Grundlagen der Chemie für Studierende des Maschinenbaus, der Werkstoffwissenschaften und NWT Lehramt, Prof. C. Heske

Chemistry for Students of Mechanical Engineering, Studiengang Bachelor

Wednesday, 18th March 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 atomic number, and what are isotopes? (2 P)

b) What method can be used to measure atomic mass? Describe briefly the three main steps in such a measurement. (2 P)

c) The emission spectrum of a chemical element is made up of discrete narrow lines. What does this tell us about the electrons in an atom? (1 P)

d) Give the electron configuration oft he phosphorus (P) atom. (1 P)

e) What does the Octet Rule tell us? (1 P)

f) Give the three-dimensional shapes of the HCN, BF_3, CH_4, SF_6, NH_3 and H_2O molecules. (3 P)

g) Draw Lewis structures for the borane (BH_3), silane (SiH_4) and phosphine (PH_3) molecules. (3 P)

h) Arrange the elements C, Br, Mg and K in order of increasing electronegativity. (2 P)

Question 2:

a) Give the equations, by which one can (with the help of tables!) calculate the enthalpy (ΔH), entropy (ΔG) and Gibbs free energy (ΔG) for a reaction. (3 P)

b) The formation of ethene (C_2H_4) from ethane (C_2H_6) is an equilibrium reaction.
(i) Give the chemical equation for the reaction.
(ii) What is the equation for the equilibrium constant K for this reaction? Give the equation that relates K to a thermodynamic quantity.
(iii) Use the values in the table below to calculate ΔH, ΔS and ΔG, together with the equilibrium constant K, for this reaction at 800°C. (n.b. The values in the table are appropriate for 800°C; you do not need to take the temperature dependence of ΔH and ΔS into account!).

	T [°C]	ΔH_f [kJ/mol]	ΔS_f [J/(mol·K)]
H_2	800	0	0
C_2H_4	800	37	-82
C_2H_6	800	-106	-216

(iv) With the help of the Gibbs-Helmholtz equation, explain why the elimination of dihydrogen from ethane takes place at temperatures above 800°C, even though the reaction is endothermic. (5P)

c) How are acidity and basicity constants (K_a and K_B) defined?
What are the concentrations of H_3O^+ ions in a 1-molar solution of HNO_2, and in a 0.05 molar solution of $Ba(OH)_2$, respectively?
{ $K_a(HNO_2) = 4 \times 10^{-4}$ mol/l, $K_B(OH^-) = 10^{-24}$ mol/l } (2 P)

d) How is the solubility product for a saturated solution of a salt AB defined?
At room temperature, 1.43×10^{-3} g AgCl can be dissolved in 1 litre of water. Calculate the solubility product L_{AgCl} of AgCl in water. {Ag: 107.8 g mol^{-1}; Cl: 35.5 g mol^{-1}) (2 P)

e) What are the oxidation states of the elements shown in **bold type** in the following compounds?
H**N**O_3 LiAl**H**$_4$ H_2**S**O_3 K**Br**O_3 (2 P)

f) For the overall reaction $2\ H_2 + O_2 \rightarrow 2\ H_2O$, give the equations for the oxidation and reduction half-reactions. (2 P)

g) Determine the stoichiometric coefficients for the following redox reactions: (2 P)
1. [ ] Fe_2O_3 + [ ] $CO \rightarrow$ [ ] Fe_3O_4 + [ ] CO_2
2. [ ] Fe + [ ] NO_3^- + [ ] $H^+ \rightarrow$ [ ] Fe^{2+} + [ ] NO + [ ] H_2O

h) What is the voltage from a Galvanic cell, in which a Zn electrode is dipped in a 1 molar solution of $ZnSO_4$ and a Cu electrode is dipped into a 1 molar $CuSO_4$ solution? What half-reactions take place? (2 P)

Question 3

a) Give the reaction equation for the partial oxidation of hexane to H_2 and CO. (1 P)

b) Draw the Lewis formula for ozone (O_3) and give the reaction equations for the formation of ozone. Give equations for reactions involving CFCs (such as CCl_3F) that lead to the formation of the Ozone Hole (3 P)

c) What is understood by "Los Angeles Smog" (also known as "Summer Smog")? Give the equation for the chemical reaction that results in such Smog. (1 P)

d) Ammonium nitrate can be produced using natural gas (CH_4) and air as starting materials. Describe the important processes involved, and give equations for the reactions that are involved. (9 P)

e) Name two raw materials from which iron can be obtained. By which process is iron obtained, and what is the substance that acts as the reducing agent? (2 P)

f) In a Blast Furnace, finely-divided carbon is formed via the Boudouard Equilibrium, and this carbon dissolves in the raw iron. Give the equation for the Boudouard Equlibrium.
What negative effect does this dissolved carbon have on the properties of the raw iron?
Give the name of a process used in steel production, by which the carbon content is reduced. (3 P)

g) Why is limestone ($CaCO_3$) added to the iron ore and coke in a blast furnace? (1 P)

h) Give the equations for the reactions that take place when iron rusts in moist air. (4 P)

i) What is understood by corrosion, and what is a local element? (2 P)

j) An important ore for the production of copper metal is chalcopyrite ($CuFeS_2$). The two important stages in the processing of this mineral are (a) roasting followed by dissolving in sulphuric acid and (b) electrolytic refining. Give the equations for the two reactions that take place during roasting and dissolution in sulphuric acid, and describe briefly what takes place during the electrolytic refining. What valuable solid by-product is obtained during the electrorefining? (4 P)

Question 4

a) What hybridisation do carbon atoms have that are involved in single, double and triple bonds? What is the three-dimensional geometry between the bonds around this central carbon atom in each case? Describe with the help of sketches the covalent bonding in double and triple bonds. (5 P)

b) Using benzene as an example, give two important structural features of aromatic molecules. Explain the distribution of the bonding electrons with the help of Lewis structures of the two mesomeric forms. (3 P)

c) With the help of simple sketches, explain the difference between a simple distillation and a distillation using a fractionating column. Which of these two types of distillation is used in oil refineries? (3 P)

d) What is a radical chain reaction? Describe the mechanism using radical polymerisation as an example. (3 P)

e) Give the Lewis structures of the repeating units in polypropene, polyacrylonitrile, polystyrene and polyvinylchloride. From which monomeric molecules are these polymers produced? (4 P)

Question 5

a) What are the main components of petrol and Diesel fuel, respectively? (1 P)

b) From where are mineral lubricationg oils obtained. Name two physical properties used to characterise the quality of a lubricating oil. (2 P)

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

d) What is understood by “knocking” in a petrol motor, and what is the corresponding problem in a Diesel motor? (1 P)

e) What numbers are used to characterise petrol and Diesel fuels, and how are these numbers defined? (2 P)

f) What pollutants result from the combustion of hydrocarbon fuels in an internal combustion motor? (2 P)

g) Which of these compounds are the main pollutants produced when a motor is running “lean”, and what catalytic system is used to remove them? (3 P)

h) Give the reaction equation for the complete combustion of *n*-octane and *iso*-octane. (1 P)

i) How much CO_2 (in g/km) is emitted by a Diesel motor with a fuel consumption of 5.65 litres per 100 km? Assume that the fuel is pure cetane ($C_{16}H_{34}$, density ρ = 0,8 g/cm³) and that this fuel is completely combusted. (3 P)