Universidad Carlos III de Madrid

Aerospace Engineering (Groups 45 &46)
May 23rd, 2013

Final exam: Chemistry

NAME..... ....

SURNAME ....

EXAM (60%)

Important: Please, write down your name. Read the exam carefully before you start. Write down the answers in the blank spaces provided right after each exercise. You may use the last page for drafts. Time available for the test is 2:30 h.

1. (1 point, 10 min) Given the following molecules: PF_5; XeF_4; CH_2Cl_2; CH_2CCl_2; CCl_4 fill in the information missing in the table shown below (hybridization of the central atom, shape of the molecule, bond angles and polarity of the molecule).

Molecule	Hybridization	Shape	Bond angles	Polarity
PF_5				
XeF_4				
CH_2Cl_2				
$CH_2=CCl_2$				
CCl_4				

2. (0.75 points, 5 mins) Suppose that three unknown pure substances are liquids at room temperature. You make vapour pressure measurements and find that substance **Q** has a pressure of 110 Torr, substance **R** has a pressure fo 42 Torr, and substance **S** has a pressure of 330 Torr. If you slowly increase the temperature, which substance will boil first and which will boil last? Provide a brief explanation to your answer.

3. **(0.75 points, 15 mins).** The decomposition of a given compound (A) has a half-lifetime of 32 minutes for an initial concentration of 0.05M. The half-lifetime is 46 minutes when the initial concentration is 0.035 M. Predict **the order of the reaction** and **the value of the kinetic constant**.

4. **(1.5 points, 10 min)** Given an aqueous solution made of in aqueous ammonia (NH_3) and ammonium chloride (NH_4Cl) with a concentration $3\cdot10^{-3}$ M in NH_3 and 1M in NH_4Cl. If $MgCl_2$ is added until a concentration $2\cdot10^{-3}$ M of $MgCl_2$ is reached, explain if magnesium hydroxide will precipitate.
Data: K_s ($Mg(OH)_2$) = $1.2\cdot10^{-11}$; $K_b(NH_3) = 1.8\cdot10^{-5}$.

5. (10 min, 1 point) Given the following electrochemical cell:

$$Co\ (s)\ |\ Co^{2+}\ (0.010\ M)\ ||\ H^{+}\ (0.010\ M)\ |\ H_2\ (1\ atm)\ |\ Pt$$

a) Write down the half reactions that take place in the anode and the cathode, label each of the electrodes and indicate the oxidizing and reducing agent in each case.

b) Which of the following changes will produce an increase in the cell potential?

i. An increase in the volume of the $CoCl_2$ solution from 100 mL to 300 mL by adding water to the solution.

ii. An increase in the concentration of [H+] from 0.010 M to 0.500 M.

iii. An increase in the mass of the electrode from 15 g to 25 g.

iv. An increase in the concentration of $[Co^{2+}]$ from 0.010 M to 0.500 M.

6. (1 points, 15 min) You want to heat the air in your house with natural gas (CH_4). Assume your house has 275m^2 of floor area and that the ceilings are 2.50m from the floors. The air in the house has a molar heat capacity of 29.1 $J \cdot mol^{-1} \cdot K^{-1}$. Assuming that 60 % of the heat of combustion is useful, how many liters of methane (S.T.P.) must be burned to heat the air from 15.0 ºC to 22 ºC? (Assume c_v to be constant in that temperature range).

Data: $\Delta H_f^{\ o}\ (CH_4)$ = -74.9 kJ/mol; $\Delta H_f^{\ o}\ (H_2O, l)$ = −285.8 kJ/mol; $\Delta H_f^{\ o}\ (CO_2)$ = −393.509 kJ/mol
Average molar mass of air M_{air} = 28.9 g/mol; Density of air = 1.22 g/L. $M_{(CH4)}$ = 16 g/mol;
R = 0.082 $atm \cdot l \cdot mol^{-1} \cdot K^{-1}$= 8.314 $J \cdot mol^{-1} \cdot K^{-1}$

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7. (1.0 marks, 15 mins) Indicate whether the following statements are true (T) or false (F).

Correct answers +0.1p; Incorrect answers -0.05p.

	1	The hydrohalogenation reaction is an addition reaction that usually yields as a product an alcohol.
	2	The solubility in water of carboxylic acids of the same homologous series decreases with the number of carbon atoms of the chain.
	3	The reaction of a CARBOXYLIC ACID with an AMINE usually yields an ester as a result of a condensation reaction.
	4	Pyrogenation of coal is based on a thermal treatment with oxygen at high temperature to obtain liquid hydrocarbons.
	5	From methane it is possible to obtain syngas ($CO + H_2$) which is used as raw material for many industrial processes.
	6	In the combustion of a fuel, a ***rich mixture*** is a mixture with an excess of air.
	7	Linear alkenes usually have higher boiling points than linear alcohols of the same number of carbon atoms.
	8	The quantity known as higher heating value (**HHV**) is determined by bringing all the products of combustion back to the original temperature, usually to 25°C.
	9	Flash distillation is used mainly to obtain substances that are temperature sensitive materials
	10	In organic reactions, a heterolytic bond cleavage yields as a result two ionic compounds, the carbocation and a carbanion.

8. **(1 points, 10 min)**. A mixture containing 45% benzene (B) and 55% toluene (T) by mass is fed to a distillation column. An overhead stream of 95 wt% B is produced, and 8% of the benzene fed to the column leaves in the bottom stream. The feed rate is 2000 kg/h.

a) Draw the flowchart
b) Determine the overhead flow rate
c) Determine the mass flow rates of benzene and toluene in the bottom stream.

9. (2 points, 30 min). Using the information given below:

a) Calculate the value of ΔH^o and ΔS^o. Assume them to be independent of the temperature in either cases i) and ii).

b) Determine the temperature for which both reactions will have the same ΔG^o and calculate the value of ΔG^o at that temperature.

ii) $CO_{2(g)}+H_{2(g)}\leftrightarrow CO_{(g)}+H_2O_{(g)}$

$\ln K_{CO2}$	-0.39144	0.43749	0.87498	1.70391
$1/T\ (K^{-1})$	$8.3.10^{-4}$	1.10^{-3}	$1.11.10^{-3}$	$1.28.10^{-3}$

iii) $SO_{3(g)}\leftrightarrow SO_{2(g)}+1/2\ O_{2(g)}$

$\ln K_{SO3}$	1.22037	0.48354	-0.8059	-1.9572
$1/T\ (K^{-1})$	$8.3.10^{-4}$	9.10^{-4}	1.10^{-3}	$1.12.10^{-3}$