Prüfung in Chemie
für Studierende des Maschinenbaus und des Lehramts an Gymnasien

Friday, 4th October 2013, 15:00-18:00

No unauthorised resources (*e.g.* lecture notes, textbooks etc.) may be used during the examination. Any attempt to use such unauthorised resources will be considered as cheating, and will lead to immediate exclusion from the examination and a mark of 5,0.

Foreign students may use a dictionary (mother tongue – English) but this may not contain any handwritten notes. The use of a calculator is not permitted.

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.

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

Section 1:

a) What is understood by atomic number, and what are isotopes? (2P)

b) Give the numbers of protons, neutrons and electrons in nitrogen atoms with atomic weights 14 and 15, respectively. (2P)

c) Name the four quantum numbers that describe the energy levels of electrons in an atom. Briefly describe the significance of each quantum number. (4P)

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

e) Give the electronic configuration of the molybdenum (Mo) atom. (1P)

f) What method is used to determine the mass of an atom? What are the three main stages in this experimental method? (4P)

g) Use the VSEPR model to determine the 3-D geometries of SF_6, $[Al(OH)_4]^-$, CO_2 and SbF_5. (4P)

h) State the ideal gas equation. (1P)

Section 2:

a) What is understood by (i) the standard enthalpy of formation of a compound, and (ii) enthalpy of reaction? (2P)

b) Give the Gibbs-Helmholtz equation.
What is the criterion for a spontaneous chemical reaction?
What conditions must be fulfilled if an endothermic process is to occur spontaneously? (3P)

c) What are the characteristics of a chemical equilibrium?
Give the equation that relates the equilibrium constant K of a typical reaction to the concentrations of the products and starting materials, and also the equation that relates K to thermodynamic quantities.

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

What is the effect of an increase in pressure on the equilibrium position of a reaction in which the number of gas-phase molecules decreases?

Which general Principle determines the effect of external influences (changes in temperature or pressure, removal of a reaction component etc) on a system such as an equilibrium? (6P)

d) Ethene can be obtained by the dehydrogenation of ethane. Write down the reaction equation.

Calculate the Standard Enthalpy of Reaction ($\Delta H°$), the Standard Entropy of Reaction ($\Delta S°$) and the Gibbs free Energy of Reaction ($\Delta G°$) using the following values:

$\Delta H^o_f(C_2H_6) = -84.7$ kJ mol^{-1}, $\Delta H^o_f(C_2H_4) = 52.4$ kJ mol^{-1}
$S^o(C_2H_6) = 229.6$ J mol^{-1} K^{-1}, $S^o(C_2H_4) = 219.3$ J mol^{-1} K^{-1},
$S^o(H_2) = 130.7$ J mol^{-1} K^{-1} (4P)

e) The formation of sulphur trioxide (SO_3) from sulphur dioxide (SO_2) and oxygen is an equilibrium reaction. Give the reaction equation, and decide if entroipy increases or decreases as the reaction proceeds.

In which direction is the equilibrium position displaced, if
- the temperature is increased
- an excess of oxygen is added to the initial gas mixture?

Explain your answers, noting that the reaction is exothermic ($\Delta H = -99$ kJ/mol). (3P)

f) Determine the stoichiometric coefficients for the following redox reactions, and give the oxidation states for the species taking part:
[ ] Cr^{3+} + [ ] H_2O_2 + [ ] OH^- → [ ] CrO_4^{2-} + [ ] H_2O
IO_3^- + [ ] HSO_3^- + [ ] H^+ → [ ] I^- + [ ] H_2SO_4 + [ ] H^+ (4P)

g) In each of the half-cells of a Galvanic cell, a sheet of platinised platinum is dipped in a 1 M H_2SO_4 solution at 25 °C, and the respective gas is passed over the platinum at a pressure of 1.013 bar. What voltage will be measured when H_2 is passed through one half-cell, and O_2 through the other? What are the two half-reactions?
(3P)

Section 3:

a) What is understood by “Los Angeles Smog” (also known as “Summer Smog”)? Give the equation for the chemical reaction that results in “Los Angeles Smog”. (2P)

b) Give the equations for the stratospheric reactions involving CFCs (chlorofluorocarbons, such as CCl_3F) that are responsible for the formation of the Ozone Hole. (2P)

c) What is the oxidation state of sulphur in the following compounds: H_2S, S_8, Na_2SO_3 and SO_3? (2P)

d) How is ammonium nitrate made from ammonia? Give the equations for the four reactions. (4P)

e) Bauxite, a mixture of Al_2O_3 and Fe_2O_3, is an important raw material in the production of aluminium. What are the three main steps in the production of aluminium from bauxite? Give chemical equations for the reaction(s) taking place in each step.
Calculate the electric current that must be passed through the electrolysis cell, if aluminium is to be produced at a rate of 54 kg/h.
Assume the Faraday constant F = 96500 C/mol, and round the atomic mass of Al to 27 g mol^{-1}. (6P)

f) Name two raw materials from which iron can be obtained.
Which industrial process is used to obtain iron? What substance is the reducing agent of the iron ore?
Why is lime ($CaCO_3$) used in iron production? Give equations for the reactions in which the lime (or a substance derived from it) is involved.
During the chemical reactions involved in the formation of iron, finely-divided carbon is formed via the Boudouard reaction, and this carbon dissolves in the liquid iron. Give the equation for the chemical equilibrium involved in the Boudouard reaction.
What negative effect does this dissolved carbon have on the properties of the raw iron?
Name a process used during steel production, to reduce the carbon content of the steel. (6P)

g) What is understood by corrosion? (1P)

h) Give equations for the chemical reactions that take place when iron rusts in moist air. What are two important methods that can be used to prevent such rusting? (4P)

i) Name three of the elements that belong to the Platinum Group of metals. What is the main industrial significance of these metals? (2P)

Aufgabe 4:

a) There are five organic compounds with the sum formula C_4H_6. Choose any two of these, and draw their Lewis formulae, give their correct names, and state which class of organic compound each of them belongs to. (3P)

b) What hybridisation do carbon atoms have that are involved in single, double or triple bonds? What is the spatial arrangement of the bonds around the carbon atom in each case? (3P)

c) Give four characteristic structural features of the benzene molecule, and draw the two mesomeric structures for the molecule. (3P)

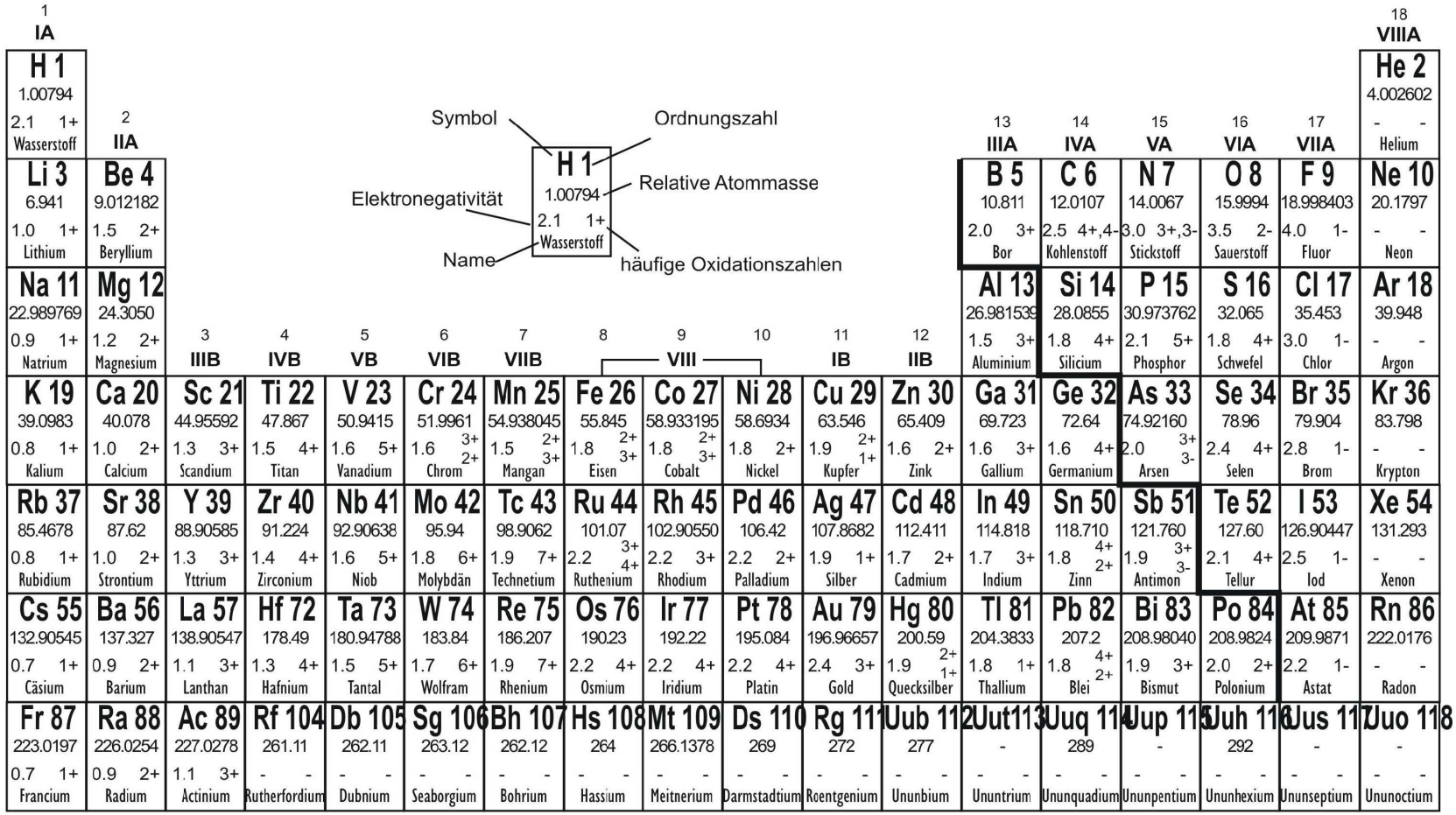
d) Draw the Lewis formulae for the characteristic functional groups of carboxylic acids, esters, ketones and alkenes. (4P)

e) Draw the Lewis formula for the compound 2-hydroxy-3-amino-4-methyl-5-ethyl-cyclohexanone. (4P)

f) What is understood by the terms macromolecule and polymerisation? (1P)

g) Give the Lewis formulae for the repeating units in polyethene, polypropene, polyvinylchloride, polystyrene and polyacrylonitrile. From which monomers are these polymers produced? (5P)

h) How much CO_2 (in g/km) is emitted by a petrol motor with a fuel consumption of 5,7 litre/100km? Assume that the fuel is 100 % isooctane, with a density of $\rho = 0{,}7\ g/cm^3$ (3P)



	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

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