Name: _____

CM1111 – Test 2 – 60 min November 9th 2018

Answer all questions.

Q1		**10**
Q2		**14**
Q3		**6**
Q4		**20**
Total		**50**

- Answers should be as precise and brief as possible.
- Please write your answers only in the space given after each question using a pen (no pencils are allowed).
- Answers written on the backsides of the test-paper won't be considered (however, you can of course use the backsides to "pre-design" your answers).
- This is a closed-book test.

Question 1

Fill in the blanks with the most appropriate terms (adjective, verb or noun). Note: Each of the correct terms can appear only once, and none of them has appeared in the rest of the sentences.

a) According to the Brønsted-Lowry concept, an acid is a proton __donor____, while the base is a species, that __accepts_____ a proton. Upon reaction, the initial acid becomes the _conjugated__ base and vice versa. This acid-base concept highlights the dynamic equilibrium of acid-base reactions.

b) In the Lewis acid-base theory, a base must contain a __lone_____ __pair_____. Through donation to a Lewis acid a Lewis acid-base _adduct_____, is formed as a new compound. In coordination chemistry, this product is called a complex.

c) Redox reactions usually involve the full transfer of _electrons__ through which the respective atoms receive a higher or lower _oxidation_ _state / number. Increase of the latter is characteristic for the _reduction_____ half reaction.

(10 marks)

Question 2

Rank the following compounds in order of increasing acidity and briefly explain your order.

a) HBr, HCl, HF and HI

HF < HCl < HBr < HI

Increasing size of the halogen atom leads to a destabilization the H-X bond, thus leading to a better dissociation of H^+.

(4 marks)

b) HOBr, HOCl and HOI

HOI < HOBr < HOCl

Increasing electronegativity of the halogen atom leads to an increased polarization of the O-H bond facilitating better dissociation of H^+.

(4 marks)

c) $HClO_4$, H_3PO_4, H_2SO_4

$H_3PO_4 < H_2SO_4 < HClO_4$

Increasing numbers of "oxo"-oxygen atoms (=O) leads to a greater O-H polarization and better dissociation of H^+.

(4 marks)

d) What is the best term to describe all three compounds of Question 2c?

Oxoacids

(2 marks)

Question 3

Complete and fully balance the following equation using the smallest set of integers. Show your working.

$Cr^{3+} + MnO_4^- + ? \rightarrow Cr_2O_7^{2-} + Mn^{2+} + ?$ (acidic solution)

Oxidation:

$2\ Cr^{3+} + 7\ H_2O \rightarrow Cr_2O_7^{2-} + 6\ e^- + 14\ H^+$ x 5

$10\ Cr^{3+} + 35\ H_2O \rightarrow 5\ Cr_2O_7^{2-} + 30\ e^- + 70\ H^+$

Reduction:

$MnO_4^- + 5\ e^- + 8\ H^+ \rightarrow Mn^{2+} + 4\ H_2O$ x 6

$6\ MnO_4^- + 30\ e^- + 48\ H^+ \rightarrow 6\ Mn^{2+} + 24\ H_2O$

Overall

$10\ Cr^{3+} + 6\ MnO_4^- + 11\ H_2O \rightarrow 5\ Cr_2O_7^{2-} + 6\ Mn^{2+} + 22\ H^+$

(6 marks)

Question 4

In the steam reforming process, methane is reacted with steam at high temperature (>1000 °C) in the presence of a nickel catalyst to form dihydrogen gas.

a) Give the fully balanced chemical equation for this simple reaction, and identify the general type of the reaction.

$CH_4 + H_2O \rightarrow CO + 3\,H_2$

Redox reaction

(4 marks)

b) Briefly discuss if the reaction is driven by (i) enthalpy, (ii) entropy or (iii) both.

2 molecules react to give to 4 molecules. Therefore, entropy increases. On the other hand, very high temperature is required for the reaction, which points to an endothermic reaction. Overall, entropy is expected to be the main driving force.

(4 marks)

c) BeH_2 and NaH are both solids at room temperature and atmospheric pressure. However, BeH_2 is air and moisture stable, while NaH reacts violently with moisture.

i) Briefly discuss the "bond character" of the two compounds in simple terms, i.e. covalent, ionic, etc, that is consistent with their reactivities. Note: Molecular orbital or valence bond theory are NOT required.

Since BeH_2 is less reactive, it is supposed to be more covalent. The smaller difference in electronegativities leads to more covalent interaction. The large electronegativity difference of Na and H leads to an ionic compound. NaH reacts violently, because it exist in an ion lattice, where the H has hydridic character of high basicity.

(4 marks)

ii) Give the fully balanced chemical equation for this simple but violent reaction. Identify the general type of the reaction and indicate the role of all species.

$NaH + H_2O \rightarrow NaOH + H_2$ Bronsted acid-base reaction.
Base1 Acid2 cBase2 cAcid1

(4 marks)

iii) BeH_2 reacts with trimethylamine to form a new compound. Give the fully balanced chemical equation for this reaction. Identify the general type of this reaction and indicate the role of each reactant.

$2\ BeH_2 + 2\ NMe_3 \rightarrow [BeH_2(NMe_3)]_2$ (dimeric with 3c-2e H bridges)

$BeH_2 + 2\ NMe_3 \rightarrow [BeH_2(NMe_3)_2]$

Lewis acid-base reaction, octet not fulfilled

BeH_2: Lewis acid NMe_3: Lewis base

(4 marks)

Appendix: The Periodic Table of The Elements

1																	18
1 H 1.008	2											13	14	15	16	17	2 He 4.003
3 Li 6.941	4 Be 9.012											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 24.31	3	4	5	6	7	8	9	10	11	12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 49.96	22 Ti 47.88	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 65.39	31 Ga 69.72	32 Ge 72.61	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 95.94	43 Tc 98.91	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	71 Lu 175.0	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po 209.0	85 At 210.0	86 Rn 222.0
87 Fr 223	88 Ra 226.0	103 Lr 262.1	104 Rf 261.1	105 Db 262.1	106 Sg 263.1	107 Bh 264.1	108 Hs 265.1	109 Mt 268	110 Uun 269	111 Uuu 272	112 Uub 277	113 Uut	114 Uuq 289	115 Uup	116 Uuh 289	117 Uus	118 Uuo 293

57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm 146.9	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0
89 Ac 227.0	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu 244.1	95 Am 243.1	96 Cm 247.1	97 Bk 247.1	98 Cf 251.1	99 Es 252.0	100 Fm 257.1	101 Md 258.1	102 No 259.1