 2CrCl_3 + 3CH_3CHO + 2KCl + 7H_2O$ (2 points)

$[Cr(H_2O)_4Cl_2]^+$ (2 points)

b. Write down the equation of the reaction proceeding and the formula of the complex particle formed at this synthesis step.

$2CrCl_3 + Zn = 2CrCl_2 + ZnCl_2$ (2 points)

$[Cr(H_2O)_4Cl_2]$ (2 points)

c. Write down the equations of the proceeding reactions and the formulae of the complex particles formed at these synthesis steps. Draw the structural formula of the complex cation of the final reaction product.

$CrCl_2 + 6NH_3 \cdot H_2O = [Cr(NH_3)_6]Cl_2 + 6H_2O$ or

$CrCl_2 + 8NH_3 \cdot H_2O = [Cr(NH_3)_6](OH)_2 + 2NH_4Cl + 6H_2O$ (2 points)

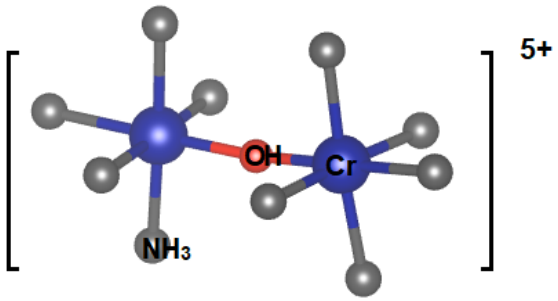
$4[Cr(NH_3)_6]Cl_2 + 2NH_4Cl + O_2 + 3H_2O = 2[(NH_3)_5Cr\text{-}(OH)\text{-}Cr(NH_3)_5]Cl_5 \cdot H_2O + 6NH_3$ or

$[Cr(NH_3)_6](OH)_2 + 10NH_4Cl + O_2 = 2[(NH_3)_5Cr\text{-}(OH)\text{-}Cr(NH_3)_5]Cl_5 \cdot H_2O + 14NH_3 + 6H_2O$

(2 points)

$[Cr(NH_3)_6]^{2+}$ (2 points)

$[(NH_3)_5Cr\text{-}(OH)\text{-}Cr(NH_3)_5]^{5+}$ (2 points)



(2 points)

d. Weigh the filter with the product and write down the value. (2 points)

Mass of the Petri dish with the filter and the product = _____ g

Mass of the Petri dish = _____ g

Mass of the filter with the product = _____ g

e. Your product will be dried by the organizers and then re-weighted, whereas its quality will be checked spectrophotometrically.

The grading scheme takes into account two values re-measured by the Jury: mass of the product (m, g) and its purity, which is evaluated using spectrophotometry. A correcting factor *α* based on the latter is applied to a student's points obtained for the yield.

Parameter	A	B	y	z	Max grade
Mass	2.8 g	4 g	0 g	4.2 g	28 points

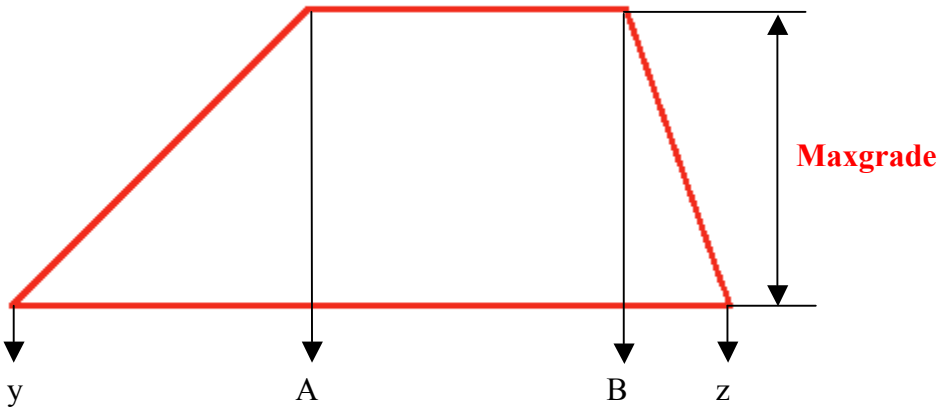
If A ≤ Value ≤ B, then Grade = Maxgrade

If Value < y, then Grade = 0, If Value > z, then Garde = 0

If y < Value < A, then Grade = Maxgrade × (Value – y)/(A – y)

If B < Value < z, then Grade = Maxgrade × (z – Value)/(z – B)

Values are the results re-measured by the Jury.



The correcting factor is α = 1, if a pure product was obtained and the spectrum coincides with the reference spectrum of a pure substance, also pre-tested by X-ray diffraction.

α = 0.5, if a no single phase product was obtained.

α = 0, if the product was not synthesized or another compound was obtained

Students result = Grade of mass * Correcting factor (α)

f. Calculate the approximate value of the reaction yield using the determined mass of the filter with the reaction product and knowing that the mass of the initial potassium dichromate was 10 g. Assume that the mass of the wet filter is 10 g.

Calculation:

$n(K_2Cr_2O_7) = 10/(39\cdot2+52\cdot2+16\cdot7) = 0.034$ mole

$n([(NH_3)_5Cr\text{-}(OH)\text{-}Cr(NH_3)_5]Cl_5\cdot H_2O) = 0.034$ mole

$m([(NH_3)_5Cr\text{-}(OH)\text{-}Cr(NH_3)_5]Cl_5\cdot H_2O) = 0.034\cdot(52\cdot2+17\cdot10+17+35.5\cdot5+18) = 16.541$ g.

Yield = m(product)/16.541=_____ % (2 points)

Question	a	b	c	d	e	f	g	h	i	Total
Points	5	22	12	1	3	1	2	3	1	50
Result										

Task 2. Rhodochromium chloride analysis (20 marks).

Question	M.V., mL	A, mL	B, mL	y, mL	z, mL	Max grade
1.1	See on a separate sheet	M.V.-0.1	M.V.+0.1	M.V.-1.0	M.V.+1.0	5 points
1.2.	See on a separate sheet	0.96*M.V.	1.03*M.V.	0.825*M.V.	1.04*M.V.	22 points
1.3	See on a separate sheet	M.V.-0.5	M.V.+0.5	M.V.-1.0	M.V.+1.0	12 points

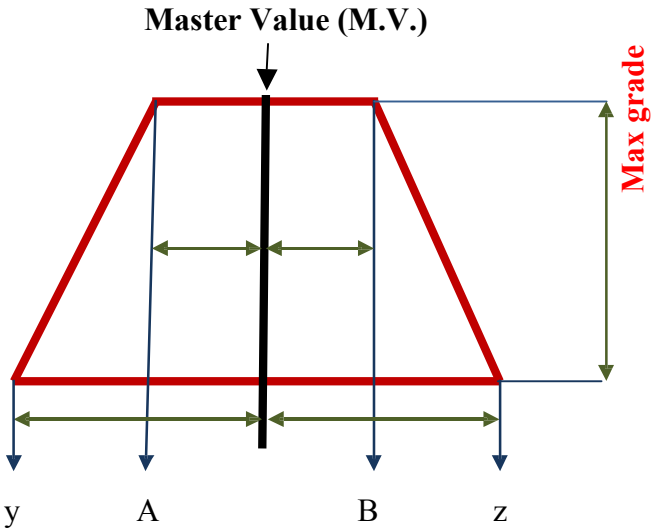
If A< Value < B, then Grade = Maxgrade

If Value < y, then Grade = 0, If Value > z, then Grade = 0

If y < Value < A, then Grade = Max grade × (Value – y)/(A – y)

If B < Value < z, then Grade = Max grade × (z – Value)/(z – B)

Value is the result reported by the student.



d. Write down the reaction equation occurring upon heating of the complex solution (you have defined the formula in task 1) with potassium hydroxide:

$[(NH_3)_5Cr(OH)Cr(NH_3)_5]Cl_5 + 5\ KOH = 2\ Cr(OH)_3 + 10\ NH_3 + 5\ KCl$ (1 point)

e. Write down the reaction equations behind chromium determination occurring upon: 1) addition of hydrogen peroxide to the solution obtained after the decomposition of the complex, 2) heating of the mixture, 3) addition of sulfuric acid:

1. $4\ KOH + 2\ Cr(OH)_3 + 3\ H_2O_2 = 2\ K_2CrO_4 + 8\ H_2O$ (1 point)
2. $2\ H_2O_2 = 2\ H_2O + O_2$ (1 point)
3. $2\ K_2CrO_4 + H_2SO_4 = K_2Cr_2O_7 + K_2SO_4 + H_2O$ (1 point)

f. Write down the reaction equation occurring upon standardization of the Mohr's salt by cerium (IV) sulphate solution. Calculate the concentration of the Mohr's salt (mol/L) from the titration results:

$2\ FeSO_4 + 2\ Ce(SO_4)_2 = Fe_2(SO_4)_3 + Fe_2(SO_4)_3$ (0.25 point)

$C(Fe^{2+}) = C(Ce^{4+})\cdot V(Ce^{4+})/\ V_{1,\,acc}\,(Fe^{2+})$ (0.75 point)

$C(Fe^{2+}) = 0.01020$ mol/L

g. Write down the reaction occurring upon titration of the product of reaction 3 in question **e** with Mohr's salt. Calculate the concentration of chromium (mol/L):

$K_2Cr_2O_7 + 6\ FeSO_4 + 7\ H_2SO_4 = Cr_2(SO_4)_3 + 3\ Fe_2(SO_4)_3 + 7\ H_2O$ (1 point)

$n\,(Cr_2O_7^{2-}) = 1/6\cdot n(Fe^{2+}) = 1/6\cdot C(Fe^{2+})\cdot V_{2,\,acc}\,(Fe^{2+})$

$n\,(Cr) = 2/6\cdot C(Fe^{2+})\cdot V_{2,\,acc}\,(Fe^{2+})$

$C\,(Cr) = 1/3\cdot C(Fe^{2+})\cdot V_{2,\,acc}\,(Fe^{2+})/100.0$ (0.75 point)

$C(Cr) = \underline{2.302\cdot10^{-3} - 2.754\cdot10^{-3}}$ mol/L

h. Write down the reactions of: 1) decomposition of rhodochromium chloride in a neutral medium, 2) interaction of ammonium salt with formaldehyde. Calculate the concentration of ammonium cation in mol/ L in the solution of rhodochromium chloride according to the formaldehyde method:

1. $[(NH_3)_5Cr(OH)Cr(NH_3)_5]Cl_5 + 10\ H_2O = 2\ Cr(OH)_3 + 5\ NH_4OH + 5\ NH_4Cl$ (1 point)
2. $4\ NH_4Cl + 6\ HCHO = (CH_2)_6N_4 + 4\ HCl + 6\ H_2O$ (1 point)

$C(NH_4^+) = C(H^+) = C(NaOH)\cdot V_{3,\,acc}(NaOH)/\ V_a$ (1 point)

$C(NH_4^+) = \underline{5.755\cdot10^{-3} - 6.886\cdot10^{-3}}$ mol/L

i. Determine the ratio of ammonia and chromium in the given sample and the mass of the sample:

$Cr : NH_3 = n(Cr) : 2\cdot n(NH_4^+) = 2 : 10 = 1 : 5$

$Cr : NH_3 = \underline{1 : 5}$ (0.5 point)

$m(sample) = M(complex\cdot H_2O)\cdot 1/2\cdot n\,(Cr)\cdot 10$ (0.5 point)

$m = \underline{0.0560 - 0.0670\ g}$