

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

Monday, 1st October 2012, 10:00-13:00

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 a point, a sketch will be sufficient, provided it clarifies the point!

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:

- What do the Pauli Principle and Hund's Rules tell us? (1P)
- What are the four quantum numbers that describe the energy levels of electrons in an atom? Briefly describe the significance of each quantum number. (4P)
- Give the electron configuration of the phosphorus (P) atom (1P)
- What is understood by electronegativity? (1P)
- Give the three-dimensional geometries of the CO₂, SF₆, CH₄ und H₂O molecules (4P)
- Which of the molecules in question e) have a non-zero dipole moment? (4P)
- What interactions between ions and water molecules compensate for the loss of lattice energy when an ionic salt is dissolved? (1P)
- Write down the ideal gas equation (1P)
- Give two important properties of metals (2P)
- What is the common characteristic of the elements in a Group of the Periodic Table? (1P)

Section 2:

- a) What does Hess's Law tell us? (1P)
- b) Give the equations used to calculate enthalpy of reaction, entropy of reaction and Gibb's free energy of reaction. (3P)
- c) Explain in terms of Gibbs free energy why NH_4Cl dissolves spontaneously in water, even though this process is endothermic (2P)
- d) What does Le Chatelier's Principle tell us?
What is the effect of raising the temperature on the equilibrium position of an endothermic reaction, and how does increasing the pressure affect the equilibrium position of a gas-phase reaction in which the number of molecules decreases as the reaction proceeds? (3P)
- e) The solubility product of PbCl_2 at room temperature is $3.2 \times 10^{-5} \text{ (mol/l)}^3$.
What is the concentration of Pb^{2+} in a saturated aqueous solution of PbCl_2 , and what is the new concentration of Pb^{2+} when the chloride concentration is increased to 0.1 mol/l? (4P)
- f) What is meant by rate of reaction, and by the order of a reaction? (2P)
- g) Give the equation that describes the effect of temperature on the rate of a chemical reaction. (1P)
- h) What is understood by oxidation and reduction? (1P)
- i) What is the oxidation state of the elements in bold type in the following compounds?
 HNO_3 , Na_3VO_4 , LiAlH_4 und KClO_4 ? (4P)
- j) Fill in the stoichiometric coefficients to balance the following redox reactions (2 P)
- $\square \text{ Cu} + \square \text{ SO}_4^{2-} + \square \text{ H}^+ \rightarrow \square \text{ Cu}^{2+} + \square \text{ SO}_2 + \square \text{ H}_2\text{O}$
 - $\square \text{ Fe}_2\text{O}_3 + \square \text{ CO} \rightarrow \square \text{ Fe}_3\text{O}_4 + \square \text{ CO}_2$
- k) What is the potential of a Galvanic fuel cell which runs using hydrogen and oxygen gases, when the hydrogen and oxygen are each introduced at a pressure of 1 bar, and the $\text{pH} = 0$? What are the half reactions that take place? (3P)

Section 3:

- a) What is “Los Angeles Smog” (also known as “Summer-Smog”)?
Give the equations for the chemical reactions that result in “Los Angeles Smog” (2P)
- b) Most of the sulphur used in Germany for the production of sulphuric acid comes from the processing of mineral oil and natural gas. In the form of which compound is most of this sulphur found?
Give the reaction equations of the processes by which this chemical is converted into sulphuric acid. You can assume that the sulphuric acid plant is a long distance away from the refinery where the oil or gas is processed!
In the production of sulphuric acid, the formation of SO_3 is an exothermic equilibrium reaction. What is the effect of raising the reaction temperature on the maximum yield of SO_3 ? What measures are taken to increase the degree of conversion?
Calculate the amount of SO_2 (in kg) emitted when 32 tonnes of sulphur are converted to H_2SO_4 . Assume that all the equations proceed quantitatively, except for the conversion of SO_2 to SO_3 , which is only 99.5% complete. (9P)
- c) State a property of iron that is made use of in its industrial applications. (1P)
- d) Why is limestone (CaCO_3) used as an additive in the Blast Furnace process? (1P)
- e) Give the equations for the reactions that take place in the Blast Furnace, in which the limestone or a substance formed from the limestone takes part. (3P)
- f) Bauxite is an important raw material in the production of aluminium, and is usually a mixture of Al_2O_3 und Fe_2O_3 .
What are the four important stages in the formation of metallic aluminium from this raw material? Give the equations for the chemical reactions that take place (5P)
- g) In the Blast Furnace, carbon is formed via the Boudouard reaction. Give the reaction equation for this equilibrium reaction.
What negative effect does dissolved carbon have on the properties of the raw („pig“) iron?
Give the name of a process which is used during steel production to reduce the content of carbon in the raw iron. (3P)
- h) What is meant by corrosion and by a local element? (2P)
- i) State two important methods for protection from corrosion (2P)

Section 4:

- a) Two organic compounds have the sum formula C_3H_6 .
Give the Lewis structures for both compounds. To which classes of organic compounds do each of these molecules belong? (3P)
- b) Give the Lewis structure for the molecule 2-methyl-5-hydroxyhex-2-enal. (3P)
- c) Give the Lewis structures of the characteristic functional groups of ketones, alcohols and carboxylic acids (3P)
- d) Give the reaction equations for the industrial productions of methanol, ethanol and ethanoic (acetic) acid (3P)
- e) What is the hybridisation of the carbon atoms in single, double and triple bonds?
What are the 3-D geometries of the bonds around such carbon atoms? (3P)
- f) Describe the mechanism of a radical chain reaction, using the formation of CH_3Br from CH_4 and Br_2 as an example (3P)
- g) What is understood by the term macromolecule, and what is polymerisation? (2P)
- h) Give the structural formulas of the repeating units in polyethylene, polypropene, polyvinylchloride and polyacrylonitrile. From which monomers are these polymers produced? What type of polymerisation reaction is involved? (5P)

Reduzierte Form	\rightleftharpoons Oxidierte Form	$+ z e^-$	Standardpotential E° in V
Li	$\rightleftharpoons \text{Li}^+$	$+ e^-$	-3,04
K	$\rightleftharpoons \text{K}^+$	$+ e^-$	-2,92
Ba	$\rightleftharpoons \text{Ba}^{2+}$	$+ 2e^-$	-2,90
Ca	$\rightleftharpoons \text{Ca}^{2+}$	$+ 2e^-$	-2,87
Na	$\rightleftharpoons \text{Na}^+$	$+ e^-$	-2,71
Mg	$\rightleftharpoons \text{Mg}^{2+}$	$+ 2e^-$	-2,36
Al	$\rightleftharpoons \text{Al}^{3+}$	$+ 3e^-$	-1,68
Mn	$\rightleftharpoons \text{Mn}^{2+}$	$+ 2e^-$	-1,19
Zn	$\rightleftharpoons \text{Zn}^{2+}$	$+ 2e^-$	-0,76
Cr	$\rightleftharpoons \text{Cr}^{3+}$	$+ 3e^-$	-0,74
S^{2-}	$\rightleftharpoons \text{S}$	$+ 2e^-$	-0,48
Fe	$\rightleftharpoons \text{Fe}^{2+}$	$+ 2e^-$	-0,41
Cd	$\rightleftharpoons \text{Cd}^{2+}$	$+ 2e^-$	-0,40
Co	$\rightleftharpoons \text{Co}^{2+}$	$+ 2e^-$	-0,28
Sn	$\rightleftharpoons \text{Sn}^{2+}$	$+ 2e^-$	-0,14
Pb	$\rightleftharpoons \text{Pb}^{2+}$	$+ 2e^-$	-0,13
Fe	$\rightleftharpoons \text{Fe}^{3+}$	$+ 3e^-$	-0,036
$\text{H}_2 + 2 \text{H}_2\text{O}$	$\rightleftharpoons 2 \text{H}_3\text{O}^+$	$+ 2e^-$	0
Sn^{2+}	$\rightleftharpoons \text{Sn}^{4+}$	$+ 2e^-$	+0,15
Cu^+	$\rightleftharpoons \text{Cu}^{2+}$	$+ e^-$	+0,15
$\text{SO}_2 + 6 \text{H}_2\text{O}$	$\rightleftharpoons \text{SO}_4^{2-} + 4 \text{H}_3\text{O}^+$	$+ 2e^-$	+0,17
Cu	$\rightleftharpoons \text{Cu}^{2+}$	$+ 2e^-$	+0,34
Cu	$\rightleftharpoons \text{Cu}^+$	$+ e^-$	+0,52
2I^-	$\rightleftharpoons \text{I}_2$	$+ 2e^-$	+0,54
$\text{H}_2\text{O}_2 + 2 \text{H}_2\text{O}$	$\rightleftharpoons \text{O}_2 + 2 \text{H}_3\text{O}^+$	$+ 2e^-$	+0,68
Fe^{2+}	$\rightleftharpoons \text{Fe}^{3+}$	$+ e^-$	+0,77
Ag	$\rightleftharpoons \text{Ag}^+$	$+ e^-$	+0,80
Hg	$\rightleftharpoons \text{Hg}^{2+}$	$+ 2e^-$	+0,85
$\text{NO} + 6 \text{H}_2\text{O}$	$\rightleftharpoons \text{NO}_3^- + 4 \text{H}_3\text{O}^+$	$+ 3e^-$	+0,96
2Br^-	$\rightleftharpoons \text{Br}_2$	$+ 2e^-$	+1,07
$6 \text{H}_2\text{O}$	$\rightleftharpoons \text{O}_2 + 4 \text{H}_3\text{O}^+$	$+ 4e^-$	+1,23
$2 \text{Cr}^{3+} + 21 \text{H}_2\text{O}$	$\rightleftharpoons \text{Cr}_2\text{O}_7^{2-} + 14 \text{H}_3\text{O}^+$	$+ 6e^-$	+1,33
2Cl^-	$\rightleftharpoons \text{Cl}_2$	$+ 2e^-$	+1,36
$\text{Pb}^{2+} + 6 \text{H}_2\text{O}$	$\rightleftharpoons \text{PbO}_2 + 4 \text{H}_3\text{O}^+$	$+ 2e^-$	+1,46
Au	$\rightleftharpoons \text{Au}^{3+}$	$+ 3e^-$	+1,50
$\text{Mn}^{2+} + 12 \text{H}_2\text{O}$	$\rightleftharpoons \text{MnO}_4^- + 8 \text{H}_3\text{O}^+$	$+ 5e^-$	+1,51
$3 \text{H}_2\text{O} + \text{O}_2$	$\rightleftharpoons \text{O}_3 + 2 \text{H}_3\text{O}^+$	$+ 2e^-$	+2,07
2F^-	$\rightleftharpoons \text{F}_2$	$+ 2e^-$	+2,87