Grundlagen der Chemie für Studierende des Maschinenbaus der Werkstoffwissenschaften und NWT Lehramt, Prof. Heske und Dr. Weinhardt, Klausur 12.10.2015

Chemistry for Students of Mechanical Engineering, Studiengang Bachelor

Monday, 12th October 2015, 14:00-17:00

No unauthorised resources (*e.g.* lecture notes, textbooks etc.) may be used during the examination.

The use of a calculator is not permitted. All calculations have been set up, so that if you build up and derive an algebraic equation, and only substitute numerical values at the end, many of these will cancel conveniently, and a calculator is thus not necessary.

Foreign students may use a dictionary (mother tongue – English) but this may not contain any handwritten notes. Enough paper will be provided; do not bring any paper of your own into the examination hall.

Any attempt to use unauthorised resources will be considered as cheating, and will lead to immediate exclusion from the examination and a mark of 5,0.

Numerical answers that are given without showing any working or explanation will receive no marks.

In general, short answers with keywords will be sufficient; long essays are not necessary! To illustrate or explain a point, a clear sketch is often sufficient!

The maximum number of points for each question is given in parentheses.

Conversion from % to Note:

0-49,5	50-54	55-59	60-64	65-70	71-75	76-80	81-85	86-90	91-95	96-100
5,0	4,0	3,7	3,3	3,0	2,7	2,3	2,0	1,7	1,3	1,0

Question 1:

a) What is understood by an element, and what are isotopes? Give the number of protons and neutrons in chlorine atoms of mass number (atomic mass) 35, and also for Cl atoms with mass number 37. (2 P)

b) What method can be used to measure atomic mass? Describe briefly the three main steps in such a measurement. (4 P)

c) What is observed when the light emitted from thermally-excited atoms is passed through a prism and separated into its constituent wavelengths? What does this tell us about the structure of atoms? (2 P)

d) What do (i) the Pauli Principle and (ii) Hund's Rules tell us? (2 P)

e) Which simple rule predicts that elements from Group 2 generally form cations with charge 2+? (1 P)

f) What do elements within the same Group in the Periodic Table have in common? (1 P)

g) What is the underlying physical principle for separation processes such as solvent extraction and chromatography? (1 P)

h) How does an osmotic pressure arise? (1 P)

i) What are hydrogen bonds? (1 P)

Question 2:

a) Give the equations that can be used (with the help of data from tables) to calculate the changes in enthalpy (ΔH), Gibbs free energy (ΔG) and entropy (ΔS) for a reaction. (3 P)

b) Use the change in free energy (ΔG) to formulate the criterion for a spontaneous reaction or process. What is then the necessary condition for an endothermic reaction to be spontaneous? (2 P)

c) What are the characteristics of a chemical equilibrium?

Give the equations relating the equilibrium constant *K* of a reaction (i) to the concentrations of the substances involved in the reaction and (ii) to thermodynamic quantities.

What is the effect of an increase in temperature on the equilibrium position of an endothermic reaction, and what is the effect of removing a product from an equilibrium reaction?

What effect does an increase in pressure have on a gas-phase equilibrium in which the number of gaseous atoms or molecules decreases as the reaction proceeds?

Which general principle underlies the effects of changes in temperature or pressure, and of the addition or removal of substances involved in the reaction? (4 P)

d) Give the formula for the solubility product L_{AB2} for a fully-dissociated salt of formula AB_2. What is the correct unit for L_{AB2}?

At room temperature the solubility product for $PbCl_2$ is 3.2×10^{-5} $(mol/l)^3$. What is the concentration of Pb^{2+} in a saturated solution of $PbCl_2$ in distilled water? What is the concentration of Pb^{2+} in a saturated solution of $PbCl_2$ in water in which the concentration of chloride ions is 0.1 mol/L? (3 P)

e) What is understood by the rate of a chemical reaction and by the (kinetic) order of a reaction? What is an elementary reaction?

Give the equation that describes the influence of temperature on the rate of a chemical reaction. (2 P)

f) What is understood by (i) oxidation and (ii) reduction? (1 P)

g) Two beakers each contain a piece of cobalt (Co). A 1 molar solution of $CuSO_4$ is added to one beaker, a 1 molar solution of $FeSO_4$ is added to the other. In each case, use the table of Reduction Potentials (at the end of the exam script) to predict whether a chemical reaction will take place. (1 P)

h) What voltage do you expect from a Galvanic fuel cell operated with hydrogen and oxygen, in which the pressures of H_2 and O_2 are each 1 bar, and the electrolyte has pH = 0? What half-reactions are taking place? (3 P)

i) Determine the stoichiometric coefficients for the following redox reaction:

$$[\ ]\ Fe + [\ ]\ NO_3^- + [\ ]\ H^+ \rightarrow [\ ]\ Fe^{2+} + [\ ]\ NO + [\ ]\ H_2O$$ (1 P)

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Question 3:

a) Name the two different molecular forms in which elemental oxygen occurs in the atmosphere. For each form give the sum formula and the Lewis structure. Which of these two forms is the more common, and why are molecules of this form attracted into a magnetic field?
The other form occurs mainly in the stratosphere, and protects us from UV radiation. What reactions are important here? (4 P)

b) Give the reaction equation for the partial oxidation of octane to hydrogen and carbon monoxide. (1 P)

c) In Germany, most of the sulphur needed for the manufacture of sulphuric acid comes from the processing of crude oil and natural gas.

As what substance is the sulphur obtained?

Give the reaction equations for the steps in the manufacture of sulphuric acid from this substance? (Note: you should assume that the refinery and the sulphuric acid factory are not close to each other, and that only “safe” chemicals can be transported between them!)

During the manufacture of sulphuric acid, SO_3 is formed in an exothermic rection. What is the effect of the resulting increase in temperature on the yield of SO_3 that can be obtained? What measures are taken to increase the yield?

Calculate the emissions of SO_2 (in kg) that result when 32 tonnes of sulphur are converted by these reactions to H_2SO_4. Assume that all the reactions are quantitative except for the formation of SO_3, which has a yield of 99.5%. (9 P)

d) Name two important properties of metals that are made use of by industry. (1 P)

e) What is understood by passivation? (1 P)

f) Name two properties of aluminium (Al) that are exploited in its industrial use.

From what raw material is aluminium mostly produced? Give the important stages of the process by which this raw material is converted to the starting material for the production of aluminium metal. Name the most important production method and an important industrial application for aluminium metal. What reactions take place during the manufacture of the metal? (7 P)

g) In a blast furnace, partial combustion of coke results in CO, which then acts as the reducing agent. CO also takes part in the Boudouard equilibrium, by which finely-divided carbon is formed which then dissolves in the iron.

Give the reaction equation for the Boudouard equilibrium.
What negative effect does this dissolved carbon have on the properties of the raw iron?
Name a process used during the manufacture of steel, by which its carbon content can be reduced. (3 P)

h) What is understood by corrosion, and what is a local element? (1 P)

i) Name two important methods for protection from corrosion. (1 P)

j) Name two (other than platinum!) metals of the “platinum metals”. What is the main industrial use of these metals? (2 P)

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Question 4:

a) What is the hybridisation of carbon atoms involved in single bonds, in a double bond, and in a triple bond. What bond angles do you expect in each case? (3 P)

b) There are two organic compounds with the sum formula C_2H_6O. For each of them, give its correct name and its Lewis formula (Lewis structure), and say to which class of organic compound it belongs. (3 P)

c) Give the Lewis formulae for the functional groups that characterise esters, ethers and amides. (3 P)

d) Give two characteristic structural features for the benzene molecule, and draw the Lewis formulae for the two mesomeric forms. (2 P)

e) Describe with the help of a simple sketch the difference between simple distillation and distillation with a fractionating column. Which of these two basic methods is used in oil refineries for the production of motor fuels? (3 P)

f) Describe the mechanism of a radical chain reaction, using radical polymerisation as an example. (3 P)

g) Give the Lewis formulae for the characteristic repeating units in polyethene, polypropene and polystyrene. From which monomers are these polymers produced? (3 P)

Question 5:

a) What are the main components of (i) petrol and (ii) diesel fuel? (1 P)

b) Which pollutants are produced during the combustion of hydrocarbons in a combustion motor? Which of these are present in a motor that is running “lean”? (3 P)

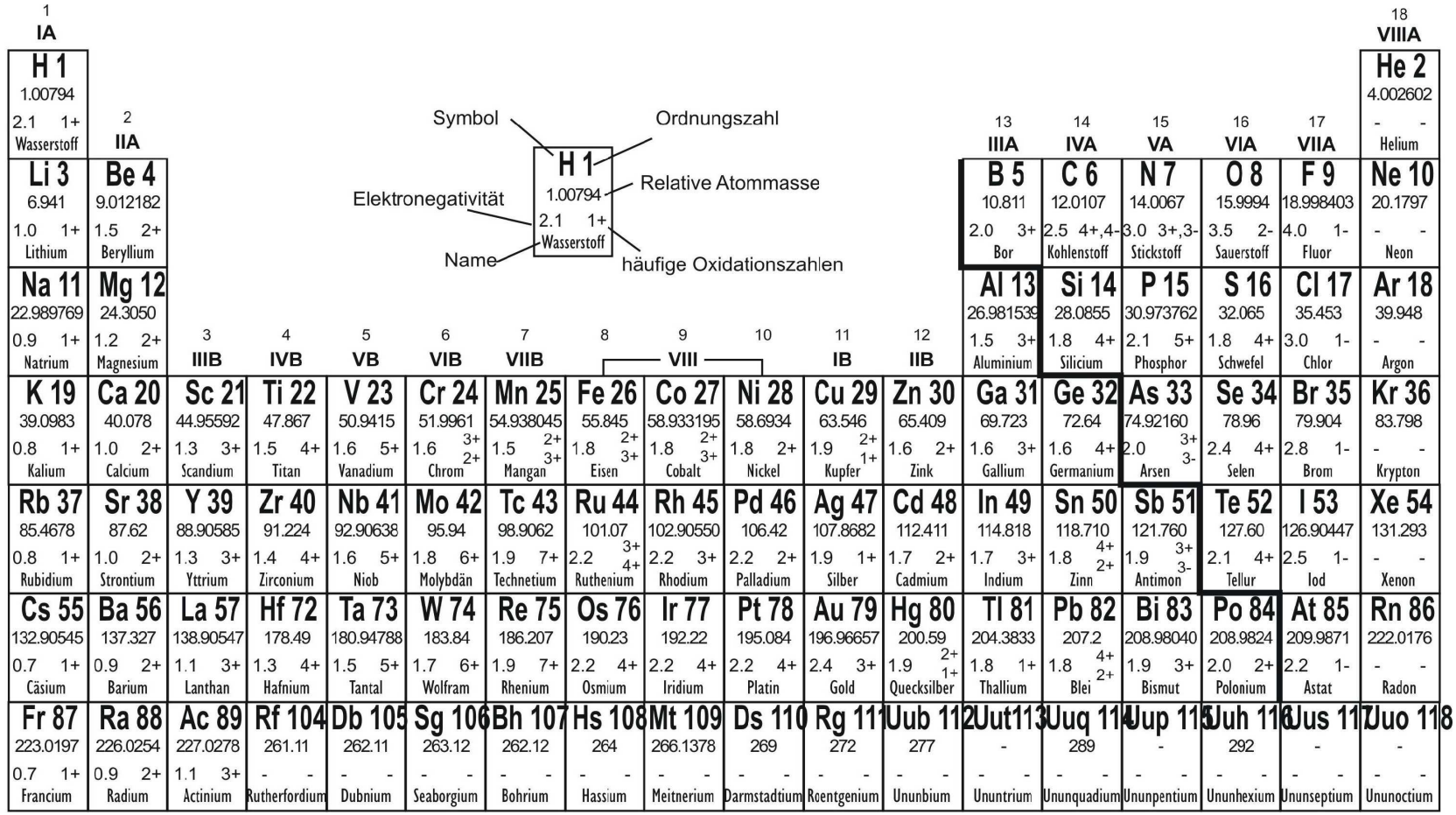
c) Describe how a storage catalyst can reduce the emission of pollutants. (2 P)

d) Name an important use of lubricants. (1P)

e) From where are mineral lubricating oils obtained? Name two important characteristic parameters for evaluating the quality of a mineral lubricating oil. (3 P)

f) Name a solid lubricant and an application of solid lubricants. (2 P)

g) How much (in g/km) is emitted by a diesel motor with a consumption of 5.65 litres per 100 km? For the calculation, assume that the fuel is pure cetane ($C_{16}H_{34}$, density ρ = 0.8 g/cm³) and that the combustion is complete. (3 P)



	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIII	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	H 1 1.00794 2.1 1+ Wasserstoff																	He 2 4.002602 - - Helium
2	Li 3 6.941 1.0 1+ Lithium	Be 4 9.012182 1.5 2+ Beryllium											B 5 10.811 2.0 3+ Bor	C 6 12.0107 2.5 4+,4- Kohlenstoff	N 7 14.0067 3.0 3+,3- Stickstoff	O 8 15.9994 3.5 2- Sauerstoff	F 9 18.998403 4.0 1- Fluor	Ne 10 20.1797 - - Neon
3	Na 11 22.989769 0.9 1+ Natrium	Mg 12 24.3050 1.2 2+ Magnesium											Al 13 26.981539 1.5 3+ Aluminium	Si 14 28.0855 1.8 4+ Silicium	P 15 30.973762 2.1 5+ Phosphor	S 16 32.065 1.8 4+ Schwefel	Cl 17 35.453 3.0 1- Chlor	Ar 18 39.948 - - Argon
4	K 19 39.0983 0.8 1+ Kalium	Ca 20 40.078 1.0 2+ Calcium	Sc 21 44.95592 1.3 3+ Scandium	Ti 22 47.867 1.5 4+ Titan	V 23 50.9415 1.6 5+ Vanadium	Cr 24 51.9961 1.6 3+, 2+ Chrom	Mn 25 54.938045 1.5 2+, 3+ Mangan	Fe 26 55.845 1.8 2+, 3+ Eisen	Co 27 58.933195 1.8 2+, 3+ Cobalt	Ni 28 58.6934 1.8 2+ Nickel	Cu 29 63.546 1.9 2+, 1+ Kupfer	Zn 30 65.409 1.6 2+ Zink	Ga 31 69.723 1.6 3+ Gallium	Ge 32 72.64 1.6 4+ Germanium	As 33 74.92160 2.0 3+, 3- Arsen	Se 34 78.96 2.4 4+ Selen	Br 35 79.904 2.8 1- Brom	Kr 36 83.798 - - Krypton
5	Rb 37 85.4678 0.8 1+ Rubidium	Sr 38 87.62 1.0 2+ Strontium	Y 39 88.90585 1.3 3+ Yttrium	Zr 40 91.224 1.4 4+ Zirconium	Nb 41 92.90638 1.6 5+ Niob	Mo 42 95.94 1.8 6+ Molybdän	Tc 43 98.9062 1.9 7+ Technetium	Ru 44 101.07 2.2 3+, 4+ Ruthenium	Rh 45 102.90550 2.2 3+ Rhodium	Pd 46 106.42 2.2 2+ Palladium	Ag 47 107.8682 1.9 1+ Silber	Cd 48 112.411 1.7 2+ Cadmium	In 49 114.818 1.7 3+ Indium	Sn 50 118.710 1.8 4+, 2+ Zinn	Sb 51 121.760 1.9 3+, 3- Antimon	Te 52 127.60 2.1 4+ Tellur	I 53 126.90447 2.5 1- Iod	Xe 54 131.293 - - Xenon
6	Cs 55 132.90545 0.7 1+ Cäsium	Ba 56 137.327 0.9 2+ Barium	La 57 138.90547 1.1 3+ Lanthan	Hf 72 178.49 1.3 4+ Hafnium	Ta 73 180.94788 1.5 5+ Tantal	W 74 183.84 1.7 6+ Wolfram	Re 75 186.207 1.9 7+ Rhenium	Os 76 190.23 2.2 4+ Osmium	Ir 77 192.22 2.2 4+ Iridium	Pt 78 195.084 2.2 4+ Platin	Au 79 196.96657 2.4 3+ Gold	Hg 80 200.59 1.9 2+, 1+ Quecksilber	Tl 81 204.3833 1.8 1+ Thallium	Pb 82 207.2 1.8 4+, 2+ Blei	Bi 83 208.98040 1.9 3+ Bismut	Po 84 208.9824 2.0 2+ Polonium	At 85 209.9871 2.2 1- Astat	Rn 86 222.0176 - - Radon
7	Fr 87 223.0197 0.7 1+ Francium	Ra 88 226.0254 0.9 2+ Radium	Ac 89 227.0278 1.1 3+ Actinium	Rf 104 261.11 - - Rutherfordium	Db 105 262.11 - - Dubnium	Sg 106 263.12 - - Seaborgium	Bh 107 262.12 - - Bohrium	Hs 108 264 - - Hassium	Mt 109 266.1378 - - Meitnerium	Ds 110 269 - - Darmstadtium	Rg 111 272 - - Roentgenium	Uub 112 277 - - Ununbium	Uut113 - - - Ununtrium	Uuq 114 289 - - Ununquadium	Uup 115 - - - Ununpentium	Uuh 116 292 - - Ununhexium	Uus 117 - - - Ununseptium	Uuo 118 - - - Ununoctium

Lanthaniden	6	Ce 58 140.116 1.1 3+ Cer	Pr 59 140.90765 1.1 3+ Praseodym	Nd 60 144.242 1.1 3+ Neodym	Pm 61 144.9127 1.1 3+ Promethium	Sm 62 150.36 1.2 3+ Samarium	Eu 63 151.964 1.2 3+ Europium	Gd 64 157.25 1.2 3+ Gadolinium	Tb 65 158.92535 1.2 3+ Terbium	Dy 66 162.500 1.2 3+ Dysprosium	Ho 67 164.93032 1.2 3+ Holmium	Er 68 167.259 1.2 3+ Erbium	Tm 69 168.93421 1.2 3+ Thulium	Yb 70 173.04 1.1 3+ Ytterbium	Lu 71 174.967 1.2 3+ Lutetium
Actiniden	7	Th 90 232.03806 1.3 4+ Thorium	Pa 91 231.03588 1.5 5+ Protactinium	U 92 238.02891 1.4 6+ Uran	Np 93 237.0482 1.3 5+ Neptunium	Pu 94 244.0642 1.3 4+ Plutonium	Am 95 243.0614 1.3 3+ Americium	Cm 96 247 1.3 3+ Curium	Bk 97 247.0703 1.3 3+ Berkelium	Cf 98 251.0796 1.3 3+ Californium	Es 99 252.03 1.3 - Einsteinium	Fm 100 257.0951 1.3 - Fermium	Md 101 258.01 1.3 - Mendelevium	No 102 259.1009 1.3 - Nobelium	Lr 103 260.1053 - - Lawrencium

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Reduzierte Form	$\rightleftarrows$ Oxidierte Form	$+z\,e^-$	Standardpotential E° in V
Li	$\rightleftarrows Li^+$	$+\ e^-$	−3,04
K	$\rightleftarrows K^+$	$+\ e^-$	−2,92
Ba	$\rightleftarrows Ba^{2+}$	$+2\,e^-$	−2,90
Ca	$\rightleftarrows Ca^{2+}$	$+2\,e^-$	−2,87
Na	$\rightleftarrows Na^+$	$+\ e^-$	−2,71
Mg	$\rightleftarrows Mg^{2+}$	$+2\,e^-$	−2,36
Al	$\rightleftarrows Al^{3+}$	$+3\,e^-$	−1,68
Mn	$\rightleftarrows Mn^{2+}$	$+2\,e^-$	−1,19
Zn	$\rightleftarrows Zn^{2+}$	$+2\,e^-$	−0,76
Cr	$\rightleftarrows Cr^{3+}$	$+3\,e^-$	−0,74
S^{2-}	$\rightleftarrows S$	$+2\,e^-$	−0,48
Fe	$\rightleftarrows Fe^{2+}$	$+2\,e^-$	−0,41
Cd	$\rightleftarrows Cd^{2+}$	$+2\,e^-$	−0,40
Co	$\rightleftarrows Co^{2+}$	$+2\,e^-$	−0,28
Sn	$\rightleftarrows Sn^{2+}$	$+2\,e^-$	−0,14
Pb	$\rightleftarrows Pb^{2+}$	$+2\,e^-$	−0,13
Fe	$\rightleftarrows Fe^{3+}$	$+3\,e^-$	−0,036
$H_2 + 2\,H_2O$	$\rightleftarrows 2\,H_3O^+$	$+2\,e^-$	0
Sn^{2+}	$\rightleftarrows Sn^{4+}$	$+2\,e^-$	+0,15
Cu^+	$\rightleftarrows Cu^{2+}$	$+\ e^-$	+0,15
$SO_2 + 6\,H_2O$	$\rightleftarrows SO_4^{2-} + 4\,H_3O^+$	$+2\,e^-$	+0,17
Cu	$\rightleftarrows Cu^{2+}$	$+2\,e^-$	+0,34
Cu	$\rightleftarrows Cu^+$	$+\ e^-$	+0,52
$2\,I^-$	$\rightleftarrows I_2$	$+2\,e^-$	+0,54
$H_2O_2 + 2\,H_2O$	$\rightleftarrows O_2 + 2\,H_3O^+$	$+2\,e^-$	+0,68
Fe^{2+}	$\rightleftarrows Fe^{3+}$	$+\ e^-$	+0,77
Ag	$\rightleftarrows Ag^+$	$+\ e^-$	+0,80
Hg	$\rightleftarrows Hg^{2+}$	$+2\,e^-$	+0,85
$NO + 6\,H_2O$	$\rightleftarrows NO_3^- + 4\,H_3O^+$	$+3\,e^-$	+0,96
$2\,Br^-$	$\rightleftarrows Br_2$	$+2\,e^-$	+1,07
$6\,H_2O$	$\rightleftarrows O_2 + 4\,H_3O^+$	$+4\,e^-$	+1,23
$2\,Cr^{3+} + 21\,H_2O$	$\rightleftarrows Cr_2O_7^{2-} + 14\,H_3O^+$	$+6\,e^-$	+1,33
$2\,Cl^-$	$\rightleftarrows Cl_2$	$+2\,e^-$	+1,36
$Pb^{2+} + 6\,H_2O$	$\rightleftarrows PbO_2 + 4\,H_3O^+$	$+2\,e^-$	+1,46
Au	$\rightleftarrows Au^{3+}$	$+3\,e^-$	+1,50
$Mn^{2+} + 12\,H_2O$	$\rightleftarrows MnO_4^- + 8\,H_3O^+$	$+5\,e^-$	+1,51
$3\,H_2O + O_2$	$\rightleftarrows O_3 + 2\,H_3O^+$	$+2\,e^-$	+2,07
$2\,F^-$	$\rightleftarrows F_2$	$+2\,e^-$	+2,87